Land Use Policy 135 (2023) 106957

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Opportunities and limitations for Nature-Based Solutions in EU policies – Assessed with a focus on ponds and pondscapes

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ARTICLE INFO

Keywords:
Barriers and enabling factors
EU policy framework
NBS implementation
Opportunities and limitations
Policy analysis
Ponds and pondscapes

ABSTRACT

Nature-Based Solutions (NBS) are growing in popularity to mitigate and adapt to climate change, enhance biodiversity, and secure human well-being. However, the emergence of NBS has not generated equal attention for all ecosystems. One such neglected ecosystem are ponds and pondscapes (i.e. groups of ponds in a landscape), which are deteriorating in quality and diminishing in quantity. As the European Union (EU) is regarded as influential in the conceptualisation and operationalisation of NBS, we conducted a qualitative content analysis of 38 EU policies to identify opportunities and limitations for the implementation of ponds and pondscapes as NBS. We focus our analysis on ponds and pondscapes, but their prevalence in different landscapes and their multitude of benefits allows us to also make some inferences about the implications of the EU policy context for NBS at large. We find that EU policies strengthen NBS linked to existing and potential Natura 2000 sites, as well as to ecosystems protected through the EU's Birds and Habitats Directives and Water Framework Directive. However, if ecosystems fall outside of these already established policies – as is the case with the vast majority of ponds and pondscapes – their implementation as NBS may be hampered. We also find that the EU emphasises natural water retention measures and carbon-rich ecosystems for climate change adaptation and mitigation, but mostly does not explicitly include ponds and pondscapes despite their potential contributions. Other findings are that the EU's Horizon Europe research policy will likely influence which ecosystems will be used and financed as NBS, while the exact ambition and selection of NBS rests with lower-level authorities or individuals. Therefore, further studies tracing the impact of the supra-national EU policy framework at lower governance levels are vital.

1. Introduction

In the Anthropocene, mitigating and adapting to climate change, reversing the biodiversity decline, and ensuring human well-being are pressing challenges (IPBES, 2019; IPCC, 2022). One increasingly popular approach to tackle these challenges are 'Nature-Based Solutions' (NBS) (Nesshöver et al., 2017). In the broadest sense, NBS involve working with nature for simultaneous biodiversity and societal benefits. The European Union (EU), a main promoter of NBS (Davies et al., 2021), places the focus on creating, restoring, or actively managing ecosystems. Other actors also consider ecosystem protection, with no or minimal intervention, as NBS (Cohen-Shacham et al., 2016; Eggermont et al., 2015). Hence, a range of actions can qualify as NBS, and there are discrepancies in the extent to which different ecosystems (or their elements) are used as NBS in practice. For example, while afforestation (Seddon et al., 2021) and urban green spaces (Garmendia et al., 2016) are frequently used as NBS (despite sometimes negligible benefits for biodiversity), other ecosystems are often overlooked (Welden et al., 2021).

One type of ecosystem that has not received much attention in the conversation on NBS is ponds and pondscapes (i.e. networks of spatially coherent ponds and surrounding terrestrial habitats) (Hill et al., 2018; Oertli, 2018), despite a wide-ranging applicability as NBS (Cuenca-Cambronero et al., 2023). Not only do ponds collectively support more than seventy percent of the freshwater species pool in Europe (Gozlan et al., 2019), they can also store water for irrigation to mitigate droughts or function as an alternative to groundwater pumps (Chen et al., 2019), constitute part of urban drainage systems for flood control (Blicharska and Johansson, 2016), serve as sites for education (Sousa et al., 2016) or leisure activities (Giampaoli et al., 2014), and provide other

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https://doi.org/10.1016/j.landusepol.2023.106957
Received 12 December 2022; Received in revised form 12 September 2023; Accepted 28 October 2023
Available online 8 November 2023

non-material benefits to human well-being (Feng and Nassauer, 2022), among other things. Yet, it has been suggested that ponds are some of the fastest disappearing and deteriorating freshwater habitats – not least in Europe (Gozlan et al., 2019; Kristensen and Globevnik, 2014). Hence, there is a discrepancy between their importance and their state or, even more, their application as NBS.

In fact, there has been some research into barriers and enabling factors for NBS implementation (including planning, design, financing, and upkeep) generally at the local and national level (Deely et al., 2020; Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Sarabi et al., 2019, 2020). Yet, there is little research into the workings of supra-national policy frameworks (Sarabi et al., 2019), despite them having a paramount importance for the regulatory and ideational margins of operation for lower governance levels (Seddon et al., 2021; van der Jagt et al., 2023). The EU policy framework, specifically, defines inter alia institutional arrangements, the markers of policy success (e.g., 'good status' in the Water Framework Directive), research priorities (e.g., defined in Horizon Europe), cross-sectoral agendas (e.g., Green Infrastructure Strategy), and conditionalities for funding (e.g., in the Common Agricultural Policy) (Ramírez-Agudelo et al., 2020; Sarabi et al., 2020). It also influences policies within and outside the EU (Garmendia et al., 2016; Mendes et al., 2020). Hence, understanding the impact of EU policies on NBS implementation is crucial (Maes and Jacobs, 2017; Mendes et al., 2020; Nesshöver et al., 2017; Pauleit et al., 2017; Welden et al., 2021), especially at a time when NBS conceptualisation and operationalisation are still malleable (O'Sullivan et al., 2020) and the EU sets political cornerstones for the future through its Green Deal (EC, 2019). Therefore, a timely assessment of the EU policy framework can help with identifying the key levers to advance NBS implementation generally and bottlenecks for the implementation of underutilised ecosystems, such as ponds, particularly.

In this paper, we employ a qualitative content analysis to assess how EU policies result in opportunities and limitations for the implementation of NBS. We define the concepts 'opportunities' and 'limitations' to describe the interactions and collective effects of enabling factors and barriers, respectively. We focus our analysis on ponds and pondscapes because they are deteriorating fast despite providing biodiversity and other co-benefits (Hill et al., 2018). Concentrating on one type of ecosystem allows for in-depth insights into how EU policies may curb or propel the implementation of particular ecosystems as NBS. Yet, due to the manifold potential ways to implement ponds and pondscapes as NBS in a range of landscapes (Cuenca-Cambronero et al., 2023), our analysis also allows us to draw some inferences for the implications of the EU policy framework for NBS at large.

2. Nature-Based Solutions and their implementation

2.1. Nature-Based Solutions: a fuzzy concept

NBS as a concept has emerged out of and incorporates under its 'umbrella' inter alia the concepts of ecosystem-based adaptation and green infrastructure (Cohen-Shacham et al., 2019; Pauleit et al., 2017). NBS was originally promoted by high-level stakeholders – primarily the EU and the International Union for the Conservation of Nature (Cohen-Shacham et al., 2019; Davies et al., 2021; Eggermont et al., 2015; Faivre et al., 2017; Mendes et al., 2020). The EU in particular has positioned itself as a global leader in NBS (Hanson et al., 2020; O'Sullivan et al., 2020) and financed research that has shaped the concept since 2012 (Davies et al., 2021; Mendes et al., 2020). For the EU, the focus is supposedly on 'ecologically engineering' ecosystems (i.e., their creation, restoration, or active management) to address societal challenges. Yet, other actors also consider less intrusive measures as NBS (e.g., the mere protection of ecosystems) (Cohen-Shacham et al., 2016; Eggermont et al., 2015). Hence, despite its recent proliferation, what NBS means in practice can be fuzzy (Sowińska-Świerkosz and García, 2022). Even though we analyse EU policies, in this study we employ a broad understanding of actions potentially qualifying as NBS to not preclude any measures from our analysis a priori.

NBS has been described as a 'boundary concept' (Hanson et al., 2020), as its broadness allows a range of disciplines to enter into dialogues (Cohen-Shacham et al., 2019; Hanson et al., 2020; Mendes et al., 2020; Seddon et al., 2021). Also, NBS, with its focus on 'solutions', has been found to be more palatable to decision-makers than comparable 'green' concepts (Melanidis and Hagerman, 2022; O'Sullivan et al., 2020). Yet, this blurriness can also hamper implementation due to the absence of clear delineations and guidance for decision-makers (Mendes et al., 2020; Gómez Martín et al., 2020; Hanson et al., 2020). It can even become corrosive to underlying objectives of NBS, for example, when projects oversell contributions of 'nature' or neglect biodiversity concerns and other societal co-benefits (O'Sullivan et al., 2020). In such cases, NBS may materialise as isolated creations of ecosystems in service of economic growth, but less so as effective measures for biodiversity enhancement, such as the extensive protection of ecosystems for habitat connectivity (Garmendia et al., 2016; Seddon et al., 2020; Welden et al., 2021).

Some of these trends may stem from the fact that the EU has prioritised generating 'green growth' through NBS over biodiversity and societal co-benefits (Davies et al., 2021; Maes and Jacobs, 2017; Mendes et al., 2020; Nesshöver et al., 2017; Pauleit et al., 2017; Welden et al., 2021). Consequently, while NBS as a concept is a powerful tool for communication, a promise of green transformation is not automatically realised (Melanidis and Hagerman, 2022). We also note that not all ecosystems have found equal consideration in the wake of the concept's emergence, so far. One of these ecosystems are ponds and pondscapes.

2.2. Ponds and pondscapes as NBS

There is no universal agreement on what a pond is (Richardson et al., 2022). Broadly defined, ponds can vary in size from a square metre to several hectares, are between a few centimetres and several metres deep, hold water at least a few months a year, and can either be man-made or natural in origin (Biggs et al., 2017; EPCN, 2008). Networks of spatially coherent ponds and surrounding terrestrial habitats make up a 'pondscape' (Briggs et al., 2019; Hill et al., 2018; Oertli and Parris, 2019). There is also no clear-cut delineation between pondscapes and wetlands either. The Ramsar Convention on Wetlands includes ponds under their category of 'inland and human-made wetlands' (UNESCO, 1994), but it is unclear whether all pondscapes qualify as wetlands. To add to the conceptual unclarity, ponds and pondscapes may be part of a river's floodplain and connect temporarily with the main stream (Sayer, 2014).

