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Review

The underexposed nature-based solutions: A critical state-of-art review on drought mitigation

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ABSTRACT

Droughts are the most expensive climate disasters as they leave long-term and chronic impacts on the ecosystem, agriculture, and human society. The intensity, frequency, and duration of drought events have increased over the years and are expected to worsen in the future on a regional and planetary/global scale. Nature-based solutions (NBS) such as wetland and floodplain restorations, green infrastructures, rainwater harvesting, etc., are highlighted as effective solutions to cope with the future impacts of these events. While the role of NBS in coping with the impacts of other disasters, such as floods, has been extensively studied, there has been a lack of comprehensive review of NBS targeting drought. The following paper provides a unique critical state-of-the-art literature review of individual drought-related NBS around the world, in Europe, and particularly in Belgium, and assesses the critical differences between the NBS applied globally and in Flanders. An extensive literature review was conducted to systematically analyze NBS, listing the type, the location, the status of the implementation, and the possible recommendations proposed to optimize future NBS applications. Finally, a comparison is made between small- and large-scale applications of NBS. By analyzing all these aspects, especially the level of effectiveness and recommendations, insight was gained into the future potential of NBS and possible improvements.

The research indicated a lack of scientific publications, especially in Belgium. Hence, grey literature was also included in the literature review. Only four papers included a quantitative assessment regarding the effectiveness of drought on a global level, all stating a positive impact on groundwater recharge. In contrast, at regional and country levels, the performance of NBS was not quantified. The number of large-scale implementations is low, where landscape- or watershed-scale holistic approaches to drought mitigation are still scarce. Some successfully implemented projects are only very local and have a long realization time, two aspects that limit achieving visible impact at a larger scale. Among the many NBS, wetlands are recognized as highly effective in coping with drought but are still degraded or lost despite their significant restoration potential. A common effectiveness evaluation framework shall be followed, which gives policymakers a clear view of the different NBS investment options. Furthermore, a more collaborative approach is recommended globally, including different stakeholder groups, with specific attention to the local communities. To conclude, future research should increase the evidence base and implementation of drought-mitigating NBS.

1. Introduction

Climate change affects the Earth in many ways, including heavy storms, floods, wildfires, sea level rises, and severe droughts (Cortinovis et al., 2022). The latter is considered one of the most expensive climate disasters globally as they leave chronic and long-term impacts on the ecosystem, agriculture (Yimer et al., 2023a), and human society (Cook et al., 2018; WWAP, UN-Water, 2018). Cook et al. (2018) define drought broadly as an “anomalous moisture deficit relative to some normal baseline”. More specifically, three types of droughts can be

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distinguished: meteorological, agricultural, and hydrological. Meteorological droughts are due to the lack of precipitation, while agricultural droughts occur as the precipitation deficit continues through time and affects soil moisture. As the deficit persists and even affects the streamflow and storage in aquifers and reservoirs, hydrological droughts arise (Cook et al., 2018; S.E. Debele et al., 2019; Wilhite and Glantz, 1985).

Droughts occurred more frequently with increased intensity and duration in the last years on a global scale (OECD, 2020; Yimer et al., 2022). The total population affected by drought is now estimated at 1.8 billion, including both the socio-economic and mortality impacts. Also, in the future, the frequency of droughts is projected to increase in most regions, except in the high northern latitudes, east of Australia, and east of Eurasia. These regions are expected to experience no significant change or even a decrease in frequency (WWAP, UN-Water, 2018). So, droughts are not only occurring in the already dryer areas, as is sometimes supposed, but they also threaten regions that are usually not facing water scarcity, such as Belgium. The predicted longer duration and frequency of droughts can be alleviated by staking nature-based solutions (NBS, WWAP, UN-Water, 2018). Enlarging and maximizing the water storage capacities and retaining the water in the aquifers (slower release of water) is one way to cope with droughts using NBS (OECD, 2020; WWAP, UN-Water, 2018). As aquifers have a large potential storage capacity, the available groundwater in the aquifers and additional water can function as a buffer in periods of high seasonal variations in the water supply. The extra water falling in wet periods can be stored on the (sub)surface and contribute to the water availability in dry periods later (S. Keesstra et al., 2018; WWAP, UN-Water, 2018). However, the potential of natural water storage in the subsurface (of aquifers) is not yet recognized. The water resources management plans should include surface or subsurface storage opportunities or a combination of those in the face of the increasing water variability (WWAP, UN-Water, 2018).

There has been growing research on the potential of NBS for climate change adaptation in the last decade (Seddon et al., 2020). They can contribute to achieving sustainable cities under climate change impacts, which is considered one of the most significant challenges that urban areas will face in the future (Kabisch et al., 2017; Seddon et al., 2020). NBS create benefits in two ways: they create opportunities to cope with the causes and consequences of climate change, but at the same time, they support biodiversity and, therefore, also the chain of ecosystem services needed to sustain human life (Seddon et al., 2020). Based on a study by Eggermont et al. (2015), three types of NBS can be distinguished according to their number of services and stakeholder groups, maximization degree of the delivery of key services, and level and type of engineering. The first type refers to restoring natural or protected ecosystems using minimum interventions to maintain existing ecosystem services. In contrast, the second type uses effective management practices to reach sustainability and multi-functionality while gaining more selected ecosystem services. Finally, the third type uses a maximum level of intervention and even creates new ecosystems to deliver the key services (Eggermont et al., 2015; Kooijman et al., 2021).

The NBS concept was developed, elaborated, and popularized by different researchers and organizations, such as the International Union for Conservation of Nature (IUCN) and the European Commission (EC), with different definitions and conceptualizations according to their perspectives (Cohen-Shacham et al., 2016). Mackinnon et al. (2008) first mentioned the principle of NBS in "Biodiversity, Climate Change, and Adaptation: Nature-Based Solutions" from the World Bank Portfolio to stress the importance of biodiversity conservation for climate change adaptation (MacKinnon et al., 2008). A year later, the IUCN put the concept in a broader context and defined NBS as "actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits. They are underpinned by benefits that flow from healthy ecosystems and target major challenges like climate change, disaster risk reduction, food, and water security and are critical to economic development" (IUCN, n.d.; Cohen-Shacham et al., 2016; Kooijman et al., 2021). Then, the European Commission defined NBS as "… nature-based solutions to societal challenges as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions" (European Commission, 2015).

The principles of NBS do not differ much from other existing concepts of Green Infrastructure (GI) and Ecosystem-Based Adaption (EBA). Furthermore, in the case of urban NBS, the concept is often used interchangeably (Dorst et al., 2019). Therefore, the literature suggests looking at NBS as 'an umbrella concept' (Kooijman et al., 2021), also covering other concepts such as sustainability and ecosystem-related approaches to address societal challenges (Cohen-Shacham et al., 2016; Dorst et al., 2019; Irfanullah, 2021). Yet, it creates the potential to attach segregated knowledge and expertise of the previous and current approaches in the world of urban green planning. A more performance-based urban planning approach makes it easier to reach a sustainable solution for urban areas (Dorst et al., 2019).

NBS are multifunctional solutions that mimic complex systems and processes of nature (European Commission, 2015; Nelson et al., 2020). Therefore, NBS implementation is challenging for green urban planners, with different barriers limiting the broader and successful adoption. To improve the future performance of NBS, it is essential to study the barriers that hinder their implementation. Also, the requirements to overcome these barriers must be well-investigated, as what is usually presented in the planning phase does not always correspond to what is realized in practice (Frantzeskaki et al., 2020). According to Frantzeskaki et al. (2020), three gaps are differentiated for implementing NBS in cities: skills gaps, governance gaps, and knowledge gaps. Nelson et al. (2020) also state many barriers, including knowledge gaps of effectiveness, lack of awareness, low costs and benefits expertise, poor stakeholder engagement and inequity, lack of policy and economic instruments, and insufficient financing.

NBS is designed to fix many societal challenges, and they are mainly promoted to create resilience in the (urban) environment and cope with the negative impacts of climate change, such as extreme weather disasters (floods, droughts, etc.) (Cortinovis et al., 2022). When mimicking the natural processes in urban infrastructure, they also provide many additional benefits (Raymond et al., 2017). Examples are carbon sequestration, water quality, land conservation, food production, biodiversity and ecosystem services, and recreation (European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation, 2021). They contribute co-benefits to urban residents, such as improved health and well-being and the local green economy (Kabisch et al., 2017). Some indirect co-benefits may also include the learning (e.g., outdoor classrooms), where awareness is raised about the potential benefits, stakeholder inclusion, and energy savings (European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation, 2021; Pagano et al., 2019).

Despite being popularized only recently (Nesshöver et al., 2017), NBS received high interest from the research community, as proved by the high number of related publications. Several literature reviews have already been conducted, focusing, for example, on hydro-meteorological risk reduction (Ruangpan et al., 2020), water management in European cities (Oral et al., 2020), stakeholders' engagement in NBS planning (Ferreira et al., 2022), health benefits (Kabisch et al., 2017; van den Bosch and Sang, 2017), and nature-based infrastructures to improve coastal resilience (Salinas Rodriguez et al., 2014). Nevertheless, the lack of a comprehensive review of NBS targeting drought led to this review paper's conception. Hence, the central part of this study aims to review the current state-of-the-art NBS measures targeted at mitigating drought at global (worldwide), regional (Europe), and country (Belgium) levels.

Belgium was chosen due to the wide range of NBS applications and their potential benefit in drought mitigation. Indeed, Northern European countries such as Belgium urge to find readily-applicable solutions to cope with drought, as this phenomenon was extremely rare in the past, and water managers lack experience and solutions to tackle it effectively. The literature review focuses on the measures maximizing the total water storage capacities in the landscape and retaining the water in the aquifers and soils. More specifically, NBS designed to mitigate droughts, their effectiveness, and future recommendations are investigated. On top of that, these NBS are compared across different countries, focusing on the critical differences between NBS applied in Belgium and worldwide. Next, the most effective future drought interventions are discussed in the face of a changing climate. Finally, small-scale and large-scale NBS applications targeting drought are assessed and compared.

Since NBS is an emerging concept, having a critical review of the current state-of-the-art with detailed and comprehensive information about the effectiveness and lessons learned from pilot projects is needed. In this regard, key objectives were formulated as follows.

- To critically assess the current state-of-the-art drought-mitigating NBS in literature at global (worldwide), regional (Europe), and country levels (Belgium).
- To critically compare NBS targeting drought across different scales and examine what Belgium (Flanders) can learn from existing NBS applications in other parts of the world and vice versa.
- To examine and compare drought-mitigating NBS applied at small and large scales.

2. Methodology

The methodology consisted of different steps. After the conceptualization of the research and the definition of the two main topics covered, namely NBS and drought, the literature string search and the criteria for inclusion or exclusion were defined. Then, different individual drought-related NBS were critically assessed at the global, regional, and country levels. Moreover, a comparison was made to examine what Belgium can learn from other parts of the world and vice versa. Finally, small- and large-scale NBS applications are analyzed. In this paper, we refer to the term “level” when considering the geographical application of the NBS, while we use “scale” to compare the application scale of the NBS.

2.1. Search strategy and geographical location

The analysis uses online information sources published in English journals, Dutch reports, and websites. Since the concept of NBS is recently introduced (Nesshöver et al., 2017), not only scientific journal articles were reviewed, but also reports and non-scientific articles. As the research focuses on NBS specifically designed to cope with droughts, only those increasing the water storage in the landscape were included. Nevertheless, some NBSs reducing the flood risk were also considered when they were also judged efficient for drought mitigation.

The critical assessment was done for different locations, where we started by investigating applications at a global level except Europe, with Europe corresponding to the regional level and Belgium as the country level. The literature review searched for relevant publications on the Scopus database using defined search terms. The search strategy for this literature review was adapted from a review on hydro-meteorological risk and NBS (Ruangpan et al., 2020). The string used to perform the literature search summarized the two main concepts, NBS, and drought, with the synonyms, and it is reported below:

(“Nature-based solutions” OR “Low impact development” OR “Sustainable Urban Drainage Systems” OR “Water Sensitive Urban Design” OR “Best Management Practices” OR “Green infrastructure” OR “Green blue infrastructure” OR “Ecosystem-based adaptation” OR “Ecosystem-based disaster risk reduction” OR “Green and grey infrastructure” OR “Landscape approach” OR “Landscape ecology” OR “Agroecology”) AND (“Drought” OR “Hydro-meteorological” OR “Streamflow deficit” OR “Hydrological drought” OR “Meteorological drought” OR “Low flow” OR “Disaster”)

The search terms were all combined into one search on the Scopus database. A few publications were taken out due to being duplicates of the same study or not being recognized as valid reviewed papers. These results were then filtered by reading titles and abstracts for publications of NBS related to drought. Papers were classified as relevant if they included the term drought or synonyms and if the paper mentioned NBS or techniques that can be classified as such.

2.2. NBS analysis and large and small-scale application comparison

A table was constructed for all levels (global, regional, and country) to compare the measures across different scales. Different aspects were delineated, including NBS type, location, beginning (and end) year of implementation, status by now, level of effectiveness, and possible recommendations set by the researcher to improve future implementation. By analyzing all these aspects, especially the level of effectiveness and recommendations, insight was gained into the potential future NBS measures and improvements.

As a final step, the relevant papers were scanned for the different types of scales for NBS regarding drought that were applied. A distinction was made between large- and small-scale NBS. Where the type of scale could not be concluded from the abstract, the whole paper was reviewed. Within this process, some papers were again excluded from the selection as, although drought was mentioned in the abstract, the case studies mentioned in the paper did not specifically address drought.

A classification of what is counted as small-scale and large-scale is reported in Table 1. For example, if a publication discussed the so-called sponge cities, this was classified as a large-scale application of NBS since it has a city-wide approach. Also, if many small-scale applications were being used simultaneously within the same region or watershed, they were classified as large-scale applications of NBS.

Table 1
Small and Large-scale Nature-based solution classification.

Small-scale solutions	Large scale solutions
1. Singular projects on a single plot of land	1. City-wide approach
2. Small experiments	2. Landscape approach
3. Singular NBS in one location within a city or landscape	3. Watershed approach
4. Modelling of a single NBS	4. Multiple projects (large-scale application of small-scale solutions)
	5. Modelling on a landscape or city-wide scale
	6. Country-wide approach

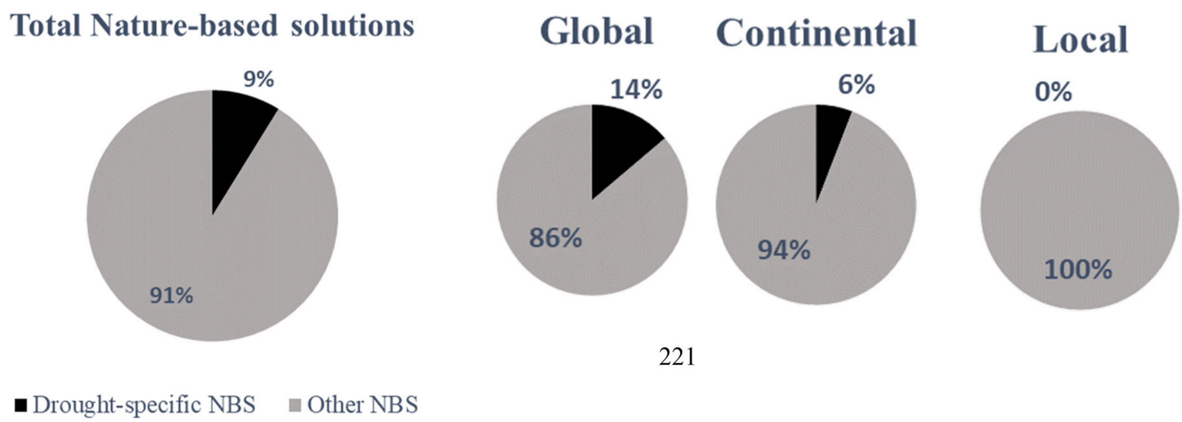

Fig. 1. The percentage of NBS applications targeting drought or other hydroclimatic extremes at global, regional (Europe), and local levels (Belgium).

3. Results

The literature search in the Scopus database yielded 1322 results within a period from 1988 until the end of 2022. After the screening process, 134 articles were finally selected for this study. The topic of NBS for drought is very underrepresented in comparison to floods as a hydrometeorological hazard, as also highlighted by Ruangpan et al. (2020). This emerged clearly from the literature review (Fig. 1), as many articles include drought as an add-on to flood mitigation or as another problem in the hydrometeorological risk list. This underrepresentation is also the result of the wide range of vocabulary with which the authors define and conceptualize these topics. Also, drought might not have been the main topic of some research and was excluded from the title or the abstract, even if, when reading the paper, drought was mentioned and assessed as part of a broader spectrum of hydro-climatic risks (e.g., Beierkuhnlein, 2021; Mugari and Nethengwe, 2022). Out of the 134 selected papers, 95 publications specifically mention drought in their title or abstract. However, only 24 also mention NBS in connection with drought. It can, therefore, be assumed that the research on NBS and drought is still very limited and underrepresented in the scientific community and requires further research into how NBS at different scales would be successful in mitigating the effects of drought.

Globally, incentives have created resilience against water scarcity using nature and ecosystem services. Table A1 in the appendix summarizes a literature review of current nature-based projects at a global level to increase water availability, including the NBS type, year of implementation, status, level of effectiveness, and possible recommendations set by the researcher to improve the application in the future. The location of the NBS varied greatly, with a few countries showing a lot of research regarding drought and NBS (Fig. 2). Among the leading countries in this literature review were China, the USA, and South Africa. Within Europe, there was a wide range of countries with different climates that also contributed to the research, such as Italy, Spain,

Table 2
The number of projects that are implemented and ongoing for the different decades.

Decades	Number of projects		
	Globally	Europe	Belgium
1990 to 2000	0	2	1
2000 to 2010	2	8	1
2010 to 2020	18	19	6
2020 onwards	6	8	1

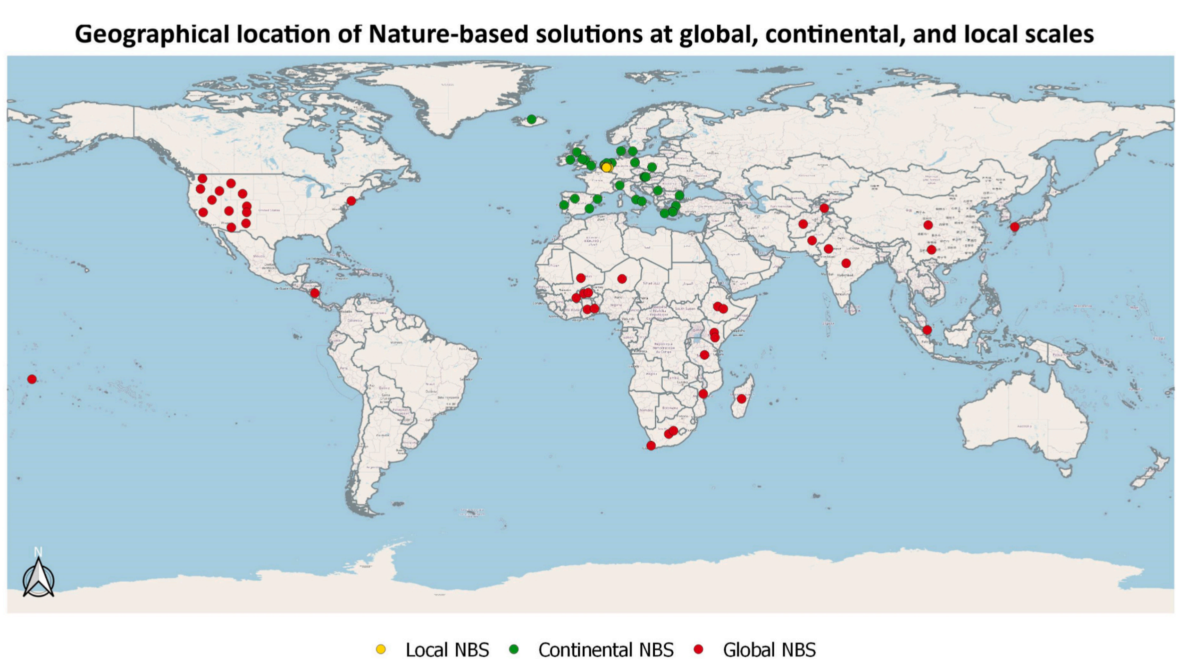

Fig. 2. The number of nature-based solutions targeting drought at different scales and their spatial distribution.

Table 3
The number of projects which are successfully implemented, ongoing, or with no status information.

