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Natural/Small Water Retention Measures: Their Contribution to Ecosystem-Based Concepts

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Abstract: The increasing incidence of droughts and heavy rainfall events is exacerbating conflicts between human and environmental demands for water. However, through providing multiple water-related ecosystem services and benefits simultaneously, Natural/Small Water Retention Measures (NSWRM) can mitigate such competing claims. Thus, they also contribute to the achievement of various Sustainable Development Goals and environmental targets set out in water- and agriculture-related policies of the European Union. In particular, NSWRM provide for the sound management of watersheds, which can significantly contribute to improved water quality and availability—as well as improving the resilience of agriculture and society. This paper demonstrates how NSWRM fit into the framework of ecosystem-based concepts, including Natural Water Retention Measures (NWRM), Green Infrastructure (GI), Sustainable Land Management (SLM), Ecosystem-based Adaptation (EbA), and Nature-based Solutions (NbS). NSWRM, as a distinct concept, bring added value to the other concepts by focussing on easy-to-implement, modestly sized, localised technical solutions to problems associated with water management, sediment, and nutrient loss. Through experience under the EU Horizon 2020 project OPTAIN ("OPtimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe"), we show what NSWRM are, how they are linked to each of the ecosystem-based concepts, and how they can help add value to these concepts. Fourteen case studies are drawn upon from diverse countries across Europe. As a result of this analysis, we present the potential for the application of NSWRM in the context of these concepts, while helping to identify planning tools, the expertise required, and potential funding mechanisms.

Keywords: Natural/Small Water Retention Measures; Natural Water Retention Measures; Green Infrastructure; Sustainable Land Management; Ecosystem-based Adaptation; Nature-based Solutions; integrated water management; Horizon2020; ecosystem restoration; Sustainable Development Goals

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1. Introduction

The increased number of extreme climatic events in many European regions has further aggravated the conflicts between human water uses and environmental demands [1,2]. It has highlighted past mistakes in watershed management and river regulations [3]. These errors include the reduction of flood plains, meanders, river connectivity, and other hydromorphological features and characteristics, as well as the increased drainage of wetlands and lowlands. In turn, this has led to reduced organic matter in soils, impairing their stability and permeability, as well as increased rainwater–runoff transfer [4]. The associated decrease in ecosystem resilience has become ever more apparent.

Water is vital for direct and indirect human use and is also key in ecosystem function. In watershed management, agriculture, as a major land use, plays a pivotal role, in particular for water retention in crop lands, rainfall–runoff transfers to surface and groundwater, and water demand for irrigation. However, the domestic and industrial sectors also significantly contribute to the overall water cycle and exhibit distinct impacts on water quality and quantity. Simultaneously, the environment must be considered, especially the need for maintaining good environmental flow in rivers, in both quantitative and qualitative terms. Thus, water is clearly a "contested resource". Climate change projections suggest that many regions in Europe will experience more frequent extreme events, including droughts, heavy rainfall, and an increasing variability in precipitation [5]. These impacts are already creating additional challenges, especially, but not exclusively, in the headwaters of agricultural catchments with respect to water scarcity, excess water, and increasing loads of nutrients and sediment in runoff [6,7].

There are a large number of environmental management practices and structural measures available to adapt to these challenges [8,9]. Nevertheless, the appropriate selection and combination of measures that address the constraints on and local competition for resources while considering their effect at a larger scale are problematic. While practices are often structural, there is a growing tendency to use solutions that rely on natural processes, or even mimic nature [10]. Their multifunctionality and resilience make it possible to combine benefits for both human needs and the environment. To group the available technologies (based on the drivers they address, for example), but also to facilitate the communication and promotion of actions, specific technologies are often categorised into overarching concepts.

Both Natural Water Retention Measures (NWRM) and Natural/Small Water Retention Measures (NSWRM) represent a recent development in concepts related to water management that take agricultural and broader human influence on the water cycle into consideration [11,12]. NWRM/NSWRM comprise clusters of related practices that are becoming more and more important as part of an overall environmental climate change adaptation strategy. In this context, a NWRM and NSWRM policy as promoted by the European Union seeks to reconcile—and optimise—the competing demands.

The focus of this paper is on NSWRM, which represent relatively small interventions, often at the field scale. Examples of NSWRM include (Figure 1) (a) wetland restoration and management, to optimise their impact on the retention of floodwaters and gradually release this water during drier periods, thus helping in flood control and maintaining water availability; (b) riparian buffer zones, where vegetated strips of land located along water bodies serve as natural filters that capture pollutants and sediments; (c) grassed waterways, which provide drainage pathways on arable land to manage runoff and enhance water quality; and (d) agricultural measures, such as reduced tillage aimed at minimising soil disturbance to preserve soil structure, reduce erosion, and enhance infiltration.

This paper provides suggestions as to how NSWRM can contribute to the objectives—and be used in the frameworks—of various ecosystem-based concepts. Furthermore, it shows, with specific examples from the EU Horizon 2020 project "OPTAIN" (OPtimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe; see Section 2.2) what NSWRM are, to which concepts they are linked, and how. The focus here is on NSWRM categories relevant to the agricultural sector. In this article, we specifically consider how this group of measures, and the overall concept, relates and can add value to (a) NWRM, (b) Green Infrastructure (GI), (c) Sustainable Land Management (SLM), (d) Ecosystem-based Adaptation (EbA), and (e) Nature-based Solutions (NbS).

Figure 1. Examples of NSWRM in OPTAIN [13]. (**a**) Experimental retention wetland (photo: Petr Fucik) [14]; (**b**) river buffer zones (photo: Dominika Krzeminska) [15]; (**c**) grassed waterway (photo: Jörg Voß) [16]; (**d**) direct driller machine for reduced tillage agriculture (photo: Zoltan Toth) [17].

All these ecosystem-based concepts address the human use of nature or natural functions and ecosystem services, defined as "the benefits people obtain from ecosystems" [18], and their associated multifunctionality. Each has been developed by different actors and articulated in different frameworks for various specific objectives at different times. It is hardly surprising, therefore, that there is considerable overlap. While the variety in terminology may appear confusing, we aim to show that this wide diversity is, in fact, valuable to help place the overarching idea of ecosystem-based concepts into practice in a structured and targeted way. We demonstrate that the different concepts address this broad goal from different angles, helping each sector or thematic actor to take part in using nature more effectively, or restoring natural functions for their designated purposes.

Through showing how NSWRM fit into the overall picture, we aim to support the further, broader implementation of the various concepts in order to improve the understanding of their common denominators or potentially conflicting aspects. It will then be progressively possible to bundle resources, use common platforms and tools, and achieve common goals through maximising co-benefits, as well as strengthening communication and exchange between different communities. The urgency of preserving biodiversity, being economical with space for people, and being more efficient in natural resource use to increase the resilience of the landscape justifies all actors starting from their own standpoints with their own resources of knowledge and finance. However, where this is carried out in collaboration with other parties, synergies can be achieved. This paper helps to establish an analytical baseline and aims to foster future collaboration between different stakeholder communities for the overall benefit of ecosystems.

2. Materials and Methods

2.1. Theoretical Framework

2.1.1. Selection and Review of Ecosystem-Based Concepts

Although the appreciation of the essential role of ecosystems is not new, the idea of using nature or natural processes to address environmental challenges as documented scientific approaches only began in the 1970s, with the development of the concept of "ecosystem services". Harnessing nature in ecosystem management for human benefits essentially means that the solutions target more than one service; in other words, the multifunctionality of ecosystems is promoted. Over the last half century, various concepts have emerged to designate such ecosystem-based approaches [19].