Ponds and pondscapes are diverse and exist in many types of landscapes, including urban areas, farmland, grassland, peatlands, salt marshes, and woodlands. Ponds provide a wide range of benefits (see details in Table A1 in Appendix A). It is difficult to generalise their benefits, as surrounding land use and proximity to other ponds affect the type and quality of benefits delivered (Oertli and Parris, 2019). Some benefits, such as biodiversity enhancement, are associated with nearly all ponds (Davies et al., 2008; Williams et al., 2003) and especially pronounced in pondscapes due to better habitat complexity and connectivity (Hill et al., 2018; Oertli and Parris, 2019). Other benefits are associated with specific types of ponds, such as irrigation with rural or stormwater detention with urban ponds.

Given their environmental and societal benefits, ponds and pondscapes can be implemented as NBS to address numerous societal challenges, such as biodiversity enhancement (e.g., increase of macrophytes), climate resilience (e.g., water retention for increased drought and/or flood resilience), water quality management (e.g., reduction of surface runoff), or health and well-being (e.g., space for relaxation). In practice, this means the creation, restoration or management of ponds and pondscapes (see Table A2 in Appendix A for examples). The suitability of interventions is contextual, and practitioners should select appropriate actions based on the state of the pond(scape) in question, local land use, and stakeholder preferences (Hassall, 2014; Sayer et al., 2012).

Despite their multiple benefits, the quality and quantity of ponds are decreasing, albeit exact numbers and assessments are lacking (Gozlan et al., 2019; Kristensen and Globevnik, 2014). Drivers of loss include climate change and shorter hydroperiods, invasive species (Oertli et al., 2009; Oertli and Parris, 2019), as well as human practices. For example, in rural areas, in-filling and drainage systems, weirs and sluices, and intensive inputs of chemical fertilisers and pesticides lead to isolated, uniform, polluted, and terrestrialised ponds (Sayer et al., 2012; Sayer and Greaves, 2020). In cities, housing and road construction, as well as uncontrolled wastewater cause similar challenges (Biggs et al., 2017; Blicharska and Johansson, 2016; Boothby, 1999; Hill et al., 2018; Oertli and Parris, 2019; Sayer, 2014).

2.3. Barriers and enabling factors for NBS implementation

To understand how NBS are implemented and which ecosystems are most likely to be used, it is useful to consider policy barriers and enabling factors to NBS implementation. We define 'barriers' as factors that hamper any stage of the implementation cycle of NBS, such as their design, planning, financing or upkeep of NBS (for more details on the NBS implementation cycle see Raymond, 2017), and 'enabling factors' as those that facilitate the aforementioned processes. Synthesising the insights of seminal publications on the matter (Deely et al., 2020; Gómez Martín et al., 2020; Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Randrup et al., 2020; Sarabi et al., 2019, 2020), below we introduce six overarching categories of barriers and enabling factors: *legal standards & regulations*, *management approaches & tools*, *institutional arrangements & cooperation*, *financing*, *stakeholder awareness & engagement*, and *knowledge development & transmission*.

Also, not all barriers and enabling factors matter to the same degree in all contexts (Gómez Martín et al., 2020) and they are more interlinked than a list suggests (Sarabi et al., 2020). For example, financing can link to legal statutory designations or stakeholder awareness can depend on the state of knowledge. Table 1 shows pond and pondscape-specific examples of these barriers and enabling factors.

Legal standards & regulations: This category includes regulatory standards (e.g., water quality standards; infrastructure standards), statutory designations (e.g., designation as protected area), and legal principles (e.g., biodiversity offsetting) that can affect NBS implementation. Most regulatory frameworks almost exclusively consider and possibly mandate grey infrastructure, excluding NBS as viable options (Deely et al., 2020; Sarabi et al., 2019). Even environmental regulations occasionally omit the protection or regulation of some ecosystems (Sarabi et al., 2019), such as the EU Birds and Habitats Directives which lay the legal foundation for the Natura 2000 (i.e. the *European* network of protected areas across the territory of the EU), but have been criticised for underrepresenting invertebrates and plants as well as their habitats in the list of species and habitats to be protected (Mammides, 2019). Updated legal provisions that protect ecosystems or account for the specificities of non-conventional infrastructure may facilitate NBS implementation, which can either happen directly through or be mandated by supra-national policies (Sarabi et al., 2019).

Management approaches & tools: This category encompasses planning, monitoring, and maintenance processes linked to NBS implementation. For example, short planning horizons can lead to unfavourable evaluations of NBS, which often need comparatively more time to develop their full benefits (Deely et al., 2020; Sarabi et al., 2020). Also, many agencies plan at small spatial scales, which can lead to disregarding 1) interactions of NBS with other infrastructure, 2) spatially distant benefits from and threats to NBS, or 3) NBS altogether, as they often cannot be 'squeezed into' the landscape a posteriori (Deely et al., 2020; Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Sarabi et al., 2019, 2020). This is compounded by inadequate monitoring standards for NBS (Deely et al., 2020; Nelson et al., 2020; Sarabi et al., 2020) and a lack of data, possibly resulting in a vicious circle with a low confidence in NBS (Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Sarabi et al., 2019). Therefore, scholars call for NBS design, monitoring, and maintenance guidelines (Deely et al., 2020; Sarabi et al., 2019, 2020). This should include, in particular, guidelines and tools to monitor both

Table 1
Pond(scape)-related examples of barriers and enabling factors.

Category	Examples of barrier	Examples of enabling factor
Legal standards & regulations	EU Habitats Directive protects few pond types and pond-associated species (Hill et al., 2018). EU Water Framework Directive does not cover water bodies <50 ha, placing ponds outside regulatory control and disregarding connections with other water bodies (Biggs et al., 2017; Boix et al., 2012; Hill et al., 2018; Oertli, 2018; Sayer, 2014).	Statutory designations as protected sites (Biggs et al., 2017; Boothby, 1999) or mandated ecological compensation for planned developments could reflect the multifunctional value of pondscapes (Boothby, 1999; Hill et al., 2018; Sayer and Greaves, 2020).
Management approaches & tools	Management regimes focus on large water bodies or grey infrastructure ('big is powerful') (Boix et al., 2012; Osti, 2017). Meanwhile, the lack of planning at larger spatial scales and absence of monitoring standards lead to overlooking pond benefits, connectivity of water bodies, and issues such as landscape fragmentation (Boothby, 1999; Hill et al., 2018; Oertli et al., 2009; Sayer, 2014).	Policies should support the clustering of ponds with associated habitats as larger coherent management units (Hill et al., 2018; Oertli and Parris, 2019), mandate or facilitate the use of low-cost monitoring tools such as eDNA (Biggs et al., 2017; Hill et al., 2018), satellite imagery (Oertli, 2018), and sentinel sites (Hill et al., 2018), and make a pondscape 'inventory' obligatory (Chen et al., 2019).
Institutional arrangement & cooperation	Pondscapes may cross administrative boundaries and cooperation can be insufficient (Boothby, 1999; Linnerooth-Bayer et al., 2015). Even within administrative units, disciplinary specialists may not synergise when designing ponds or pondscapes (Blicharska and Johansson, 2016; Kati and Jari, 2016).	Policies should mandate or incentivise cooperation between authorities and disciplines to explore the plurality of benefits provided by a habitat-complex pondscape and the measures necessary for it (Blicharska and Johansson, 2016; Oertli, 2018).
Financing	Reserving land for pond (scapes) can pose a financial obstacle for public entities (Blicharska and Johansson, 2016). Agencies may also focus on large water bodies as managing numerous ponds may seem costly (Boothby, 1999; Hill et al., 2018).	It is recommended to expand public funding and move away from a focus on merely water streams to also include ponds and pondscapes (Boothby, 1999; Hill et al., 2018; Linnerooth-Bayer et al., 2015; Sayer, 2014; Sayer and Greaves, 2020).
Stakeholder awareness & engagement	Stakeholders are typically unaware of threats to and benefits from pond and pondscapes (Boix et al., 2012; Sawadgo et al., 2021; Sayer, 2014; Sayer and Greaves, 2020). They may seem needless compared to other land uses (Kati and Jari, 2016; Osti, 2017).	Policies should incentivise long-term partnerships to restore and manage ponds (Sayer and Greaves, 2020). Likewise, education programmes can raise awareness regarding benefits of ponds and instil a sense of stewardship (Sousa et al., 2016).
Knowledge development & transmission	Exact biodiversity benefits of pond or pondscapes (Boix et al., 2012; Oertli and Parris, 2019) or interactions with other water bodies (Biggs et al., 2017) are uncertain. Quality of co-benefits is often unknown, too (Linnerooth-Bayer et al., 2015).	European Pond Conservation Network advances research and is a forum for exchange with practitioners (Oertli et al., 2009). Policies may set up or finance other research projects and exchange platforms.

physical and non-physical benefits of NBS as well as interactions of NBS with the landscape (Sarabi et al., 2019).

Institutional arrangements & cooperation: This category relates to roles and responsibilities of institutions for NBS implementation and their collaboration. In fact, the management-related barriers described above are often linked to unclear institutional arrangements (Deely et al., 2020; Sarabi et al., 2019, 2020) – not least due to a complex web of EU and lower-level policies which can create overlapping, but not necessarily complementary institutional structures (Linnerooth-Bayer et al., 2015). Also, organisational silos may inhibit cooperation across sectors and scales (Nelson et al., 2020; Randrup et al., 2020), which can lead to suboptimal outcomes in terms of plurality and quality of NBS benefits (Blicharska and Johansson, 2016; Kati and Jari, 2016; Oertli, 2018). Therefore, policies should mandate or incentivise clear responsibilities for the NBS implementation cycle and promote institutional cooperation, if applicable (Oertli, 2018).

