EIP-AGRI Focus Group
Nature-based Solutions for water management under climate change

FINAL REPORT – October 2022

funded by European Commission

Executive summary

The EIP-AGRI Focus Group (FG) was tasked with answering the question: How could Nature-based Solutions (NbS) have an impact on water management and water availability at farm level and contribute to sustainable farming under climate change? To begin with, two actions were carried out in parallel: 1) compiling case studies implementing NbS based on direct contacts of the FG members and 2) reviewing definitions of NbS formulated in other contexts. The parallel actions converged in a collection of NbS specific for agricultural water management (**see examples booklet**).

The NbS identified were grouped into:

a) practices aiming to increase water storage in the soil root zone

b) interventions to protect watercourses and boundaries (vegetative buffers and barriers)

c) green infrastructures to retain, regulate and store water in the farm or agricultural watershed.

The agreed FG definition of NbS for agricultural water management was as follows: Solutions that, inspired and supported by nature, improve the availability of water, the quality of water, the efficiency of its use and/or the protection of the farm against flooding or excess water. These solutions must i) be cost-effective, simultaneously provide environmental, social and economic benefits, help build resilience and contribute to good water governance; ii) bring more diverse natural features and processes into farms and landscapes, through locally adapted, resource-efficient and systemic interventions and iii) benefit biodiversity and support the delivery of a range of ecosystem services.

In the lack of appropriate criteria adapted to agricultural water management, the qualification of the inventoried NbS as such was based on the fulfilment of the general features contained in the above definition. In addition, the socio-economic benefits and ecosystem services of each of the proposed NbS were identified. The former included higher yield, reduced cropping costs, better product price, more water availability, flood protection, reduced health risks and better landscapes. The latter included reduction of water pollution, increase of biodiversity, reduction of soil erosion and carbon sequestration enhancement.

Quantifying both benefits and services of NbS at different scales (temporal, geographical, environmental, social) is difficult, and so the FG proposed possible research projects to find solutions to this. Operational Group (OG) topics were also proposed in response to the inexperience on the application of NbS for agricultural water management, to facilitate their implementation and dissemination. The OG topics were related to the adoption of good water management practices using a variety of NbS (e.g., soil water conservation and green filters), to the design and management of green infrastructures (e.g., surface water storage and ground water recharge), actions beyond field implementation (such as market recognition, mechanisms of reward, assessment of social benefits), and ecosystem services.

The research needs identified, as might be expected, have some overlap with the OG topics, although with a focus on processes (e.g. water fluxes and water balance), conceptual frameworks and assessment models, and the design of new governance models. Other recommendations, aimed at disseminating and facilitating the adoption of NbS, include decision support systems, design and management manuals for specific NbS for agricultural water management, catalogues of successful NbS, and perception surveys and social awareness of NbS for agricultural water management.

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Content

1. Introduction

The agricultural sector faces increasing water challenges. Agriculture is the main user of fresh water and a major source of water pollution in Europe and around the world. The increase in temperature and rainfall variability (Intergovernmental Panel on Climate Change, IPCC, 2022) aggravates water challenges. At the same time, a growing global population is increasing demand for food. Therefore, the solution cannot be simply to reduce production, but farmers are forced to rethink how to produce their crops. Water and agricultural policies have a role to play by supporting farmers' resilience in areas which face increasing water challenges. Moreover, innovation partnerships are expected to foster competitive, sustainable farming by developing innovative solutions to address major challenges, including agricultural water scarcity and quality degradation.

The EIP-AGRI Focus Group "Water & agriculture: adaptive strategies at farm level" (2016) compiled and systematised on-farm management strategies to counteract the negative impacts of water scarcity under climate change. Conventional water management practices in agriculture and the most recent innovations are undoubtedly contributing to the improvement of productivity and adaptation to stress conditions. However, they do not always lead to the conservation and restoration of agricultural ecosystems and their natural environment and thus to long term solutions. Nature-based Solutions (NbS) may provide opportunities to reinforce the nexus 'agriculture–ecosystem–water' enhancing sustainable food production and profiting from well-functioning ecosystems (Fig. 1).