The different environmental elements of water, soil, and/or biodiversity are the focus of specific scientific communities, just as environmental concerns of climate change or land degradation are the interest of other disciplines. For each of these communities and disciplines, it is generally most practical to develop targeted categories of measures adapted to their particular scope of work. The result, however, is that the same practices are often promoted and implemented in different contexts to restore and maintain ecosystems—but with different labels, under various funding mechanisms and projects, using different knowledge management and planning tools as well as diverse experts.

We will demonstrate this with a special focus on NSWRM, as used and implemented under the OPTAIN project, and through the examination of the five other concepts already introduced in this paper (NWRM, GI, SLM, EbA, and NbS). We are aware that there are many other specific concepts that have been popularized at local, national, or regional levels or in different thematic domains. Our selection of concepts relies on their similar approaches to addressing the challenges of human needs by finding solutions based on restoring ecosystem functions (see Table 1). The other criterion for selecting these concepts is that they are widely used at the global and especially at the European level and are referred to in policies and projects related to OPTAIN and the NSWRM defined therein.

Among these concepts, **Sustainable Land Management** is the oldest. It emerged in the years following the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, as a follow-up to the global discussion on "sustainable development" [20]. The principles of SLM revolve around the promotion of production through conservation, the active participation of local communities, and the implementation of integrated conservation strategies. Initially, the terminology used was "soil conservation" and then "soil and water conservation", until the term "sustainable land management" evolved, gaining ascendency and then wide acceptance [3]. A first definition of SLM was established in 1991 by the Framework for Evaluating Sustainable Land Management (FESLM) [21], and it was proposed as a remedy for the challenges arising from population growth and the escalating demand for fertile land [22]. SLM encompasses the active involvement of people and their harmonious coexistence with nature, adopting a long-term perspective to ensure the provisioning, regulating, cultural, and supporting services for ecosystems [23]. By considering the complex interplay between environmental, social, and economic factors, SLM responds to the pressing need for land management practices that ensure long-term sustainability.

Green Infrastructure was then conceptualised in the USA and Western Europe at the end of the 20th century, before spreading around the world. Green Infrastructure is based on the principle that the protection and enhancement of nature and natural processes, along with the numerous benefits that human society derives from nature, are consciously integrated into spatial planning and territorial development. The official definition of the European Commission was derived from the EC Communication "Green Infrastructure—Enhancing Europe's Natural Capital" [24].

Later, in the early 2000s, **Nature-based Solutions** emerged, to promote nature as a source of solutions to the challenges associated with climate change [25]. NbS embrace approaches that promote the protection, sustainable management, and restoration of ecosystems. Several definitions (or descriptions) exist, the most authoritative of which come from the IUCN, who have developed a standard for the verification and design of NbS, and from the European Commission. While NbS tend to exclude "grey infrastructure", the need to account for people in ecosystem services can lead to some flexibility. Depending on their objectives, NbS promote a gradation of direct human intervention in the ecosystem. With their very broad framework and remit, NbS are often positioned as an easy to grasp, popular, umbrella concept. However, the term lends itself to criticism for being vague, and, as *Nature* [26] puts it: "the latest attempt to brand green practices".

The increasing focus on climate change led to the birth of **Ecosystem-based Adaptation** in 2008, which was initially applied with a geographical focus on the global South, but later also in the global North, and is now used internationally [27]. It was first included in the Bali Action Plan under the United Nations Framework Convention on Climate Change in 2008. The formal definition of EbA was subsequently established in the Convention on Biological Diversity in 2009 [28]. Since 2010, the United Nations Environment Programme (UNEP) has been mandated to work on EbA under UNEA Resolution 1/8 on EbA [29].

Natural Water Retention Measures and, derived from these, **Natural/Small Water Retention Measures** are focused on the water cycle in river basins and water management. The term NWRM was introduced in the 2012 Blueprint to Safeguard Europe's Water Resources [30] and included in the 2013–2015 Work Programme of the Common Implementation Strategy (CIS) for the Water Framework Directive (WFD). An EU policy document on NWRM was produced by a dedicated expert group in 2014 [31]. Simultaneously, the Directorate General for Environment (DG ENV) started to frame and grow the concept with a study on the cost, benefits, and climate proofing capacity of NWRM [32] and continued with a more ambitious NWRM initiative to develop sound and comprehensive knowledge and a community of practices through the NWRM project (2013–2015) [33].

Within the Integrated Drought Management Programme in Central and Eastern Europe (IDMP), a specific project on NSWRM was implemented by a group of experts from Hungary, Poland, Slovakia, and Slovenia. The outcomes of this project and the lessons learned from the activities carried out in the period 2013–2015 are summarised and presented in the guidelines "Natural/Small Water Retention Measures: Combining drought mitigation, flood protection, and biodiversity conservation" [11]. The Interreg project "Framework for improving water balance and nutrient mitigation by applying small water retention measures" (FramWat) developed methodologies to incorporate NWRM and NSWRM into river basin management planning [34].

A typical portrait of an NSWRM, as used under the OPTAIN project, is as follows:

- Implemented mainly within catchments characterised by predominant land use of agriculture and forestry, encompassing headwaters;
- Aims to protect and manage water resources, with a focus on the retention, recovery, and re-use of water, nutrients, and sediments;
- Yields multiple benefits, including the reduction of floods and droughts and water quality improvement;
- Small in size, which keeps costs low but also limits the effects, and therefore a combination of NSWRM is required over a wide area to have a significant broad impact;
- Pragmatic for technical implementation by local practitioners, fostering local engagement;
- Has impacts that are easy to quantify and thus can readily be included in models for the optimisation of their combinations.

Table 1 presents definitions and an indication of the origins and use of ecosystem-based approaches. As definitions have been developed by different communities, they are not fully consistent in what they cover or how they are phrased (some are descriptions rather than precise "definitions"). The table is organised according to the typical geographical size of the projects or measures implemented, from the smallest to the largest.

Table 1. Selected ecosystem-based concepts: definitions, origin, and use.