Financing: This category considers issues related to paying for NBS. Currently, there is a lack of (long-term) financing specifically dedicated to NBS, especially at lower governance levels (Deely et al., 2020; Sarabi et al., 2019, 2020; Seddon et al., 2020). Even if financing is available, stakeholders are often unaware of it or deem applying for funds (including EU funds) too complex (Kabisch et al., 2016; Linnerooth-Bayer et al., 2015; Villanueva and Glenk, 2021). Therefore, it is important to either increase (access to) public financing directed to NBS or engage the private sector. Private financing is possible, but contingent on NBS offering a business case. This can be difficult, as often NBS benefits are undervalued by the market (Wild et al., 2017), difficult to measure (Mayor et al., 2021; Watkins et al., 2019), or scattered across beneficiaries, timescales, and locations (Topoxeus and Polzin, 2021; Sewell et al., 2016). In addition, NBS are often perceived as riskier investments than grey infrastructure (Mayor et al., 2021; Watkins et al., 2019).

Stakeholder awareness & engagement: This category comprises participation opportunities for stakeholders as well as stakeholders' perceptions of NBS benefits and the urgency to employ NBS. An unwillingness by stakeholders to employ NBS may stem from underestimating net benefits from and threats to ecosystems (Deely et al., 2020; Nelson et al., 2020; Sarabi et al., 2020). For example, socio-cultural norms – shaped by a 'paradigm of growth' (Kabisch et al., 2016) – make stakeholders expect economic growth from investments and thus prioritise measures whose benefits are amenable to an expression in economic terms, which currently is more likely to be grey infrastructure (Deely et al., 2020; Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Sarabi et al., 2020). There is hence a need for policies to promote improved participatory processes around NBS to raise awareness, distribute benefits equitably, pre-empt conflicts, and nurture stewardship (Boelee et al., 2017; Deely et al., 2020; Nelson et al., 2020; Sarabi et al., 2019, 2020; Randrup et al., 2020; Seddon et al., 2021; Welden et al., 2021).

Knowledge development & transmission: This category relates to determining NBS benefits, their valuation, and the transmission of this knowledge. Understanding, particularly, social and environmental NBS benefits is still in its infancy, particularly over long temporal and wide spatial scales (Deely et al., 2020; Nelson et al., 2020; Ramírez-Agudelo et al., 2020; Sarabi et al., 2020; Seddon et al., 2020). Consequently, NBS fare poorly compared to grey infrastructure in standard valuation methods (e.g. Linnerooth-Bayer et al., 2015). Also, available knowledge is rarely transmitted to policy-makers (Deely et al., 2020; Sarabi et al., 2019). In response, scholars recommend research that ascertains stakeholder preferences and implements NBS accordingly, and animating action through exchange platforms (Nelson et al., 2020; Sarabi et al., 2019, 2020).

3. Methodology

3.1. Data set

Based on the literature, snowball sampling, and a targeted search, we selected 38 policies to assess barriers and enabling factors for implementing pond and pondscape NBS in the EU policy framework (see Table 2). Snowball sampling was used because it was not evident from the start which policies would affect NBS implementation. If key policies referred to other policies and seemed to be interacting with them in a relevant way, we included these policies in the sample. Meanwhile, the targeted research was based on prior knowledge of policies that would likely be relevant or focused on policies from sectors that had not yet been covered by the previously included policies, but in which pond NBS (could) play a role.

Given the manifold benefits of ponds and pondscapes and drivers of pond deterioration, we considered an array of policy areas (see Table 2). We also included policies focused on management (e.g. environmental impact assessments) and funding (e.g. for regional development). We sought out the most recent binding policy in each policy area, as they are assumed to carry the most weight on-the-ground. Where there were no binding policies for a particular policy sector or issues or binding policies lacked detail, they were supplemented by relevant non-binding policies (see Appendix B for selection criteria). Non-binding policies were also assessed, if considered substantially relevant for NBS implementation (e.g., Green Infrastructure Strategy). Ultimately, our data set consists of many policies that are not NBS-specific – with some even predating the concept. Nonetheless, they contain relevant provisions for NBS implementation.

3.2. Data analysis

We conducted an extractive qualitative content analysis of the policies to familiarise ourselves with the data, filter out and synthesise relevant information, and highlight first linkages, commonalities, and contradictions between policies (Gläser and Laudel, 2013). Extractive qualitative content analysis is particularly apt in organising data from different and/or a large number of data sources into manageable amounts, while maintaining the core meaning of the data and not unduly splitting text into fragments that are isolated from their original context (ibid.). Additionally, it has shown great utility in research that is guided by existing categories, but also provides flexibility to adjust the analytical framework, if needed (ibid.). We supplemented this with analytic matrices to identify key relations and comparisons (Miles et al., 2013). See Fig. 1 for a graphic representation of the analysis process.

In the first stage of the analysis, we read the policies paragraph by paragraph through the lens of the categories of barriers and enabling factors identified in the literature. These functioned as our initial theory-derived 'categories', to which we assigned summarised text segments. When selecting relevant text segments, we paid particular, attention to the issues raised under each overarching category (e.g., monitoring regimes under 'Management Approaches & Tools'), as they present known, impactful barriers/enabling factors. We did however also track emerging issues under each category. The categories were further broken down into 'dimensions', namely: time frame, geographic and thematic scope, type of policy measure or tool, roles and responsibilities for the implementation of a policy aspect, rationale, objective, and (expected) effects – which provided a standardised template for data entries. In the process, we also identified policy objectives and targets as their own 'category' because we deemed them relevant but dissimilar from the information recorded under the other barriers and enabling factors. Thereafter, we subsumed (near-)identical data entries and supplemented each of the remaining entries with our reflections on the implications of the recorded information for the implementation of ponds and pondscapes as NBS.

In the second stage, we rearranged the information into three

Table 2
List of the policies analysed, incl. year of adoption, degree of bindingness, and the acronym used in the Results and Discussion sections.

Policy area	Name of the policy	Year	Binding	Acronym
Agriculture	Nitrates Directive	1991	Yes	ND
	Pesticides Directive	2009	Yes	PD
	Common Agricultural Policy	2013 (current) 2021 (future)	Yes	CAP1 CAP2
	Farm to Fork Strategy	2020	No	F2F
Biodiversity Conservation	Habitats Directive	1992	Yes	HD
	Birds Directive	2009	Yes	BD
	Green Infrastructure Strategy	2013	No	GI
	Invasive Alien Species Regulation	2014	Yes	IAS
	Action Plan for Nature, People, and the Economy	2017	No	APNPE
	Pollinators Initiative	2018	No	PI
	Biodiversity Strategy 2030	2021	No	BS
	Zero Pollution Action Plan	2021	No	ZPAP
	Nature Restoration Law	2022	Proposal	NRL
Climate & Environment	Strategic Environmental Assessment Directive	2001	Yes	SEA
	Environmental Impact Assessment Directive	2011	Yes	EIA
	Adaptation Strategy	2021	No	AS
	Climate Law	2021	Yes	CL
	Forest Strategy 2030	2021	No	FS
	Just Transition Fund	2021	Yes	JTF
	Programme for Environment and Climate Action (LIFE)	2021	Yes	LIFE
	8th Environmental Action Programme to 2030	2022	Yes	EAP
Economic Development	Making Public Procurement Work in and for Europe	2017	No	PP
	Circular Economy Action Plan	2020	No	CEAP
	Taxonomy Regulation	2020	Yes	TR
	Financing the Transition to a Sustainable Economy	2021	No	FTSE
	Common Provisions for the MFF 2021–2027	2021	Yes	MFF
	European Regional Development Fund and Cohesion Fund	2021	Yes	ERDF/ CF
	Recovery and Resilience Facility	2021	Yes	RRF
Tourism	Strategy for Sustainable Tourism	2021	No	SST
Research	Horizon Europe	2021	Yes	HE
Water	Urban Waste Water Treatment Directive	1991	Yes	UWWTD
	Water Framework Directive	2000	Yes	WFD
	Recommendation on Integrated Coastal Zone Management	2002	No	ICZM
	Dangerous Substances Directive	2006	No	DSD
	Floods Directive	2007	Yes	FD
	Industrial Emissions Directive	2010	Yes	IED
	Water Blueprint	2012	No	WB
	Priority Substances Directive	2013	Yes	PSD

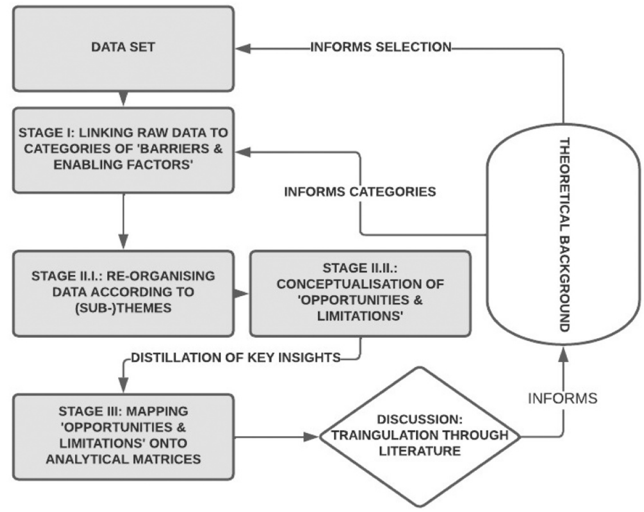

Fig. 1. Graphic illustration of analysis process.

themes, according to 1) landscape type (all landscapes, coastal, rural, urban), 2) NBS type (all NBS types, NBS creation, NBS restoration, and NBS management), and 3) intended benefit of an NBS measure (biodiversity; climate change adaptation and/or mitigation; water and soil management; other benefits such as contributions to human well-being). In addition, we sorted information into sub-themes (e.g. land use restrictions for water and soil management in rural areas), where appropriate. The first two themes were informed by literature which suggests that the type of NBS can vary depending on the landscape (see e.g. Eggermont et al., 2015; Krauze and Wagner, 2019), whereas the themes on benefits and any sub-themes emerged empirically.