Implementation status	Globally	Europe	Belgium
Successfully implemented	20	20	2
On going	7	14	4
Not stated	2	1	0

Germany, and the Czech Republic. What is visible from the range of countries is the fact that drought is becoming a widespread phenomenon and that mitigation strategies for different climates and landscape types need to be found. Furthermore, the highest drought impacts typically occur in Sub-Saharan Africa, but most applications are spread across Europe and north America. The past decade experienced increased applications of NBS targeting drought, with Europe leading the way. The number of projects in the world, Europe, and Belgium is reported in Tables 2 and 3, ordered by decade and implementation status, respectively.

3.1. NBS to mitigate drought and water scarcity in the world

Most of the existing global NBS are successfully implemented or still in the active stage (pilot project stage). A major pilot project is the implementation of sponge cities in China. Although the main reason for this project is to cope with the effect of rapid urban development on the natural environment and its water-related problems, such as urban flooding, it will also be efficient in coping with droughts by improving the urban water logging (Liu et al., 2017; T.T. Nguyen et al., 2019). The implemented NBS (such as green infrastructure and infiltration ponds) infiltrate and store the excess rainwater, which can be used for future water use (Liu et al., 2017). However, this solution's effectiveness is not yet quantified; there are still many technical, physical, financial, legal, and regulatory challenges to overcome before successful implementation can be achieved (Nguyen et al., 2019).

Similar to the sponge cities in China, many other papers do not evaluate the effectiveness of NBS for drought. Some examples are the river restoration and riparian wetland restoration projects in Colorado (Cohen-Shacham et al., 2016), the beaver restoration projects in the Western USA (Pilliod et al., 2018), the green infrastructure projects in New York City (Kalantari et al., 2018), (rain)water harvesting in Tucson (Radonic, 2019) and the Sub-Saharan countries (Critchley and Di Prima, 2012), and the implementation of greenways in Burkina Faso (Sy et al., 2014). As the dynamics and impacts of drought are difficult to understand fully, Cohen-Shacham et al. (2016) recommend examining further the lower-flow scenarios related to drought, while Pilliod et al. (2018) state the requirement of more quantitative data on the NBS performance. A critical recommendation set by Kalantari et al. (2018) is the exigency of good stakeholder involvement to fully understand the potential impacts. Critchley and Di Prima (2012) offer a more holistic and integrated approach for improving the implementation while also gaining insight into the farmer's knowledge about the NBS technologies integrated into their practices on the field.

Other papers evaluate drought-related benefits and co-benefits without quantitative assessment and evaluation of the effectiveness. Cui et al. (2021) explored the implementation of green infrastructure (urban park) in combination with the river restoration in the Bishan AMK Park in Singapore. An increase in the water supply and many other co-benefits are expected, such as the increase in water and food supply, recreation, and tourism. Although the benefits are recognized, a quantitative understanding of the effectiveness and other benefits of the project (such as mental health benefits and access to green space) is still lacking. The World Bank Group (2022) and WWAP, UN-Water (2018) also provide some examples of drought-mitigating NBS, such as many reforestation and sustainable management projects in African countries (Ghana, Mali, Madagascar, Togo, Ethiopia, Burkina Faso, Niger, Kenya, Mozambique, and Nicaragua) and landscape restoration, sustainable management, and green solution projects in Asian regions (India, Pakistan, Afghanistan, Tajikistan). The recognized benefits are increased groundwater recharge, including water table stabilization, and improved water retaining capacity of the soil, which reduces the risk in periods of droughts (The World Bank Group, 2022; WWAP, UN-Water, 2018). The widely applied NBS are afforestation, wetland, and rainwater harvesting (Fig. 3). Note that some studies, such as Koiv-Vainik et al. (2022), although they have investigated and has significant implication on stormwater retention across different climates to cope with hydroclimatic extremes, it was excluded from the analysis as drought is not mentioned inside the abstract. Similarly, Mabon et al. (2022) were excluded for the same reason, though they have a unique perspective where mere stakeholder participation is inadequate; rather, a diverse stakeholder group/knowledge is required to enforce NBS. Thus, future work shall account for multiple research arenas by widening the search strategy.

Four papers obtained a quantitative model result regarding the effect of specific NBS on drought. P.B. Holden et al. (2022) assessed the impact of catchment restoration, specifically invasive tree species clearing, on streamflow drought. The modelling improved the low flows caused by climate change by 3–16%. Therefore, removing alien tree species is an important technique to reduce the climate drought risk. However, combining with other adaptation techniques must be considered to reduce climate change acceleration. A second study by Amano and

Fig. 3. The widely applied nature-based solutions (NBS) at a global scale (except in Europe). The bigger the text's size, the wider the NBS application.

Iwasaki (2022) estimated the groundwater recharge due to artificial groundwater recharge in abandoned paddy rice fields using Geographic Information Systems (GIS) and found a substantial increase in recharge. Most of the total recharge (33.61%) is the groundwater recharge from paddy fields. Another paper by Gathagu et al. (2018) modeled the impacts of structural conservation measures (e.g., terraces and grassed waterways) on the sediment and water yield in the Thika-Chania catchment in Kenya. The presence of terraces showed a substantial increase of 8.38% in the baseflow component due to infiltration, while a general increase in recharge was found in the shallow groundwater aquifers by 5.08%. However, the effectiveness can still be improved by combining this implementation with other NBS types. Lastly, Welderufael et al. (2013) simulated the effect of rainwater harvesting on groundwater recharge in South Africa using the Soil Water Assessment Tool (SWAT). The modelling resulted in improved water infiltration in the case of in-field rainwater harvesting and a general increase in groundwater recharge (40 mm/year) compared to the reference consisting mainly of pasture (32 mm/year). Solely, there are still many uncertainties in the model results, which could affect the water yield components, such as the lateral and groundwater flow components.

3.2. NBS to mitigate drought and water scarcity in europe

In recent decades, meteorological droughts occurred more frequently in the European region (Kumar et al., 2020). For example, during the summer months of 2018–2020, Europe had to cope with droughts due to a combination of heatwaves and limited precipitation (Trémolet et al., 2019). In addition, there are increased human-caused pressures, such as (over)-abstraction for agriculture (Yimer et al., 2023d), domestic and industrial water use, and degradation or loss of aquatic ecosystems, on the ecosystems triggering water scarcity and droughts (Trémolet et al., 2019). The widely applied NBS in Europe is wetland restoration, rainwater harvesting, and green roofs. Contrarily, less afforestation is applied (Fig. 4). The number of successfully implemented and ongoing projects is higher in Europe (Table 3).

Since 2013, the European Commission has shown increased attention to NBS: the concept of NBS is made more concrete, and its relation is defined to the other ecosystem-based approaches. The following year, the European Commission put together an expert group for further analysis and to increase awareness of the use of NBS in European cities. In 2015, a survey on the public perceptions of nature in cities was conducted for developing future projects (Faivre et al., 2017). The Horizon 2020 program, a funding program for research and innovation (2014–2020), provided nearly 80 billion of funding to create opportunities for new ideas and remove barriers to innovation in Europe. Some subprojects of the program, such as CONNECTING, URBAN GreenUP, GROW GREEN, and UNALAB, have implemented NBS to improve climate resilience and water security (Faivre et al., 2017).

Following the successful Horizon 2020 funding program for research and innovation, the current Horizon Europe program until 2027 provides a budget of 95.5 billion euros to tackle climate change impacts and achieve the Sustainable Development Goals (SDGs) ("Horizon Europe"; Ricciardiello et al., 2021). The program is comparable to the previous one and consists of three general objectives and newly introduced separate missions (Innovation Funding, n.d.). In general, they aim to strengthen collaboration between different sectors and emphasize the power of research and innovation in the development and growth of cities. It also supports science and knowledge and boosts the EU's competitiveness ("Horizon Europe").

Several NBS for water security have been proposed and implemented in Europe to face the increasing drought and its impacts. However, the extent to which European countries have implemented NBS is challenging to assess as the available information is limited and fragmented (Trémolet et al., 2019). Table A2 inside the appendix shows a literature review of the current nature-based projects in Europe.

In line with NBS in the world, most existing regional projects are also successfully implemented (Table 3). An example of an ongoing project is given in an assessment by the European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation (2021). From 2009 to 2019, the first multi-functional wetland restoration and remeandering project (Tullstorpsån 1.0) was carried out in the rural areas of Sweden. As the 1.0 project gained success, the 2.0 project was arranged in 2019 to enlarge the agricultural resilience against floods and droughts. It is crucial to notice that this experiment was initially set up by a few local landowners, covering almost 100 NBS projects within a decade along 30 km of the river course. Another important aspect of this project is the created evidence base by the project itself and the extensive fair stakeholder involvement. The lessons learned from the past projects convinced current project holders in other areas to participate in the project. Also, more than ninety farmers, four hundred villagers, and local people are considered in the economic environment to discuss future projects and problems.

The latter aspect is also recommended in other reviewed papers. Ricart and Rico-amoros (2021) suggest a total involvement of the primary water consumers (in this case, farmers) in the process as they possess potential information about when and how constructed wetlands are efficient solutions to drought, water scarcity, and water pollution challenges. New forms of collaboration between and among different stakeholder groups might help face water scarcity and reduce water conflicts. Frantzeskaki et al. (2020) also affirms the need for a collaborative governance approach to successfully implement and operate NBS (a collaboration between urban planners and urban officers, citizens, NGOs, social innovation networks, and experts). In addition, different fora for the co-creation and co-design of NBS are required

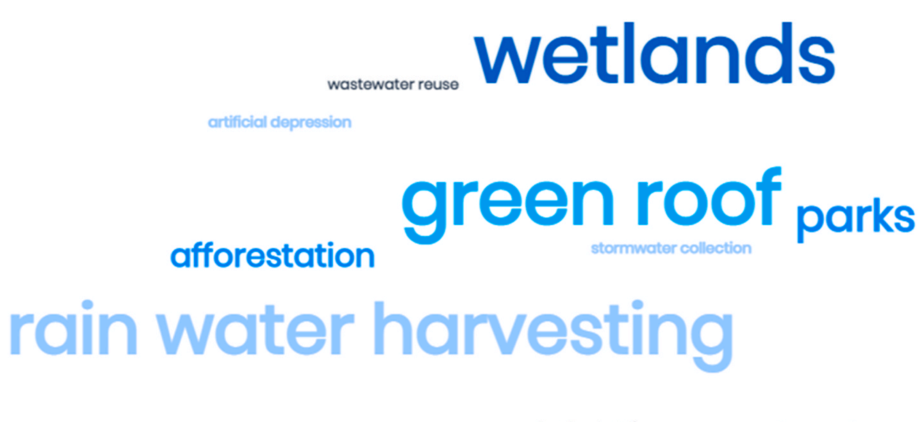

Fig. 4. The widely applied nature-based solutions (NBS) at the European scale (except in Belgium). The bigger the size of the text, the more widely the NBS application.

using urban social innovation as an essential instrument. A case study by ("NAIAD") opts for clear communication with water users about the situation to reach a successful solution. Based on a summary of existing NBS by Davies et al. (2021), bottom-up projects from citizens have an essential role in realizing green spaces. As they influence and change public policies, it is recommended to integrate these projects into the policies. Finally, the total involvement of different stakeholder groups and a collaborative approach are thus considered essential elements in climate change adaptation.

Based on a critical review by Oral et al. (2020) on NBS for urban water management in the Mediterranean region, the most frequently mentioned NBS are constructed wetlands. They are designed for water storage and infiltration, which are important functions to mitigate drought and remove nutrients and emerging micropollutants while providing additional co-benefits. Solely limited data is available about the implementation of treated wetlands in cities. Davies et al. (2021) also state that the limitation of space is a remaining challenge for successful implementation since it is difficult to create new green spaces due to the fast-growing and densely-populated cities. To realize the full range of potential benefits, urban planning and architecture must be combined to accommodate NBS more efficiently (Oral et al., 2020). Other challenges to the success of NBS in cities are related to private ownership (de Boer and Bressers, 2011), climate change, economy, expertise and knowledge, quality of life, and water-related hazards (Davies et al., 2021).

Many studies also show the benefits of each NBS and whether they can cope with droughts or other societal challenges (Frantzeskaki et al., 2020; Trémolet et al., 2019; "NetworkNature"; "CMCC"). Frantzeskaki et al. (2020) evaluate NBS in different European cities and mention for each implementation the benefits, including increased water retention, flood protection, food production, habitat restoration, and recreation. Trémolet et al. (2019) also offer both environmental and social benefits for natural wetland restoration and construction of wetlands in Spain. In Castilla y Leon, water availability and water security improvements are recognized. Equivalently, in the North Metropolitan Area of Barcelona, improved water quality and biodiversity, adaptation to floods and droughts, and more recreational opportunities are offered potential benefits. The riparian forest restoration and riverbank protection in Greece, described by Nikolaidis (z.d), also propose many benefits, including an increased resilience against climate change impacts, improved infiltration and water storage, reduction of drought risk, and additional benefits for the biodiversity and quantity and quality of the green (& blue) infrastructure. Hein et al. (2016) state the need for quantitative and comparable data to control the success of NBS restoration projects. However, in contrast to the NBS projects in the world, a quantitative assessment of the effectiveness of regional NBS for drought is lacking for each paper. Although the benefits and co-benefits are often mentioned and recognized, no evidence or modelling results are available to demonstrate the usefulness of each implemented NBS type for drought mitigation.

3.3. NBS to mitigate drought and water scarcity in Belgium

Belgium is one of the hotspots for water shortage and scarcity (De Ridder et al., 2020). Apart from the southeast region of England, Belgium has been registered as the most drought-hit region of Europe for some time (Trémolet et al., 2019). Current data indicates an increasing trend in more frequent and prolonged occurrences of low or very low groundwater levels in the past few years (2017–2022), particularly during the summer months when drought conditions are prevalent ("VMM", 2022). Belgium is characterized by a dense population, mainly in Flanders and Brussels, which consumes an intensive amount of water (e.g., households and industry) and leads to a high vulnerability to drought and water stress (De Ridder et al., 2020). Also, an overall decrease in extreme high and low flows is expected in the future climate. However, the direction and magnitude of change remain highly uncertain, and these uncertainties must be considered in future climate change adaptation measures (Leta and Bauwens, 2018).

Sigmaplan Flanders is an initiative to cope with the impact of climate change. It is not only designed for flood protection in the Scheldt and its tributaries, but it also offers solutions and measures in periods of extreme drought. They aim to catch and retain the rain and surface water to increase groundwater levels and storage ("Flemish Waterway"). Remeandering as a NBS plays a crucial role as it creates a longer trajectory and reduces the natural drainage of water, resulting in higher water availability. Secondly, the construction of wetlands and flood control areas contributes to a decrease in floods and droughts due to its "sponge function". They soak up the excess water in wet periods and slowly release it in periods of drought ("Flemish Waterway").

The Flemish "Blue Deal" (2019–2024) plays an essential role in the fight against drought and water scarcity. This prime initiative, deployed by the Flemish government, focuses on using specific structural instruments while involving important stakeholders such as industry and farmers. One of the six aims of the blue deal is to consider nature and the environment as part of the solution against climate change and, in turn, drought. It intends to restore specific ecosystems, such as forests, grasslands, meandering rivers, and wetlands. Therefore, the Blue Deal is in line with the concept of implementing NBS as a drought mitigation measure. Additionally, it not only focuses on staking NBS but also emphasizes saving water, efficient water use, circular use of water, use of alternative water sources, etc. ("Blue deal").

Many small projects have already been planned or carried out to secure water in the future. Table A3 in the appendix shows a literature review of the existing and ongoing NBS projects, including the NBS type, year of implementation, status, level of effectiveness, and possible recommendations set by the researcher to improve the results in the future. The number of projects aiming at restoring rivers and wetlands comprises the highest number (Fig. 5).

Although there is a recent upswing of small NBS-related projects in Belgium, only two scientific papers regarding regional NBS for drought mitigation were included in the review (Frantzeskaki, 2019; Gorissen et al., 2018). Frantzeskaki (2019) analyzes existing NBS projects in different cities, including "The Green Corridor" in Antwerp. This current project aims to connect people with nature and their sense of place in the city of Sint-Andries. Equivalent to the wetland restoration and remeandering project in Sweden (Tulltorpsån 1.0), an important aspect is the involvement of different stakeholder groups with divergent backgrounds and knowledge while creating the space. Although this linear park was initially constructed for flood protection, it also brings other benefits related to water retention, recreation, and biodiversity (Frantzeskaki, 2019). The second drought-coping group of NBS in Belgium is the (Food) & Nature conservation and restoration projects (including blue-green infrastructure) in Genk, namely the Green Corridor (Stiemerbeek Valley), Bee Plan, Heempark, and Organic allotment gardens projects (Gorissen et al., 2018; Kabisch et al., 2017). Although these projects increase resilience against climate change, there are also many other co-benefits, such as increased sustainable urbanization, restoration of the ecosystems and their functions, and increased education about NBS ("Genk").

The Sigmaproject comprises different nature-based projects in

Fig. 5. The widely applied nature based solutions (NBS) in Belgium. The bigger the size of the text, the more widely the NBS application.

Flanders, for example, the Project Bovendijle and Dijlemonding, located in the Dijle-Zenne basin. The Sigmaproject Bovendijle also has different subprojects, such as the construction of wetlands and flood control areas in Rijmenam, Pikhaken, and Hollaken-Hoogdonk ("Sigma project"). The Sigmaproject handles a different approach to coping with rivers' embankments. High dikes were built on both sides of the riverbed in the past, so the river only overflowed its banks during very extreme events. During the floods of 1953 and 1976, this method proved to be insufficient. The Sigmaproject opted for a different approach: lowering and reinforcing the existing dikes and constructing a higher ring dike further away, creating a flood control area between the two dikes. This approach allows the river to overflow regularly in the flood control area, removing large volumes of water from the bed and reducing the flood risk in the more downstream urban areas. Next to flood protection, the ecology is also allowed to develop in and around the flood control area. The subproject in Rijmenam and Hollaken-Hoogdonk, respectively covering an area of 60 and 70 ha, will be fully established as a flood control area ("Sigma plan").

In the subproject of Pikhaken, a wetland of 30 ha is constructed instead of a flood control area. The reason can be explained by the tides and the flow of the water. The controlled flooding can be most easily provoked in the other two areas. Those areas are located where the rising of the tides collides with the water from the upper reaches at elevated water levels due to, for example, abundant precipitation. Additionally, Pikhaken is established as a habitat directive area. So, the aim is to invest in fully reconstructing the natural ecological state. In the case of a flood control area, the pollution with Dijle water could harm the area's natural value. Therefore, constructing a wetland is a better option in the area around Pikhaken. The implementation of wet grasslands can bring back some rare species that used to be abundant in the valleys of the tidal rivers.

The Sigmaproject Dijlemonding is divided into subprojects: Grote Vijver, Tien Vierendelen, and Zennegat. At the Dijle's mouth, the Zenne, Nete, and the Canal of Leuven-Dijle converge with an additional influence of the tides. This place is a very important water junction, which creates the opportunity to implement different nature-based projects to reduce climate change risks and increase nature's value (Coordinatiecommissie Integraal Waterbeleid, 2021). Both projects include the implementation of a flood control area. In the Zennegat (65 ha) and the Grote Vijver (100 ha), the flood control areas have reduced tides that mimic a tidal river's natural processes. Via combined inlet and outlet sluices, a small amount of water can flow into the flood control area during flow tides; in ebb tides, the water flows back to the river. Thence, the sporadic tidal nature of mudflats and salt marshes is recovered ("Sigma plan"; Coordinatiecommissie Integraal Waterbeleid, 2021). However, in line with the existing NBS in Flanders, the information is collected from non-scientific literature (e.g., publications from Sigmaplan or website articles).