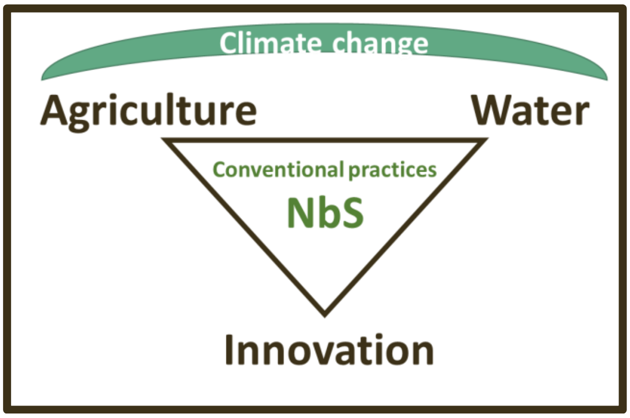

Fig. 1. Nature-based and conventional agricultural water management solutions in the nexus 'agriculture-water-innovation' under climate change

This report presents the outcomes of the EIP-AGRI Focus Group "Nature-based Solutions for water management under climate change". The Focus Group (FG) aimed to promote a better understanding of the practical application of NbS at farm level and to facilitate knowledge and innovation exchange between farmers, farm advisors, researchers, and other relevant actors at local, regional and national levels. It evaluated the primary benefits of implementing NbS in terms of improving water availability, considering both its quantity and quality, at the required time and place, as well as their complementary ecosystem services. The identification of existing NbS in different farming systems under different climate zones contributed to understanding and quantifying the socio-economic and environmental benefits of these solutions. The scales of interest were farm and small agricultural catchments in the European Union. The solutions covered drainage, water supply and water demand strategies, in both rainfed and irrigated agroecosystems.

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2. Brief description of the process

The FG included farmers, consultants, environmentalists and researchers from 12 EU countries (Annex A). **The main question to address was: How could NbS have an impact on water management and water availability at farm level and contribute to sustainable farming under climate change?** The specific tasks of the FG were:

- Collect and highlight good practices and inspiring success stories, approaches and methodologies for applying NbS at farm level in different farming systems and small agricultural catchments.
- Analyse and, if possible, value the benefits or potential drawbacks of NbS, including water availability in terms of quantity and quality, both at farm and small agricultural catchment levels.
- Identify challenges and opportunities for applying NbS in different European agroecosystems.
- Identify capacity building experiences and socio-economic needs for implementation of proposed NbS.
- Suggest innovative models to foster links between farmers, small watershed managers, advisors and applied research when identifying and applying NbS.
- Identify knowledge gaps and research needs for the implementation of NbS for agricultural water management.
- Suggest innovative solutions and provide ideas for EIP-AGRI Operational Groups and other innovative projects.

The FG members individually proposed NbS (Fig. 2). Each proposal included a description of the solutions, its origin, the region and the agroecosystem where it is applied, the benefits it brings to the farmers, its social and environmental benefits, the extent of its application, the actors involved and its limitations and success factors. The result was an inventory of NbS ([Booklet], which also includes posters describing some of the examples selected by FG members) that nourished and inspired the discussions within the Focus Group and the recommendations that emerged from it.

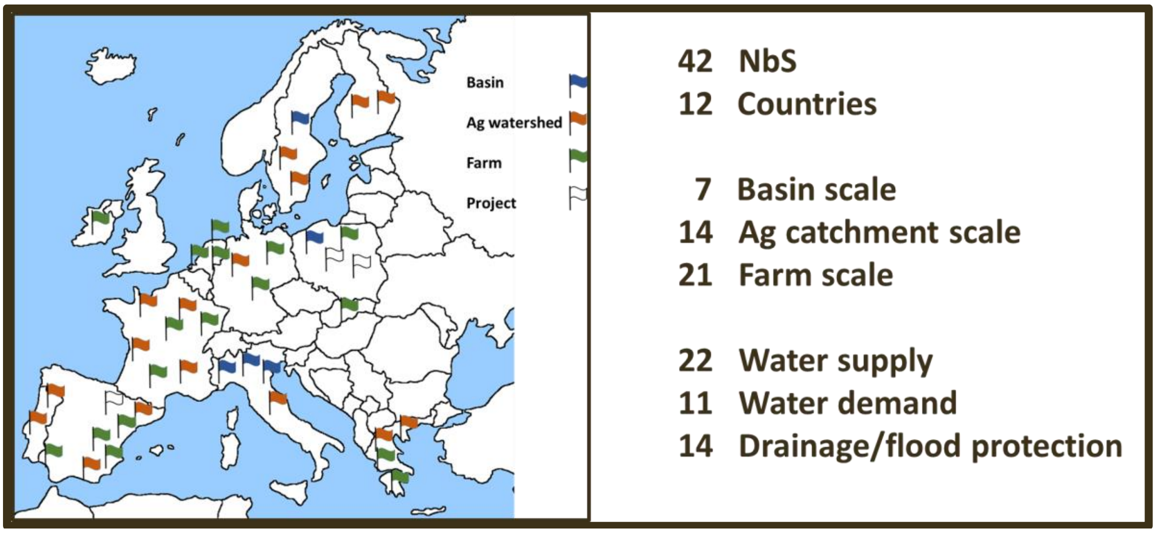

Fig. 2. Localisation of the Nature-based Solutions for agricultural water management proposed by the Focus Group members distinguishing their scale with different colours and indicating (on the right) the number of solutions according to their purpose

The second element that fed and catalysed the debate in the FG was the **discussion paper** drafted by the coordinator. This paper reviewed NbS definitions and qualification criteria proposed by other organisations. It also compiled and grouped the NbS proposed by the members of the FG to facilitate the debate during the first meeting.