Term --- Origin --- Users	Definition/Description
Natural/Small Water Retention Measures (NSWRM) ---------------------- Integrated Drought Management Programme in Central and Eastern Europe (IDMP) 2015 [11] ---------------------- FramWat project, OPTAIN project	Natural/Small Water Retention Measures aim to safeguard and enhance the water storage potential of landscapes, soils, and aquifers and foster ecosystem services for mitigating the impacts of floods and droughts, while contributing to the achievement of multiple Sustainable Development Goals and environmental targets formulated in several European Union policies. NSWRM are in line with the NWRM concept. Applied in the OPTAIN project, they focus on headwater catchments and farms, with the aim of developing easy-to-implement and efficient solutions at the farm and headwater catchment scales (OPTAIN definition).
Natural Water Retention Measures (NWRM) ---------------------- Blueprint of Water Framework Directive 2012 [30] ---------------------- EU Commission DG Environment, Work Programme of the Common Implementation Strategy (CIS)	NWRM are multifunctional measures that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes (NWRM.EU).
Green Infrastructure (GI) ---------------------- EU Commission DG Environment 2013 [24] ---------------------- European Commission [35], The European Green Belt [36]	Green Infrastructure is defined by the European Commission as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services". It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in both rural and urban settings.
Sustainable Land Management (SLM) ---------------------- United Nations Conference on Environment and Development (UNCED) 1992 [20] ---------------------- UNCCD; WOCAT; FAO; IPCC	The use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions [37].
Ecosystem-based Adaptation (EbA) ---------------------- Bali Action Plan under the UNFCCC 2008 [27]; Convention on Biological Diversity 2009 [28] ---------------------- United Nations Environment Programme (UNEP) UNEA Resolution 1/8 on EbA; IUCN	The use of biodiversity and ecosystem services to help people adapt to the impacts of climate change [38,39]. EbA aims to maintain and increase resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. EbA is promoted for not only environmental but also socio-economic benefits [39]. Examples of EbA include the restoration of coastal ecosystems; the management of wetlands and floodplains; the conservation and restoration of forests and natural vegetation; and the establishment of diverse agroforestry systems to help maintain crop yields under changing climates [40].
Nature-based Solutions (NbS) ---------------------- IUCN 2016 [41]; European Commission 2017 [25] ---------------------- IUCN and EU Commission DG Environment	The European Commission defines NbS 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. Nature-based Solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services" [25]. However, different definitions coexist (e.g., IUCN), each of which distinguishes three types of NbS based on the level of intervention and type of engineering.

2.1.2. Review of Similarities and Differences

While all these concepts share a common focus on nature, ecosystem services, and multibenefit approaches, they differ in their primary objectives and target communities, and to some extent in their geographical and temporal scope. For example, NWRM and

NSWRM aim to protect and manage water resources; GI aims to maximise the potential of natural resources in spatial planning and territorial development; SLM seeks to prevent, reduce, and reverse land degradation; EbA seeks to maintain and increase the resilience of ecosystems to climate change; and, finally, NbS focus on improving the status of biodiversity together with social benefits.

Each concept also has its own dedicated funding mechanisms, projects, knowledge management and planning tools, platforms, applications, and expert groups. However, it is important to identify the common denominators by looking beyond the primary goals of the individual concepts and ensuring that all co-benefits are taken into account. In this way, it is possible to envisage how different sectors and thematic actors—through their various concepts—can create synergies and thus make more effective and sustainable use of nature and restore natural functions for the benefit of all involved parties. Promoting the combination of efforts can be a more resource-efficient way of ensuring the effective multifunctionality of landscapes.

To identify similarities, differences, and overlaps among and between the six concepts and to understand their specificities, we categorised the concepts based on geographical scale, timeframe, main challenges addressed, co-benefits, and the ecosystems and Sustainable Development Goals (SDGs) that they address. The categorisation was based on a literature review and the specialist knowledge of the authors. It is recognised that we were essentially reductionist in the comparison because there are complexities that are not easy to capture. In particular, only three of the six concepts include both technical and non-technical measures or approaches (SLM, EbA, NbS), and the latter are not easily captured in a simple table. Furthermore, individual measures may be unable to reach the overall concept's objectives and cannot always be assessed in isolation.

While the SDGs were defined by the 2030 Agenda of the United Nations [42], the level of detail for other categories had to be defined. For the ecosystems, we followed the eight types defined by the UN Decade on Ecosystem Restoration [43], and the challenges and co-benefits were captured and harmonised across all six concepts following a European Commission panel [44]. In relation to their importance for NSWRM, the relevant scales and timeframes are defined as follows. Spatially, scale is relevant for the implementation of NSWRM: small (fields, plots, river sections); medium (sub-catchments and catchments); and large (large river basins). Regarding the time frame, the short term ($\leq$years), medium term (decade(s)), and long term ($\geq$generations) are considered as the most important periods with respect to the delivery of the expected benefits from these measures.

These scale definitions were based on the categories of Walz et al. [22], and more specifically on those from hydrology [45–47], agriculture [48,49], landscape ecology [50], and ecosystem science [51], since NSWRM touch on these disciplines to different degrees. NSWRM are mostly implemented on smaller spatial scales, especially fields, plots, and river sections, but when combined, their impacts can reach up to medium and larger scales such as catchments and river basins [11,52,53].

2.2. Showcasing NSWRM and Related Concepts

To showcase the nature and relevance of NSWRM and their link to the different concepts, we selected specific examples by taking 14 case studies from the EU Horizon 2020 project OPTAIN (duration: 2020–2025). The project aims to: (i) identify efficient techniques for the retention and re-use of water and nutrients in small agricultural catchments across different biogeographical regions of Europe and, in close cooperation with local actors, (ii) select NSWRM at the farm and catchment level and optimise their spatial allocation and combination, based on environmental and economic sustainability indicators. The 14 case studies of OPTAIN are located in the continental (7), Pannonian (3), and boreal (4) regions of Europe and are distributed across 12 countries (Figure 2). Thus, they represent a wide range of soil-climatic zones and agricultural systems. All case studies face individual challenges related to water management (floods, droughts) and nutrient losses, which are summarised in Table A1 (Appendix A).

Figure 2. Biogeographical regions covered by the OPTAIN project (boreal, continental, Pannonian) and location of the 14 case studies. European Environment Agency base map [54] with grey-scale colouring for the biogeographical regions not addressed in OPTAIN ('other').

The OPTAIN project prioritises the involvement of end-users in the selection of relevant NSWRM. To this end, a Multi-Actor Reference Group (MARG) was established in each of the 14 case studies [55–57]. In a first series of MARG workshops, relevant NSWRM were discussed and prioritised based on a common guideline [58], with a total of 165 participants from different stakeholder groups across all 14 case studies. Based on the outcome of these workshops, the OPTAIN case study teams each selected up to seven measures that could be classified as NSWRM and were relevant for the specific case study area as well as the purposes of the OPTAIN project. All 66 selected NSWRM will be documented; assessed (e.g., using the Soil and Water Assessment Tool, SWAT+ [59]); and integrated into the SLM and NWRM databases within the framework of the OPTAIN project. However, this article focuses on 14 selected NSWRM (see Table 2 below) representing different NWRM categories and all four NWRM sectors [60] and biogeographical regions (see Figure 2).

In addition, five measures are included that cannot be classified as NSWRM but are specifically related to NWRM, GI, SLM, EbA, or NbS (either one or more). This is to illustrate instances where concepts do not overlap and enhances our ability to compare classification approaches and concepts more effectively. The additional measures selected are:

- **Fish ladder** (GI): A fish ladder is designed to facilitate the movement of fish upstream over a dam by creating a flow of water with a reduced velocity that allows fish to pass through it while swimming upstream [61].
- **Mangrove reforestation** (EbA): The reestablishment of mangroves where they were previously degraded [62].
- **Sustainable native beekeeping** (SLM): Native beekeeping protects stingless bees and plants found in forest and savannah ecosystems, while sustainably producing honey [63].
- **Landscape management for reducing gravitational risk** (NbS): The use of an NbS to limit landslides and avalanches [64].
- **Green roofs** (NWRM): Green roofs are multilayered systems that cover the roof of a building with vegetation and/or green landscaping over a drainage layer [65].

Table 2. Selection of NSWRM documented under the OPTAIN project.