3.4. Comparison of NBS across the different scales

As shown in Fig. 6, small- and large-scale NBS are equally represented in the analyzed literature. For 21% of the publications, the scale could not be clearly defined, while both scales can be assigned to 8% of the papers. The full table summarizing small- and large-scale applications is available in the appendix (Table A4). From the literature review, 44 publications assessed the effect of small-scale solutions. These differed from common methods such as rain gardens, bio-swales, and retention ponds (Chalid and Prasetya, 2020a; Gülbaz and Kazezyilmaz-Alhan, 2017; Hankins et al., 2008) to lesser-known techniques such as a wicking tank, which supplies trees with water through synthetic wicks from a storage tank underneath (Nichols and Lucke, 2015). Additionally, some indigenous techniques that have been used for centuries, such as "Careo" channels and "amunas", that supply water through channels that are constructed in the mountains, which hold and infiltrate water (Jódar et al., 2022), were also mentioned within the literature. There is a vast range of small-scale methods at hand that are already being implemented, as can be seen from the 28 applied small-scale projects that this literature review was able to identify. The application ranges in variety, from multiple methods being used within one location, as was done in a retrofitting project of an Avenue in Los Angeles (Belden and Steele, 2011), or a single method, such as a retention basin in Germany (Fröhle et al., 2022). Also included in this category were experiments, which included ten examples. The experiments include innovative ideas such as Microbially induced Calcite Precipitation (MICP), which is a method applied at the soil level (Liu

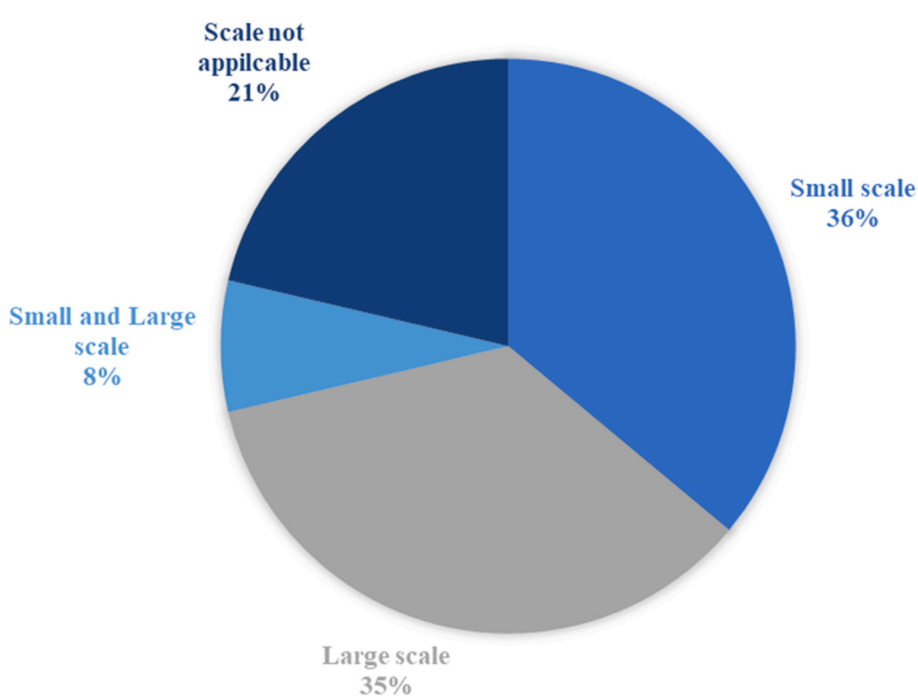

Fig. 6. The number of literature that corresponds to small scale, large scale, and without scale mentioned.

et al., 2021).

Furthermore, 43 of the publications mentioned large-scale projects such as sponge cities or water-sensitive urban design strategies, green infrastructure, or agroecology. Among these large-scale NBS were also efforts to apply small-scale solutions in a broader way, such as in a city-wide implementation of green infrastructure (Jokar et al., 2021; Zhang et al., 2022). Some of the studies included in this category also tried to model the large-scale effects of NBS on drought or the potential for such solutions, such as Jakubínský et al. (2022), where the suitability of different areas for infiltration was assessed. For the large-scale application of NBS, it became visible from the literature that watershed or even country-wide policies are not yet being implemented in many places. For the large-scale implementation of NBS for drought, only 19 applied projects could be found. These included approaches such as the monitoring of the adoption of drought-proof landscaping (Lassiter, 2022) or forests (McCauley et al., 2022; Y. Wang et al., 2019) and wetlands (Belle et al., 2018; Nolan et al., 2018). The concept of a sponge city was also mentioned several times. The scale of the projects often depended on the location but not on the methods themselves, meaning that small-scale solutions were applied on a bigger scale. An exception to this is agricultural and farmland practices that could be adopted on a large scale, such as the use of drought-adapted crops (Hussain et al., 2020) or rangeland resting (Ouled Belgacem et al., 2019).

Nine of the publications had to be classified for both categories, as they mentioned small-scale and large-scale applications within the same study, even if in different projects. An example of this is the publication by Rogé et al. (2014), which discusses different methods used by farmers in Mexico (Table A4), which are small-scale solutions but used within a whole region, therefore possibly having a large-scale impact. Twenty-six of the articles were relevant to the topic of NBS and drought but did not have a project that could be classified to a certain scale (Fig. 6). An example of this would be the Framework *Hydro-meteorological risk assessment methods and management by nature-based solutions* by Sahani et al. (2019).

When assessing the scale of the projects, no distinction was made between theoretical and practical approaches. Therefore, modelling of the effects of NBS for drought was considered in their scale in the same way as practical examples of implemented projects. This is why the number of large-scale implementations might seem high, although the implementation of landscape- or watershed-scale holistic approaches to drought mitigation is still scarce (Fig. 7). The study by Koiv-Vainik et al. (2022) examines the stormwater retention capacity of NBS under different climatic conditions. Although this study focused on mitigating the flooding risks as a response to climate change and was left out of the review, they suggest performing more large-scale case studies to fill missing data gaps, resulting in reduced or eliminated barriers of NBS implementation.

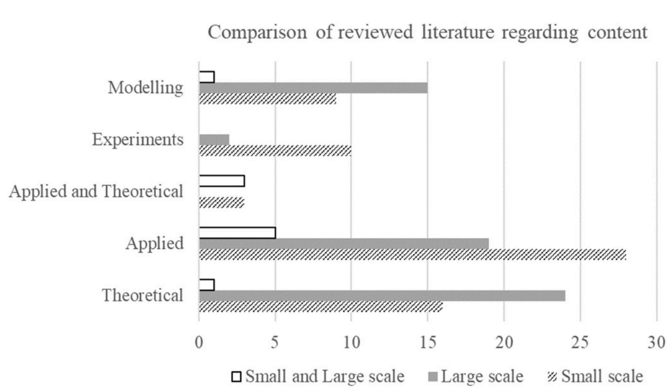

Fig. 7. Comparison of reviewed literature regarding content - Applied or Theoretical, Methods (Focus on Experiments and Modelling).

3.5. Lessons learned from different projects

Diverse NBS types are implemented globally, at regional and country levels. Typical examples are landscape (catchment) restoration, remeandering, flood control areas, green infrastructure, forest and river restoration, and restoration and construction of wetlands. The latter is mentioned in most research and appears to be a frequently-mentioned NBS type in Belgium and the Dijle-Zenne catchment (Oral et al., 2020; Ricart & Rico-amoros, 2021; The World Bank Group, 2022; Frantzeskaki, 2019; Trémolet et al., 2019; Cohen-Shacham et al., 2016).

In contrast to the global and regional NBS, only a couple of projects in Belgium have reached the prosperous implementation state: the Food & Nature conservation and restoration projects in Genk (Gorissen et al., 2018) and the river restoration and remeandering pilot project along the Demer in Rotselaar ("Aarschot"). Similar to the regional NBS and unlike the global NBS, a quantitative understanding of the effectiveness of drought-specific NBS is absent. Moreover, there is no evidence or modelling results to validate the effectiveness of each implemented NBS type. Although the NBS in the Dijle-Zenne catchment are effective and build resilience against floods and droughts, no research is available to recognize the (co)-benefits and the performance against drought. Quantitative validation of the effectiveness of each implemented NBS type for drought mitigation is also missing.

Flanders can still learn from other parts of the world. Although the Blue Deal provides several million euros to subsidize nature-based projects to cope with drought and water scarcity, there are still many limitations. First, because there is no sense of urgency and insufficient funding, projects are only implemented locally. Only a few pilot projects have been realized at a small scale in Flanders yet ("Blue deal 2"; "Blue deal"). There is thus still room to scale up these initiatives all over the country or region, like some global initiatives such as the "Sponge Cities in China" (Liu et al., 2017; Nguyen et al., 2019), the beaver restoration projects in the Western USA (Pilliod et al., 2018), or the rainwater harvesting technologies in Southwestern USA (Radonic, 2019). Although pilot projects are primarily voluntary, implementing stricter legislation might motivate people to carry out projects.

A second lesson might be to shorten the time between planning and realizing projects in the fields of Flanders. In the world, pilot projects are realized in less than one year (Sy et al., 2014). Many extensive worldwide projects also have a short implementation time. Peculiar examples are the WHaTeR project in Sub-Saharan-Africa (Critchley and Di Prima, 2012) and the HYDROUSA projects in the Mediterranean region (Oral et al., 2020), which are both implemented in four years. Another successful example is Sweden's multifunctional wetland restoration and remeandering project, implemented in only a decade. In Belgium, the lack of cooperation of local authorities slows down some potential projects, such as the restoration of wetlands in the 'Valei van de Zwarte Beek' due to permission declines. Not only the local authorities must be blamed, as the Flemish policy might also contribute more to achieving the goals of the Blue Deal.

The primary obstacles are the regulatory and institutional barriers, along with financial constraints ("Blue deal 2"; "Blue deal", Coordinatiecommissie Integraal Waterbeleid, 2021). Legislative regulations and policies might not fully support NBS projects for drought mitigation, and some policies can even hinder their adoption. Implementing these projects requires collaboration between agencies, private organizations, and local authorities. The complex governance structure and institutional barriers might slow decision-making and stakeholder coordination. Additionally, the lack of budgets, such as the Blue Deal, may limit the available funding for these projects, making it challenging to scale up beyond pilot projects (Coordinatiecommissie Integraal Waterbeleid, 2021). Secondly, the lack of social engagement plays a role. The success rate of NBS relies on the active engagement of local communities and stakeholders. If communities are not adequately involved in the decision-making process or do not perceive direct benefits, resistance or opposition to these projects may arise. As demonstrated in the case of

Genk, one of the challenges is the knowledge gap on how to insert effective collaborative governance to implement and maintain NBS (Frantzeskaki et al., 2020). Furthermore, Flanders, being a heavily urbanized region in Belgium, faces a scarcity of land suitable for NBS implementation. This is mainly because rapid urbanization has resulted in the disappearance of natural landscapes. Compared to other densely populated European regions, Flanders has the highest proportion of urban and built-up areas and the lowest proportion of natural ecosystems (Bastiaensen et al., 2023). As the population continues to grow and urban areas expand, the loss of natural ecosystems persists, leading to a potential further reduction in suitable space for NBS. This presents a significant challenge for implementing NBS effectively in the region.

On the contrary, worldwide projects can also learn from the European and Flanders projects. Many European publications mention the importance of collaboration and stakeholder involvement (Frantzeskaki, 2019). They are essential in bringing together different kinds of expertise. Especially by involving local communities and farmers in the decision-making process, the region's knowledge is transferred, ensuring all aspects are considered and increasing the successful implementation of NBS. Moreover, involving stakeholders from the early stages of a project helps build trust, a sense of ownership and enhances acceptance and stakeholder awareness. Individuals who are included in decision-making tend to be more supportive and actively engaged in NBS. Involving not only bottom-up projects from locals and citizens but also policymakers and government agencies early in the process helps align NBS with existing policies and regulations, creating opportunities for new water management policies that ensure sustainable water and other natural resources use. Additionally, the learning process is significant. Stakeholders can learn from what has worked or not worked in the past on similar projects. By sharing their successes and failures, they can develop better ways to manage the project over time and improve its outcomes (Davies et al., 2021; European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation, 2021; Frantzeskaki et al., 2020; Ricart & Rico-amoros, 2021). Although Flanders still has much to learn, the Blue Deal stresses this aspect. Everyone must contribute, including the citizens, government, farmers, scientists, companies, and other associations, to be able to roll out positive results and battle drought in the future. Two important existing examples are the food & nature conservation and restoration projects and the multifunctional wetland restoration and remeandering in Genk (Flanders) and Sweden (Europe), respectively. Notably, the local communities initiated those NBS projects (Gorissen et al., 2018).

Different aspects related to stakeholder participation, including fair public participation, recognition of diverse expertise, and the importance of balancing diverse knowledge perspectives, can influence the extent to which stakeholder involvement contributes to the effectiveness of environmental management policy responses in urban planning (Mabon et al., 2022). Sustainable urban planning often relies on active community engagement, as it can lead to policies and initiatives more aligned with local communities' needs. Effective public participation can contribute to sustainability by fostering a sense of ownership and cooperation among stakeholders. However, Mabon et al. (2022) argue that mere participation will not significantly influence the policy responses in cases where the insights and expertise of residents cannot change the direction in which the city plans the adaptation strategies. Recognition and valuing diverse forms of expertise are essential for sustainable environmental management policies. Different experts can provide insights into various aspects of sustainability, such as ecological resilience, social equity, and economic viability. Knowledge in the context of urban NBS may lead to policies focused solely on measurable targets, as depicted by Mabon et al. (2022). This suggests a more balanced approach, which considers a diversity of knowledge perspectives, to contribute to the development of more sustainable environmental management policies. These elements contribute to the development of holistic, equitable policies that are capable of addressing the complex challenges of urban sustainability.

The occurrence of wetlands in many studies is not random, as they have a great potential to mitigate slow-onset drought events in the future (Endter-wada et al., 2020). Wetlands are not only indispensable for humans' survival but also belong to one of the world's most productive ecosystems. Apart from drought mitigation, wetlands contribute to other ecosystem services such as flood, stormwater, and coastal protection, regulating regional climate and soil moisture, improving water quality and biodiversity, increasing water efficiencies, carbon sequestration, and groundwater regeneration (Alikhani et al., 2021). Many studies prove the disappearance of wetlands due to major trends such as climate change, land use change for intensive agriculture, domestic and industrial infrastructure, and over-exploitation of freshwater and wetland resources to sustain a growing population (The Ramsar Convention Secretariat, 2017). Additionally, quantitative research has stated the fast global loss of wetlands in the near past. 64–71% of the wetland area has been degraded or lost during the 20th and early 21st centuries (Davidson, 2014).

In Flanders, the same trend is observable. A study by Decleer et al. (2016) claims that about 75% of the total wetland ecosystems have been lost in the last 50–60 years due to rapid urbanization, intensification of agriculture, and increased forest area. Although only 5% of the total area of Flanders remains (68.000 ha), there is still a great potential for restoration. Calculations show the possibility of creating or restoring more or less the appropriate biophysical and ecological conditions of 147.000 ha of wetlands (Decleer et al., 2016). Although the Flemish Blue Deal has already funded the restoration of 1.600 ha of wetland area, it is not enough to mitigate droughts and only a minor fraction (less than one percent) of the covered area in mid 20th century. Wetlands are highly valuable ecosystems that offer a multitude of benefits, especially in the context of drought mitigation in Flanders. According to a study conducted by Decleer et al. (2016), wetlands provide essential ecosystem services that play crucial roles in sustaining the environment and supporting human well-being.

One of the key ecosystem services of wetlands is drought regulation. During periods of drought, wetlands act as natural buffers by storing water accumulated during wet spells and gradually releasing it during dry periods. This function helps to maintain water levels in surrounding areas and recharge groundwater reserves. Through their porous soil and vegetation, they allow water to percolate into the ground, recharging aquifers and providing a sustainable and natural water supply that is vital in mitigating the impacts of droughts ("Natuurpunt"). Furthermore, wetlands serve as natural filters, effectively removing pollutants and excess nutrients from water before it enters streams, rivers, and groundwater. This purification process enhances water quality, reducing the risk of contamination and benefiting both human populations and aquatic life. In addition to their role in drought and water quality regulations, wetlands act as effective flood control measures. They can absorb and store excess water during heavy rainfall or flooding events, thereby reducing the risk of downstream flooding and protecting communities and infrastructure ("Natuurpunt"). Moreover, wetlands are rich and diverse ecosystems that offer habitat and breeding grounds for a wide range of plant and animal species. They contribute significantly to biodiversity conservation in Flanders, supporting various rare flora and fauna ("Natuurpunt"). Beyond their ecological significance, wetlands hold cultural and recreational value for local communities. They offer recreational opportunities such as birdwatching, hiking, and nature appreciation while also serving as places of traditional practices and cultural heritage ("Natuurpunt").

Wetlands in Flanders have faced the impact of both global trends and local factors, resulting in significant loss during the 20th century. Among the local factors contributing to this loss, intensive agricultural practices and land use changes have been particularly detrimental (Schoukens, 2022). Presently, about 45% of the region is devoted to intensive agriculture, which involves heavy fertilization, drainage, and irrigation, leading to wetland conversion for farming purposes (Meyer et al., 2011). This transformation has significantly diminished natural wetland habitats, sacrificing them for agricultural expansion. Urbanization has also taken a toll on wetlands, with approximately 13% of the region's soil now paved and 26% urbanized (Meyer et al., 2011). As human settlements and infrastructure expanded, they encroached upon wetland areas, further contributing to their decline. The remaining wetlands, covering only a small portion of the region, face additional threats like eutrophication and pollution due to disrupted hydrological regimes (Decleer et al., 2016). Local pollution sources, including industrial discharges, urban runoff, and agricultural runoff, continue to contaminate wetlands, negatively impacting water quality and harming flora and fauna.

While the above-mentioned local factors are primary drivers, climate change acts as a global aggravator, compounding the challenges faced by these vulnerable ecosystems. Climate-induced changes, such as reduced summer precipitation, higher temperatures, and increased evaporation, lead to drier soil conditions. This poses a threat to habitats and species adapted to moist climates, including wetland ecosystems, which face increased vulnerability as extreme droughts become more frequent. The intensified frequency of extreme droughts may even lead to the reduction or complete elimination of these ecosystems (Effecten van klimaatverandering op bos en natuur in Vlaanderen, 2015).

Future research and initiatives focusing on wetland restoration as a NBS for drought mitigation can significantly enhance ecosystem resilience and sustainability. To achieve this, several key recommendations have been proposed. Firstly, conducting more hydrological studies related to low-flow conditions during droughts will help understand the role of wetlands in water storage and groundwater recharge (Cohen--Shacham et al., 2016; Moeskops, 2018). Secondly, raising awareness through education and training is crucial in changing perceptions about the importance of wetland restoration for drought mitigation among the public, decision-makers, and stakeholders (Nguyen et al., 2019). Thirdly, long-term monitoring of wetland restoration projects will provide valuable insights and support future efforts. Once the effectiveness of a project is assessed in mitigating drought, other projects will more likely be setup, and other local people will be convinced to participate in the project (European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation, 2021). Integrating these measures into climate change projections and models is also essential to ensure that restored wetlands can withstand future climate challenges and garner support from local authorities and citizens (Moeskops, 2018). Collaboration between researchers, local communities, and policymakers is recommended for a holistic approach (Frantzeskaki, 2019; Ricart & Rico-amoros, 2021). Community engagement is particularly vital, as local knowledge can determine when and how wetlands effectively address water scarcity and pollution challenges, leading to successful implementations (Ricart & Rico-amoros, 2021). Lastly, while wetland restoration is valuable, additional measures such as wetland recovery or carbon sequestration may be necessary to further mitigate water availability issues (Trémolet et al., 2019).

4. Discussion and conclusion

The paper presents a critical state-of-the-art literature review on NBS for climate change mitigation at different levels, including the global (worldwide), regional (Europe), and country (Belgium) levels. Focusing on NBS specifically targeting drought, this paper is unique as the effectiveness of drought mitigating NBS is scarcely studied. Moreover, the major obstacle is the assumption of flooding-based NBS applications as a direct measure of drought. Due to this, less attention is given to drought-mitigating NBS, and appropriate measures should be adopted targeting specifically drought. The review procedure started by constructing a table for all levels. Different aspects were delineated, and then a comparison was made between small- and large-scale applications, which can indicate the degree of mitigation.

As few scientific publications evaluate existing drought-relevant NBS, the information is collected from various sources. Scientific reports, non-scientific papers, and website articles are included to incorporate as much local knowledge as possible. Especially regarding the NBS in Belgium, for which only two scientific publications are found, non-scientific articles and grey literature (books and reports) were considered. To ensure publications are not excluded, articles focusing on floods are also included if they are recognized as beneficial in increasing water storage and infiltration.