During the first meeting, each FG member presented their NbS study examples. Some were challenged to evaluate their examples according to criteria proposed by International Union for Conservation of Nature (2020). The discussion revealed that, despite the shared definitions of NbS, the concept remains blurred, leaving room for subjectivity. FG members did not always accept the nature-based character of the solutions proposed by other members. The exercise of applying standard criteria to determine the NbS character of the proposed solutions demonstrated the inadequacy of these criteria when the NbS addresses agricultural water management specifically instead of societal challenges. Some members even questioned the scope and the scale of the FG, arguing that the focus itself (agricultural water management) and the scale (farm and small agricultural catchment) are constraints that prevent NbS being able to tackle societal challenges. Despite these concerns and being aware of the limitations, the FG tacitly decided to go ahead, concentrating its work on the initial focus and scale.

Expanding on this debate, the FG brainstormed, in breakout sessions followed by plenary sessions, on the challenges for implementing NbS for agricultural water management and the economic benefits and ecosystem services provided by these NbS. Furthermore, the FG experts proposed topics for mini-papers, some transversal and others delving into specific types of NbS. These mini-papers were drafted collaboratively in sub-groups of the FG experts.

The mini-paper topics (MP) were:

- MP1. **NbS at field scale**
- MP2. **NbS as green infrastructures for agricultural water retention, treatment, and availability**
- MP3. Identification/Selection/Classification of NbS for water management under climate change
- MP4. **Agricultural NbS as biodiversity hotspots for river ecosystems**
- MP5. **Assessing the socioeconomic and environmental benefits of NbS: Challenges and future perspectives**
- MP6. Paving the way for the adoption of NbS in rural landscapes: Bridging the gap between science and practice

Drafts of all the 6 MPs fed into the FG discussions and this final report, although only MPs 1, 2, 4 and 5 were published.

During the second FG meeting, there was time for the subgroups to work on their mini-papers. The FG then held breakout sessions (followed by plenary sessions) to discuss research challenges, opportunities and needs. The starting point for this discussion was a systematised synthesis of the results of the first meeting. Finally, the FG identified project ideas for potential Operational Groups. The results of these discussions are summarised in section 5.

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3. State of play

Framing key issues

NbS, more than a concept, is the qualification of certain solutions that work with nature to meet their primary objective and provide additional ecosystem services. The definition of NbS varies depending on who makes it:

NbS are defined by the **International Union for Conservation of Nature** (IUCN) as "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016). Note the breadth of this definition, which includes protection, management, and restoration of both natural and modified ecosystems. Note that it does not mention costs or economic benefits.

In contrast, the definition in a report published by the **European Commission** emphasises the productive context, highlighting the cost-effective character: "Nature-based solutions to societal challenges are 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 benefit biodiversity and support the delivery of a range of ecosystem services" (Bulkeley, 2020).

The above definitions refer to solutions that address societal challenges. However, the primary objective of agriculture is the production of crops. As an economic activity, this production must be profitable, hence the importance of optimising the use of resources and minimising its cost. When referring to water as a resource, management implies maximising water availability and using it efficiently. The **Food and Agriculture Organization of the United Nations (FAO)** describes NbS for agricultural water management in the following terms: "NbS can mimic natural processes and build on fully operational water-land management concepts that aim to simultaneously improve water availability and quality and raise agricultural productivity. As such, NbS comprise closely related concepts such as improved water use efficiency, integrated watershed management, source-to-sea initiatives, ecosystem approaches, eco-hydrology, agroecology and green and blue infrastructure development" (Sonneveld et al, 2015). A differentiating nuance here is the idea of building on existing operational management concepts. Cost effectiveness is implicit in this nuance, since the FAO's report also states that the evaluation of NbS should ideally include economic benefit.