Although the themes were still relatively coarse, we were able to explore relationships between categories (i.e. barriers and enabling factors) by rearranging the information. In the process we realised that many of the barriers and enabling factors do not work in isolation, but interlink within and across policies. For example, a policy may award a statutory designation such as Natura 2000 status to a habitat, which in return makes this habitat eligible for financing and receive prioritisation for land use management activities or knowledge development support decreed by other policies. To account for such interactions, we conceived the concept of 'opportunities', which refers to the collective effect of different enabling factors creating favourable circumstances which responsible political entities and private stakeholders can make use of to implement one or several types of NBS for a given purpose and/or in a given landscape. Likewise, we conceptualised 'limitations' which describe the collective effect of barriers negating or narrowing opportunities. In short, individual barriers and enabling factors add up to opportunities and limitations.

In the last stage, the two first authors independently mapped opportunities and limitations on matrices with changing combinations of themes to obtain "a workable and productive set of partitions and/or clusters" (Miles et al., 2013: Ch. 6). Matrices are not only tools to display information, but also a heuristic to make comparisons and note relations (Miles et al., 2013). The two first authors discussed each entry in the matrices iteratively to a) eliminate information that did not provide sufficient substance to understand implications for the implementation of pond and pondscape NBS, b) identify relationships between opportunities that were originally mapped separately and merge this information, and c) recapitulate how entries emerged from the original data set to ensure that there are no distorted findings. In the results section, we display our final matrices which show salient opportunities and limitations for the implementation of pond and pondscape NBS provided by the EU policy framework. We also include a column that displays information for which it remained ambiguous or uncertain whether effects of barriers and enabling factors would amount to opportunities or limitations. Additionally, we present relevant cross-cutting findings that apply to all themes and could not be assigned to any particular matrix.

3.3. Limitations of methodology

Given that qualitative research aims "not just to transform data, but to transcend them" (Saldaña, 2013: 208), we took decisions and made interpretations which inevitably reduced complexity. Like most qualitative analysis, our analysis process is imbued with interpretation, and our results are an expression of that (Miles et al., 2013). The deductive nature of the analysis ensured that our results are informed by existing insights on both the concept of NBS and barriers/enabling factors, also increasing validity (Hsieh and Shannon, 2005). Meanwhile, we increased the results' reliability through writing memos and discussing interpretations continuously, as well as recording collated and synthesised data at the various research stages (see Tables C1 & C2 in Appendix C). Ultimately, the presented results reflect the interpretation we agreed to be the most compelling based on the data considered.

Policies are often the product of compromises and hence ambiguous. Given that policy documents are our only data source, we consulted academic literature after our analysis to fill data gaps and triangulate findings (Bowen, 2009; Cardno, 2018). Insights generated in this process are embedded in the Discussion section. Beyond that, we recognise that our data set is non-exhaustive, but consider it sufficient to make accurate judgements.

4. Results

EU policies contain barriers and enabling factors, which together amount to opportunities and limitations for the implementation of pond and pondscape NBS. In the first section, we show cross-cutting findings. Thereafter, we present findings differentiated by intended NBS benefits. These findings apply, at least to some degree, to all landscapes and NBS types. Subsequently, we show findings specific to pond and pondscape NBS located in coastal, urban, and rural areas. Lastly, we capture findings for the creation, restoration, and management of ponds and pondscapes. Tables 3, 4, and 5 summarise the findings.

4.1. Cross-cutting findings

The EU intends to improve the monitoring of NBS and their benefits (EAP; for policy acronyms see Table 2). This aligns with an ambition to incorporate non-cost-based selection criteria in tenders, which shall boost the integration of NBS into decision-making processes (BS; PP), next to planning guidelines for lower-level authorities (i.e., national, regional, and local authorities) (AS; CAP2; GI; PI). In addition, stakeholders' awareness of threats to ecosystems and NBS benefits shall be nurtured via citizen science (i.e. involving the public into research) and education (AS; EAP; NRL). Some policies even earmark financing for community-led strategies, which may include NBS (CAP2; MFF). Yet, whether these findings will benefit ponds and pondscapes may depend on which NBS and benefits will be monitored and raised awareness for under these policies.

4.2. Opportunities & limitations for pond(scapes) depending on NBS benefits

Biodiversity: A main objective of the EU is to strengthen inland aquatic biodiversity and connected terrestrial ecosystems and wetlands (EAP; WFD), including through a wide adoption of the 'net gain' principle (BS; NRL). Furthermore, habitat connectivity and pollinator health are two foci to enhance biodiversity. Habitat connectivity is a common motif (BD; CAP2; EAP; GI; HD; PI), and reflected in proposed conservation targets, of which one mandates reconnecting rivers with floodplains and wetlands (NRL). Likewise, Member States shall be obliged to reverse pollinator decline by 2030, lower-level authorities shall receive support with planning for pollinator needs, and there is funding for researching and implementing relevant NBS (BS; PI; NRL; CAP2). There is even funding for landscape-level strategies and projects incorporating

Table 3

Opportunities and limitations for pond(scape) NBS divided by intended benefit. *Legend: ++/— Data also in binding policies, +/– Data only in non-binding policies. O&T Objectives & Targets, LS&R Legal Standards & Regulations, M Management Approaches & Tools, IA Institutional Arrangements, F Financing, K Knowledge Development & Transmission, SH Stakeholder Awareness & Engagement.*

	Opportunities	Ambiguous	Limitations
Biodiversity	Boost **inland water biodiversity** in all ecosystems (incl. via NBS), and promote the net-gain principle globally (++O&T-LS&R-M-K) Ensure **habitat connectivity**, incl. via NBS (e.g., restoring rivers, ponds as 'stepping stones') (++O&T-LS&R-F-K-SH) Reverse the **pollinator** decline (++O&T-M-F-K)	Re-establish **BHD habitats** and **protect 30 % of EU territory**, esp. BHD habitats at the brink of disappearance and habitats with umbrella effect (O&T-LS&R) Focus on **N2000 and priority habitats**, which impacts monitoring, management and planning, and financing (O&T-LS&R-M-F) Better **biodiversity monitoring** (incl. via citizen science), using **existing data** (M-SH) Generate €20bn/year for **N2000** and **green infrastructure** (F)	*No identified definite limitations.*
Climate Change Adaptation and Mitigation	Boost resilience through NBS (esp. **NWRM**), promoted via research, planning, and financing (++O&T-M-IA-SH-K-F) Provide guidance on '**climate proofing**' investments regarding climate risks (+F-K) Make citizens and policy-makers **aware of climate risks and NBS benefits** (++SH-F-K)	Maintain/restore all ecosystems, but first **BHD habitats with adaptation** or **mitigation co-benefits** (O&T-LS&R-M) Study and finance **NBS with mitigation potential** and develop a system for the carbon removal certification via NBS (LS&R-M-F-K) Identify NWRM (mainly restoring **wetlands**) in **FRMPs** (M-F-K)	*No identified definite limitations.*
Water & Soil Management	Achieve **Zero Pollution** through monitoring, NBS investments, stakeholder platforms, and pledges (+O&T-M-F-SH-K) Revise **wastewater and water reuse** regulations, and research and finance NBS (++LS&R-F-K)	Research and finance NBS based on aquatic ecosystems for the integration of water, soil, and land use objectives, and plan them (e.g., retention ponds) in **RBMPs/FRMPs** (O&T-M-F-K)	Achieve a **'good status' for water bodies > 50 ha**, incl. through NBS, and control emissions of dangerous substances through inventories (–O&T-M)
Other Benefits	Determine and meet **human need for green infrastructure** (++O&T-K-SH)	Research potential of NBS for **job creation** and **reducing inequalities** (F-K) Finance measures for **natural and cultural heritage** sites to exploit **economic potential** (F)	Study and use **natural capital for economic growth** (-O&T-K) EIAs/SEAs are often not required or recommended, unless **cultural heritage** is affected (esp. at **N2000** sites) (–LS&R)

Table 4
Opportunities and limitations for pond(scape) NBS divided by landscape type. *Legend: See* Table 3.