Most existing NBS projects have reached the requested implementation state worldwide, and in Europe, while in Flanders (Belgium), most projects linger in the pilot project stage. Despite the launch of the Flemish "Blue Deal," there is still a lack of funding and a sense of urgency, which hinders the successful implementation. A second remark concerns the longer time between the planning and implementation stages in Flanders. Possible solutions might be providing financial incentives, implementing stricter legislation motivating stakeholders to carry out projects, and strengthening cooperation among local authorities. There are two major benefits of fiscal incentives: 1) suggesting fiscal incentives instead of implementing stricter legislation can be a viable approach to encourage the development of innovative technologies by providing financial rewards for those who invest in green solutions (Köhler and Kaiser, 2021). 2) by introducing financial incentives, policymakers can create a system where compliance with certain policies or regulations becomes more attractive due to the potential economic benefits or advantages associated with it, encouraging implementation or maintenance of NBS by the public (Lemos and Minzner, 2013). However, while valuable, fiscal incentives might not be fully effective on their own and should be integrated into a comprehensive approach that includes strict regulations, education, and public awareness campaigns. As concluded by Mendonça et al. (2021), different policy instruments are needed to encourage the implementation of NBS. Stricter legislation becomes essential in situations where voluntary measures fall short or when the severity of drought impacts poses significant risks to human and environmental health. By combining fiscal incentives with robust regulations, we can tackle the challenges of drought and promote sustainable water management practices.

Specifically for Flanders, a comprehensive and integrated approach is required to promote collaboration among policymakers, scientists, local communities, and relevant stakeholders. Aligning policies, limiting institutional barriers, and providing adequate financial support are essential steps to pave the way for the successful implementation of NBS projects for drought mitigation in Flanders, Belgium.

However, the world can also learn something from Belgium: participation of different stakeholder groups played an important role in the realization of different projects by including diverse voices, ideas, and values. Although the Blue Deal is not fully realized yet, it embraces this concept and pleads for a collaborative approach between the citizens, government, farmers, scientists, companies, and other associations. In particular, the involvement of the local communities is essential. Considering the local knowledge of residents contributes to a better project design and might even improve the implementation.

Furthermore, (co-)benefits are stated, and the effectiveness is mentioned globally and regionally. However, for Europe, it is only stated whether they are effective against droughts or not without any quantitative evidence or model validation results to control the success of restoration/construction projects. On the contrary, a quantitative assessment of the effectiveness of drought is given in a few publications in the world, which proved to have a positive impact on groundwater recharge. As most information is taken out of grey literature for Flanders, no information on the benefits and no quantitative model validation on the effectiveness of drought is given. Consequently, a common effectiveness evaluation framework shall be followed, which gives policymakers a clear view of the different NBS investment options. Finally, the comparison between small- and large-scale applications indicated the lack of implemented projects at a larger scale. Moreover, the assessment of NBS for drought mitigation is still at the modelling stage, indicating less attention is given to drought regarding NBS applications.

Among the various drought-mitigating NBS, wetlands are recognized to have significant restoration potential from worldwide to Belgium. Despite its potential for future drought mitigation and the additional help of the Flemish Blue Deal, few initiatives were taken to improve the conditions of wetlands in Flanders. Future research is recommended to investigate the effectiveness of wetland restoration and implementation at a larger scale. Once the evidence base is enlarged and the sense of urgency is spread, more initiatives will be taken to mitigate droughts. A good and effective stakeholder engagement approach, including residents, will also make room for collaboration and help convince people that NBS are creating a better future. In future research, geohydrological modelling will be the key to assessing and quantifying drought's future impacts before and after wetland restoration.

Geohydrological modelling might play a crucial role in assessing the impact of NBS on drought. It involves integrating geological and hydrological data to simulate and understand the behavior of water in the Earth's subsurface (Yimer et al., 2023b, 2023c). A previous study by (Ejaz et al., 2022)predicts long-term changes in groundwater storage and depletion by considering not only the rainfall-runoff processes but also the groundwater stores and exchange fluxes together with streamflow throughout the whole geohydrological modelling process. It is possible to simulate water movement in the subsurface, including flow through aquifers and the interactions between surface water and groundwater. Understanding these dynamics is essential for evaluating how NBS may influence water flow and availability during drought periods, as we need to get more insight into how groundwater storage is changed after the implementation.

It is to be noted that due to the search string, some NBS projects/papers are not included in our analysis. The study made by Mabon et al. (2022), Koiv-Vainik et al. (2022), and Meilinger and Monstadt (2022) are few examples of such studies which are excluded from our review. The latter has a unique point from a sustainability standpoint, where communities can lessen their reliance on centralized stormwater methods and increase their resistance to climate change and other environmental concerns by supporting the use of decentralized and green infrastructures. Cities may share the costs and benefits of public infrastructure development and encourage more equitable and sustainable methods of stormwater governance by modifying legislation and finance tools to support green infrastructure. Additionally, communities may improve their ability to manage stormwater effectively and encourage more integrated and sustainable land use by enhancing the synergies between stormwater and land use regulation.

Droughts' frequency, duration, and intensity have increased in the last few years. This trend is also expected to continue in some parts of the world. Therefore, staking NBS as the solution is put in the spotlight instead of a technical solution because they create multiple benefits, not only for droughts but also for climate change and other essential ecosystem services needed to sustain human life. With this review, we exposed the urgency of exploring the potential of drought-mitigating NBS and producing more quantitative evidence of their effectiveness. More research is certainly needed at the global level, but even more in those regions of the world, such as Sub-Saharan Africa, that are currently facing strong negative impacts caused by drought.

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Web reference list

Source	Last accessed	Abbreviation
https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en	10/31/2022	Horizon Europe
https://connectingnature.eu/oppla-case-study/20457	January 11, 2022	NAIAD (Mayor et al. 2020)
https://networknature.eu/embedded-case-study/18366	February 11, 2022	NetworkNature
https://www.cmcc.it/projects/etccca-european-topic-centre-on-climate-change-impacts-vulnerability-and-adaptation-2019-2021	March 11, 2022	CMCC
https://www.dov.vlaanderen.be/page/actuele-grondwaterstandindicator	July 28, 2023	VMM
https://www.vlaamsewaterweg.be/rivier-en-natuurherstel	May 11, 2022	Flemish waterway
https://www.zuhaldemir.be/sites/parlement.n-va.be/files/generated/files/news-attachment/blue_deal_clean_0.pdf	June 11, 2022	Blue deal
https://networknature.eu/casestudy/19455	July 11, 2022	Genk
https://www.integraalwaterbeleid.be/nl/bekkens/dijle-en-zennebekken/in-de-kijker/okt-2019-sigmaproject-dijlemonding-en-bovendijle	August 11, 2022	Sigma project
https://www.sigmaplan.be/nl/	September 11, 2022	Sigma plan
https://www.sigmaplan.be/nl/nieuws/er-stroomt-opnieuw-water-door-de-meander-in-aarschot/	October 11, 2022	Aarschot
https://www.vrt.be/vrtnws/nl/2022/07/25/blue-deal-twee-jaar-later/	October 11, 2022	Blue deal 2
https://www.natuurpunt.be/pagina/wetlands4cities	July 28, 2023	Natuurpunt

Declaration of competing interest

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

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Data availability

Data will be made available on request.

Appendix. 8

Table A1
Current nature-based solutions at a global scale along with their type, year of implementation, current status, level of effectiveness, and recommendations set by the researchers for the future.

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
(2022); Zheng et al. (2021)	Kumamoto (Japan)	Artificial groundwater recharge in abandoned paddy rice fields with payment for ecosystem services (PES)	2004	Successfully implemented	Yes: Increase in recharge: majority of total recharge is the groundwater recharge from paddy fields (33,61% in 2016)

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Table A1 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
	Further recommendations	This concept of groundwater recharge with PES is less feasible in developing countries due to the high rate of payments, so other methods need to be developed similar to PES to support nature-based solutions. Other studies are essential that improve the accuracy of the estimated groundwater recharges.			
Cohen-Shacham et al. (2016)	Fort Collins, Colorado (USA)	River restoration and riparian wetland restoration	2004	Successfully implemented	–
	Further recommendations	Lower-flow scenarios need to be examined further during the design stage to better understand the interaction between floodplain and river. Restoration and flood risk control practices need to be reconsidered in the face of increasing flash floods. Riparian restoration practices need to be done carefully.			
(2018); Engström et al. (2017)	New York City (USA)	Green infrastructure: extensive green roofs, rain gardens	–	Successfully implemented	–
	Further recommendations	Including more interventions in the analysis and additional analytical techniques is recommended. The existing framework should be enlarged by additional resource interactions and targeted data collection. Different stakeholders must be included to understand the potential impact of the approach fully.			
(2018); Wild (2011)	New Mexico, Nevada, Colorado, Idaho, Montana, Oregon, Utah, Washington, California, Wyoming (Western USA)	Beaver restoration projects	–	Successfully implemented	–
	Further recommendations	Further research is necessary to establish clear guidelines for efficiency and best practices: - Further research may be done to assess the most suitable (both social and ecological) locations for beaver restoration projects. - More research is required to state the importance of beaver restoration projects for climate change mitigation (drought). - There is also a need for a better understanding of the regulatory requirements, social impacts, and the costs and benefits of different restoration projects. - Also needed is research on the harmful effects of those restoration projects and how to mitigate them. - More in-depth research into the perceptions and impacts of those projects on public and private lands is required.			
Radonic (2019)	Tucson, Arizona (Southwestern USA)	Rainwater harvesting	–	–	Yes: Recognized benefits are more water supply resulting in demand reduction in potable freshwater
	Further recommendations	Water conservation must be understood in order to include waste reduction and reuse of captured water for diverse uses in cities.			
Cui et al. (2021); Lim and Xenarios (2021)	Bishan (Singapore)	Green urban park and river restoration	2012	Successfully implemented	Yes: Increased water supply (also increase in water quality, food management, and recreation and tourism)
	Further recommendations	Further research is needed to quantify the effectiveness and other benefits of the project, such as mental health benefits, access to green space, and reducing low-income communities. For new projects, nature-based solutions need to be planned from the beginning during the city build-up, not in the already existing urban infrastructure (considered from an urban-upgrade perspective).			
Liu et al. (2017); Nguyen et al. (2019)	China	'Sponge Cities': green infrastructure, permeable pavement, reconstruction of lakes and wetlands, and reuse of rainwater	2013 – on-going	Active - Pilot project stage	Yes: Improved urban water logging (also improved water-related ecosystems, industrial development, overall health, and well-being)
	Further recommendations	Solving technical and physical challenges by: - Providing guidelines and sufficient performance data for each city - Building a new simulation model for 'Sponge City' design before implementation - Developing specific green materials for each city - Increasing the involvement of local experts Financial challenges need to be addressed by constructing an economic assessment tool and raising awareness about the projects' potential environmental and economic benefits to attract funding from the private and public sectors. Legal and regulatory challenges can be solved by strengthening the coordination between agencies and improving integrated water management. Also, the local legislation frameworks need to be enhanced. Public awareness and local acceptance can be achieved through education and training, which changes public perceptions.			
Wang et al. (2019)	Southern China	Forest Ecosystem-Based Adaptation (EBA)	–	–	Yes: Natural forests and not planted forests have a positive impact on the availability of water for irrigation
	Further recommendations	Forest EBA should be included in the national development plans for climate change adaptation. China needs to adapt the policy around 'The Natural Forest Protection Project' by including the forests lying outside the reserves. Understanding the role of 'Forests' in climate change adaptation is essential, especially in developing countries.			
Sy et al. (2014)	Bobo-Dioulasso, Burkina Faso (Sub-Saharan Africa)	Green spaces: greenways	March 2013–February 2014	Successfully implemented (Pilot project)	–
	Further recommendations	More technical assistance is required in the field, as well as more political support. There is great potential to mimic this project in other greenways in the city, but only if it is effectively implemented and legally approved. The fund "Fund for Interventions in the Environment" allows promoting this NBS on a bigger scale to tackle climate change impacts and ensure food safety.			
Critchley and Di Prima (2012)	Burkina Faso, Ethiopia, South Africa, and Tanzania (Sub-Saharan Africa)	Water harvesting technologies (Project: WHaTeR)	2011–2015	Successfully implemented	Yes: the water harvesting storage tanks in South Africa increase the water security of most of the households and reduce the pressure on water supply (other benefits are recognized: improved food quantity and quality security)

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Table A1 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
	Further recommendations	In all countries, it is shown that a more holistic approach will increase the understanding of water harvesting structures and improve the implementation of water harvesting technologies. If a systems approach is applied, insight can get gained into how and why downstream and upstream farmers integrate their knowledge about water harvesting technologies into their farming practices. A more participatory approach is also essential to reach a sustainable water harvesting technology. Farmers, both upstream and downstream, must be involved in the designing and implementing stage to avoid further conflicts and to give them a feeling of ownership.			
Welderufael et al. (2013)	Central region South-Africa	Infield rainwater harvesting	–	Successfully implemented	Yes: Improvement of water infiltration: the infield rainwater harvesting scenario resulted in more groundwater recharge (40 mm/year) compared to the baseline scenario (32 mm/year) and conventional agricultural scenario (19 mm/year)
	Further recommendations	There are still uncertainties in the modelling results. The limited data on soil and subsoil physical properties affects the water yield components, including the lateral and groundwater fluxes. Although the monthly water yield increased, the annual water yield remains the same after implementing the infield rainwater harvesting technique.			
The World Bank Group (2022)	Ghana (West Africa)	Reforestation and land restoration (Project: Sustainable Land and Water Management (SLWM))	2014 – on-going	Active (on-going)	Yes: Recognized benefits are groundwater recharge and water table stabilization (+ additional benefits related to employment enterprise property, tourism recreation, biodiversity, and carbon sequestration)
	India	Forests: construction of recharge pits, ponds, and vegetative structures; perimeter rehabilitation with Napier and other grasses; forestry activities (Project: Uttarakhand Decentralized Watershed Development II Project)	2014–2022	Successfully implemented	Yes: Recognized benefits are groundwater recharge and water table stabilization (+ additional benefits related to agriculture, fisheries, and forestry income)
	Pakistan	Eco-solutions: implementation of vegetation to protect embankments (Project: Sindh Resilience Project)	2016–2022	Successfully implemented	Yes: Recognized benefits are disaster risk reduction and water conservation
	Mali	Reforestation: natural resource management	2014–2020	Successfully implemented	Yes: Recognized benefits are groundwater recharge and water table stabilization (+ additional benefits related to agriculture, fisheries, and forestry income, employment enterprise property, biodiversity, and carbon sequestration)
	Madagascar	Reforestation (Project: Madagascar Emergency Food Security and Social Protection Project)	2014–2018	Successfully implemented	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income)
	Togo	Reforestation, restoration natural waterways and wetlands (Project: Integrated Disaster and Land Management Project)	2012–2017	Successfully implemented	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income, biodiversity, and carbon sequestration)
	Ethiopia	Afforestation, sustainable land management (SLM) (Project: Ethiopia Sustainable Land Management-II)	2014–2019	Successfully implemented	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income)
	Tajikistan	Afforestation, SLM (Project: Environmental Land and Management and Rural Livelihoods Project)	2013–2018	Successfully implemented	Yes: Recognized benefits are groundwater recharge and water table stabilization (+ additional benefits related to agriculture, fisheries, and forestry income, employment enterprise property)
	Samoa	Afforestation, river floodplain restoration, coastal wetland restoration, mangroves, and coral reef restoration	2014–2021	Successfully implemented	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income, and biodiversity)
	Afghanistan	Integrated watershed management, sustainable land, and water management techniques (Project: Emergency Agriculture and Food Supply Project)	2021 – on-going	Active (on-going) until 2022	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income, climate adaptation or resilience, and flood risk reduction)
	Burkina Faso	Natural resource management, protection and rehabilitation of woodlands, agro-forestry (Project:	2014 – on-going	Active (on-going)	Yes: Recognized benefits are groundwater recharge and water table stabilization (+ additional

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Table A1 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
		Decentralized Forest and Woodland Management)			benefits related to carbon sequestration)
	Niger	Sustainable management (Project: Community Action Project for Climate Resilience)	2012–2021	Successfully implemented	–
	Kenya	(Project: Coastal Region Water Security and Climate Resilience)	2015 – on-going	Active (on-going) until 2027	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to agriculture, fisheries, and forestry income)
	Mozambique	(Project: Agriculture and Natural Resources Landscape Management)	2016 – on-going	Active (on-going) until 2023	Yes: Recognized benefits are disaster risk reduction (+ additional benefits related to biodiversity)
	Nicaragua	Watershed protection measures, mangrove, and coastal wetland management (Project: Adaptation of Nicaragua's Water Supplies to Climate Change)	2013–2018	Successfully implemented	Yes: Recognized benefits are groundwater recharge and water table stabilization
Gathagu et al. (2018)	Kenya (East Africa)	Structural conservation measures: terraces and grassed waterways	–	Successfully implemented	Yes: Modelling terraces resulted in an increased baseflow (due to infiltration) by 8.38% and increased recharge in the shallow aquifer by 5.08%
	Further recommendations	The structural conservation measures seem to impact the total water yield significantly. However, the effectiveness of these NBS can still be increased by combining this implementation with other NBS. More research is needed to evaluate the costs and benefits of structural conservation measures implemented at a small scale.			
WWAP, UN-Water, 2018	Rajasthan (India)	Landscape restoration (small-scale water harvesting structures in combination with reconstruction of forests and soils)	–	Successfully implemented	Yes: Improved water security, water-retaining capacity of the soil
	Further recommendations	–			
Holden et al. (2022)	Cape Town (South-Africa)	Catchment restoration (e.g., invasive alien tree species clearing)	Not mentioned - 2025	Active (on-going)	Yes: Improvement of the low flows by 3–16% in case of moderate invasions levels
	Further recommendations	Removing invasive alien tree species is an important technique to restore the catchment and reduce the climatic drought risk. However, it is not enough to reduce climate change acceleration and must be combined with other adaptation techniques.			

Table A2
Current nature-based solutions in Europe along with their type, year of implementation, current status, level of effectiveness, and recommendations set by the researchers for the future.

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
(S. Keesstra et al., 2018)	Rangárvellir (Iceland)	Land restoration	Early 20th century	Successfully implemented	Yes: Results of the Soil Conservation Service of Iceland (SCSI) show an increased resilience of the freshwater resources and a lower depletion rate of the groundwater levels during dry periods.
	Portugal	Implementation of water retention landscapes (artificial lakes)	–	Successfully implemented	–
	Further recommendations	–			
Hein et al. (2016); European Commission (2015)	Danube catchment between Vienna and Bratislava (Austria, Slovakia)	Floodplain restoration	1996 - ongoing	Active (on-going)	Yes: Recognized benefits are moderated extreme events (floods and droughts) and improved water availability
	Further recommendations	Further research is required to fill the knowledge gap concerning floodplain restoration. The conflicting social stakeholder needs, legal frameworks, and budget limitations restrict the successful implementation. Climate change and the introduction of invasive species must be considered in future restoration projects in this catchment to increase the resilience of floodplains. The success factor of this NBS must be further evaluated as the lack of quantitative and comparable data constraints it.			
de Boer and Bressers (2011)	Regge river (The Netherlands)	Re-naturalisation of the river: remeandering, floodplain restoration	2010 – on-going	Active (on-going) until 2025	Yes: Improved protection against flood events and improved conditions during drought events
	Further recommendations	At some locations along the river, private ownerships hinder the implementation of the projects.			
Ricart and Rico-amoros (2021)	Alicante (southern Spain)	Constructed (coastal) wetlands (+ use of treated wastewater)	Early 20th century	Successfully implemented	Yes: Increased water supply (and reduced water pollution)
	Further recommendations (only drought-related)	Water scarcity and water pollution beneficial practices should be promoted locally and nationally. Farmers are the primary water consumers and should be fully involved in the process. They possess potential information about when and how constructed wetlands are efficient solutions to water scarcity and water pollution challenges.			