#	NSWRM (Country/Name of OPTAIN Case Study [1])	Short Description [2] [58]
1	**Grassing targeted into recharge area** (Czech Republic/Cechticky)	Recharge (infiltration) areas of agricultural drainage systems are grassed to significantly improve drainage water quality.
2	**Riparian buffer zones** (Sweden/Sävjaan)	Riparian areas proximal to streams and ditches are maintained to slow the movement of particulate matter and water from fields to receiving waters, thereby potentially limiting peak flows.
3	**Crop rotations** (Italy/Cherio)	Different crops or varieties of crops are cultivated on the same area or parcel, either in sequence or during the same cropping season to deliver multiple benefits.
4	**Slope subdivision** (Switzerland/Petite Glâne)	Fields at risk of erosion by water are divided with grass strips and hedges to prevent soil loss and offsite damage during heavy rainfall.
5	**Reduced tillage—no tillage in autumn** (Norway/Hobol)	Reduced tillage, involving no ploughing in the autumn, is employed to preserve stubble and residue cover during the autumn and winter—which in turn reduces soil erosion and the loss of particles and nutrients from cropland into watercourses.
6	**Mulch-till** (Slovenia/Pesnica)	Mulch tillage is a plough-less method of tillage that is used to avoid soil disturbance and maintain soil structure and organic matter. Over 30% of the cultivated field area remains covered with organic residues from the previous crop.
7	**Green cover in vineyards** (Hungary/Csorsza)	Permanent grass cover is established under grape vines to protect the soil surface against erosion and compaction and provide better conditions for traffic within the rows during mechanised field operations.
8	**Forest riparian buffers** (Belgium/La Wimbe)	Riparian forest buffers comprising trees and shrubs are planted adjacent to a stream, to filter nutrients, pesticides, sediments, and animal waste from agricultural land runoff; stabilise riverbanks to reduce bank erosion; protect the river from non-point pollution; and provide habitats for organisms.
9	**Converting cropland to grazing land** (Slovenia/Kebele patak)	Cropland is converted into pasture due to shallow soils with a high stone content, which have led to lower yields or yield losses during drought periods.
10	**Sediment capture pond** (Hungary/Tetves)	Ponds are located along networks of ditches that drain watersheds. They slow water velocity to reduce sedimentation in the ditches and diminish both the sediment and nutrient pollution of water bodies downstream.
11	**Wetland installation** (Lithuania/Dviete)	A wetland is constructed by artificially flooding the valley. Over time, the surface layer of the wetland is altered by specific plants. Sediments washed down from the fields accumulate, and this creates typical habitats of saturated organic soils to retain nitrogen and, especially, phosphorus.
12	**Wetland restoration and management** (Poland/Upper Zglowiaczka)	The restoration and management of wetlands establish a permanent regulated outflow through ditches and dykes on peatlands to restore optimal feeding conditions for endangered species. Spring pluvial floods are extended, the deglaciation of peat soils is stopped, and open areas are maintained through mowing.
13	**Grassed waterways** (Germany/Schwarzer Schöps)	Drainage pathways on arable land that are particularly vulnerable to water erosion are converted to permanent grassland to prevent soil erosion and associated nutrient loss. Greening the line of lowest elevation (thalweg) slows surface runoff, increases infiltration, and stabilises the soil surface.
14	**Water level adjustment threshold** (Latvia/Dotnuvele)	Small water level adjustment dams are built on the drainage lines of floodplain meadows and pastures using local materials. The dams create prolonged standing water bodies to reduce water and nutrient runoff at the farm scale.

[1] The NSWRM has been documented and assessed within the OPTAIN project (see Table A1 in the Appendix A for more information on the OPTAIN case studies). [2] Detailed information on the individual NSWRM is in the process of being uploaded to the WOCAT's global SLM database [13].

3. Results and Discussion

3.1. Comparison of Ecosystem-Based Concepts

The comparison of ecosystem-based concepts is based on the selection of six key features to highlight their distinct and specific aspects, but also to underline what they have in common with the other concepts. Table 3 summarises this analysis and presents a cross-comparison between all concepts and criteria. In the following, each of the six concepts is described according to these criteria, and both the overlaps and differences are identified.

Table 3. Selected key features of six different ecosystem-based concepts, based on expert assessment and key literature [11,22,29,39,42,44,53,66–68].

Concept	Scale	Timeframe for Delivering Expected Benefits	Main Challenges Addressed/Benefits Delivered	Co-Benefits	Ecosystems Addressed (UN Decade on Ecosystem Restoration)	Key Sustainable Development Goals Addressed
	Small *Medium* *Large*	*Short term* *Medium term* *Long term*	*1. Biodiversity enhancement; 2. Water management; 3. Natural and climate hazards; 4. Green space management; 5. New economic opportunities and green jobs; 6. Land regeneration; 7. Air quality; 8. Social justice and social cohesion; 9. Climate resilience; 10. Participatory planning and governance; 11. Knowledge building for sustainable urban transformation; 12. Health and well-being*		*1. Farmlands; 2. Grasslands;* *3. Forests; 4. Mountains;* *5. Peatlands; 6. Urban areas;* *7. Freshwaters;* *8. Oceans and coasts*	*17 categories of the Sustainable Development Goals*
NSWRM	Small Medium	Short term Medium term Long term	2. Water management 4. Green space management	1. Biodiversity enhancement; 3. Natural and climate hazards; 6. Land regeneration; 7. Air quality; 9. Climate resilience; 10. Participatory planning and governance; 11. Knowledge building for sustainable urban transformation; 12. Health and well-being	1. Farmlands 2. Grasslands 3. Forests 7. Freshwaters	6: Clean water and sanitation; 11: Sustainable cities and communities; 13: Climate action; 15: Life on land
NWRM	Small Medium Large	Medium term Long term	2. Water management 4. Green space management	1. Biodiversity enhancement; 3. Natural and climate hazards; 6. Land regeneration; 7. Air quality; 9. Climate resilience; 10. Participatory planning and governance; 11. Knowledge building for sustainable urban transformation; 12. Health and well-being	1. Farmlands 2. Grasslands 3. Forests 4. Mountains 5. Peatlands 6. Urban areas 7. Freshwaters	6: Clean water and sanitation; 11: Sustainable cities and communities; 13: Climate action; 15: Life on land
GI	Small Medium Large	Medium term Long term	4. Green space management 1. Biodiversity enhancement 9. Climate resilience	2. Water management; 3. Natural and climate hazards; 6. Land regeneration; 7. Air quality; 8. Social justice and social cohesion; 12. Health and well-being	All	11: Sustainable cities and communities; 13: Climate action; 15: Life on land; 16: Peace, justice, and strong institutions

Table 3. *Cont.*

Concept	Scale	Timeframe for Delivering Expected Benefits	Main Challenges Addressed/Benefits Delivered	Co-Benefits	Ecosystems Addressed (UN Decade on Ecosystem Restoration)	Key Sustainable Development Goals Addressed
SLM	Small Medium Large	Short term Medium term Long term	6. Land regeneration 1. Biodiversity enhancement 2. Water management	3. Natural and climate hazards; 4. Green space management; 9. Climate resilience; 10. Participatory planning and governance; 12. Health and well-being	All	1: No poverty; 2: Zero hunger; 3: Good health and well-being; 5: Gender equality; 6: Clean water and sanitation; 11: Sustainable cities and communities; 12: Responsible consumption and production; 13: Climate action; 15: Life on land; 16: Peace, justice, and strong institutions
EbA	Small Medium Large	Medium term Long term	9. Climate resilience 3. Natural and climate hazards 1. Biodiversity enhancement 12. Health and well-being	2. Water management; 4. Green space management; 6. Land regeneration; 7. air quality; 8. Social justice and social cohesion	All	1: No poverty; 6: Clean water and sanitation; 7: Affordable and clean energy; 11: Sustainable cities and communities; 12: Responsible consumption and production; 13: Climate action; 14: Life below water; 15: Life on land
NbS	Medium Large	Medium term Long term	NbS can contribute to addressing all challenges and providing all co-benefits		All	NbS can contribute to achieving all SDGs.