	Opportunities	Ambiguous	Limitations
Coastal	Maintain **ecological and cultural integrity** of ES, incl. through ICZM plans and collaborating with stakeholders (++O&T-M-SH-F)	Make use of and study **coastal ES** (e.g. salt marshes/wetlands) for biodiversity and/or climate change mitigation (+O&T-K)	*No identified definite limitations.*
Urban	Ensure **habitat connectivity**, incl. through studying and integrating NBS into urban, landscape-level planning (++O&T-M-F-IA-K) Meet **human need** for GI, focussing on reducing **social inequalities** in access (++O&T) **Limit soil sealing** via FRMPs and a Strategy for a Sustainable Built Environment (+M-K)	Ensure **'no net loss'** and medium-term increase of green space (O&T-LS&R)	*No identified definite limitations.*
Rural	Ensure a positive trend of **high-diversity landscape** features (incl. ponds) (++O&T) Reduce **pesticide/fertiliser inputs** (incl. via research) or use statutory designations and management plans to **protect aquatic and connected ecosystems** (++O&T-LS&R-K-M) Protect and restore **peatlands and wetlands,** incl. beyond N2000 sites (++O&T-LS&R-F) Accelerate the green transition of agriculture via **NBS from farm to landscape level** (++O&T-F-K) Invest in **energy and water-efficient irrigation** projects (++F)	Manage **pollution** of WFD/N2000 **protected areas**, providing resources to landowners for extra management requirements and incentives to change practices (O&T-LS&R-F-SH-M) Plan a WFD-aligned **greening** of and better **land use** in **agriculture**, with Member States steering the implementation of NBS with adaptation, mitigation, and soil co-benefits (L&R-M-F-SH) Manage **NWRM** as **high-diversity landscape features**, with ambition being up to Member States (LS&R-M-F) Consider **N2000** (and to some extent **HNV)** needs and related NBS measures in planning (e.g. CAP Strategic Plans), finance esp. **community** project for greater impact, and reimburse landowners for additional burdens due to **N2000** (O&T-LS&R-M-F-SH-K)	*No identified definite limitations.*

Table 5
Opportunities and limitations for pond(scape) NBS divided by NBS type**.** *Legend: See* Table 3.

	Opportunities	Ambiguous	Limitations
Creation and Restoration	Control pollution and improve energy efficiency through **water reuse and wastewater**, including via research, investments into NBS and a review of key legislation (++O&T-LS&R-F-K)	Restore **rivers** and create or restore **NRWM** for 'good status', habitat connectivity between N2000, and adaptation and mitigation, financed via schemes for rural landscape features and funds measuring outputs by population benefitting (O&T-M-F) Increase **green space** in **urban** areas by 2050 (O&T-M-F-K) Restore **priority habitats** (or generally **N2000** and **HNV** in rural areas) for habitat connectivity, prioritising climate and economic co-benefits (O&T-M-F)	*No definitive limitations identified.*
Management	Maintain the **integrity** of **coastal ecosystems**, incl. through access restrictions and voluntary agreements with local stakeholders (+O&T-M-SH-F) Achieve **zero pollution** through stakeholder pledges (+SH)	Minimise **pesticide and nutrient input** through reduction targets, plans, research, WFD protected areas, providing resources to farmers for additional burdens (O&T-LS&R-M-F-SH) Retain high-diversity landscape features and consider **NWRM** in this context (LS&R-F) Manage **protected habitats** through dedicated plans and funds or consider N2000 and HNV needs in rural planning, reimbursing farmers (O&T-LS&R-M-F-SH) Finance **economic diversification** , e.g. through eco-tourism (F)	EIAs/SEAs or development bans do often not apply, unless WFD **protected areas**, waters not in '**good status**', or **wetlands** and peatlands are affected (–LS&R-M)

NBS (ERDF/CF; PI). In fact, ponds, and natural water retention measures (NWRM) generally, are suggested as "stepping stones" to improve Natura 2000 network connectivity (HD: Art. 10; PI).

Yet, opportunities for pond and pondscape NBS at large may be limited by a focus on habitats and habitats of the species listed in the Birds and Habitats Directives (BHD). Policies underscore the need for good health of all ecosystems (EAP; NRL), but proposed biodiversity targets emphasise re-establishing BHD habitats, expanding Natura 2000, or better managing existing sites (BS; NRL). Specifically, Member States are advised to focus measures on priority habitats as per the BHD first, then expand their focus to other habitats and habitats of species under the BHD, and ultimately consider all ecosystems (BS; NRL). Thereby, most ponds may at least initially remain outside key targets and linked policy mechanisms – besides Mediterranean temporary ponds and turloughs, which are priority habitats (HD), and ponds that provide a habitat for, for example, the European fire-bellied toad in Natura 2000 sites (Annex II/HD) or newts generally (Annex IV/HD). For example, the WFD and the Strategic Environmental Assessment Directive command strict monitoring of Natura 2000 sites, but not of other areas (SEA; WFD). Likewise, biodiversity monitoring shall eventually be enhanced generally, but initially focus and rely on reporting under the BHD (which largely concentrates on priority habitats) and WFD (IAS; NRL; PI). This is compounded by funds particularly financing measures identified in Natura 2000-focused biodiversity strategies (HD; LIFE) or determining progress by Natura 2000 surface area supported (CAP2; ERDF/CF).

Climate Change Adaptation and Mitigation: When Member States select BHD habitats to re-establish or protect, they must prioritise those with adaptation and mitigation co-benefits (BS; CL; NRL). In particular, carbon-rich areas (e.g. peatlands, salt marshes, wetlands) with "swift and predictable" (CL: Art. 4) mitigation contributions shall be strictly protected (BS) and restored (CAP2; ERDF/CF). Beyond protecting and restoring BHD habitats, the EU strives to use "nature [as] a vital ally" for adaptation and mitigation generally (BS: Section 1). In this context, measures for disaster risk reduction, and particularly NWRMs, receive strong support – both as a financing and research priority (AS; BS; CL; EAP; ERDF/CF; FD; GI; HE; PP; WB). Also, public entities are encouraged to conduct "climate proofing" of budgets and investments, considering effects for resilience and carbon storage of green infrastructure (AS: Section 2.3.2.; BS; MFF).

Opportunities for ponds as NBS for adaptation and mitigation remain unclear. In general, most ponds are not BHD habitats, which means they may not be prioritised at first when Member States decide which habitats to maintain and restore. Also, uncertainty remains about the relationships between ponds and wetlands, which is relevant because the latter is identified as a key ecosystem for both adaptation and mitigation with financing and planning instruments being available to implement the respective NBS (e.g., CAP2; ERDF/CF; FD). Possibly, ponds for climate change mitigation may find more application in the long run if research into NBS as carbon sinks were to focus on them and prove their value for such purposes (HE). When it comes to adaptation, most policies focus on floodplains, wetlands, and soils, but a consideration of NWRM can be an opportunity for ponds. At the same time, it has to be acknowledged that the performance of Member States will be assessed based on the "share of utilised agricultural area under supported commitments or to maintain or enhance carbon storage" or "to improve climate change adaptation" (CAP 2: Annex I), drawing into question whether small-scale NBS will be implemented.

Largely, opportunities will hinge on choices that implementing authorities make when drawing up CAP Strategic Plans, Drought and Flood Risk Management Plans, National Adaptation Plans, etc. This, in turn, may depend on which NBS will be developed and disseminated through exchange platforms and research efforts such as the HE Mission "Adaptation to Climate Change", which shall help communities to develop adaptation actions and explore synergies with EU-funding instruments (AS; HE: Annex VI).

Water & Soil Management: There is commitment to a zero pollution target, to be achieved through improved monitoring, stakeholder platforms and pledges, and NBS investments (ZPAP). Particularly, amending key regulations, research, and funding shall propel wastewater treatment and water reuse via NBS (CEAP; FS; GI; HE; WB; ZPAP). While these aspirations are non-binding, regulations already allow villages (agglomeration of less than 2000 persons) and small coastal cities (agglomerations of between 10,000 and 150,000 persons) using wetlands and ponds therein for wastewater treatment (UWWTD: Art. 6 and 7).

Newly created and restored ponds could help integrating water, soil, and land use management objectives, for example by reducing mud floods (FS; WB). As for existing ponds, they may be exposed to pollution and in-filling as land use and the use of water resources is mainly defined by WFD-related River Basin, Flood Risk, and Drought Management Plans (AS; WB), and the WFD makes managing water bodies smaller than fifty hectares optional (Annex II, Paragraph 1.2.2.). Consequently, most ponds do not have a defined reference condition that should prevail in the absence of human disturbance, are not covered in inventories tracking emissions of 'priority substances' into water bodies, and are unprotected from detrimental measures (CAP 1; WFD).

Other Benefits: Overall, the EU still wants to generate green growth through natural capital, including through NBS (e.g. BS; CL; NRL). Research shall focus on economic growth opportunities and contribute to the economic valuation of NBS (HE). Likewise, funding shall target those NBS with job creation potential (ERDF/CF; LIFE; RRF). A preoccupation with nature as an economic service provider is also reflected in policies that shall protect ecosystems, as they allow for activities with detrimental ecological impacts if there is an 'overriding public interest' (EIA; PD; SEA). In fact, even policies that acknowledge intangible natural and cultural heritage contextualise it with economic use (e.g. through eco-tourism) (CAP1) – unless Natura 2000 is affected, as heritage is then treated as a greater intangible good (EIA; FD; SEA). This may limit the implementation of NBS without a clear business case, such as is often the case for ponds and pondscapes.

Yet, some policies do indicate an awareness for non-economic benefits, acknowledging a human need for a healthy environment or green infrastructure for well-being (BS; EAP; ICZM; ZPAP). Research shall help ascertain these benefits (HE), but there are no dedicated policy mechanisms to foster NBS providing primarily non-economic benefits.

4.3. Opportunities & limitations for pond(scapes) depending on landscape types

Coastal areas: There are no concrete opportunities for pond and pondscape NBS located in coastal areas, but the EU intends to better understand and make use of coastal wetlands as NBS, as "it could save the insurance industry around €50 billion annually" and "it is estimated that the monetised benefits from carbon storage alone already exceed the estimated costs of ecosystem restoration" (BS: Section 1; EAP; GI; NRL: Section 3). In general, the implementation of coastal NBS should be coordinated through Integrated Coastal Zone Management (ICZM) Plans, which can include a wide range of NBS and shall help maintain the ecological and cultural integrity of coastal ecosystems (ICZM). Importantly, the ICZM Recommendation states that economic concerns shall not be prioritised over environmental or social matters. The impact of these provisions depends on whether decision-makers consider ponds and pondscapes ecologically and culturally significant components of coastal ecosystems.