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Table A2 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
		New forms of collaboration among stakeholders could help face water scarcity and reduce water conflicts in semi-arid regions.			
European Topic Centre on Climate Change impacts, Vulnerability, and Adaptation, 2021				Tulltorpsån (Sweden) 2009–2019 (1.0 project) 2019–2025 (2.0 project)	Multifunctional wetland restoration/ remeandering Successfully implemented Active (on-going)
Yes: Increased agricultural resilience to drought (and protection against floods; improved water quality and biodiversity; increased human living quality and well-being, including increased recreation)					
Further recommendations	Convincing farmers to leave a part of their field for wetland restoration and remeandering is more manageable once they see the effects of the implementation. Farmers must see the long-term perspective of a project. The lessons learned from those projects can convince farmers in other areas to participate in the project.				
Frantzeskaki (2019)	Lambhill Stables, Glasgow (United Kingdom)	Constructed wetland, urban agriculture, and bioremediation ponds	2007 – not mentioned	Successfully implemented	Yes: Recognized benefits are restoration of ecosystems; increased social capital, environmental education, and green jobs
	Serpentone neighborhood, Potenza (Italy)	Urban park	2010 – (2016)	Successfully implemented: park is used by both children and elderly	Yes: Recognized benefits are increased water retention and recreation
	Rotterdam (The Netherlands)	Linear urban waterfront park (project: 'Boompjes Promenade')	–	Successfully implemented	Yes: Recognized benefits are increased water retention, flood protection and recreation
	Rotterdam (The Netherlands)	Rain gardens	2016	Successfully implemented	Yes: Recognized benefits are increased water retention and flood protection
	Rotterdam (The Netherlands)	Urban agriculture & green roofs (project: 'Dakakkers Roof Garden')	–	Successfully implemented	Yes: Recognized benefits are increased water retention, food production and recreation
	Ślepiotka, Katowice (Poland)	River restoration, linear park and green waterfront	2008–2012	Successfully implemented	Yes: Recognized benefits are ecosystem and habitat restoration, increased water retention and flood protection and recreation
	Dolno Ezrovo District, Burgas (Bulgaria)	Pocket park	2016 – on-going	Active (on-going)	Yes: Recognized benefits are increased water retention and flood protection
	City Centre District, Potenza (Italy)	Urban park	2017 – on-going	Active (on-going)	Yes: Recognized benefits are increased water retention and recreation
	Further recommendations (7 general lessons)	1 To appreciate the value of nature-based solutions, they must be aesthetical, multi-functional, and attractive for citizens. Co-creation and co-design with different designers and architects are required. 2 Nature-based solutions should create green urban 'welcoming and community spaces' as this, in turn, creates new relationships between citizens and nature and between citizens themselves. 3 Nature-based solution experiments require trust between the city and the citizens to gain the full potential benefits and success of the experimenting process itself. 4 Different fora for co-creation and co-design of nature-based solutions are required using urban social innovation as an important instrument. 5 A collaborative governance approach is required to implement and operate nature-based solutions successfully (a collaboration between urban planners and urban officers, citizens, NGOs, social innovation networks, and experts, etc.). 6 A narrative of mission across departments of urban cities can be used as an integrated tool to reach consensus and avoid departmental disputes. 7 The design of nature-based solutions should not be too complex or contextually bound so that it is reproducible to other locations.			
Trémolet et al. (2019)	North Metropolitan Area of Barcelona (Spain)	Construction wetlands and targeted land restoration	1999–2007	Successfully implemented	Yes: Environmental and social benefits: increased water quality and biodiversity, adaptation to floods and droughts (increased water retention capacity of the river) and more recreational opportunities
	United Kingdom	Targeted land restoration: peatland restoration	2018–2040	Active (on-going)	Yes: Over more than 200 peatland restoration projects gained success: water, climate and biodiversity benefits are recognized
	North – West England	Land restoration, forestry Best Management Practices (BMP), improvement of agricultural practices	2005–2010 (SCaMP 1)	–	–

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Table A2 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
		and targeted land protection and restoration (project: Sustainable Catchment Management Program (SCaMP))	2010–2015 (SCaMP 2)		
	Further recommendations	–			
Oral et al. (2020); Oral et al. (2020); Oral et al. (2020); C2C-CC, n.d.	General: Mediterranean region	Constructed wetlands in the food-water-energy nexus, constructed wetlands for grey water treatment and reuse, rainwater harvesting systems, and agroforestry (General Project: HYDROUSA)	2018–2022	Successfully implemented	–
	Lesvos (Greece)	Municipal wastewater treatment in combination with constructed wetlands (Project: HYDRO1)	2020–2021	Successfully implemented	Yes: Increased water supply
	Mykonos (Greece)	Innovative rainwater harvesting systems (Project: HYDRO3)	2019	Successfully implemented	Yes: Cheap water supply for remote areas without other water resources
	Ano Mera, Mykonos (Greece)	Water management system: rainwater, stormwater, and surface runoff collection (Project: HYDRO4)	2020	Successfully implemented	Yes: Increased water supply, production of drinking water, and aquifer recharge to reduce saltwater intrusion
	Tinos (Greece)	Rainwater harvesting and water vapor recovery systems in combination with constructed wetlands (Project: HYDRO6)	2020	Successfully implemented	Yes: Self-sufficiency in water for ecotourist facilities
	The Gorla Maggiore Water Park (Northern Italy)	Constructed wetlands	2013–2015	Successfully implemented	Yes: Flood & drought (hydraulic risk) reduction; pollution removal; increased recreation, and biodiversity
	Berlin (Germany)	Rainwater harvesting (Project: KURAS)	2016 – on-going	Active (on-going)	–
	Denmark	Permeable coating of streets and paths (Project: C2C-CC)	2016 – on-going	Active (on-going) until December 2022	–
	Further recommendations	Only limited data is available about the implementation of treatment wetlands in the cities; most examples are in the rural environment. The application of NBS in the cities is limited as it still must cope with some challenges, such as limited available space. So, urban planning and architecture should be combined to accommodate NBS more efficiently and realize the full range of potential benefits. Further research is required to combine more effectively different disciplines, following the holistic perspective.			
Davies et al. (2021)	Utrecht (The Netherlands)	Central Station: green roofs and stormwater retention measures Leidsche Rijn: sustainable urban drainage systems and green streets	2009 – on-going	Active (on-going) until 2030	Yes: Recognized benefits are reduction of drought and reduction of damages related to drought (+ many additional benefits)
	Further recommendations	Street greenery has an aesthetic value for people. Ample street greenery and extensive cover of trees are recommended in street design. There are still many challenges: including the limitation of space for transportation, climate change, health, and the fast urbanization and densification of the city.			
	Rotterdam (The Netherlands)	Blue-green corridors in urban cities (Projects: Delta Plan, Tidal Park Program)	Not mentioned - 2025	Active (on-going) until 2025	Yes: Recognized benefits are reduction of drought risk (+ many additional benefits)
	Further recommendations	Collaboration is essential in climate change adaptation: municipal and other governmental services, citizens, and private organizations should work together to achieve a successful implementation. The implementation of NBS is area specific. The implementation follows the 'rhythm of the city.' The city's infrastructure renovation and adaptation to climate change occurs in a specific timeframe (every thirty or fifty years). There are still many challenges: including flooding, a fast-growing population, and climate change.			
	London (United Kingdom)	Green infrastructure (green walls and roofs), natural flood control measures, and nature reserve restoration (Projects: Barking Riverside Project, Queen Elizabeth Olympic Park, Beetle Bump)	2009–2020	Successfully implemented	Yes: Recognized benefits are reduction of drought risk (+ many additional benefits)
	Further recommendations	Cost-benefit analysis: implementing natural water retention measures (NWRM) was cheaper than the traditional measures. Although the costs of remeandering and construction of detention basins are generally high, they create a greater range of benefits. The early consultation with the local community during the entire project helped the successful implementation and operation. Communication and a positive attitude are necessary during the planning and implementation phases. The specific measures implemented at the catchment scale also helped achieve a greater overall improvement than those implemented at one location. Flexibility is necessary, and legacy management must be consulted in the beginning phase.			
	Dublin (Ireland)	Green infrastructure, sustainable urban drainage systems (permeable pavement, green roofs, rainwater harvesting systems, detention basins, wetlands, etc.)	2011 – on-going	Active (on-going) until 2022	Yes: Recognized benefits are reduction of drought and reduction of damages related to drought (+ many additional benefits)

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Table A2 (*continued*)

Reference	City/country	NBS type	Year	Current status	Effectiveness for drought
	Further recommendations	The Dublin Mapping tool is helpful for long-term solutions for identifying spaces for urban regeneration and meeting housing needs. There are still many challenges related to the economy, lack of housing, and climate change.			
	Berlin (Germany)	Green solutions (Projects: Urban greening (BENE), Green Moabit, Mixed forests Program, School gardens, Green Walks, Nomadic gardening)	2004 and 2009	Successfully implemented	Yes: Recognized benefits are reduction of drought and reduction of damages related to drought (+ many additional benefits)
	Further recommendations	Bottom-up projects from citizens have an essential role in realizing green infrastructure. They can influence and change public policies. Therefore, it is recommended to integrate these citizens' projects into the policies. It remains challenging to decouple the city's growth from the nefast impacts of climate change on the city. Due to the fast-growing population, it is challenging to create new green spaces.			
	Amsterdam (The Netherlands)	Green infrastructure: green spaces	2010 – on-going (city) 2015–2018 (Green Agenda)	Active (on-going) Successfully implemented	Yes: Recognized benefits are reduction of drought risk (+ many additional benefits)
	Further recommendations	The knowledge about implementing NBS in cities is often lacking (for example, understanding the soil conditions). Not enough attention is given to subsequent management. It is still costly and takes much time. The relationship between the city and the local population is not easy. There are still many challenges related to water-related hazards, city densification, quality of life, and the accessibility of green spaces.			
Nikolaidis, z.d.	Evrotas (Greece)	Riparian forest restoration and riverbank protection	–	Successfully implemented	Yes: Increased resilience to climate change impacts; increased infiltration and water storage; reduction of drought risk; (enhanced biodiversity and quality and quantity of green and blue infrastructure)
	Further recommendations	There are still some barriers (policy and legislation, financial and technological barriers) that hinder the widespread implementation of this nature-based solution type.			
Trémolet et al. (2019); Mayor et al., 2020	Castilla y Leon (Spain) Medina del Campo aquifer	Restoration natural wetlands: natural aquifer recharge	2016 – on-going	Active (on-going)	Yes: Improvement water availability and water security
	Further recommendations	It is essential to reach a good water body status to get the full potential of ecosystem services to build natural resilience against drought. As groundwater cannot be seen, the notion of "groundwater shortage" is not evident to water users (for example, farmers). Therefore, clear communication with the users and raising awareness about the situation will contribute to reaching a successful solution. The proposed nature-based solution alone may not be sufficient to solve drought risks. Other measures, such as recovery of wetlands or carbon sequestration, may be necessary to reduce the impact of water availability issues.			
The World Bank Group (2022)	Serbia	Forestry management (Project: Sava and Drina Rivers Corridors Integrated Development Program)	2020–2026	Active (on-going)	–
	Further recommendations	–			

Table A3
Current nature-based solutions in Belgium with their type, year of implementation, current status, level of effectiveness, and recommendations set by the researchers for the future.

Reference	City	NBS type	Year	Current status	Effectiveness for drought
Frantzeskaki (2019)	Sint-Andries, Antwerp	Green spaces: linear park (Projects: Green Corridor, Multi-functional Rooftops)	2017 – on-going	Active (on-going)	Yes: Recognized benefits are increased water retention and flood protection, increased recreation, and biodiversity
	Further recommendations	–			
Gorissen et al. (2018); Kabisch et al., 2017; Meynaerts & Vos, z.d.	Genk	(Food) & Nature conservation and restoration, green-blue infrastructure Projects: - Green Corridor (Stiemerbeek Valley) - Bee Plan - Heempark - Organic allotment gardens	2014–2019 2013 – not mentioned 1991 – not mentioned 2005 – not-mentioned	Successfully implemented	Yes: Climate change mitigation (improved risk management and resilience against floods and droughts)
	Further recommendations	There is no evidence base regarding the upscale of these NBS because they do not use quantitative indicators to measure the progress, hence, further research is needed. Replication of transformative ways of thinking is necessary to achieve diversity within the city and avoid the limits of growth. A complete shift to transformative solutions, and infrastructures is vital to reach systematic change (e.g., low carbon transitions). It is only possible when the social structures and the social arrangements around them are co-evolved.			

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Table A3 (*continued*)

Reference	City	NBS type	Year	Current status	Effectiveness for drought
Sishah et al. (2017)	Lier, Duffel, Nijlen, Grobbendonk, Berlaar, Zandhoven	Nete river restoration: restoration of wetlands & construction of flood control areas (FCA) Subproject areas: - Varenheuvel-Abroek (Zone 2) - Grote Nete estuary (Zone 3) - Beneden-Nete (Zone 1)	2019 (start zone 1) – on-going	Active (on-going)	–
	Further recommendations	–			
Moeskops,	From Kasterlee (N19) to Grobbendonk	Kleine Nete river restoration: remeandering, construction of wetlands, nature reserves, and ecological water storage areas Projects: - Remeandering 'Olens Broek' nature reserve - Ecological water storages in recreational areas (Bobbejaanland, camping Korte Heide, Ark van NOE) - Remeandering and construction of wetland in Geel	2018 – on-going	Design completed Pre-design stage Active (on-going)	–
	Further recommendations	For the ecological water storage in recreational areas: The measures must be further linked with detailed climate models to convince local authorities and citizens to implement these measures instead of single-purpose solutions. Further research is required into their potential for dealing with dry periods. Further research is needed into the transferability potential of these measures to other locations.			
Agentschap and Zeekanalen, 2017a	Werchter, Begijnendijk, Aarschot, Scherpenheuvel-Zichem, Rotselaar, Diest	Demer river restoration: restoration of multiple meanders and natural land development (in combination with sills constructions and levee projects) Pilot project: Meander 13 14 15 16 Meander 23	2018–2020 2020 – on-going	Successfully implemented Active (on-going)	No information yet: goal is to create more than 2 million m^3 extra storage to combat floods and droughts
	Further recommendations	–			

Table A4
Small scale and large scale applications, their methodology, type of nature based solution and country where they are applied.

Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
2016	Andrés-Valeri et al. (2016)	Applied Projects	Case studies	Different small-scale applications in different cities in the Mediterranean		Mediterranean, Europe
2019	Arahuetes and Olcina Cantos (2019)	Theoretical Discussion	Literature review	Green Infrastructure in cities, SUDS, Management actions taken by cities across Europe	Paper is more focused on flooding measures, but mentions water storage and associated methods	Spain, Europe
2022	Bak and Barjenbruch (2022)	Theoretical	Review	Raingardens	A review on rain gardens, also mentioning how they could help with mitigation of drought	N.A.
2022	Basel et al. (2022)	Theoretical	Literature review	Small Scale managed aquifer recharge: wetlands, check dams, contour bunds, propus roadside ditches, infiltration wells	Focuses on sociohydrological factors of MAR	N.A.
2011	Belden and Steele (2011)	Applied	Retrofitting project	Different NbS mentioned: infiltration gallery, bio-swales, permeable surfaces, rain gadens, drought-tolerant landscaping		Los Angeles, America
2018	Bogie et al. (2018)	Experiment, Applied	Experiment	Woody vegetation within agricultural fields - hydraulic redistribution		Sahel Area, Africa
2022	Boogaard (2022)	Theoretical and Applied		Swales	Performance of NbS tested in extreme events, including drought	Netherlands
2018	Bordoloi et al. (2018)	Experiment, Applied	Experiment	Use of Organic matter to improve water retention: Use of Eichhornia Crassipes		N.A.

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Table A4 (*continued*)

Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
				fibres to influence water retention in drought prone regions		
2020	(Chalid and Prasetya, 2020)	Theoretical	Calculations	Retention pond		Jakarta, Indonesia
2019	Chan et al. (2019)	Theoretical		Sustainable urban drainage systems: vegetated surfaces		N.A.
2019	Csete and GulyÁs (2019)	Theoretical	Modelling	Vegetation covered areas		Hungary, Europe
2021	Csete et al. (2021)	Theoretical and Applied	Modelling	Rainwater harvesting	Modelling	Hungary, Europe
2010	DeBusk et al. (2010)	Applied Project	Measurements	Rainwater harvesting - cisterns		North Carolina, USA
2022	(duToit and Chilwane, 2022)	Applied Technique	Survey	Rainwater harvesting, porous pavement	Looks at adoption of these measures	South Africa
2012	Enopala et al. (2012)	Applied Project	Experiment	Drought-Adapted crops		Mexico
2022	Fröhle et al. (2022)	Theoretical Assessment	Modelling	Retention basin		Germany
2021	Gallotti et al. (2021)	Applied Project	Modelling	Water Retention pond		Greece
2021	Gooden and Pritzlaff (2021)	Applied Projects	Literature review and surveys	Rock detention structures		Arizona and Mexico
2017	Gülbaz and Kazezyilmaz-Alhan (2017)	Applied Experiment	Modelling	Bioretention		Turkey
2017	Gülbaz and Kazezyilmaz-Alhan (2017)	Applied Experiment	Modelling	Bioretention		Turkey
2016	Haefele et al. (2016)	Theoretical Discussion of Implemented Projects	Lit Review	Landscape approach: Ricefield managment		N.A.
2008	(Hankins et al., 2008a)	Theoretical and Applied	Summary of Methods	Bioinfiltration Raingardens		USA
2017	Holmes et al. (2017)	Theoretical Assessment	Modelling	Floodplain infiltration		Montana, USA
2022	Jiang et al. (2022)	Applied Techniques	Review	Natural Drainage system		China
2022	Jódar et al. (2022)	Applied Techniques	Review	Careo channels and amunas		Spain and Peru
2021	Kiedrzyńska et al. (2021)	Theoretical Proposal	Case study assessment	Reservoir		Poland
2019	Kim et al. (2019)	Applied Projects	Modelling	Dumbeong system		Korea
2021	Köhler and Kaiser (2021)	Applied Project	Analysis	Green roofs		Germany
2022	Kraemer and Kabisch (2022)	Applied Project	Analysis	Parks		Germany
2022	Lee et al. (2022)	Theoretical calculations	Modelling	Permeable pavement		Korea
2021	Liu et al. (2021)	Applied Experiment	Experiment	microbially induced calcite precipitation		N.A.
2016	Maria Raquel et al. (2016)	Applied Experiment	Experiment	Vegetation reactions to flood and droughts in Green Infrastructure		USA
2013	Morgenroth et al. (2013)	Applied Experiment	Experiment	Porous pavements experiments		New Zealand
2020	Nanfuka et al. (2020)	Applied Projects	Interviews and questionnaires	use of drought resistant shade trees, water reservoirs and dams		Uganda
2015	Nichols and Lucke (2015)	Applied Experiment	Experiment	Wicking tank		Australia
2021	Norbury et al. (2021)	Applied Project	Analysis	willowed engineered log jams		UK
2022	Norman et al. (2022)	Theoretical Discussion	Literature review	Natural Infrastructure in Dryland Streams (NIDS)		USA
2009	Nuti et al. (2009)	Applied Technique	Experiment	Furrow diking		USA
2018	Pilliod et al. (2018)	Theoretical Discussion of Implemented Projects	Analysis of records	Beaver restoration		USA
2020	Prudent et al. (2020)	Applied Experiment	Experiment	Soil microbial diversity		France

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Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
2021	Renwick et al. (2021)	Applied Experiment	Experiment	Agricultural practices -Crop rotation diversification		Canada
2021	Ronnquist and Westbrook (2021)	Applied techniques	Cross site survey	Beaver dams		Canada
2021	Spyrou et al. (2021)	Applied project	Assessment and climate change scenario analysis	NbS at River		Greece
2022	Spyrou et al. (2022)	Applied project	Data measurements	NbS at River		Greece
Large scale and small scale combined						
Publication Year	**Author**	**Applied Project or Techniques or Theoretical Assessment or Discussion)**	**Method**	**Type of NbS**	**Comments**	**Country**
2021	Cassin and Ochoa-Tocachi (2021)	Theoretical Review, but Applied practices	Review	Infiltration basins, Sand dams, Wetlands and infitration enhancement systems, Landscape scale systems, Tank cascades,	Both scales applicable	N.A.
2018	Jamei and Tapper (2018)	Applied Projects	Literature review	Parks, street trees, green roofs, and green walls and WSUD approaches		N.A.
2021	Le and Awal (2021)	Theroetical and Applied	Case study Analysis	For drought: wetland restoration		Worldwide
2022	Locatelli et al. (2022)	Applied Projects	Framework	Dams, reservoirs and wetlands	More focused on stakeholders	Peru
2020	Rizzo et al. (2020)	Theoretical Assessment	Assessment tool			EU
2014	Rogé et al. (2014)	Applied Methods by farmers and Theoretical Discussion	Workshops	Agroecology: contour ditches, crop rotations	Not focused on drought adaptation but mentions methods	Mexico
2011	Sawadogo (2011)	Applied Projects	Survey	Rock bunds, filter walls, zaï, half-moons and agroforestry		Burkina Faso
2019	Silvertooth et al. (2019)	Applied Projects	Review	Green Infrastructure: Bioretention, Bioswales, Green roofs,etc.		USA
2010	Zimmerman et al. (2010)	Applied Projects	Modelling and Field studies	Low Impact Development: permeable pavement, raingardens, green roof		Massachusettes, USA
Large scale						
Publication Year	**Author**	**Applied Project or Techniques or Theoretical Assessment or Discussion)**	**Method**	**Type of NbS**	**Comments**	**Country**
2022	Alfie-Cohen and Garcia-Becerra (2022)	Theoretical, Socio-ecological, Different proposed solutions to mitigate drought, Strategy	Q Method	Green Infrastructure	Theoretical plan to implement Green Infrastructure	Mexico, South America
2013	Bai et al. (2013)	Applied Project	Case study Analysis	Landscape management, Forest		China
2021	Ballesteros and Isaza (2021)	Applied methods by farmers	Interviews and observations	Landscape approach, Agricultural NbS, multitude of techniques e.g. mulch, irrigation systems, water storage through artificial reserves, other more structural methods that cannot be counted as NbS but might influence	Techniques could be seen as NbS	Colombia, South America
2019	Bardati (2019)	Theoretical, as NbS are proposed	Interviews	Suggestion of Agroecological practices, which can be seen as Agricultural NbS	Large scale because mutliple farmers were interviewed and agricultural NbS would	Malawi, Africa