NSWRM are a specific case of NWRM, focusing on farmlands, grasslands, forests, and freshwater ecosystems that are affected, particularly in terms of the retention of water, nutrients, and sediments. Like NWRM, they have an effect at small to medium scales, within a short- to long-term timeframe. However, NSWRM concentrate on small and simple measures that can be easily implemented in agricultural catchments, including their headwaters. In contrast to NWRM, this could also include single-function measures like small technical retention measures, for instance small hydro-technical systems and new methods of using existing water systems [11], in particular controlled drainage. Like NWRM, multifunctional NSWRM can have a variety of co-benefits, and with their strong focus on water retention they contribute to SDG 6 (on clean water), but also to SDG 11 (sustainable cities and communities), SDG 13 (climate action), and SDG 15 (life on land).

NWRM are usually applied on a relatively small scale in relation to the size of their catchments and are often implemented in combination with other NWRM [53] to achieve a significant impact on water resources. In essence, they are multifunctional, and the challenge is to find appropriate combinations of measures that respond to the characteristics as well as the management issues and planning process of a particular catchment. NWRM address a broader range of ecosystems than NSWRM. For example, NWRM can be implemented in urban areas. As they have a strong focus on water retention, they contribute to the same SDGs as NSWRM [66].

GI includes a wide range of different environmental practices that can operate at different scales, from small features such as hedgerows, fish ladders, or green roofs to entire functional ecosystems such as intact floodplain forests, peatlands, or transboundary river basins [69]. Each of these elements can contribute to GI in urban, peri-urban, and rural areas, inside and outside protected areas. Some forms of GI can also be implemented in coastal areas. Hanna and Comín [70] conducted a literature review of Urban Green Infrastructure and Sustainable Development Goals and showed that most of the topics of interest in the literature are related to SDG 11 (sustainable cities and communities), SDG 13 (climate action), SDG 15 (life on land), and SDG 16 (peace, justice, and strong institutions). Conversely, there is very little information about the relationships between Urban Green Infrastructure and most of the other SDGs.

SLM plays a central role in all eight ecosystem types through combating land degradation, enhancing biodiversity, and improving hydrological function. This can be achieved at the field; catchment; and, potentially, river basin scales [71]. SLM practices are mainly applied in terrestrial and freshwater ecosystems. SLM generates multiple co-benefits, including climate change mitigation and adaptation, resilience and disaster risk reduction, better hydrological function, improved biodiversity, and enhanced production. However, to benefit whole ecosystems, a combination of SLM practices is required, which must be spread widely and maintained and adapted over time [71]. SLM directly supports the achievement of SDG 15 (life on land) and has a specific and targeted impact on SDG 15.3 (land degradation neutrality), SDG 13 (climate action), and SDG 6 (clean water and sanitation), thereby contributing to SDG 1 (no poverty), SDG 2 (zero hunger), and SDG 3 (good health and well-being). Implementing SLM can furthermore contribute to enhanced gender equality (SDG 5), good governance, and sustainable consumption and production (SDG 12). In specific situations—for example, approaches designed to reduce conflict in rangeland management [72]—it can contribute to SDG 16 (peace, justice, and strong institutions).

EbA has certainly made progress as an adaptation approach; however, there is still a lack of understanding of how "EbA approaches contribute to 'effective' adaptation, including the circumstances where they face constraints and limits" [73]. Moreover, Nalau et al. [73] claimed that "the implementation of EbA approaches ideally requires a level of understanding about ecosystem structure, productivity and dynamics, and how these are affected by climate change and other direct anthropogenic stressors, that are rarely available in developing countries", where EbA are often applied. Although FOE [38] presented the connections between EbA and each of the 17 SDGs, such connections are most often reported for SDG 1 (no poverty), SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), SDG 12 (sustainable consumption and production), SDG 13 (climate action), SDG 14 (life below water), and SDG 15 (life on land).

NbS deliver benefits that flow from healthy ecosystems. Such solutions target major challenges like climate change, disaster risk reduction, water security, biodiversity loss, and human health [25,74]. NbS can also theoretically contribute to the achievement of all SDGs, because they both rely on a sustainable approach (social, environmental, and economic development are considered) and address public interest objectives at the same time [68,75]. The temporal aspects of NbS are complex, dynamic, and difficult to assess within conventional planning and policy-making periods [76]. By definition, NbS must be implemented in a way that is compatible with the temporal dynamics and complexity of ecosystems [77] so that the services provided by the ecosystem are sustainable and resilient to future environmental change. This is why the effectiveness of some NbS may only become apparent after years or even decades. For the same reason, to achieve their full benefits, NbS need to be implemented at a scale large enough to be consistent with ecosystem functioning.

In summary, multifunctionality is at the core of all of the above concepts, to a greater or lesser extent, with a set of different dimensions for each, which may be specific to one concept or shared with several. This means that they are not easy to characterise or compare. However, it is possible to show, broadly, where they overlap—to what extent and in which dimensions, and this is presented in a simplified manner for scale and ecosystems in Figure 3.

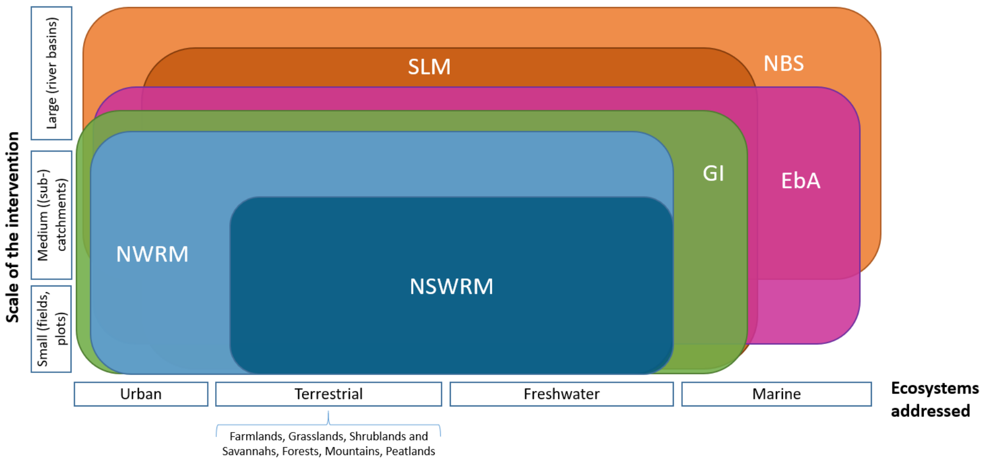

Figure 3. How the ecosystem-based concepts overlap with respect to scale and key ecosystems. The following concepts were considered: Natural/Small Water Retention Measures (NSWRM), Natural Water Retention Measures (NWRM), Green Infrastructure (GI), Sustainable Land Management (SLM), Ecosystem-based Adaptation (EbA), Nature-based Solutions (NbS).