One key feature of a NbS is its **alignment with natural ecosystems**. This is different to solutions that use nature (e.g., solar water pumping) or solutions inspired by nature (e.g., pipe network optimisation using genetic algorithms). It implies **enhancement of ecosystem functions, resilience, health, and conservation**. However, this does not exclude some degree of alteration of the ecosystems where it is applied. The point is that exploiting the ecosystem for productive purposes produces parallel benefits, which can include internal benefits (benefits to the farm itself) but must necessarily include **societal and environmental externalities** (e.g., biodiversity, climate change mitigation, water conservation). Therefore, **multi-functionality** is a second key feature of NbS. A third feature of NbS that is often emphasised is that they must be **locally appropriate** (i.e., context-based, as what may be appropriate in one location may not be suited to another). In agricultural water management, this is a requirement for any solution, whether it is based on nature or not. However, it is pertinent to highlight this characteristic here because some of the NbS applied to water management are traditional practices (even ancestral) or adaptations of them. Another feature of NbS is that they bring **social benefits**. When they are applied to production systems, the emphasis on social benefits can be lowered, while cost-effectiveness and economic viability become a condition.

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In the specific case of water, as a production factor and shared natural resource, NbS must be **aligned with governance and collective stewardship**. NbS for agricultural water should emphasise communal and integrated resources management. In fact, governance is considered in the NbS definitions proposed by both the University of Oxford ("full engagement and consent of local communities"; Nature-based Solutions Initiative, 2021) and IUCN ("inclusive, transparent and empowering governance processes"; IUCN, 2020).

Based on the above premises, NbS for agricultural water management are those solutions that, inspired and supported by nature, improve the availability of water and its quality, the efficiency of its use and/or the protection of the farm against flooding or excess water. They:

i. must be cost-effective, simultaneously provide environmental, social and economic benefits, help build resilience and contribute to and be involved in good water governance;
ii. should bring more diverse natural features and processes into farms and landscapes, through locally adapted, resource-efficient and systemic interventions; and
iii. must benefit biodiversity and support the delivery of a range of ecosystem services.

The strength and originality of the NbS concept lies in its "umbrella" characteristic. However, this can be a weakness when determining whether a solution qualifies as nature-based or not. To address this concern and to reflect the intensity of engineering intervention of the NbS in the ecosystem, Eggermont et al. (2015) proposed (and FAO, reproduced; Sonneveld et al, 2015) three NbS typologies. The three typologies are:

- "**Typology 1**. None or minimal intervention in ecosystems. This type maintains/improves delivery of ecosystem services of preserved ecosystems. This NbS incorporates areas where people live and work in a sustainable way including nature conservation and national parks.
- **Typology 2**. Partial interventions in ecosystems. This type develops sustainable and multi-functional ecosystems and landscapes that improve delivery of selected ecosystem services. This type of NbS is strongly connected to benefitting from natural systems agriculture and conserving agroecology.
- **Typology 3**. Intrusive intervention in ecosystems. This type manages ecosystems in intrusive ways and includes full restoration of degraded or polluted areas using grey infrastructures."

NbS for agricultural water management

NbS for agricultural water management identified in the FG may be roughly classified into three groups:

1) solutions aiming to increase the water storage in the soil root zone (MP1),

2) solutions to protect watercourses and field boundaries (MP2 and MP4),

3) water sowing and harvesting, including water treatment (MP2).

1) Regarding the first group (**solutions aiming to increase the water storage in the soil root zone**), soil water storage can be increased by favouring infiltration in cropped soils or exploiting deep soil layers. Conservation agriculture (the combination of minimum soil disturbance, maintaining soil organic cover, and diversification of plant species) (Fig. 3a) reduces soil evaporation and improves soil porosity and infiltrability; thus, it reduces runoff (Basch et al., 2012). In-furrow micro-dams retain rainfall or irrigation water in row crops, thus increasing infiltration and reducing runoff (Olivier et al., 2014) (Fig. 3b). Keyline pattern cultivation (Yeomans, 1958) (Fig. 3c) allows redirecting the shallow overland flow (resulting from rainfall runoff) from its natural path (downslope to the valley floor) to contour lines toward the ridges, so water is spread over the slopes, improving infiltration and its uniform distribution across the field. Deep-rooted crops explore layers of soil that other crops cannot reach, so their root-zone water storage capacity is greater and therefore more rain or irrigation water can be retained in the soil available for the crop. The result of these three practices is represented in Fig. 4 as the transition from 4a to 4b. Terracing (represented as the transition from Fig. 4c to Fig. 4d) transforms steep slopes

into an artificial sequence of relatively flat surfaces (Fig. 5a), thereby decreasing slope length and gradient, which significantly reduces runoff and favours infiltration. Therefore, conservation agriculture, in-furrow micro-dams, deep-rooted crops, keyline pattern cultivation and terracing are farming practices that increase the amount of water available for the crop. In addition, the reduction of runoff implies reduction of soil erosion and surface water contamination with sediments, organic matter, nutrients and pesticides. This environmental benefit could already qualify these solutions as nature-based. If, compared to their conventional equivalents, they contribute to shaping cultural landscapes, creating biodiversity, enhancing carbon storage, reducing greenhouse gas emissions, as in fact different studies show, their nature-based qualification is reinforced. On the other hand, the reasons against this qualification are the risk of surface- and ground-water contamination with agrochemicals (particularly with herbicides if their use is necessary), the intensive use of labour or heavy machinery for a radical transformation of the landscape, and the vulnerability of some of these transformations.