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Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
					potentially be used at large scales	
2021	Bedla and Halecki (2021)	Theoretical	Literature review	Different NbS mentioned, including Sponge city, meadows and green areas in cities	Review of several practices, NbS mentioned within the paper but not the abstract	N.A.
2018	(Belle et al., 2018)	Existing wetlands were assessed	Questionnaires, surveys and field observations	Wetlands	Large scale due to number of assessed wetlands	South Africa, Africa
2018	Broadbent et al. (2018)	Applied	Calculations	Different NbS: swales, wetlands, water courses, artificial lakes	Review on effectiveness of WSUD	Adelaide, Australia
2020	Ellison and Ifejika Speranza (2020)	Theoretical	"Forest-water and land-atmosphere interactions lens"	Landscape approach, Agroforestry		Sahel region
2022	Fennell et al. (2022)	Theoretical	Modelling	Runoff Attenuation Features		Scotland, United Kingdom
2018	Gebremeskel et al. (2018)	Theoretical Discussion	Literature review	Soil and water conservation interventions: stone and soil bunds, trenches and percolation pits, micro basins, check dams, etc.		Ethiopia
2020	Ghaleh and Ghaleh (2020)	Applied Project	Case study assessment	Blue Green infrastructure in an ancient city		Qazvin, Iran
2020	Hernández-Hernández et al. (2020)	Applied Projects and Proposed Projects	Analysis	Rainwater harvesting and Floodplains		Alicante, Spain
2020	Hewett et al. (2020)	Theoretical	Modelling		Not NbS, but model to assess effect of NbS	N.A.
2022	Holden et al. (2022)	Thereotical Assessment	Modelling	Alien tree clearing		South Africa
2020	Hussain et al. (2020)	Theoretical Discussion	Literature Review	Drought-Adapted crops		N.A.
2022	Jakubínský et al. (2022)	Theoretical Assessment	Modelling	Infiltration areas		Czech Republic
2021	(Jokar et al., 2021a)	Theoretical	Modelling	Bioretention, Subsurface infiltrating Systems, Rainwater harvested Cisterns and porous pavements		Iran
2018	(S. Keesstra et al., 2018)	Applied Projects	Literature Review	Landscape approaches such as: Reiwilding, Agroforestry, stone bunds		Various
2013	La Rosa and Privitera (2013)	Theoretical Assessment	Analysis and Modelling	Potential Impact of Vegetated spaces		Italy
2015	Ladányi et al. (2015)	Existing Projects	Modelling	Modelling of performance of landscape under drought conditions		Hungary
2022	Lara-Valencia et al. (2022)	Theoretical Assessment	Analysis and Modelling	Green infrastructure across international borders		Arizona, Mexico
2022	Lassiter (2022)	Applied Projects	Data Analysis	Drought tolerant landscaping	Monitoring of adoption of drought resistant landscaping on private grounds	California, USA
2019	Lewellyn and Wadzuk (2019)	Theoretical Assessment	Modelling	Bioinfiltration		Philadelphia, USA
2019	Li et al. (2019)	Theoretical	Description of Method	Sponge city		China
2017	Madsen et al. (2017)	Applied Techniques	Framework and interviews	WSUD - Water Sensitive Urban Design - several techniques	Paper does not focus on implemented techniques	Australia
2022	(McCauley et al., 2022)	Applied - Existing Forests	Modelling	Reforestation effects		USA
2007	McDonald et al. (2007)	Applied law and actions	Review	Applying soil best management practices across several cities		USA
2019	Nguyen et al. (2019)	Theoretical Discussion	Literature review	Sponge city		China
2018	(Nolan et al., 2018b)	Applied or Potential Projects	Observation	Wetlands		Australia

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Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
2020	Onderka et al. (2020)	Theoretical Assessment	Modelling	green roofs, rain tanks, infiltration trenches		Slovakia
2019	Ouled Belgacem et al. (2019)	Applied Techniques	Experimental resting of rangelands	Rangeland resting		Tunisia
2017	Pease et al. (2017)	Theoretical Assessment	Modelling	Modelling the effect of controlled drainage		USA
2019	Piedelobo et al. (2019)	Applied Projects	Modelling	Modelling of Green Infrastructure		Italy
2020	Qiu et al. (2020)	Theoretical Assessment	Modelling	Best Management Practices - Agricultural and water retention		China
2018	Quin and Destouni (2018)	Applied - existing wetlands	Calculations	Wetlands		Sweden
2021	Rahman et al. (2021)	Applied Experiment	Experiment	Shade of trees and grass surfaces		Germany
2022	Rebelo et al. (2022)	Theoretical Assessment	Modelling	Alien tree species clearing		South Africa
2021	Ribeiro (2021)	Theoretical Discussion	Literature review	Inca and pre-Inca techniques		Peru
2016	Rivera-Ferre et al. (2016)	Theoretical Discussion	Literature Review and questionnaire	Rainwater harvesting		Indo-Gangetic Plain
2022	Siehr et al. (2022)	Theoretical Assessment	Literature review	Blue-Green Infrastructure, Sponge Cities		China
2019	Wang et al. (2019)	Applied projects	Survey	Forests		China
2018	Yuan et al. (2018)	Theoretical Assessment	Analysis of climate conditions		Modelling of Drought-risk, proposal of LIDs	China
2022	(Zhang et al., 2022)	Applied projects	Case study presentation	Sponge city: constructed wetland, bioswales, detention plazas		China
Scale not applicable Publication Year	**Author**	**Applied Project or Techniques or Theoretical Assessment or Discussion)**	**Method**	**Type of NbS**	**Comments**	**Country**
2022	Adil et al. (2022)	Applied projects, but theoretical calculations	Calculations			Worldwide
2015	Altieri et al. (2015)	Theoretical Discussion				N.A.
2014	Bonzanigo and Sinnona (2014)	Theoretical		Water sensitive Urban design	Not applied, more focused on sociological context	Italy, Europe
2022	De Kauwe et al. (2022)	Theoretical Assessment	Modelling		Does not mention NbS, but model approach that could lead to use of NbS	Australia
2019	Debele et al. (2019)	Theoretical	Literature review		Cannot be divided into scale, but relevant for discourse	N.A.
2022	Ferreira et al. (2022)	Theoretical	Survey			Portugal
2021	Gómez Martín et al. (2021)	Theoretical	Participatory modeliing activities		More focused on including all stakeholders	Spain
2018	Kalantari et al. (2018)					East-Africa
2021	Khadse (2021)			Water sensitive urban design strategies		N.A.
2016	Kloos and Renaud (2016)	Theoretical Discussion	Literature review		Various scales	Sub-Saharan Africa
2022	Kuhlemann et al. (2022)	Experiment, Applied	Isotopes, Calculations and modelling		Application if green Infrastructure in a city	Germany
2021	Kumar et al. (2021)	Thereotical Discussion	Literature Review			N.A.
2021	Kumar et al. (2021)	Theoretical Discussion	Literature Review			N.A.
2018	Kunapo et al. (2018)	Theoretical Assessment	Modelling	Model for adopting grey and green infrastructure		N.A.
2019	Lafortezza and Sanesi (2019)					N.A.

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Small scale						
Publication Year	Author	Applied Project or Techniques or Theoretical Assessment or Discussion)	Method	Type of NbS	Comments	Country
2021	López Gunn et al. (2021)		Framework			Italy
2022	Niemeyer and Vale (2022)					Brasil
2018	O'Hogain and McCarton (2018)				Relevant, but not focused on drought	N.A.
2021	Ossola and Lin (2021)			Different types of NbS are mentioned		Australia
2022	Ruangpan and Vojinovic (2022)				Framework	N.A.
2020	Ruangpan et al. (2020)				Review	N.A.
2019	Sahani et al. (2019)				Review of methods, relevant in the context, but not in a category of scale	N.A.
2014	Salinas Rodriguez et al. (2014)				Overview, no specific scalable action mentioned	N.A.
2021	Smith et al. (2021)	Applied projects	Systematic review			Bangladesh
2015	Voskamp and Van de Ven (2015)					N.A.
2021	Zalewski (2021)				No scalable NbS mentioned	N.A.

References

Adil, M., Yao, Z., Zhang, C., Lu, S., Fu, S., Mosa, W.F.A., Hasan, M.E., Lu, H., 2022. Climate change stress alleviation through nature based solutions: a global perspective. Front. Plant Sci. 13 https://doi.org/10.3389/fpls.2022.1007222.

Agentschap, Waterwegen & Zeekanalen, N.V., 2017a. Projectbrochure Bovendijle - Februari 2017. http://www.sigmaplan.be/. Accessed 01.05.2023.

Alfie-Cohen, M., Garcia-Becerra, F.Y., 2022. A multi-stakeholder participatory methodology to facilitate socio-ecological climate change vulnerability–adaptation–resilience strategies: application of the Q Method. Mitig. Adapt. Strategies Glob. Change 27. https://doi.org/10.1007/s11027-021-09988-9.

Alikhani, S., Nummi, P., Ojala, A., 2021. Urban wetlands: a review on ecological and cultural values. Water (Switzerland) 13, 1–47. https://doi.org/10.3390/w13223301.

Altieri, M.A., Nicholls, C.I., Henao, A., Lana, M.A., 2015. Agroecology and the design of climate change-resilient farming systems. Agron. Sustain. Dev. 35, 869–890. https://doi.org/10.1007/s13593-015-0285-2.

Amano, H., Iwasaki, Y., 2022. Estimation of groundwater recharge in kumamoto area, Japan in 2016 by mapping land cover using GIS data and SPOT 6/7 satellite images. Sustainability 14, 545. https://doi.org/10.3390/su14010545.

Andrés-Valeri, V.C., Perales-Momparler, S., Sañudo Fontaneda, L.A., Andrés-Doménech, I., Castro-Fresno, D., Escuder-Bueno, I., 2016. Sustainable drainage systems in Spain. In: Sustainable Surface Water Management: A Handbook for SUDS. Wiley Blackwell, pp. 355–369. https://doi.org/10.1002/9781118897690.ch26.

Arahuetes, A., Olcina Cantos, J., 2019. The potential of sustainable urban drainage systems (SuDS) as an adaptive strategy to climate change in the Spanish Mediterranean. Int. J. Environ. Stud. 76, 764–779. https://doi.org/10.1080/00207233.2019.1634927.

Bai, Y., Min, Q., Liu, M., Yuan, Z., Xu, Y., Cao, Z., Li, J., 2013. Resilience of the hani rice terraces system to extreme drought. J. Food Agric. Environ. 11, 2376–2382.

Bak, J., Barjenbruch, M., 2022. Benefits, Inconveniences, and Facilities of the Application of Rain Gardens in Urban Spaces from the Perspective of Climate Change—A Review, vol. 14. Water, Switzerland. https://doi.org/10.3390/w14071153.

Ballesteros, S., Isaza, C., 2021. Adaptation measures to climate change as perceived by smallholder farmers in the andes. J. Ethnobiol. 41, 428–446. https://doi.org/10.2993/0278-0771-41.3.428.

Bardati, D., 2019. Participatory agroecological assessment of farmers' capacity to adapt to climate change in Malawi. Int. J. Clim. Change Impacts Responses 11, 15–33. https://doi.org/10.18848/1835-7156/CGP/v11i03/15-33.

Basel, B., Hoogesteger, J., Hellegers, P., 2022. Promise and paradox: a critical sociohydrological perspective on small-scale managed aquifer recharge. Frontiers in Water 4. https://doi.org/10.3389/frwa.2022.1002721.

Bastiaensen, T., Van Wambeke, E., El Bakkali, C., Desair, J., Noël, C., Kenis, K., Vincke, L., Jacobs, S., 2023. Beyond biodiversity: eliciting diverse values of urban green spaces in Flanders. Land 12, 1186. https://doi.org/10.3390/land12061186.

Bedla, D., Halecki, W., 2021. The value of river valleys for restoring landscape features and the continuity of urban ecosystem functions – a review. Ecol. Indicat. 129 https://doi.org/10.1016/j.ecolind.2021.107871.

Beierkuhnlein, C., 2021. Nature-based solutions must be realized - not just proclaimed - in face of climatic extremes. Erdkunde 75, 225–244. https://doi.org/10.3112/erdkunde.2021.03.06.

Belden, E., Steele, N.L.C., 2011. Green infrastructure and sustainable design for streets: the elmer avenue neighborhood retrofit demonstration. In: Presented at the World Environmental and Water Resources Congress 2011: Bearing Knowledge for Sustainability - Proceedings of the 2011 World Environmental and Water Resources Congress, pp. 3166–3173. https://doi.org/10.1061/41173(414)331.

Belle, J.A., Collins, N., Jordaan, A., 2018. Managing wetlands for disaster risk reduction: a case study of the eastern Free State, South Africa. Jamba: Journal of Disaster Risk Studies 10. https://doi.org/10.4102/jamba.v10i1.400.

Bogie, N.A., Bayala, R., Diedhiou, I., Conklin, M.H., Fogel, M.L., Dick, R.P., Ghezzehei, T. A., 2018. Hydraulic redistribution by native sahelian shrubs: bioirrigation to resist in-season drought. Front. Environ. Sci. 6 https://doi.org/10.3389/fenvs.2018.00098.

Bonzanigo, L., Sinnona, G., 2014. Present challenges for future water sustainable cities: a case study from Italy. Drink. Water Eng. Sci. 7, 35–40. https://doi.org/10.5194/dwes-7-35-2014.

Boogaard, F.C., 2022. Spatial and time variable long term infiltration rates of green infrastructure under extreme climate conditions, drought and highly intensive rainfall. Water 14. https://doi.org/10.3390/w14060840 (Switzerland).

Bordoloi, S., Gadi, V.K., Hussain, R., Sahoo, L., Garg, A., Sreedeep, S., Mei, G., Poulsen, T. G., 2018. Influence of Eichhornia crassipes fibre on water retention and cracking of vegetated soils. Géotech. Lett. 8, 130–137. https://doi.org/10.1680/jgele.17.00181.

Broadbent, A.M., Coutts, A.M., Tapper, N.J., Demuzere, M., Beringer, J., 2018. The microscale cooling effects of water sensitive urban design and irrigation in a suburban environment. Theor. Appl. Climatol. 134, 1–23. https://doi.org/10.1007/s00704-017-2241-3.

Cassin, J., Ochoa-Tocachi, B.F., 2021. Learning from indigenous and local knowledge: the deep history of nature-based solutions. In: Nature-Based Solutions and Water Security: an Action Agenda for the 21st Century. Elsevier, pp. 283–335. https://doi.org/10.1016/B978-0-12-819871-1.00012-9.

Chalid, A., Prasetya, B., 2020. Utilization of a pond in East Jakarta for a sustainable urban drainage system model. In: Presented at the IOP Conference Series: Earth and Environmental Science. Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/437/1/012018.

Chan, N.W., Tan, M.L., Ghani, A.A., Zakaria, N.A., 2019. Sustainable urban drainage as a viable measure of coping with heat and floods due to climate change. In: Presented at the IOP Conference Series: Earth and Environmental Science. Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/257/1/012013.

Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based Solutions to Address Global Societal Challenges.

Cook, B.I., Mankin, J.S., Anchukaitis, K.J., 2018. Climate change and drought : from past to future. Curr. Clim. Change Rep. 4, 164–179.

Coordinatiecommissie Integraal Waterbeleid, 2021. Ontwerp Stroomgebiedbeheerplannen Schelde en Maas 2022-2027 SGBP sectie: Dijle- en Zennebekken.

Cortinovis, C., Olsson, P., Boke-Olén, N., Hedlund, K., 2022. Scaling up nature-based solutions for climate-change adaptation: potential and benefits in three European cities. Urban For. Urban Green. 67 https://doi.org/10.1016/j.ufug.2021.127450.

Critchley, A., Di Prima, F., 2012. Water harvesting technologies revisited. Deliverable 2.1 of the FP7 Project Water Harvesting Technologies: Potentials for Innovations, Improvements and Upscaling in Sub-saharan Africa.

Csete, Á.K., GulyÁs, Á., 2019. Investigating the role of green infrastructure in sustainable urban water management, a case study in szeged. Carpathian Journal of Earth and Environmental Sciences 14, 483–494. https://doi.org/10.26471/cjees/2019/014/097.

Csete, A.K., Kolcsar, R.A., Gulyas, A., 2021. Rainwater harvesting potential and vegetation irrigation assessment derived from building data-based hydrological modeling through the case study of szeged, Hungary. Carpathian Journal of Earth and Environmental Sciences 16, 469–482. https://doi.org/10.26471/cjees/2021/016/192.

Cui, M., Ferreira, F., Fung, T.K., Matos, J.S., 2021. Tale of two cities: how nature-based solutions help create adaptive and resilient urban water management practices in singapore and lisbon. Sustainability 13, 10427. https://doi.org/10.3390/su131810427.

Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Mar. Freshw. Res. 65, 936–941. https://doi.org/10.1071/MF14173.

Davies, C., Chen, W.Y., Sanesi, G., Lafortezza, R., 2021. The European Union roadmap for implementing nature-based solutions: a review. Environ. Sci. Pol. 121, 49–67. https://doi.org/10.1016/j.envsci.2021.03.018.

de Boer, C., Bressers, H., 2011. Complex and dynamic implementation processes: the renaturalization of the Dutch Regge River. J. Thromb. Haemostasis. https://www.hydrology.nl/images/docs/dutch/key/2011.10_Regge_River.pdf. Accessed 01.05.2023.

De Kauwe, M.G., Sabot, M.E.B., Medlyn, B.E., Pitman, A.J., Meir, P., Cernusak, L.A., Gallagher, R.V., Ukkola, A.M., Rifai, S.W., Choat, B., 2022. Towards species-level forecasts of drought-induced tree mortality risk. New Phytol. 235, 94–110. https://doi.org/10.1111/nph.18129.

De Ridder, K., Couderé, K., Depoorter, M., Liekens, I., Pourria, X., Steinmetz, D., Vanuytrecht, E., Verhaegen, K., Wouters, H., 2020. Evaluation of the Socio-Economic Impact of Climate Change in Belgium.

Debele, Sisay E., Kumar, P., Sahani, J., Marti-Cardona, B., Mickovski, S.B., Leo, L.S., Porcù, F., Bertini, F., Montesi, D., Vojinovic, Z., Di Sabatino, S., 2019. Nature-based solutions for hydro-meteorological hazards: revised concepts, classification schemes and databases. Environ. Res. 179, 108799 https://doi.org/10.1016/j.envres.2019.108799.

DeBusk, K.M., Hunt, W.F., Wright, J.D., 2010. Demonstration and monitoring of rainwater harvesting technology in North Carolina. In: Presented at the World Environmental and Water Resources Congress 2010: Challenges of Change - Proceedings of the World Environmental and Water Resources Congress 2010, pp. 455–464. https://doi.org/10.1061/41114(371)51.

Decleer, K., Wouters, J., Jacobs, S., Staes, J., Spanhove, T., Meire, P., van Diggelen, R., 2016. Mapping wetland loss and restoration potential in Flanders (Belgium): an ecosystem service perspective. Ecol. Soc. 21, 46. https://doi.org/10.5751/ES-08964-210446.

Dorst, H., van der Jagt, A., Raven, R., Runhaar, H., 2019. Urban greening through nature-based solutions – key characteristics of an emerging concept. Sustain. Cities Soc. 49, 8. https://doi.org/10.1016/j.scs.2019.101620.

duToit, J., Chilwane, L., 2022. Urban household uptake of water sensitive urban design source control measures: an exploratory comparative survey across Cape Town and Pretoria, South Africa. Urban Water J. 19, 141–150. https://doi.org/10.1080/1573062X.2021.1968008.

Effecten van klimaatverandering op bos en natuur in Vlaanderen, 2015. www.vlaanderen.be. https://www.vlaanderen.be/publicaties/effecten-van-klimaatverandering-op-bos-en-natuur-in-vlaanderen. accessed 8.15.23.