All of these concepts can be applied at least at the medium scale, and each also addresses most terrestrial and freshwater ecosystems. Some go beyond this and can be implemented in urban or coastal/marine ecosystems.

There is a strong link between the SDGs and ecosystem-based concepts, as they share a common view of sustainability (esp. NbS and EbA). However, Figure 4 highlights that, while most concepts cover SDG 6 (clean water and sanitation), 11 (sustainable cities and communities), 13 (climate action), and 15 (life on land), others, including SDG 4 (quality education) and 5 (gender equality), are poorly covered. However, it can be argued that the co-benefits generated from improved ecosystem-based management for SDG implementation are often overlooked and underreported and their potential underexploited [78].

The concepts differ in their scale of applicability (e.g., small and medium for NSWRM to medium and large for NbS), and particularly in their main challenges/key objectives, which are water management for NSWRM and NWRM, green space management and biodiversity enhancement for GI, land restoration for SLM, and climate resilience and natural hazards for EbA, whereas NbS—as the broadest concept—address a very wide range of environmental, social, and economic challenges.

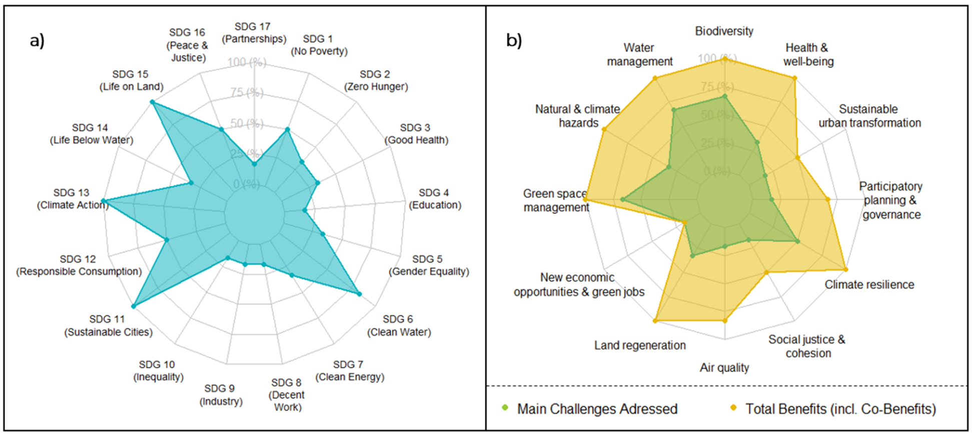

Figure 4. Share of ecosystem-based concepts that contribute to (**a**) each of the 17 sustainable development goals (SDGs) and (**b**) provide specific benefits and co-benefits. Six ecosystem-based concepts (NSWRM, NWRM, GI, SLM, EbA, NbS) were included in the analysis.

Seddon et al. [79] suggested that SLM and EbA should be listed under the "terms that are encompassed by NbS". While NbS indeed address a wide range of challenges, drivers, and goals, the other two concepts address more specific objectives [22]. In their analysis, Walz et al. [22] found many similarities between SLM, EbA, and NbS. They all use measures for the conservation, restoration, and sustainable use of land, and they employ SLM technologies. Moreover, the authors found that their implementation is based on multiple similar characteristics, such as "their people-centred nature, their transdisciplinarity, their focus on equity and inclusion and the integration of traditional and indigenous environmental knowledge and practices" [22]. The differences between the three approaches are mainly driven by their stated goals, and how these form a guide to establish their baselines for monitoring and evaluation. The implementation of SLM aims to sustainably manage watersheds or even landscapes with the participation of all stakeholders [80]. EbA addresses the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change [39]. NbS are viewed by IUCN [41] as actions that address societal challenges (e.g., climate change, or food and water security) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits.

According to Pauleit et al. [27], NbS, EbA, and GI are all concepts that strengthen the role of nature in policy making, from the global to the local level. They also focus on human interests and seek to identify the economic, social, and environmental benefits that people can obtain. NWRM and NSWRM also aim at strengthening the role of nature—or natural processes—in policy making and in water management practices. They are more focussed at the local level, with an attempt to link the measures to their direct benefits, allowing implementers to clearly choose the measures adapted to their local needs. In contrast to NbS or EbA, NWRM and NSWRM are more water-resource-oriented, and some may have negligible benefits for biodiversity. However, they must be implemented in a way that meets the expectations of the European legislation to which they are bound (e.g., the Water Framework Directive, Flood Directive, Biodiversity strategy), i.e., providing co-benefits to the environment beyond the mere retention of water.

All these ecosystem-based concepts define a specific framework and rely on a multidisciplinary and integrated approach, with the need to involve a wide range of stakeholders in the decision-making and implementation processes.

3.2. NSWRM in Relation to the Different Concepts

Having compared the concepts in relation to key characteristics, we now use the 14 case-study-specific NSWRM implemented under the OPTAIN project to examine the extent to which each measure would fit under the other conceptual frameworks (Table 4). In order to illustrate cases where the concepts do not overlap, we included five measures that cannot be classified as NSWRM but are specifically related to other ecosystem-based concepts.

Table 4. Classification of specific practices into the spectrum of six different ecosystem-based concepts. The specific NSWRM were selected from the 14 case studies of the EU Horizon 2020 project OPTAIN. In addition, five measures were included that cannot be classified as NSWRM but are specifically related to other ecosystem-based concepts. Key: measures in CAPITALS and grey shading; green = strong match; orange = partial match; red = mismatch. Based on [12,29,81–88].

NSWRM	NWRM Categories	GI	SLM Technology Group	EbA	NbS
GRASSING TARGETED INTO RECHARGE AREA	a01 meadows and pastures	Buffer zones	Improved ground/vegetation cover	- Ecosystem restoration - Ecosystem protection approaches	Restoring or creating ecosystems
RIPARIAN BUFFER ZONES	a02 buffer strips and hedges	Buffer zones	Area closure (stop use, support restoration)	Ecosystem-based management approaches	- Preserving ecosystems - Restoring or creating ecosystems
CROP ROTATIONS	a03 crop rotation	Multifunctional zones	Rotational systems (crop rotation, fallows, shifting cultivation)	Ecosystem-based management approaches	Improving the sustainable management of ecosystems
SLOPE SUBDIVISION THROUGH A FIELD SEAM	a04 strip cropping along contours	Multifunctional zones	Cross-slope measure	Ecosystem-based management approaches	Not NbS
REDUCED TILLAGE—NO TILLAGE IN AUTUMN	a06 no-till agriculture	Multifunctional zones	Minimal soil disturbance	Ecosystem-based management approaches	Improving the sustainable management of ecosystems
MULCH-TILL	a07 low-till agriculture	Multifunctional zones	- Improved ground/vegetation cover - Minimal soil disturbance - Integrated soil fertility management	Ecosystem-based management approaches	Not NbS
GREEN COVER IN VINEYARDS	a08 green cover	Buffer zones	Improved ground/vegetation cover	Ecosystem-based management approaches	- Preserving ecosystems - Restoring or creating ecosystems
FOREST RIPARIAN BUFFERS	f01 forest riparian buffers	Natural features	Natural and semi-natural forest management	Infrastructure-related approaches	- Preserving ecosystems - Restoring or creating ecosystems
CONVERTING CROPLAND TO GRAZING LAND	f05 land use conversion	Buffer zones	Pastoralism and grazing land management	- Ecosystem-based management approaches - Ecosystem protection approaches	Restoring or creating ecosystems