*Fig. 3. a) Maize crop under conservation agriculture in southern Spain (photo by L. Mateos); see example cases in Posters 14 and 19, **Booklet**. b) Potato crop with in-furrow mini-dams in The Netherlands (photo by T. Gielen); see example case in Example 22, **Booklet** c) Keylines pattern cultivation in Southern Spain (photo by M. Almagro); see example case in Poster 20, **Booklet**.*

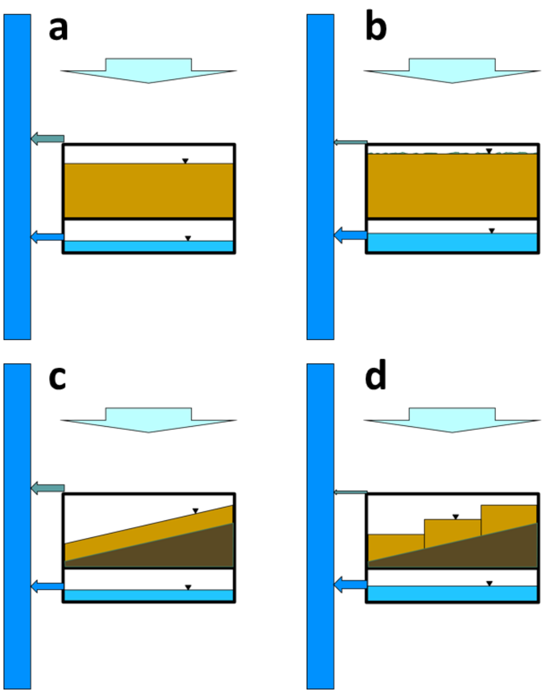

Fig. 4. a ▪ b: Illustration of the transition to an increase of soil water storage (by increasing soil infiltration and/or water holding capacity or cultivating deep-rooted crops). c ▪ d: illustration of the transformation of steep slope into terraced land. The vertical dark blue bars represent surface water and the horizontal light blue bars, groundwater.

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2) The second group of NbS for on-farm water management aims to **protect watercourses and boundaries using vegetative buffers and barriers** (Lerch et al. 2017). Buffers can be further identified as "edge-of-field" and "in-field" buffers. Edge-of-field buffers include vegetative filter strips, hedges, riparian forest, and riparian herbaceous cover (Fig. 6a). In-field buffers include conservation cover, contour strips, alley cropping, and grassed waterways (Fig. 5b). Moreover, streams with highly variable flow can be shaped into two-stage channels. Artificial surface drainage can be reverted into its natural shape recreating meandering, S-shape water courses (Fig. 5c). These structures require soft or relatively soft interventions that result in multiple ecosystem services: reducing the sediment and contaminants loadings in runoff; enhancing biodiversity and the habitat for beneficial predators; reducing sheet, rill, and gully erosion; conveying runoff from terraces, diversions, or other water concentrations preventing erosion or flooding.

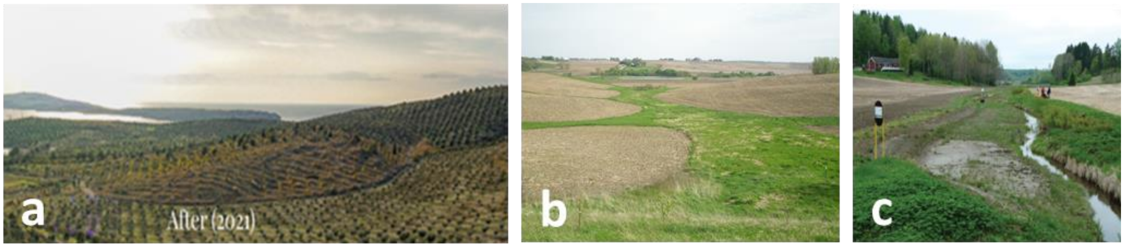

*Fig. 5. a) Terraces planted with olive trees in Greece (photo by E. Pana); see example case in Poster 3, **Booklet**. b) grassed water way in a cultivated field (photo by L. Mateos); see example case in Poster 15, **Booklet**. c) Two-stage channel in Finland (photo provided by A. Kulmala); see example case in Poster 5, **Booklet***