Urban areas: There are a range of provisions which could affect the implementation of pond and pondscape NBS in cities. The objective to study the potential of NBS and their integration into urban planning is reiterated across policies (BS; ERDF/CF; GI; MFF: NRL; PI). NBS shall also improve habitat connectivity through planning at landscape scale and strengthening urban-rural linkages, which shall be particularly supported via 'integrated territorial strategies' and Urban Greening Plans (BS; EAP; ERDF/CF; GI; MFF; PI).

While ponds and pondscapes are not directly mentioned, their potential to address various urban societal challenges (e.g. water retention, leisure spaces, aesthetics, cooling) and their capacity as stepping stone habitats may help with achieving the above-mentioned objectives and provide implementation opportunities. Further opportunities may come out of the planned EU Strategy for a Sustainable Built Environment which shall promote the reduction of soil sealing and the restoration of brownfields with NBS (BS; CEAP; MFF), which could be implemented inter alia via Flood Risk Management Plans (WB).

The non-binding Biodiversity Strategy stresses the importance of physical and mental well-being through urban green spaces and reducing inequities in terms of access to such spaces. This could offer opportunities for pondscapes, as they are relatively easy to construct and accessible compared to other NBS. However, the targets proposed by the European Commission to increase urban green space (NRL) do not mention aquatic ecosystems or 'blue spaces' in the list of considered ecosystems.

Rural areas: There are some opportunities for pond and pondscape NBS in rural areas, as there is an ambition to advance NBS from farm to landscape level (CAP2; HE). For example, on-farm ponds could be used as NWRM, including to make irrigation less water and energy-intensive (CAP1; CAP2; WB), or benefit from wetland and peatland restoration and protection (CAP2). The latter is also supported by proposed targets for nature restoration (NRL). Opportunities may also arise from the target to turn 10 % of agricultural area into high-diversity landscape features (including ponds) by 2030 (BS). Ponds and, especially, landscape-scale pondscape NBS could also mean efforts to reduce pesticide and fertiliser inputs, which threaten their ecological state. This is to be achieved through research, statutory designations, voluntary commitments, and corresponding management plans for 'Nitrate

Vulnerable Zones' or National Action Plans for pesticide reduction (BS; CAP2; NRL; PD).

However, the majority of policies have unclear impacts on pond and pondscape NBS in rural areas, mainly because their implementation is up to Member States. Member States largely control the implementation of NBS via CAP Strategic Plans (in alignment with River Basin and Drought Management Plans), as they define details on how landowners can fulfil the CAP's mandatory conditionality rules and which voluntary environmentally-friendly measures to finance (AS; CAP2). The current CAP, for example, does not longer mandate the retention of *existing* landscape features for farms larger than 5 ha, as the former CAP did (which explicitly mentioned ponds for this purpose); and buffer strips for pollution management are obligatory only along watercourses and optional around other waterbodies (CAP1; CAP 2). Therefore, it is also undetermined whether NWRMs as one type of high-diversity landscape feature will find widespread application – or whether ponds will even be recognised as such by responsible authorities.

Another potential complication is that nature management and restoration in agricultural areas, and related planning processes and financing support, are focused on the needs of Natura 2000 areas, excluding many types of ponds (CAP2). In the same way, mandatory pollution management focuses on Natura 2000 sites and other protected areas as per the WFD (e.g. drinking water sources and nitrate vulnerable zones) (PD; ZPAP), whereas additional efforts, such as 'codes of good agricultural practice', are defined by Member States (ND; CAP2). However, the CAP does not exclusively emphasise the value of Natura 2000, and there might be some openings for a larger set of pond types if considered a priority by Member States as 'high nature value (HNV) farmlands' or 'stepping stones' between Natura 2000 sites (CAP1; GI).

4.4. Opportunities & limitations for pond(scapes) depending on NBS type

Creation and Restoration: There are few concrete opportunities for the creation and restoration of ponds and pondscapes. An obstacle is the non-integration of objectives or targets with other enabling factors. For example, the Birds Directive recommends creating suitable biotopes between protected areas, and NWRM shall function as NBS with biodiversity as well as climate change adaptation and mitigation benefits (EAP; ERDF/CF; GI; WB). However, except for the target to re-connect 25.000 km of rivers longitudinally and laterally (NRL), there is a lack of specificity regarding targets, planning guidelines, and financing instruments that would promote small-scale NBS (CAP2; ERDF/CF).

Sometimes, enabling factors for NBS implementation are integrated with each other, but not necessarily in an advantageous way for most ponds and pondscapes. For example, re-establishing BHD habitats – priority habitats in non-agricultural areas, in particular – is prioritised through targets as well as planning and funding mechanisms (CAP2; ERDF/CF; LIFE; NRL); yet, most ponds are not listed under the BHD. Moreover, even when there is a wider focus – like in rural areas, where HNV farming can be financed or ponds could function as, for example, small-scale reservoirs for irrigation (CAP1) – planning guidelines only emphasise restoring Natura 2000 sites (CAP2).

Similarly, the proposed target to increase urban green spaces implicitly excludes blue spaces (NRL), and hence research and financing may not benefit associated ecosystems equally. However, ponds and pondscapes might be considered as NBS for wastewater treatment and water reuse (GI; HE; UWWTD; ZPAP).

Management: When it comes to NBS as management, there are policies that suggest both strict measures (e.g. eminent domain or other access restrictions) and amicable agreements with stakeholders to help preserve an ecosystem's integrity while acknowledging the socio-economic context (ICZM; ZPAP). However, these policies are non-binding and do not provide strong legal levers. On the contrary, for policies with strong legal tools, particularly in the agricultural sector, implementation priorities often depend on Member States. For example, policies pertaining to pesticide and nutrient input provide reduction targets (BS), and mandate management (ND; PD), financing, good practice guidelines, and advisory services (CAP2). However, defining good practices and mandated measures is the prerogative of Member States, which may focus on water bodies that have a defined reference condition under the WFD, i.e. those larger than fifty hectares, or have any other protective status. Similar factors come into play regarding the retention of landscape features on farm land, for which Member States can principally define themselves which features shall be prioritised to achieve EU targets (CAP2).

Lastly, Natura 2000 sites, protected areas as per the WFD, and carbon-rich areas, such as grasslands, peatlands, and wetlands, have strong legal protections which have been or are set to be extended (CAP2; EIA; FS; NRL; SEA). For example, the CAP limits grassland conversion (maximum decrease of 5 % annually compared to 2018 and no conversion in Natura 2000) (Annex III). Moreover, funds and awareness-raising shall incentivise landowners to carry extra burdens and communities to implement joint Natura 2000 projects (CAP2; ZPAP).

5. Discussion

We assessed, by identifying barriers and enabling factors for NBS implementation, the opportunities and limitations for ponds and pondscapes in the EU policy framework. While we focused on ponds and pondscapes, we also gained some insights into the implications of EU policies for NBS at large. Below we discuss key findings and contextualise them with existing literature. We first discuss opportunities and limitations, then reflect on the issues that could define further whether ponds and pondscapes could benefit from the opportunities in practice. Fig. 2 visualises the main points of the discussion.

5.1. Opportunities and limitations

Overall, we find considerable support for NBS across EU policies. Although explicit mention of NBS in policies mostly refers to the creation and restoration of ecosystems, there are a multitude of policies (e.g.; BS; NRL) that indicate that the EU has not turned a blind eye to the management and protection of ecosystems either. Management actions aimed at reducing human impact on biodiversity (e.g. pollutant input reductions and set-aside landscape features) are envisaged particularly for rural areas, confirming others' observations that one would expect less engineered NBS in these areas (Eggermont et al., 2015; Krauze and Wagner, 2019). Generally, we find that the EU policy framework focuses on a broad range of NBS. This stands in contrast to recent assessments, which suggest that the EU predominantly supports NBS as an eco-engineered measure in cities (Cohen-Shacham et al., 2019; Davies et al., 2021).

Moreover, the EU policies not only show support for different NBS types, but also an awareness of strategically employing them for habitat connectivity. The EU seems to move from indiscriminately 'piecemeal approaches' (Kabisch et al., 2016) or 'random acts of kindness' (Nelson et al., 2020) toward NBS networks with ecosystems of 'different maturity and complexity' (Krauze and Wagner, 2019). The EU calls on authorities to adopt the net-gain principle for biodiversity, finances integrated territorial strategies to manage urban-rural linkages, and supports lower-level authorities in integrating NBS into land use planning through research projects and guidelines. Noticeably, though, it seems that the responsibility to implement NBS at landscape scale for habitat connectivity in urban areas rests with planners and decision-makers, whereas in coastal and rural areas the responsibility rests on individuals joining forces. This can limit opportunities, as, for example, the CAP recognises the added value of jointly implemented environmental measures, but does not mandate any specific mechanisms to facilitate coordination between farmers (Leventon et al., 2017). In other words: the ambitions to improve habitat connectivity miss 'legal teeth' (Borgström and Kistenkas, 2014).