Table 4. *Cont.*

NSWRM	NWRM Categories	GI	SLM Technology Group	EbA	NbS
SEDIMENT CAPTURE PONDS	f09 sediment capture ponds	Buffer zones	- Water harvesting - Surface water management - Wetland protection/management	Not EbA	Restoring ecosystems
WETLAND INSTALLATION	n01 basins and ponds	Restored habitats	- Water harvesting - Surface water management - Wetland protection/management	Ecosystem restoration approaches	Restoring or creating ecosystems
WETLAND RESTORATION AND MANAGEMENT	f09 sediment capture ponds	Restored habitats	- Wetland protection/management - New wetland establishment	- Ecosystem restoration approaches - Infrastructure-related approaches	Restoring or creating ecosystems
GRASSED WATERWAYS	n05 stream bed re-naturalisation	Restored habitats	- Improved ground/vegetation cover - Water diversion and drainage	- Ecosystem-based management approaches - Ecosystem protection approaches	Restoring or creating ecosystems
WATER LEVEL ADJUSTMENT THRESHOLD	u10 detention basins	Buffer zones	- Natural and semi-natural forest management	Not EbA	Not NbS
Not NSWRM	**U01 GREEN ROOF**	Artificial feature: green roof	- Improved ground/vegetation cover - Home gardens	Infrastructure-related approaches	Restoring or creating ecosystems
Not NSWRM	Not NWRM	**ARTIFICIAL FEATURE: FISH LADDER**	Not SLM	Not EbA	Not NbS
Not NSWRM	Not NWRM	Not GI	**SUSTAINABLE NATIVE BEE KEEPING**	Not EbA	Improving the sustainable management of ecosystems

Table 4. *Cont.*

NSWRM	NWRM Categories	GI	SLM Technology Group	EbA	NbS
Not NSWRM	Not NWRM	Restored habitat	- Forest plantation management - Ecosystem-based disaster risk reduction	**MANGROVE REFORESTATION**	Restoring or creating ecosystems
Not NSWRM	Not NWRM	Not GI	Not SLM	The landscape approach may cover one or more ecosystems.	**LANDSCAPE MANAGEMENT FOR REDUCING GRAVITATIONAL RISK**

Based on the specific practices analysed in Table 4, there are both similarities and differences between NSWRM and the other concepts. Some concepts follow a classification depending on the type of measure (either technical or management: "green roofs" or "crop rotation", for example), whereas others rely on main objectives (e.g., protecting or restoring).

NWRM and NSWRM are very closely related, as both concepts aim at protecting and managing water resources. As NSWRM can be seen as a recent development of the NWRM concept, NSWRM can often be classified as a specific form of NWRM [58,89]. However, NSWRM related to drainage or nutrient recovery with limited or no retention effect cannot be associated with any existing NWRM. NSWRM may also be effectively monofunctional. Examples of such technologies include drought-resistant plants, controlled drainage, or subsoiling. Thus, NSWRM cannot be characterised as a simple subset of NWRM.

NSWRM and Green Infrastructure: Green Infrastructure measures use natural and human-made materials to enhance nature's ability to deliver multiple valuable ecosystem goods and services, such as clean air or water. The benefits emerging can range from improved biodiversity and quality of life to contributing to adaptation to climate change and extreme events [82,90]. NSWRM, on the other hand, are more water-focussed, with a common emphasis on nutrient retention. Green infrastructure can operate at different spatial scales, from the very localised to the scale of a city or a whole region. In this, they also differ from NSWRM, which focus on the small scale, usually at the farm level, but can be extended to the headwaters of a basin. With respect to the measures themselves, GI includes green roofs, permeable pavements, ponds, riparian buffers, and fish ladders. The latter do not qualify as an NSWRM. Conversely, NSWRM related to drainage or water and nutrient recovery, such as drought-resistant plants, cannot be designated as GI. GI also has to be more than simply a "green space", it needs to form part of an interconnected network. An individual tree may, for example, be an element of GI, but it will only be of value if it is part of a larger habitat or ecosystem that provides wider functions [24].

NSWRM and SLM: All NSWRM can be classified as SLM practices because they involve the sustainable management of land and natural resources in order to ensure their long-term potential and maintain their environmental functions. SLM is a broad concept that encompasses more than just water retention measures, and thus NSWRM remain a sub-set of SLM. For instance, sustainable native beekeeping is a key practice for pollinating various plant species and, in addition, honey harvesting also motivates people to conserve forests and trees. However, it obviously does not retain and store water and is therefore classified as an SLM practice, but not as an NSWRM.

NSWRM and EbA: EbA is a nature-based solution for adaptation to climate change. EbA is people-centric and focuses on reducing vulnerability and building resilience to the impacts of climate change through the use of biodiversity and ecosystem services [29]. EbA is a strategy that may (or may not) include one or several NSWRM, especially if they contribute to adapting to the impacts of climate change. However, NSWRM specifically designed for nutrient retention cannot be considered as an EbA.

NSWRM and NbS: These two concepts have some points in common. They both have the capacity to address several challenges simultaneously, while producing co-benefits [91]. An NSWRM project can only qualify as an NbS if it (i) combines several interrelated measures in the landscape (usually a catchment) area, (ii) is part of a long-term landscape management plan (project scale and quality of integration), and (iii) results in a net benefit for biodiversity. On the contrary, some NSWRM projects do not fall under the NbS concept, mainly because the benefit of the project for biodiversity is low or too indirect. This is the case, for example, for measures that affect infiltration while maintaining artificial soils (changes in soil cultivation practices, the development of forestry roads, permeable pavements), but also for measures related to drainage or small hydro-technical systems. Additionally, NSWRM cannot be classified as NbS if applied at a very small scale or in isolation in the catchment area, without being part of an integrated water resource management project. On the other hand, some NbS measures may not focus on water and its retention and may not include NSWRM.

Another difference between the two concepts also relates to the fact that NSWRM are classified into specific measures (e.g., forest riparian buffers), whereas the NbS classification corresponds to categories of actions (the protection, sustainable management, or restoration of ecosystems). The same difference applies to the comparison between NSWRM and EbA, with EbA being classified into different approaches. This can constitute a limitation to the comparison of the concepts as presented in Table 4.

3.3. NSWRM: How They Add Value to Other Ecosystem-Based Concepts

The preceding section helped to put NSWRM into context and to develop an understanding of the scope of NSWRM and why and how these measures can be used. It also showed that the other concepts tend to cover relatively large areas and a range of actors, requiring the mobilisation of multistakeholder communities, various funding sources, and strong coordination.

From this perspective, NSWRM as a distinct concept bring added value to the other concepts by focussing on easy-to-implement, modestly sized, localised technical solutions to problems associated with water management, sediment, and nutrient loss. The small-scale and localised nature of NSWRM usually allows for rapid implementation and rapid localised impact. It also allows them to be incorporated into existing modelling tools, enabling different scenarios to be developed and optimised prior to implementation. This then provides a sound basis for decision making at the farm and basin scale. When implemented over a significantly large area, they also contribute to tackling the urgent need for the restoration of the natural functioning of ecosystems and for the retention of water and nutrients in river basins for both the natural environment and human needs. However, it is not necessary to wait until a significant area is reached to achieve some local benefits, and their implementation can start small and grow progressively. NSWRM will contribute to better adaptation to the extreme events that exacerbate conflicts between water uses.