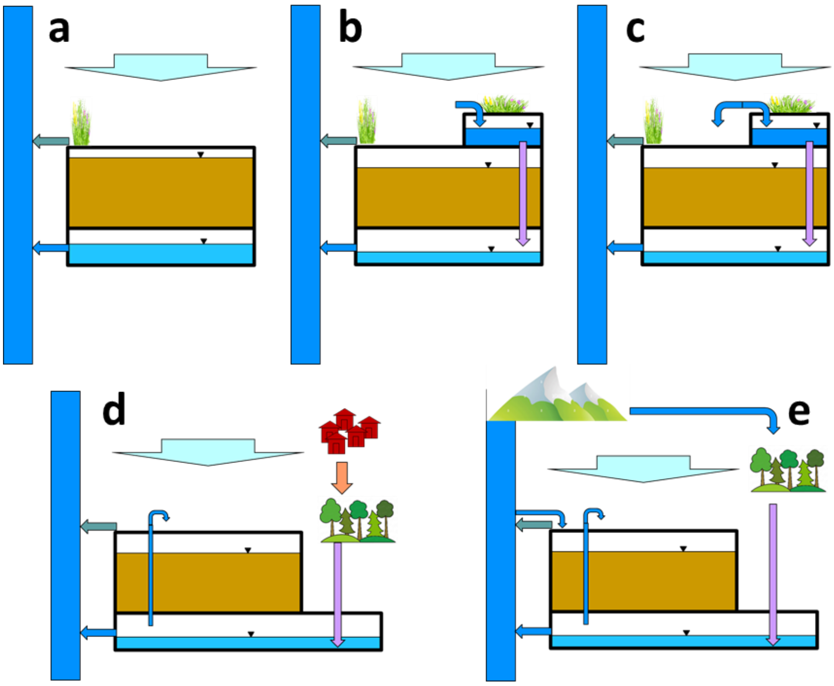

Fig. 6. Illustration of edge-of-field buffer (a) plus artificial wetland or drainage pond (b) or multipurpose reservoir (c). Illustration of artificial groundwater recharge using urban waste water (d) or by means of recharge ditches (e). The vertical dark blue bars represent surface water and the horizontal light blue bars, groundwater.

3) The third group of NbS for agricultural water management includes **green infrastructures to retain, regulate, store and treat water in the farm or agricultural watershed**, for productive or protective purposes, in most cases responding to the water sowing and harvesting notion. The storage can be underground or on the surface. Constructed wetlands (Takavakoglou et al., 2022) (Fig. 6b, Fig. 7b) are artificial systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality in the farm. Drainage collection ponds and constructed wetlands (Fig. 7a) provide both irrigation runoff and stormwater attenuation and treatment (Lavrnić et al., 2020). Emergent and submerged aquatic vegetation grows along their shoreline. Multipurpose reservoirs (Fig. 6c) collect on-farm rainfall or irrigation runoff water, as drainage collection ponds do. This water may be reused for other purposes, namely irrigation. At larger watershed scale, the water may come from outside the farm, from the upper watershed or from urban areas. Urban wastewater can be treated using NbS and reused for irrigation (Fig. 6d). In some mountain areas, snowmelt runoff is diverted during spring from high-altitude streams into contoured recharge ditches that convey the water to areas of high infiltration (shallow aquifers) (Martos-Rosillo et al., 2019) (Fig. 6e, Fig. 7c). This regulates and delays discharge into the main river from which downstream flow is diverted during late spring and summer to irrigation ditches that supply terraces and fields on river plains. In rivers that both suddenly overflow or suffer severe droughts, the reconnection of the floodplain with the river, which also allows river nutrients to enrich the soil during high waters, or the construction of hotspots (in- and off-line interconnected refugia waterholes) facilitates recolonising and restoring biodiversity after long-lasting drought spells or floods. These infrastructures are above the domain of the farm or small agricultural watershed, however, even if promoted by the public water authority, they should involve water user associations where farmers are main actors.

Fig. 7. a) *Constructed wetland in Italy (photo by A. Toscano); see example case in Poster 21, **Booklet**. b) constructed wetland in Sweden (photo by L. Mateos); see example case in poster 17, **Booklet**. c) recharge ditch and infiltration area in Spain (photo by S. Martos-Rosillo); see example case in Poster 4, **Booklet**.*

Drainage collection ponds, constructed wetlands, multipurpose reservoirs, urban wastewater treatment and reuse, recharge and irrigation ditches and hotspots may be designed following the principles of NbS, working with nature, using green infrastructure, and generating ecosystem services. The water retention time promotes agrochemicals degradation and removal through sedimentation and uptake of nutrients. Retained surface water and infiltration areas mimic natural habitats and support biodiversity. Artificial wetlands and ponds and recharged aquifers gradually release water to eventually feed natural water bodies. These green infrastructures can be supra-farm. In that case, their management corresponds to a community of farmers that must equip themselves with governance instruments that also comply with national legislation and EU directives.