Eggermont, H., Balian, E., Azevedo, José Manuel N., Beumer, V., Brodin, T., Claudet, J., Fady, B., Grube, M., Keune, H., Lamarque, P., Reuter, K., Smith, M., Van Ham, C., Weisser, W.W., Le Roux, X., 2015. Nature-based solutions: new influence for environmental management and research in Europe nature-based solutions, an emerging term. Gaia 24, 243–248.

Ejaz, F., Wöhling, T., Höge, M., Nowak, W., 2022. Lumped geohydrological modelling for long-term predictions of groundwater storage and depletion. J. Hydrol. 606, 127347 https://doi.org/10.1016/j.jhydrol.2021.127347.

Ellison, D., Ifejika Speranza, C., 2020. From blue to green water and back again: promoting tree, shrub and forest-based landscape resilience in the Sahel. Sci. Total Environ. 739 https://doi.org/10.1016/j.scitotenv.2020.140002.

Endter-wada, J., Kettenring, K.M., Sutton-grier, A., 2020. Protecting wetlands for people: strategic policy action can help wetlands mitigate risks and enhance resilience. Environ. Sci. Pol. 108, 37–44. https://doi.org/10.1016/j.envsci.2020.01.016.

Engström, R.E., Howells, M., Destouni, G., Bhatt, V., Bazilian, M., Rogner, H., 2017. Connecting the resource nexus to basic urban service provision – with a focus on water-energy interactions in New York City. Sustain. Cities Soc. 31, 83–94. https://doi.org/10.1016/j.scs.2017.02.007.

Enopala, J.T., González, F.J., De La Barrera, E., 2012. Physiological responses of the green manure, vicia sativa, to drought. Botanical Sciences 90, 305–311. https://doi.org/10.17129/botsci.392.

European Commission, 2015. Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. In: Final Report of the Horizon 2020 Expert Group on "Nature-Based Solutions and Re-naturing cities.".

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., Vandewoestijne, S., 2017. Nature-Based Solutions in the EU: innovating with nature to address social , economic and environmental challenges ☆. Environ. Res. 159, 509–518. https://doi.org/10.1016/j.envres.2017.08.032.

Fennell, J., Soulsby, C., Wilkinson, M.E., Daalmans, R., Geris, J., 2022. Assessing the role of location and scale of Nature Based Solutions for the enhancement of low flows. Int. J. River Basin Manag. https://doi.org/10.1080/15715124.2022.2092490.

Ferreira, V., Barreira, A.P., Pinto, P., Panagopoulos, T., 2022. Understanding attitudes towards the adoption of nature-based solutions and policy priorities shaped by stakeholders' awareness of climate change. Environ. Sci. Pol. 131, 149–159. https://doi.org/10.1016/j.envsci.2022.02.007.

Frantzeskaki, N., 2019. Seven lessons for planning nature-based solutions in cities. Environ. Sci. Pol. 93, 101–111. https://doi.org/10.1016/j.envsci.2018.12.033.

Frantzeskaki, N., Vandergert, P., Connop, S., Schipper, K., Zwierzchowska, I., Collier, M., Lodder, M., 2020. Examining the policy needs for implementing nature-based solutions in cities: findings from city-wide transdisciplinary experiences in Glasgow (UK), Genk (Belgium) and Poznan (Poland). Land Use Pol. 1–22.

Fröhle, P., Manojlovic, N., Tadesse, Y., Gruhn, A., Dittrich, H., Ebel, C., 2022. Managing Droughts in Northern Germany—The Reconect NBS Approach and Water Resources Model for Vier- Und Marschlande Area. Springer Water. Springer Nature, Hamburg, Germany, pp. 529–549. https://doi.org/10.1007/978-981-19-1600-7_34.

Gallotti, G., Santo, M.A., Apostolidou, I., Alessandri, J., Armigliato, A., Basu, B., Debele, S., Domeneghetti, A., Gonzalez-Ollauri, A., Kumar, P., Mentzafou, A., Pilla, F., Pulvirenti, B., Ruggieri, P., Sahani, J., Salmivaara, A., Basu, A.S., Spyrou, C., Pinardi, N., Toth, E., Unguendoli, S., Pillai, U.P.A., Valentini, A., Varlas, G., Zaniboni, F., Di Sabatino, S., 2021. On the management of nature-based solutions in open-air laboratories: new insights and future perspectives. Resources 10. https://doi.org/10.3390/resources10040036.

Gathagu, J.N., Sang, J.K., Maina, C.W., 2018. Modelling the impacts of structural conservation measures on sediment and water yield in Thika-Chania catchment, Kenya. International Soil and Water Conservation Research 6, 165–174. https://doi.org/10.1016/j.iswcr.2017.12.007.

Gebremeskel, G., Gebremicael, T.G., Girmay, A., 2018. Economic and environmental rehabilitation through soil and water conservation, the case of Tigray in northern Ethiopia. J. Arid Environ. 151, 113–124. https://doi.org/10.1016/j.jaridenv.2017.12.002.

Ghaleh, M.R., Ghaleh, M.R., 2020. The role of smart flood management in the ancient blue-green infrastructure. In: Presented at the International Symposium on Technology and Society, Proceedings. Institute of Electrical and Electronics Engineers Inc., pp. 417–421. https://doi.org/10.1109/ISTAS50296.2020.9462209

Gómez Martín, E., Máñez Costa, M., Egerer, S., Schneider, U.A., 2021. Assessing the long-term effectiveness of Nature-Based Solutions under different climate change scenarios. Sci. Total Environ. 794 https://doi.org/10.1016/j.scitotenv.2021.148515.

Gooden, J., Pritzlaff, R., 2021. Dryland watershed restoration with rock detention structures: a nature-based solution to mitigate drought, erosion, flooding, and atmospheric carbon. Front. Environ. Sci. 9 https://doi.org/10.3389/fenvs.2021.679189.

Gorissen, L., Spira, F., Meynaerts, E., Valkering, P., Frantzeskaki, N., 2018. Moving towards systemic change? Investigating acceleration dynamics of urban sustainability transitions in the Belgian City of Genk. J. Clean. Prod. 173, 171–185. https://doi.org/10.1016/j.jclepro.2016.12.052.

Gülbaz, S., Kazezyilmaz-Alhan, C.M., 2017. An evaluation of hydrologic modeling performance of EPA SWMM for bioretention. Water Sci. Technol. 76, 3035–3043. https://doi.org/10.2166/wst.2017.464.

Haefele, S.M., Kato, Y., Singh, S., 2016. Climate ready rice: augmenting drought tolerance with best management practices. Field Crops Res. 190, 60–69. https://doi.org/10.1016/j.fcr.2016.02.001.

Hankins, K., Welker, A.L., Mandarano, L., 2008. An Integrated Monitoring Plan for BioInfiltration BMPs. Presented at the Geotechnical Special Publication, pp. 1097–1104. https://doi.org/10.1061/40971(310)137.

Hein, T., Schwarz, U., Habersack, H., Nichersu, I., Preiner, S., Willby, N., Weigelhofer, G., 2016. Current status and restoration options for floodplains along the Danube River. Sci. Total Environ. 543, 778–790. https://doi.org/10.1016/j.scitotenv.2015.09.073.

Hernández-Hernández, M., Olcina, J., Morote, Á.-F., 2020. Urban stormwater management, a tool for adapting to climate change: from risk to resource. Water (Switzerland) 12. https://doi.org/10.3390/w12092616.

Hewett, C.J.M., Wilkinson, M.E., Jonczyk, J., Quinn, P.F., 2020. Catchment Systems Engineering: an Holistic Approach to Catchment Management, vol. 7. Wiley Interdisciplinary Reviews: Water. https://doi.org/10.1002/wat2.1417.

Holden, P.B., Rebelo, A.J., Wolski, P., Odoulami, R.C., Lawal, K.A., Kimutai, J., Nkemelang, T., New, M.G., 2022. Nature-based solutions in mountain catchments reduce impact of anthropogenic climate change on drought streamflow. Communications Earth and Environment 3. https://doi.org/10.1038/s43247-022-00379-9.

Holmes, D., McEvoy, J., Dixon, J.L., Payne, S., 2017. A geospatial approach for identifying and exploring potential naturalwater storage sites. Water (Switzerland) 9. https://doi.org/10.3390/w9080585.

Hussain, M.I., Farooq, M., Muscolo, A., Rehman, A., 2020. Crop diversification and saline water irrigation as potential strategies to save freshwater resources and reclamation of marginal soils—a review. Environ. Sci. Pollut. Control Ser. 27, 28695–28729. https://doi.org/10.1007/s11356-020-09111-6.

Irfanullah, H.Md, 2021. Nature-based solutions should be an integral part of locally-led adaptation. Climate Tribune.

Jakubínský, J., Pechanec, V., Cudlín, O., Purkyt, J., Cudlín, P., 2022. Identification of surface runoff source areas as a tool for projections of NBS in water management. In: Handbook of Environmental Chemistry. Springer Science and Business Media Deutschland GmbH, pp. 313–338. https://doi.org/10.1007/698_2021_775.

Jamei, E., Tapper, N., 2018. WSUD and urban heat island effect mitigation. In: Approaches to Water Sensitive Urban Design: Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions. Elsevier, pp. 381–407. https://doi.org/10.1016/B978-0-12-812843-5.00019-8.
Jiang, H., Xie, W., Xiang, W.-N., Zhao, H., 2022. When the natural pendulum swings between drought and flood, a bifunctional natural drainage system safeguards a mountain village's water security incessantly for centuries. Socio-Ecological Practice Research 4, 117–129. https://doi.org/10.1007/s42532-022-00109-7.
Jódar, J., Martos-Rosillo, S., Custodio, E., Mateos, L., Cabello, J., Casas, J., Salinas-Bonillo, M.J., Martín-Civantos, J.M., González-Ramón, A., Zakaluk, T., Herrera-Lameli, C., Urrutia, J., Lambán, L.J., 2022. The recharge channels of the sierra Nevada range (Spain) and the Peruvian andes as ancient nature-based solutions for the ecological transition. Water (Switzerland) 14. https://doi.org/10.3390/w14193130.
Jokar, D., Khakzand, M., Faizi, M., 2021. The application of low impact development approaches toward achieving circularity in the water sector: a case study from Soltan Abad, shiraz, Iran. J. Clean. Prod. 320 https://doi.org/10.1016/j.jclepro.2021.128712.
Kalantari, Z., Ferreira, C.S.S., Keesstra, S., Destouni, G., 2018. Nature-based solutions for flood-drought risk mitigation in vulnerable urbanizing parts of East-Africa. Current Opinion in Environmental Science and Health 5, 73–78. https://doi.org/10.1016/j.coesh.2018.06.003.
Keesstra, Saskia, Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., Cerdà, A., 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. Sci. Total Environ. 610, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077.
Khadse, A.A.P., 2021. Parameters for quantitative evaluation of non-structured sustainable strategies for the management of water in urban area. In: Presented at the Environmental Science and Engineering. Springer Science and Business Media Deutschland GmbH, pp. 41–54. https://doi.org/10.1007/978-3-030-61891-9_3.
Kiedrzyńska, E., Belka, K., Jarosiewicz, P., Kiedrzyński, M., Zalewski, M., 2021. The enhancement of valley water retentiveness in climate change conditions. Sci. Total Environ. 799 https://doi.org/10.1016/j.scitotenv.2021.149427.
Kim, G., Kang, W., Lee, D., Vaswani, R.T., Chon, J., 2019. A spatial approach to climate-resilient infrastructure in coastal social-ecological systems: the case of dumbeong in Goseong County, South Korea. Environ. Int. 131 https://doi.org/10.1016/j.envint.2019.105032.
Kloos, J., Renaud, F.G., 2016. Overview of ecosystem-based approaches to drought risk reduction targeting small- scale farmers in Sub-Saharan Africa. In: Advances in Natural and Technological Hazards Research. Springer Netherlands, pp. 199–226. https://doi.org/10.1007/978-3-319-43633-3_9.
Köhler, M., Kaiser, D., 2021. Green roof enhancement on buildings of the university of applied sciences in neubrandenburg (Germany) in times of climate change. Atmosphere 12. https://doi.org/10.3390/atmos12030382.
Koiv-Vainik, M., Kill, K., Espenberg, M., Uuemaa, E., Teemusk, A., Maddison, M., Palta, M.M., Török, L., Mander, Ü., Scholz, M., 2022. Urban stormwater retention capacity of nature-based solutions at different climatic conditions. Nature-Based Solutions, 100038. https://doi.org/10.1016/j.nbsj.2022.100038.
Kooijman, E.D., McQuaid, S., Rhodes, M.L., Collier, M.J., Pilla, F., 2021. Innovating with nature: from nature-based solutions to nature-based enterprises. Sustainability 13, 1263. https://doi.org/10.3390/su13031263.
Kraemer, R., Kabisch, N., 2022. Parks under stress: air temperature regulation of urban green spaces under conditions of drought and summer heat. Front. Environ. Sci. 10 https://doi.org/10.3389/fenvs.2022.849965.
Kuhlemann, L.-M., Tetzlaff, D., Marx, C., Soulsby, C., 2022. The imprint of hydroclimate, urbanization and catchment connectivity on the stable isotope dynamics of a large river in Berlin, Germany. J. Hydrol. 613 https://doi.org/10.1016/j.jhydrol.2022.128335.
Kumar, P., Debele, S.E., Sahani, J., Aragão, L., Barisani, F., Basu, B., Bucchignani, E., Charizopoulos, N., Di Sabatino, S., Domeneghetti, A., Edo, A.S., Finér, L., Gallotti, G., Juch, S., Leo, L.S., Loupis, M., Mickovski, S.B., Panga, D., Pavlova, I., Pilla, F., Prats, A.L., Renaud, F.G., Rutzinger, M., Basu, A.S., Shah, M.A.R., Soini, K., Stefanopoulou, M., Toth, E., Ukonmaanaho, L., Vranic, S., Zieher, T., 2020. Towards an operationalisation of nature-based solutions for natural hazards. Sci. Total Environ. 731, 138855 https://doi.org/10.1016/j.scitotenv.2020.138855.
Kumar, Prashant, Debele, S.E., Sahani, J., Rawat, N., Marti-Cardona, B., Alfieri, S.M., Basu, B., Basu, A.S., Bowyer, P., Charizopoulos, N., 2021. An overview of monitoring methods for assessing the performance of nature-based solutions against natural hazards. Earth Sci. Rev. 217, 103603 https://doi.org/10.1016/j.earscirev.2021.103603.
Kumar, P., Debele, S.E., Sahani, J., Rawat, N., Marti-Cardona, B., Alfieri, S.M., Basu, B., Basu, A.S., Bowyer, P., Charizopoulos, N., Gallotti, G., Jaakko, J., Leo, L.S., Loupis, M., Menenti, M., Mickovski, S.B., Mun, S.-J., Gonzalez-Ollauri, A., Pfeiffer, J., Pilla, F., Pröll, J., Rutzinger, M., Santo, M.A., Sannigrahi, S., Spyrou, C., Tuomenvirta, H., Zieher, T., 2021. Nature-based solutions efficiency evaluation against natural hazards: modelling methods, advantages and limitations. Sci. Total Environ. 784 https://doi.org/10.1016/j.scitotenv.2021.147058.
Kunapo, J., Fletcher, T.D., Ladson, A.R., Cunningham, L., Burns, M.J., 2018. A spatially explicit framework for climate adaptation. Urban Water J. 15, 159–166. https://doi.org/10.1080/1573062X.2018.1424216.
La Rosa, D., Privitera, R., 2013. Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. Landsc. Urban Plann. 109, 94–106. https://doi.org/10.1016/j.landurbplan.2012.05.012.
Ladányi, Zs, Blanka, V., Meyer, B., Mezosi, G., Rakonczai, J., 2015. Multi-indicator sensitivity analysis of climate change effects on landscapes in the Kiskunság National Park, Hungary. Ecol. Indicat. 58, 8–20. https://doi.org/10.1016/j.ecolind.2015.05.024.
Lafortezza, R., Sanesi, G., 2019. Nature-based solutions: settling the issue of sustainable urbanization. Environ. Res. 172, 394–398. https://doi.org/10.1016/j.envres.2018.12.063.
Lara-Valencia, F., Garcia, M., Norman, L.M., Anides Morales, A., Castellanos-Rubio, E.E., 2022. Integrating urban planning and water management through green infrastructure in the United States-Mexico border. Frontiers in Water 4. https://doi.org/10.3389/frwa.2022.782922.
Lassiter, A., 2022. Identifying causal changes in landscape greenness with very high-resolution airborne multispectral imagery and a panel data model. Urban For. Urban Green. 67 https://doi.org/10.1016/j.ufug.2021.127380.
Le, T.D.N., Awal, R., 2021. Adaptation to climate extremes and sea level rise in coastal cities of developing countries. In: Climate Change and Extreme Events. Elsevier, pp. 145–170. https://doi.org/10.1016/B978-0-12-822700-8.00003-2.
Lee, S., Kim, D., Maeng, S., Azam, M., Lee, B., 2022. Runoff reduction effects at installation of LID facilities under different climate change scenarios. Water (Switzerland) 14. https://doi.org/10.3390/w14081301.
Lemos, M., Minzner, M, 2013. For-Profit Public Enforcement. Harvard Law Review 127, 853–913.
Leta, O.T., Bauwens, W., 2018. Assessment of the impact of climate change on daily extreme peak and low flows of Zenne basin in Belgium. Hydrology 5, 38. https://doi.org/10.3390/hydrology5030038.
Lewellyn, C., Wadzuk, B., 2019. Evaluating the risk-based performance of bioinfiltration facilities under climate change scenarios. Water (Switzerland) 11. https://doi.org/10.3390/w11091765.
Li, Y., Guo, F., Mao, K., Chen, F., 2019. Response strategy for drought and flood in sponge city construction risk under the background of climate change. In: Presented at the IOP Conference Series: Earth and Environmental Science. Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/252/4/042015.
Lim, M., Xenarios, S., 2021. Economic assessment of urban space and blue-green infrastructure in Singapore. J. Urban Econ. 7, 1–11. https://doi.org/10.1093/jue/juab020.
Liu, B., Tang, C.-S., Pan, X.-H., Zhu, C., Cheng, Y.-J., Xu, J.-J., Shi, B., 2021. Potential drought mitigation through microbial induced calcite precipitation-MICP. Water Resour. Res. 57 https://doi.org/10.1029/2020WR029434.
Liu, H., Jia, Y., Niu, C., 2017. " Sponge city " concept helps solve China 's urban water problems. Environ. Earth Sci. 76, 473. https://doi.org/10.1007/s12665-017-6652-3.
Locatelli, B., Laurenceau, M., Chumpisuca, Y.R.C., Pramova, E., Vallet, A., Conde, Y.Q., Zavala, R.C., Djoudi, H., Lavorel, S., Colloff, M.J., 2022. In people's minds and on the ground: values and power in climate change adaptation. Environ. Sci. Pol. 137, 75–86. https://doi.org/10.1016/j.envsci.2022.08.002.
López Gunn, E., Rica, M., Zorrilla-Miras, P., Vay, L., Mayor, B., Pagano, A., Altamirano, M., Giordano, R., 2021. The natural assurance value of nature-based solutions: a layered institutional analysis of socio ecological systems for long term climate resilient transformation. Ecol. Econ. 186 https://doi.org/10.1016/j.ecolecon.2021.107053.
Mabon, L., Barkved, L., de Bruin, K., Shih, W.-Y., 2022. Whose knowledge counts in nature-based solutions? Understanding epistemic justice for nature-based solutions through a multi-city comparison across Europe and Asia. Environ. Sci. Pol. 136, 652–664. https://doi.org/10.1016/j.envsci.2022.07.025.
Mackinnon, K., Sobrevila, C., Hickey, V., 2008. Biodiversity, Climate Change, and Adaptation: Nature-Based Solutions from the World Bank Portfolio, Climate Change and Adaptation.
Madsen, H.M., Brown, R., Elle, M., Mikkelsen, P.S., 2017. Social construction of stormwater control measures in Melbourne and Copenhagen: A discourse analysis of technological change, embedded meanings and potential mainstreaming. Technol. Forecast. Soc. Change 115, 198–209. https://doi.org/10.1016/j.techfore.2016.10.003.
Maria Raquel, C.D.S., Montalto, F.A., Palmer, M.I., 2016. Potential climate change impacts on green infrastructure vegetation. Urban For. Urban Green. 20, 128–139. https://doi.org/10.1016/j.ufug.2016.08.014.
McCauley, L.A., Bradford, J.B., Robles, M.D., Shriver, R.K., Woolley, T.J., Andrews, C.A., 2022. Landscape-scale forest restoration decreases vulnerability to drought mortality under climate change in southwest USA ponderosa forest. For. Ecol. Manag. 509 https://doi.org/10.1016/j.foreco.2022.120088.
McDonald, D., Salisbury, S., Beatty, K., 2007. Building soils for storm water compliance and successful landscapes. Biocycle 48, 48+50–51.
Meilinger, V., Monstadt, J., 2022. The material politics of integrated urban stormwater management in Los Angeles, California. Local Environ. 27, 847–862. https://doi.org/10.1080/13549839.2022.2078292.
Mendonça, R., Roebeling, P., Fidélis, T., Saraiva, M., 2021. Policy instruments to encourage the adoption of nature-based solutions in urban landscapes. Resources 10, 81. https://doi.org/10.3390/resources10080081.
Meyer, A.D., Tirry, D., Gulinck, H., Orshoven, J.V., 2011. Actualisatie MIRA Achtergronddocument Bodem - Thema Bodemafdichting n.d.
Moeskops, S., 2018. River Kleine Nete: Creating Ecological Flooding Zones at Recreation Areas n.d.
Morgenroth, J., Buchan, G., Scharenbroch, B.C., 2013. Belowground effects of porous pavements-Soil moisture and chemical properties. Ecol. Eng. 51, 221–228. https://doi.org/10.1016/j.ecoleng.2012.12.041.
Mugari, E., Nethengwe, N.S., 2022. Mainstreaming ecosystem-based disaster risk reduction: towards a sustainable and just transition in local development planning in rural South Africa. Sustainability 14. https://doi.org/10.3390/su141912368.