Despite a comprehensive set of techniques available to increase water retention at both the catchment and farm levels, knowledge is, as yet, lacking as to the conditions under which measures perform best and how they are best combined with each other. NSWRM planning and implementation will be supported by information that is being gathered to help optimise the spatial allocation and combination of measures, based on environmental and economic sustainability indicators: these data are being gathered and analysed and will be provided by the OPTAIN project. The results generated by the project's 14 case studies will be processed in a way that makes it possible to estimate the potential impact of using NSWRM elsewhere. This will increase the acceptance and implementation of NSWRM for improved water and nutrient management and resilient agricultural production.

In this article, we provided examples of how NSWRM are being used in practice. From field experience, we can already specify some elements that need to be considered to assist in NSWRM implementation. These are presented in Box 1.

Box 1. NSWRM implementation considerations in a nutshell.

Technical Guidance

- A list of technical references is available for the implementation of measures (a catalogue of 70 measures in the OPTAIN project), as well as 14 case studies [58].
- The OPTAIN project will also provide access via a dedicated tool called "Learning Environment" to references showing under which weather/climate conditions, at what scale (field/catchment), at which location in the catchment, and in what combinations NSWRM perform best, considering environmental but also socio-economic indicators.

Policy and Governance Compliance

As they deliver multiple benefits, NSWRM can contribute to the achievement of the following EU policy objectives [53]:

- Enhancing the status of aquatic ecosystems and improving water quality are in line with the objectives and requirements of the Water Framework Directive;
- Reducing flood risk coheres with the objectives of the Floods Directive;
- Enhancing biodiversity contributes to the objectives of the EU Biodiversity Strategy;
- Enhancing the adaptive capacity of systems contributes to climate change adaptation, as well as addressing water scarcity and drought (multiple policy objectives);
- Improving the quality of the environment in which people live (multiple policy objectives).

Multifunctionality and Visibility

The multifunctionality of NSWRM resonates with the Green Deal [92], which relies on policy coherence and integration. The objectives of NSWRM are also in line with those of the Common Agricultural Policy (CAP), in particular the efficient management of natural resources and the conservation of landscapes.

Because they are local and small-scale measures, NSWRM are generally visible (e.g., buffer zones). They provide an opportunity for co-construction with local stakeholders—often neighbours—involving them in their own territorial management and helping them to perceive, articulate, and address problems within their natural environment, as well as helping them to understand and appreciate the benefits, thus stimulating greater acceptance of the measures [93].

Financial Support

- As NSWRM contribute to different policy objectives, several funding instruments can be used, such as European (LIFE+, CAP, ERDF); national; or regional funds. Thanks to the multifunctionality of the measures, the funds can also be used as a contribution to several policy goals.
- Because they are implemented on a relatively small scale, they can also be financed by local instruments, coming from either the public or private sector.
- Payment for Ecosystem Services (PES) is a voluntary mechanism whereby suppliers of ecosystem goods and services are paid by the beneficiaries to manage the ecosystems in a way that maintains and/or enhances the provision of ecosystem services. PES is relevant for financing NSWRM, as these measures are applied at the local level, and their impacts and related benefits also concern the downstream areas [94].

4. Conclusions and Outlook

This paper, for the first time, explored and presented the concept and practices of Natural/Small Water Retention Measures and compared them to five other overarching ecosystem-based concepts. In contrast to grey infrastructure—engineering measures that are usually implemented to address a single, discrete, and locally bounded problem or to provide a single or few benefit(s)—these ecosystem concepts cover a much broader spectrum. It could be said that they all have their "roots in nature and branches in ecosystem services". Furthermore, with their common emphasis on achieving sustainable development, these six ecosystem-based concepts share another broad commonality. However, despite their overlaps, they are different in several ways. There is also the important point that each concept is commonly bound to specific policies and often associated with, and promoted by, different agencies.

Against this background, we attempted to provide context for and similarities and distinctions between NSWRM, NWRM, GI, SLM, EbA, and NbS with respect to various dimensions such as geographical and temporal scope, challenges, co-benefits, and ecosystems addressed. It became clear that their overlaps and distinct character make it possible for specific scientific communities with their own focuses to structure their thinking and mobilise dedicated knowledge and resources to choose a particular ecosystem concept and its associated measures to address their core target issues. Where different concepts are mixed and matched in a given ecosystem, this can be a means of achieving complementarity.

This provides an opportunity to address, in the same location, the interests of different stakeholder communities regarding the restoration and utilisation of ecosystem services in conjunction with a rehabilitated ecosystem.

It is important to understand that while "working with nature" offers multiple benefits to people, it is also complex. In essence, these concepts all rely on an integrated approach and multidisciplinary management, with the need to involve many stakeholders in the decision-making and implementation processes. This article focused on NSWRM and the OPTAIN project and is one possible way to represent and organise knowledge for one defined overall purpose. Other metrics or mechanisms may be needed to tailor the use of the NSWRM concept for a different community, or to link NSWRM to other ecosystem-based concepts.

A vast number of projects and programmes are being implemented worldwide under the banner of one ecosystem concept or another. It is essential to simultaneously analyse their results and benefits so that the knowledge gained can help to identify ways and means of extending the scope of benefits and finding gaps. Though the positive image of "green solutions" is still convincing and funders are keen to pay for "no-regret" solutions, this support may not be sustainable in the long term. There needs to be a better understanding of how the various concepts can work best and give value for money—and in what ways they can deliver synergies. Scientists have an important role to play in supporting the analyses of implemented projects and solutions, identifying beneficiaries and benefits, and developing the adaptation of existing concepts and the harmonisation of concept application.

In the midst of this broader, complex discussion, this paper demonstrated how NSWRM fit into the framework of the longer-established ecosystem-based concepts. We contend that NSWRM, as a distinct concept, bring added value to the other concepts by concentrating on easy-to-implement, modestly sized, localised technical solutions to problems associated with water management, sediment, and nutrient loss. This particular focus—previously undervalued and underplayed—is becoming increasingly important with the exigencies of climate change and ecosystem degradation.

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Conflicts of Interest: All authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A

Table A1. Overview of the OPTAIN case studies and their challenges.

						Problems			
N°	Country	Name	Size (km^2)	Bioregion	Agric. Area (%)	Phosphorus Losses	Nitrogen Losses	Floods	Droughts
1	Germany	Schwarzer Schöps	136	Continental	72	X		X	
2	Switzerland	Petite Glâne	101	Continental	79	X			X
3	Hungary	Csorsza	21	Pannonian	59	X		X	
4	Poland	Upper Zglowiaczka	78	Continental	>90	X	X	X	X
5	Austria/ Slovenia	Pesnica	137	Continental	65			X	X
6	Slovenia/ Hungary	Kobiljski/ Kebele	247	Continental/ Pannonian	55	X	X	X	X
7	Belgium	La Wimbe	112	Continental	32			X	X
8	Lithuania	Dotnuvele	176	Boreal	61	X	X		
9	Italy	Cherio	153	Continental	45		X	X	X
10	Norway	Hobøl	56	Boreal	41	X	X	X	
11	Hungary	Tetves	117	Pannonian	36	X		X	
12	Czech Rep.	Čechtický	72	Continental	65	X	X	X	
13	Latvia	Dviete	254	Boreal	47	X	X	X	
14	Sweden	Sävjaån	125	Boreal	60	X		X	X

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