Green infrastructures such as vegetative buffers and barriers, terracing, constructed wetlands and reservoirs require costly investment and may occupy land that otherwise would be used for growing crops. These are the main reasons that hinder the adoption of these infrastructures as part of NbS. Therefore, they require additional measures related to financing, land tenure, communal property, right of way, etc. Moreover, such infrastructures add complexity to already complex agroecosystems. This implies that interventions must be supported by knowledge-intensive site-specific designs.

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All these **NbS must be implemented in an integrated manner**. For example, a constructed wetland should not be fed with runoff from fields with soil tillage that causes erosion or where agrochemicals are improperly applied. Moreover, NbS addressing agricultural practices other than water management (e.g., integrated pest management and biological control) must be part of the holistic approach.

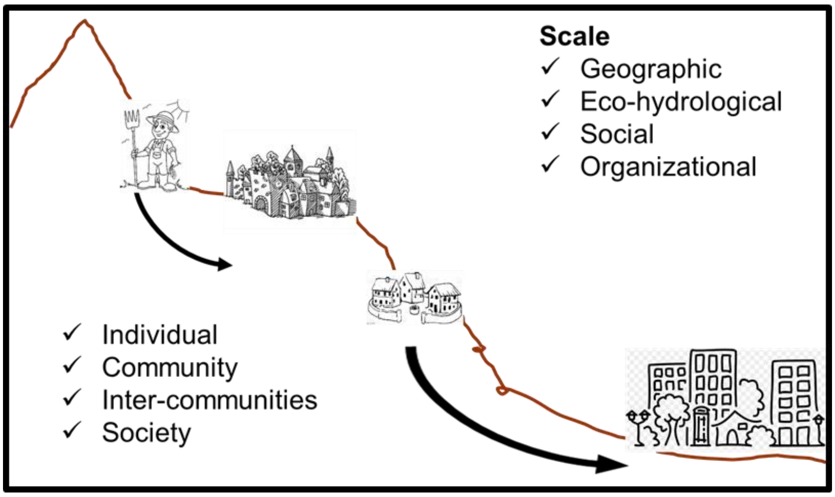

Fig. 8. Infographic of scale types and links when applying Nature-based Solutions for agricultural water management

These last considerations lead to the **scaling** inherent to the NbS concept. This scaling is not only geographical, but also eco-hydrological, social and organisational. A single farmer can implement NbS which may have an impact in all of these dimensions (Fig. 8). But we have seen that some of the proposed NbS must necessarily be a community initiative, particularly those involving irrigation schemes and supra-farm watersheds. Other NbS may require water user associations at two levels (for example, the irrigation and recharge ditches described in Sierra Nevada, Spain). Other NbS that benefit different stakeholders may require the creation of multi-stakeholder/multisectoral consortia to jointly design and manage NbS interventions. All of them must participate and respect the regulations of the basin authorities as well as the regional, national and EU directives.

Assessing economic and social benefits and ecosystem services

In a survey conducted among the FG members to inventory NbS for agricultural water management, three types of benefits were registered: economic, environmental and social. A non-exhaustive summary of the reported benefits can be found below:

1. Economic benefits:
   - Less damage to the crops and less maintenance cost (NbS concerning drainage and flood protection)
   - Higher yield (NbS increasing water availability to the crops)
   - Reduced cultivation costs
   - Better prices for the products and alternative business models

2. Environmental benefits:
   - Reduction of water pollution by nutrients and agrochemicals
   - Increase of biodiversity
   - Groundwater and wetlands conservation
   - Reduction of soil erosion and siltation of watercourses and wetlands
   - Carbon sequestration

- Improvement of soil health and fertility
- Creation and improvement of wild animal niches

3. Social benefits:
- Flood protection
- Recreation and tourism
- Educational activities
- Regeneration of rural communities and creation of green jobs
- Less health risks
- Diverse landscapes
- Increase of water availability and quality

The assessment of socioeconomic and environmental benefits of NbS may follow qualitative valuations, for instance applying standard criteria as the ones proposed by IUCN (2020) (Table 1 below). These criteria refer, for instance, to the contribution of NbS to "human well-being". Reports published by the European Commission (Bulkeley, 2020) highlight **cost effectiveness** as a required feature of NbS. Cost-effectiveness analysis relates the costs of a project to its key outcomes or benefits.