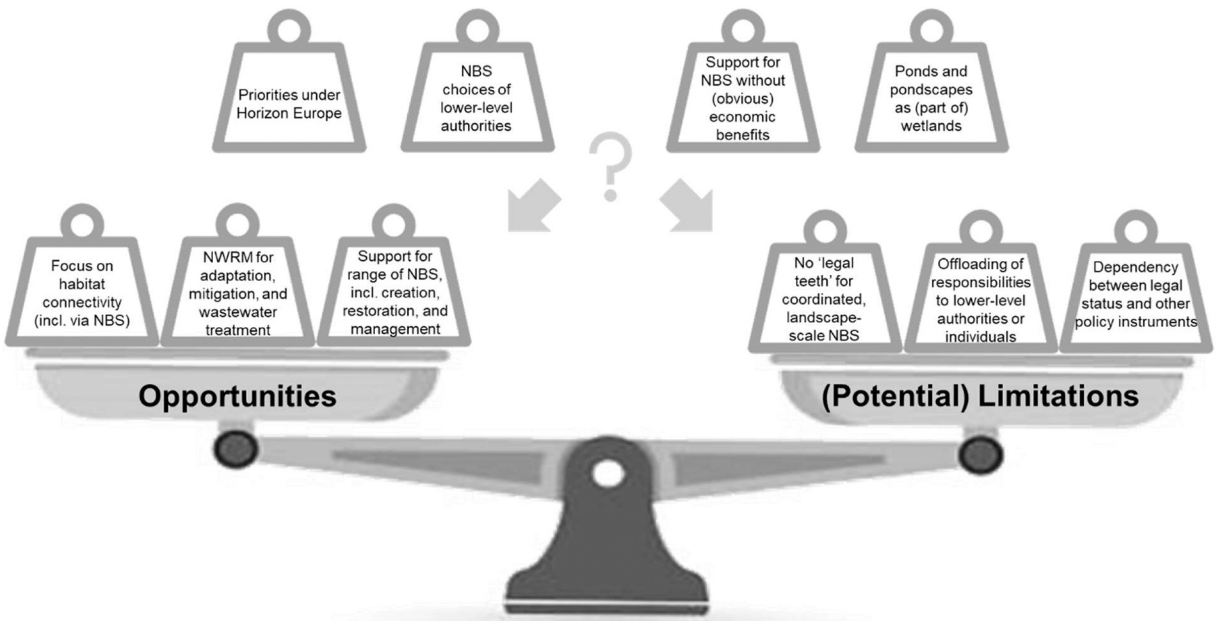

Fig. 2. Visual summary of the main opportunities and limitations, as well as the issues that can 'tip the scales'.

Furthermore, it emerged that binding targets and regulations, financing and planning tools, as well as monitoring and stakeholder engagement strategies focus on habitats and habitats of species listed in the BHD Annexes (i.e. existing and prospective Natura 2000 sites). This creates a path dependency between the legal status of habitats and opportunities for NBS implementation. While there are intentions to restore all ecosystems to good health, regulatory, managerial, and financial tools for non-BHD habitats are not as 'sharp'. For rural areas, for example, this may mean that HNV farmlands should also find consideration in planning and as landscape features, but so far non-Natura 2000 sites have been poorly monitored and at a higher risk of conversion to arable land (Anderson and Mammides, 2020; Lomba et al., 2014). Also, in the past, farmers often registered low-cost measures already existing on their farms, instead of creating or retaining additional landscape features with biodiversity in mind (Pardo et al., 2020; Świtek and Sawinska, 2017; Zinngrebe et al., 2017); with authorities in Member States likewise prioritising flexibility for farmers in terms of how to achieve the conditionality rules of the CAP over actions benefitting biodiversity (Nilsson et al., 2019). Therefore, many opportunities for NBS may only apply to a small subset of habitats – with projects historically concentrating on (the habitats of) vertebrates, rather than invertebrates (Mammides, 2019; Mammola et al., 2020). Ultimately, to advance NBS also outside protected areas will require Member States and individuals to show ambition beyond what is legally required.

This focus on BHD habitats carries over to other key benefits the EU pursues through NBS – namely, climate change adaptation and mitigation. Member States must prioritise those BHD habitats for restoration and protection with adaptation and mitigation co-benefits. However, the focus on these co-benefits also extends beyond protected areas to carbon-rich areas and NWRM generally, such as wetlands. Whether ponds and pondscapes will benefit from this may depend both on whether they will be considered (part of) wetlands and the choices implementing authorities make who are responsible inter alia for drought and flood management – although previous experiences have shown that authorities are slow to adopt NWRM for drought and flood management due to institutional silos, uncertainty about costs and benefits, and disagreements over who pays for them when benefits may accrue in another place than the location of the NBS (Collentine and Futter, 2018; Linnerooth-Bayer et al., 2015).

Similarly, with regard to water quality management, much of the protection awarded to water bodies is organised through the WFD and its implementing authorities. Unfortunately, ponds are rarely considered here, as they are smaller than fifty hectares (Kristensen and Globevnik, 2014) and consequently may not benefit from regulatory (e.g. pollutant input limits), managerial (e.g. emissions monitoring), or financial (e.g. control measures financed through CAP) measures. Concerning the use of ecosystems for pollution control though, ponds may find application after a planned overhaul of wastewater and water reuse legislation as well as due to green public procurement criteria that recommend NBS (incl. ponds) for such purposes. Pathways toward implementation, particularly in urban areas, are still blurry though.

5.2. *What may tip the scales*

Much of the information contained in the policies is attributable to either barriers or enabling factors, which collectively emerge as opportunities or limitations. However, we also identified policy provisions that may, depending on how policies are interpreted and prioritised by national, regional, and local authorities and other stakeholders, influence the extent of the opportunities or limitations for NBS implementation generally but also for ponds and pondscapes specifically.

To begin with, provisions that prescribe institutional cooperation or specific roles and responsibilities to particular institutions for implementing NBS are largely absent from the policies. There are exceptions, such as earmarked funding for cross-scalar and cross-sectoral integrated territorial strategies (ERDF/CF), the role of CAP-implementing authorities to determine landscape features for the fulfilment of conditionality rules and to offer additional eco-schemes (CAP2), or the call on River Basin Districts to consider NWRM for drought and flood management (e.g., WB). Yet, even in those cases, it is the prerogative of implementing authorities which NBS to prioritise. Hence, ultimately, the scale, type, quantity, and connectedness of NBS may depend on the ambition and awareness of lower governance levels or even individual landowners.

Therefore, in line with existing literature on barriers and enabling factors (e.g., Deely et al., 2020; Nelson et al., 2020; Sarabi et al., 2019, 2020), we expect that enhancing knowledge on and raising stakeholder awareness for the benefits of NBS will influence whether NBS generally are considered as solutions to societal challenges, and if so, which NBS will be considered. For ponds and pondscapes, it will be crucial to more closely define their relationships to wetlands, to pursue research to better understand their benefits (especially regarding climate change mitigation), and to communicate these benefits through research projects, advocacy campaigns, stakeholder exchanges (including the valuation of benefits), citizen science, and environmental education. In this context, EU-financed research efforts, and in particular Horizon Europe Missions, will likely be of outstanding importance, as they are supposed to bring together scientists with policy-makers and other stakeholders. With those efforts, the EU not only intends to address persisting knowledge and awareness gaps (Nelson et al., 2020; Ramírez-Agudelo et al., 2020), but also guide authorities toward the integration of NBS into planning instruments, such as CAP Strategic Plans, WFD-related plans, and urban development plans, and identify viable EU or national funding sources for implementation and upscaling.

Beyond that, it remains to be seen which NBS benefits researchers and stakeholders will prioritise. Previous studies asserted that the EU focuses mostly on the economic growth and job creation potential of NBS (Cohen-Shacham et al., 2019; O'Sullivan et al., 2020). While our findings corroborate this, we cannot confirm that this translates to an exclusive support for eco-engineered types of NBS (i.e. creation and restoration of ecosystems) to capitalise on natural capital for green growth, as others have suggested (Davies et al., 2021; O'Sullivan et al., 2020). In fact, there are policies that support the large-scale protection of ecosystems, which scholars have advocated for to safeguard existing ecosystems and avoid unintended consequences of new, possibly poorly planned, ecosystems (Seddon et al., 2020; Welden et al., 2021). It appears though that some policies do indicate an awareness for non-economic benefits of NBS, but still mainly promote NBS whose benefits are amenable to monetisation (e.g., eco-tourism or payment-for-ecosystem-services schemes). If so, what would this imply for NBS without a business case – such as most ponds – but with predominantly biodiversity and societal benefits that are not amenable to monetisation? In relation to that we suggest, like other authors (Louiseau et al., 2016), that authorities would need to step in and steer investments toward NBS that are not economically viable by themselves or support awareness-focused projects to nurture a sense of stewardship and care amongst citizens (Randrup et al., 2020; Seddon et al., 2021). So far, we can only see limited evidence for that in EU policies.

6. Conclusion

In this paper, we assessed the opportunities and limitations for the implementation of ponds and pondscapes as NBS contained in the EU policy framework. While we find significant support for NBS generally, opportunities for ponds and pondscapes are much sparser. Legally binding targets and protections, efforts to improve biodiversity management and monitoring, and the provision of financing for NBS converge to strengthen protected areas as per the WFD, current and prospective Natura 2000 sites, and carbon-rich areas. Most ponds and pondscapes do not fall under these categories. Some opportunities for ponds and pondscapes may come from the EU's ambition to achieve zero pollution. This concerns both the creation and restoration of ponds and pondscapes, for example as wastewater treatment ponds, as well as pondscape-scale management actions, such as the reduction of pollutants in agriculture. Likewise, the objective to enhance climate change adaptation and mitigation through NBS, for example through NWRM, could provide opportunities for ponds and pondscapes, especially if they were considered (part of) wetlands. However, we argue that implementation pathways are blurrier in these cases and rely much more on the ambition and awareness of lower-level governance entities and individual landowners. In this context, research projects, particularly those part of Horizon Europe Missions, may play a prominent role in the operationalisation of NBS, as they shall pool research efforts together with policy-making, financing, and stakeholder engagement to mobilise action.