Nanfuka, S., Mfitumukiza, D., Egeru, A., 2020. Characterisation of ecosystem-based adaptations to drought in the central cattle corridor of Uganda. Afr. J. Range Forage Sci. 37, 257–267. https://doi.org/10.2989/10220119.2020.1748713.

Nelson, D.R., Bledsoe, B.P., Ferreira, S., Nibbelink, N.P., 2020. Challenges to realizing the potential of nature-based solutions. Curr. Opin. Environ. Sustain. 45, 49–55. https://doi.org/10.1016/j.cosust.2020.09.001.

Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O.I., Wilkinson, M.E., Wittmer, H., 2017. The science, policy and practice of nature-based solutions: an interdisciplinary perspective. Sci. Total Environ. 579, 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106.

Nguyen, Thu Thuy, Ngo, H.H., Guo, W., Wang, X.C., Ren, N., Li, G., Ding, J., Liang, H., 2019. Implementation of a specific urban water management - sponge City. Sci. Total Environ. 652, 147–162. https://doi.org/10.1016/j.scitotenv.2018.10.168.

Nichols, P.W.B., Lucke, T., 2015. Local level stormwater harvesting and reuse: a practical solution to the water security challenges faced by urban trees. Sustainability 7, 8635–8648. https://doi.org/10.3390/su7078635.

Niemeyer, J., Vale, M.M., 2022. Obstacles and opportunities for implementing a policy-mix for ecosystem-based adaptation to climate change in Brazil's Caatinga. Land Use Pol. 122 https://doi.org/10.1016/j.landusepol.2022.106385.

Nolan, R.H., Vesk, P.A., Robinson, D., 2018. Recovery potential of microwetlands from agricultural land uses. Ecol. Manag. Restor. 19, 81–84. https://doi.org/10.1111/emr.12283.

Norbury, M., Phillips, H., Macdonald, N., Brown, D., Boothroyd, R., Wilson, C., Quinn, P., Shaw, D., 2021. Quantifying the hydrological implications of pre- and post-installation willowed engineered log jams in the Pennine Uplands, NW England. J. Hydrol. 603 https://doi.org/10.1016/j.jhydrol.2021.126855.

Norman, L.M., Lal, R., Wohl, E., Fairfax, E., Gellis, A.C., Pollock, M.M., 2022. Natural infrastructure in dryland streams (NIDS) can establish regenerative wetland sinks that reverse desertification and strengthen climate resilience. Sci. Total Environ. 849 https://doi.org/10.1016/j.scitotenv.2022.157738.

Nuti, R.C., Lamb, M.C., Sorensen, R.B., Truman, C.C., 2009. Agronomic and economic response to furrow diking tillage in irrigated and non-irrigated cotton (Gossypium hirsutum L.). Agric. Water Manag. 96, 1078–1084. https://doi.org/10.1016/j.agwat.2009.03.006.

OECD, 2020. Nature-based Solutions for Adapting to Water-Related Climate Risks: Policy Perspectives. Organization for Economic Cooperation and Development Paris, France.

O'Hogain, S., McCarton, L., 2018. A Technology Portfolio of Nature Based Solutions: Innovations in Water Management, A Technology Portfolio of Nature Based Solutions: Innovations in Water Management. Springer. https://doi.org/10.1007/978-3-319-73281-7.

Onderka, M., Pecho, J., Nejedlík, P., 2020. Storage capacity of rain tanks optimized for the local climate in two metropolitan areas of Slovakia. Acta Hydrologica Slovaca 21, 152–159. https://doi.org/10.31577/ahs-2020-0021.02.0019.

Oral, H.V., Carvalho, P., Gajewska, M., Ursino, N., Masi, F., van Hullebusch, E.D., Kazak, J.K., Exposito, A., Cipolletta, G., Andersen, T.R., Finger, D.C., Simperler, L., Regelsberger, M., Rous, V., Radinja, M., Buttiglieri, G., Krzeminski, P., Rizzo, A., Dehganian, K., Nikolova, M., Zimmermann, M., 2020. A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature. Blue-Green Systems 2, 112–136. https://doi.org/10.2166/bgs.2020.932.

Ossola, A., Lin, B.B., 2021. Making nature-based solutions climate-ready for the 50 °C world. Environ. Sci. Pol. 123, 151–159. https://doi.org/10.1016/j.envsci.2021.05.026.

Ouled Belgacem, A., Ben Salem, F., Gamoun, M., Chibani, R., Louhaichi, M., 2019. Revival of traditional best practices for rangeland restoration under climate change in the dry areas: a case study from Southern Tunisia. International Journal of Climate Change Strategies and Management 11, 643–659. https://doi.org/10.1108/IJCCSM-02-2018-0019.

Pagano, A., Pluchinotta, I., Pengal, P., Cokan, B., Giordano, R., 2019. Engaging stakeholders in the assessment of NBS effectiveness in flood risk reduction: a participatory System Dynamics Model for benefits and co-benefits evaluation. Sci. Total Environ. 690, 543–555. https://doi.org/10.1016/j.scitotenv.2019.07.059.

Pease, L.A., Fausey, N.R., Martin, J.F., Brown, L.C., 2017. Projected climate change effects on subsurface drainage and the performance of controlled drainage in the Western Lake Erie Basin. J. Soil Water Conserv. 72, 240–250. https://doi.org/10.2489/jswc.72.3.240.

Piedelobo, L., Taramelli, A., Schiavon, E., Valentini, E., Molina, J.-L., Xuan, A.N., González-Aguilera, D., 2019. Assessment of green infrastructure in Riparian zones using copernicus programme. Rem. Sens. 11 https://doi.org/10.3390/rs11242967.

Pilliod, D.S., Rohde, A.T., Charnley, S., Davee, R.R., Dunham, J.B., Gosnell, H., Grant, G. E., Hausner, M.B., Huntington, J.L., Nash, C., 2018. Survey of beaver-related restoration practices in rangeland streams of the western USA. Environ. Manag. 61, 58–68. https://doi.org/10.1007/s00267-017-0957-6.

Prudent, M., Dequiedt, S., Sorin, C., Girodet, S., Nowak, V., Duc, G., Salon, C., Maron, P.-A., 2020. The diversity of soil microbial communities matters when legumes face drought. Plant Cell Environ. 43, 1023–1035. https://doi.org/10.1111/pce.13712.

Qiu, J., Shen, Z., Hou, X., Xie, H., Leng, G., 2020. Evaluating the performance of conservation practices under climate change scenarios in the Miyun Reservoir Watershed, China. Ecol. Eng. 143 https://doi.org/10.1016/j.ecoleng.2019.105700.

Quin, A., Destouni, G., 2018. Large-scale comparison of flow-variability dampening by lakes and wetlands in the landscape. Land Degrad. Dev. 29, 3617–3627. https://doi.org/10.1002/ldr.3101.

Radonic, L., 2019. Re-Conceptualising water conservation: rainwater harvesting in the desert of the southwestern United States. Water Altern. (WaA) 12, 699–714.

Rahman, M.A., Dervishi, V., Moser-Reischl, A., Ludwig, F., Pretzsch, H., Rötzer, T., Pauleit, S., 2021. Comparative analysis of shade and underlying surfaces on cooling effect. Urban For. Urban Green. 63 https://doi.org/10.1016/j.ufug.2021.127223.

Ramsar Convention Secretariat, 2017. Ramsar. https://www.ramsar.org/news/wetlands-worlds-most-valuable-ecosystem-disappearing-three-times-faster-forests-warns-new. Accessed 01.05.2023.

Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D., Calfapietra, C., 2017. A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environ. Sci. Pol. 77, 15–24. https://doi.org/10.1016/j.envsci.2017.07.008.

Rebelo, A.J., Holden, P.B., Hallowes, J., Eady, B., Cullis, J.D.S., Esler, K.J., New, M.G., 2022. The hydrological impacts of restoration: a modelling study of alien tree clearing in four mountain catchments in South Africa. J. Hydrol. 610 https://doi.org/10.1016/j.jhydrol.2022.127771.

Renwick, L.L.R., Deen, W., Silva, L., Gilbert, M.E., Maxwell, T., Bowles, T.M., Gaudin, A. C.M., 2021. Long-term crop rotation diversification enhances maize drought resistance through soil organic matter. Environ. Res. Lett. 16 https://doi.org/10.1088/1748-9326/ac1468.

Ribeiro, L., 2021. Revisiting ancestral groundwater techniques as nature based solutions for managing water. In: Advances in Science, Technology and Innovation. Springer Nature, pp. 483–487. https://doi.org/10.1007/978-3-030-59320-9_103.

Ricart, S., Rico-amoros, A.M., 2021. Constructed wetlands to face water scarcity and water pollution risks: learning from farmers' perception in alicante, Spain. Water 13, 2431. https://doi.org/10.3390/w13172431.

Ricciardiello, L., Leja, M., Ollivier, M., 2021. Horizon Europe, the new programme for research & innovation: which opportunities for GI research in the years to come? United European Gastroenterology Journal 9, 407–409.

Rivera-Ferre, M.G., Di Masso, M., Vara, I., Cuellar, M., Calle, A., Mailhos, M., López-i-Gelats, F., Bhatta, G., Gallar, D., 2016. Local agriculture traditional knowledge to ensure food availability in a changing climate: revisiting water management practices in the Indo-Gangetic Plains. Agroecology and Sustainable Food Systems 40, 965–987. https://doi.org/10.1080/21683565.2016.1215368.

Rizzo, A., Banovec, P., Cilenšek, A., Rianna, G., Santini, M., 2020. An innovative tool for the management of the surface drinking water resources at european level: GOWARE-Transnational guide towards an optimal WAter REgime. Water (Switzerland) 12. https://doi.org/10.3390/w12020370.

Rogé, P., Friedman, A.R., Astier, M., Altieri, M.A., 2014. Farmer strategies for dealing with climatic variability: a case study from the mixteca alta region of oaxaca, Mexico. Agroecology and Sustainable Food Systems 38, 786–811. https://doi.org/10.1080/21683565.2014.900842.

Ronnquist, A.L., Westbrook, C.J., 2021. Beaver dams: how structure, flow state, and landscape setting regulate water storage and release. Sci. Total Environ. 785 https://doi.org/10.1016/j.scitotenv.2021.147333.

Ruangpan, L., Vojinovic, Z., 2022. A framework for evaluating performance of large-scale nature-based solutions to reduce hydro-meteorological risks and enhance Co-benefits. In: Springer Water. Springer Nature, pp. 515–527. https://doi.org/10.1007/978-981-19-1600-7_33.

Ruangpan, L., Vojinovic, Z., Di Sabatino, S., Leo, L.S., Capobianco, V., Oen, A.M.P., Mcclain, M.E., Lopez-Gunn, E., 2020. Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. Nat. Hazards Earth Syst. Sci. 20, 243–270. https://doi.org/10.5194/nhess-20-243-2020.

Sahani, J., Kumar, P., Debele, S., Spyrou, C., Loupis, M., Aragão, L., Porcù, F., Shah, M.A. R., Di Sabatino, S., 2019. Hydro-meteorological risk assessment methods and management by nature-based solutions. Sci. Total Environ. 696 https://doi.org/10.1016/j.scitotenv.2019.133936.

Salinas Rodriguez, C.N.A., Ashley, R., Gersonius, B., Rijke, J., Pathirana, A., Zevenbergen, C., 2014. Incorporation and application of resilience in the context of water-sensitive urban design: linking European and Australian perspectives. Wiley Interdisciplinary Reviews: Water 1, 173–186. https://doi.org/10.1002/wat2.1017.

Sawadogo, H., 2011. Using soil and water conservation techniques to rehabilitate degraded lands in Northwestern Burkina Faso. Int. J. Agric. Sustain. 9, 120–128. https://doi.org/10.3763/ijas.2010.0552.

Schoukens, H., 2022. The conservation of aquifers in Flanders as a regulatory challenge: how to avoid a death by a thousand cuts? Chinese Journal of Environmental Law 6, 323–347. https://doi.org/10.1163/24686042-12340090.

Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J., Smith, A., Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Phil. Trans. Biol. Sci. 375, 20190120 https://doi.org/10.1098/rstb.2019.0120.

Siehr, S.A., Sun, M., Aranda Nucamendi, J.L., 2022. Blue-green Infrastructure for Climate Resilience and Urban Multifunctionality in Chinese Cities, vol. 11. Wiley Interdisciplinary Reviews: Energy and Environment. https://doi.org/10.1002/wene.447.

Silvertooth, D.L., Neris, B.L., Solek, C.W., Wilson, D.D., 2019. Green infrastructure inventory review in southern California. In: Presented at the World Environmental and Water Resources Congress 2019: Groundwater, Sustainability, Hydro-Climate/Climate Change, and Environmental Engineering - Selected Papers from the World Environmental and Water Resources Congress 2019. American Society of Civil Engineers (ASCE), pp. 461–478. https://doi.org/10.1061/9780784482346.047.

Sishah, B., Thapa, Y., Roose, A., Muhlhame, T., Mendieta, H., Kukral, J., Louise, J., Choudalaki, E., Griensven, A., 2017. Wetland Restoration at Varenheuvel-Abroek.

Smith, A.C., Tasnim, T., Irfanullah, H.M., Turner, B., Chausson, A., Seddon, N., 2021. Nature-based solutions in Bangladesh: evidence of effectiveness for addressing climate change and other sustainable development goals. Front. Environ. Sci. 9 https://doi.org/10.3389/fenvs.2021.737659.

Spyrou, C., Loupis, M., Charizopoulos, N., Apostolidou, I., Mentzafou, A., Varlas, G., Papadopoulos, A., Dimitriou, E., Panga, D., Gkeka, L., Bowyer, P., Pfeifer, S., Debele, S.E., Kumar, P., 2021. Evaluating nature-based solution for flood reduction in spercheios river basin under current and future climate conditions. Sustainability 13. https://doi.org/10.3390/su13073885.

Spyrou, C., Loupis, M., Charizopoulos, N., Arvanitis, P., Mentzafou, A., Dimitriou, E., Debele, S.E., Sahani, J., Kumar, P., 2022. Evaluating nature-based solution for flood reduction in spercheios river basin Part 2: early experimental evidence. Sustainability 14. https://doi.org/10.3390/su141610345.

Sy, M., Baguian, H., Gahi, N., 2014. Multiple use of green spaces in bobo-dioulasso, Burkina Faso. Urban Agriculture 27, 33–36.

Trémolet, S., Favero, A., Karres, N., Toledo, M., Makropoulos, C., Lykou, A., Hanania, S., Rebollo, V., Anton, B., 2019. Investing in Nature for Europe Water Security.

Voskamp, I.M., Van de Ven, F.H.M., 2015. Planning support system for climate adaptation: composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Build. Environ. 83, 159–167. https://doi.org/10.1016/j.buildenv.2014.07.018.

Wang, Y., Huang, J., Chen, X., 2019. Do forests relieve crop thirst in the face of drought? Empirical evidence from South China. Global Environ. Change 55, 105–114. https://doi.org/10.1016/j.gloenvcha.2019.01.008.

Welderufael, W.A., Woyessa, Y.E., Edossa, D.C., 2013. Impact of rainwater harvesting on water resources of the modder river basin, central region of South Africa. Agric. Water Manag. 116, 218–227. https://doi.org/10.1016/j.agwat.2012.07.012.

Wild, C., 2011. Beaver as a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico.

Wilhite, D., Glantz, M., 1985. Understanding the drought phenomenon: the role of definitions. Water Int. 10, 111–120. https://doi.org/10.4324/9780429301735-2.

World Bank Group, 2022. The World Bank. https://projects.worldbank.org/en/projects-operations/project-detail/P132100?lang=en. Accessed 01.05.2023.

WWAP (United Nations World Water Assessment Programme), UN-Water, 2018. The United Nations World Water Development Report 2018: Nature-Based Solutions for Water. Unesco.

Yimer, E.A., Riakhi, F.-E., Bailey, R.T., Nossent, J., van Griensven, A., 2023a. The impact of extensive agricultural water drainage on the hydrology of the Kleine Nete watershed, Belgium. Sci. Total Environ., 163903 https://doi.org/10.1016/j.scitotenv.2023.163903.

Yimer, E.A., T Bailey, R., Van Schaeybroeck, B., Van De Vyver, H., Villani, L., Nossent, J., Van Griensven, A., 2023b. Regional Evaluation of Groundwater-Surface Water Interactions Using a Coupled Geohydrological Model (SWAT+gwflow) 50. https://doi.org/10.1016/j.ejrh.2023.101532.

Yimer, E.A., T Bailey, T.B., Leda Piepers, L., Nossent, J., Van Griensven, A., 2023c. Improved representation of groundwater–surface water interactions using SWAT+gwflow and modifications to the gwflow module. Water 15. https://doi.org/10.3390/w15183249.

Yimer, E.A., Van Schaeybroeck, B., Van de Vyver, H., Van Griensven, A., 2022. Evaluating probability distribution functions for the standardized precipitation evapotranspiration index over Ethiopia. Atmosphere 13, 364. https://doi.org/10.3390/atmos13030364.

Yimer, E.A., Yadollahi, S., Riakhi, F.-E., Alitane, A., Weerasinghe, I., Wirion, C., Nossent, J., van Griensven, A., 2023d. A groundwater level-based filtering to improve the accuracy of locating agricultural tile drain and ditch networks. Int. J. Appl. Earth Obs. Geoinf. 122, 103423.

Yuan, Z., Liang, C., Li, D., 2018. Urban stormwater management based on an analysis of climate change: a case study of the Hebei and Guangdong provinces. Landsc. Urban Plann. 177, 217–226. https://doi.org/10.1016/j.landurbplan.2018.04.003.

Zalewski, M., 2021. Ecosystem biotechnologies for the enhancement of ecohydrological potential of the catchments - water, biodiversity, ecosystem services, resilience, culture and education. In: Presented at the IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd. https://doi.org/10.1088/1755-1315/789/1/012031.

Zhang, J., Fu, D., Zevenbergen, C., 2022. Moving towards water sensitive cities: a planning framework, underlying principles, and technologies—case study kunshan sponge city. In: Encyclopedia of Inland Waters, second ed. Elsevier, pp. 399–416. https://doi.org/10.1016/B978-0-12-819166-8.00185-7.

Zheng, Y., Ross, A., Villhoth, K.G., Dillon, P., 2021. Managing Aquifer Recharge: A Showcase for Resilience and Sustainability.

Zimmerman, M.J., Waldron, M.C., Barbaro, J.R., Sorenson, J.R., 2010. Effects of low-impact-development (LID) practices on streamflow, runoff quantity, and runoff quality in the Ipswich River Basin, Massachusetts: a summary of field and modeling studies. US Geol. Surv. Circular 6–41.

ETC/CCA - European Topic Centre on Climate Change impacts, vulnerability and Adaptation (2019-2021), 2021. CMCC [WWW Document], n.d. URL https://www.cmcc.it/projects/etccca-european-topic-centre-on-climate-change-impacts-vulnerability-and-adaptation-2019-2021 (accessed 11.10.22).