Beyond that, our study points to a number of future research needs. Building on previous literature on barriers and enabling factors for NBS implementation, we provide a conceptual tool through 'opportunities' and 'limitations' to help describe potential collective effects of these factors. Future endeavours may apply the concept of opportunities and limitations to NBS other than ponds and pondscapes to, on the one hand, identify possible recurring patterns and, on the other hand, enhance the concept's analytical purchase through further refinement. Such research may also trace how European policies translate to and interact with local level policies to understand what can tip the scales for the future of ponds and pondscapes. As far as we are aware, our analysis is the first one to lay out the space a supranational framework provides for NBS implementation in such detail. However, while our study provides initial insights into the EU policy framework's support for NBS, the next step would be an in-depth analysis of the actual implementation on-the-ground, as many decisions remain at the discretion of lower-level public and private stakeholders. For ponds and pondscapes, specifically, this raises questions regarding a) the consideration of non-priority BHD habitats and generally non-BHD habitats as NBS, b) the utility of wetland-focused measures for ponds, and c) the appreciation of non-economic benefits in practice.

Lastly, given the EU's role as a proponent of NBS even beyond its borders, future research should evaluate the impacts of the EU's focus on the restoration and management of carbon-rich areas as NBS, especially considering the question of land rights to these areas and the communities potentially affected by NBS projects.

CRediT authorship contribution statement

Blicharska Malgorzata: Conceptualization, Funding acquisition, Project administration, Supervision, Visualization, Writing – review & editing. **Lago Manuel:** Supervision, Writing – review & editing. **Ryfisch Simon:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **McDonald Hugh:** Supervision, Writing – review & editing. **Seeger Isabel:** Data curation, Formal analysis, Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

Data Availability

The original data set are publicly accessible policies. The processed data is depicted in the Tables C1 and C2 in Appendix C.

Acknowledgements

This work was supported through the POND Ecosystems for Resilient Future Landscapes in a changing climate (PONDERFUL) project (Grant Agreement no 869296), which is financially supported by the EU Research and Innovation Programme Horizon 2020. The authors would also like to thank Aurélie Boissezon, Pascale Nicolet, Jacques Aristide Perrin, and Joël Robin for their contributions to Table A2.

Appendix A

Table A1
Summary of pond(scape) benefits (own elaboration). Note: This table provides an overview of the range of benefits of ponds and pondscapes, but it neither indicates the prevalence or significance of these benefits, nor the level of evidence. It also does not distinguish between different types of ponds and pondscapes.

Benefit	Description
Water quality improvement	• Reduction of pollution through sedimentation, flotation, infiltration, adsorption, biological uptake, biological conversion, or pollutant degradation (Carpenter et al., 2014) • Interception of agricultural runoff, thereby mitigating nitrate, phosphorus and pesticide pollution (Díaz et al., 2012; Jia et al., 2019) • Treatment of wastewaters in waste stabilisation ponds and use of pond-wetland complexes as preliminary processors (Díaz et al., 2012; Kumar and Kumar, 2020; Wang et al., 2016)
Water source	• Storage of water for agricultural irrigation (Chen et al., 2019), providing an alternative to aquifer exploitation and reducing energy use of irrigation (López-Felices et al., 2020; Sikka et al., 2018; Vico et al., 2020; Villanueva and Glenk, 2021) • Drinking water source for livestock (Chen et al., 2019) • Natural or artificial fire retention ponds as reservoirs for extinguishing water (Kaulfuß, 2011)
Flood management	• Postponement and decrease of flood peaks (Linnerooth-Bayer et al., 2015) • Stormwater detention and retention ponds as part of urban drainage systems, which can also manage water quality of runoff (Blicharska and Johansson, 2016; Nayeb Yazdi et al., 2021; Oertli and Parris, 2019; Morales and Oswald, 2019)
Groundwater recharge	• Recharge of aquifers from ponds through permeable sand and rocks (Healy, 2010) • Artificial groundwater recharge through man-made infiltration ponds (Dillon et al., 2020)
Habitat provision	• Habitat for fauna and flora (Hill et al., 2016; Oertli et al., 2010; Williams et al., 2020) • Habitat for pollinating insects, thus increasing the quantity and quality of pollinator-dependent crops (Stewart et al., 2017; Walton et al., 2021) • Stepping-stone habitats for enhanced habitat connectivity (Oertli et al., 2009; Simaika et al., 2016; Watts et al., 2015) • Biodiversity hotspots in often ecologically poor areas such as cities or agricultural land (Biggs et al., 2017; Blicharska and Johansson, 2016;Céréghino et al., 2014;Sayer, 2014)
Cooling	• Mitigation of urban heat island effect - *more evidence needed* (Jacobs et al., 2020; Manteghi et al., 2015) • Improvement to thermal comfort in urban areas due to trees and natural ventilation (Coutts et al., 2013; Jacobs et al., 2020)
Greenhouse gas sequestration	• Carbon sequestration and storage, but also release of carbon dioxide, nitrous oxide and methane - *more evidence needed* (Downing, 2010; Peacock et al., 2019, 2021; van Bergen et al., 2019; Taylor et al., 2019)
Erosion control	• Sediment trapping from run-off water (Chen et al., 2019; Fiener et al., 2005)
Recreation and well-being	• Recreational pursuits (Giampaoli et al., 2014; Ghermandi and Fichtman, 2015; Moore and Hunt, 2012) • Support to physical and mental health in nearby residents and visitors (Blicharska and Johansson, 2016; Pedersen et al., 2019; Völker and Kistemann, 2013; White et al., 2021) • Aesthetic scenery (Moore and Hunt, 2012; Oertli and Parris, 2019; Zhou et al., 2020)
Education and research	• Opportunities for research and environmental education (Ghermandi and Fichtman, 2015; Oertli and Parris, 2019; Sousa et al., 2016; Welker et al., 2010; Zhou et al., 2020)
Food and materials	• Food e.g. fish, watercress, and materials e.g. reeds (Hill et al., 2018; Nicholas, 1991) • Aquaculture production (Bostock et al., 2016; Tucker and Hargreaves, 2012)
Conservation value	• Opportunity for future generations to know and experience ponds as they are now (Davenport et al., 2010; Hassall, 2014; Zhou et al., 2020)

Table A2
Summary of actions to use ponds and pondscapes as NBS (PONDERFUL project (unpublished)).

Pond and pondscape NBS actions: type and description
1) Pond or pondscape creation • Creating a pond or pondscape in a site where there was formerly no waterbody
2) Pond or pondscape restoration • Creating or restoring a pond/pondscape in a site where formerly a pond/pondscape was existing, e.g. excavating a pond that had been filled in • Significant alterations to an existing pond or existing pondscape, e.g. depth, morphometry, slopes, shoreline design, flora or fauna
3 A) Pond infrastructure and management actions **On-site infrastructure measures *(acting on areas surrounding a pond)*:** • Access restrictions, e.g. fencing to prevent access or allow access for animals and/or humans; • Development of trails or wildlife observatories; • Management of riparian vegetation and wetland plants; • Removing invasive alien plant species; • Implementing (or enlarging) the buffer area immediately surrounding the pond; • Creation of terrestrial habitats in the vicinity of the pond (e.g. for reptiles or amphibians); • Removing hard infrastructure (e.g. concrete edge); • … **Pond management measures *(actions within a pond)*:** • Removing invasive alien plant and animal species; • Reintroducing or protecting threatened plant and animal species; • Pond water management, e.g. manage input, output (e.g. sluice adjustments, lining), drying rate; • Routine management measures for pond design and depth (e.g. re-profiling of banks, sediment removal, creation/removal of islands, scraping edges to maintain populations of pioneer species); • Mowing and removal of submerged, floating or emergent plants; • Regular monitoring of physical, chemical or biological indicators; • Planting or introducing structured vegetation into ponds (e.g. planted coil rolls); • Shade management (e.g. a few trees or large % of cover); • Partial desilting; • ….

(*continued on next page*)

Table A2 (*continued*)

Pond and pondscape NBS actions: type and description
3B) Pondscape-scale land use and management actions • Placing (part of) the pondscape under protective status (e.g. protected areas regulations); • Changing land use in the pondscape area (e.g. convert arable land or intensive livestock grazing area to extensive grassland; decrease impervious surfaces e.g. asphalt in neighbouring areas); • Enhancing the connectivity between ponds or pondscapes. This involves the creation of terrestrial or aquatic corridors, removing obstacles, or active transport of propagules; • …. Specific management measures (at pondscape scale), depending on landscape: • In agricultural land, 1) Soil Management (e.g. allow drainage systems to deteriorate or reinstate/increase infiltration to decrease sediment load), 2) Livestock Management (e.g. reduce the length of the grazing day or grazing season), 3) Fertiliser Management (e.g. reduce fertiliser application rates), 4) Manure Management (e.g. change from slurry to a solid manure handling system) and 5) Farm infrastructure (e.g. Fence off pondscape from livestock) • In urban land, 1) Manage water quality (e.g. inputs of nutrient, salt, other pollutants); 2) Increase good quality terrestrial habitats in neighbouring areas (e.g. other green/blue spaces); 3) Promote natural hydroperiods, 4) Encourage water harvesting from buildings (rainwater) • …

Appendix B

To limit the scope of the study, we established the following criteria for the inclusion of a given policy into the data set:

1. Must be a *Directive* or *Regulation* passed by the European Parliament and the Council of the European Union; OR
2. A *Recommendation* or *Decision* adopted by the above-mentioned institutions, IF:
   a. There is no *Directive* or *Regulation* regulating a given policy issue, OR
   b. It outlines key aspects of the policy agenda relevant to NBS implementation for the future; OR
3. A *Communication* drafted by the European Commission, IF:
   a. There is no *Directive, Regulation, Decision*, or *Recommendation* regulating a given policy issue, OR
   b. It provides details regarding the status or future pathways of implementation of one or more *Directive*, *Regulation, Decision*, or *Recommendation,* AND/OR
   c. It outlines key aspects of the policy agenda relevant to NBS implementation for the future; AND
4. Must be the latest amendment or iteration of a policy; AND
5. Must be in force OR will likely enter into force (applies to *Directives, Regulations, and Decisions*).

Appendix C. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2023.106957.

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