Table 1. Global standards for Nature-based Solutions to address societal challenges according to IUCN (2020)

Criterion 1 refers to the societal challenge(s) addressed by the NbS: climate change, disaster risk reduction, ecosystem degradation and biodiversity loss, food security, human health, social and economic development, and water security.
Criterion 2 refers to the scale of the issue, geographic scale but also economic, ecological and societal scales. While an NbS is applied to a specific site, its applicability, replicability and responsiveness should consider the broader systems where it is applied, or which are affected by its application.
Criteria 3, 4 and 5 refer to the three pillars of sustainable development: environmental sustainability, economic viability and social equity, respectively.
Criterion 6 concerns trade-offs and short and long-term gains, and transparency, equity and inclusiveness of the trade-offs assessment.
Criterion 7 addresses the adaptability of the NbS to systemic changes.
Criterion 8 refers to the long-term implementation and upscaling, including policy or regulatory frameworks. Given the dynamic nature of the systems where the NbS is applied, it is essential to continuously assess its implementation against reference baselines.

Key challenges in the assessment of the benefits of NbS are explored in MP5. The FG noticed a lack of frameworks for assessing the benefits and co-benefits of NbS for agricultural water management. Several of the few existing frameworks focus mainly on NbS for urban areas and are related to the climate change challenge (e.g., Raymond et al., 2017). These frameworks include performance questions and qualitative indicators (IUCN, 2020) and some also include cost-effectiveness analyses (Sowinska-SwierKosz and García, 2021). The assessments are oriented to multicriteria decision-making (MP5). A source of inspiration to fill the lack of assessment frameworks for NbS with specific goals, such as agricultural water management, are sustainability assessment frameworks (MP5). A review of such frameworks is in Alaoui et al. (2022), including at least 6 frameworks for the assessment of water use in agricultural areas (MP5).

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Dealing with NbS for agricultural water management, the FAO takes the assessment one step further attempting to compare costs with the monetary value of all (or most) of the many benefits of a NbS (Sonneveld et al, 2015). Recognising the difficulty of valuing ecosystem services based on **cost-benefit analysis**, Sonneveld et al. (2015) proposed indirect techniques to value NbS for agricultural water management: market-imputed, surrogate market or non-market-based.

NbS interventions for agricultural water management partly rely on **market-based approaches**. Production function analysis and defensive expenditures are examples of such approaches. Production functions quantify the marginal contribution of the ecosystem service to a marketed commodity (e.g., yields can be related to the economic value of water). In the defensive expenditures approach, expenditures equal the cost of conserving the productivity of ecosystems. However, many ecosystem services cannot directly be related to market prices. Then, Sonneveld et al. (2015) proposes surrogate market or non-market-based valuation approaches. Pricing methods for surrogate markets include "hedonic pricing" and "travel cost". For instance, the former values a recreational site by the economic costs of the travel to visit the site. Non-market-based techniques obtain information from interviewees inquiring about both their willingness to pay for the conservation or restauration of an ecosystem service.

Table 2. Main challenges, opportunities and relevance of the opportunities (votes) identified by the Focus Group during its first meeting

Main challenges	Opportunities	Votes
Confusing concept of NbS	Define, map and classify NbS for agricultural water management	2
	Establish clear criteria for NbS qualification	5
	Inventory of NbS for agricultural water management	1
Not enough good examples of NbS for agricultural water management	"Showroom" with illustrative NbS for agricultural water management	6
Lack of environmental awareness	Building awareness	2
Break innovation barriers	Support science-based co-innovation processes	5
	Target youth and pioneers	
	Target early adopters in the diffusion of innovation process	1
	AKIS, OG	
Scaling up	Rural Development Programmes & Common Agricultural Policy	3
Cost/benefit	Cost sharing	1
	Financing schemes	3
	Farm to Fork Strategy	1
	Agricultural product eco-labelling	4
	Environmental value transfer	5

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Opportunity cost of unproductive land use	Mechanisms of rewards for ecosystem services	12
Benefits are long term (aggravated when land is leased)	Connect climate financing to NbS	1
Unclear land and water rights	Creating enabling environment. Building trust and developing appropriate legal frameworks	4
Insufficient knowledge	Support science-based participatory action research for innovating through NbS	5
	Eco-hydrology research	2
	Agroecosystem research	3
	NbS engineering handbook	9

Challenges and opportunities of NbS for agricultural water management

The Focus Group discussion on challenges and opportunities of NbS for agricultural water management that took place during the first meeting was synthesised and then scored (by voting) by the FG members during the second meeting. The results are in Table 2.

Several types of challenges are presented in Table 2. First, the FG's perception is that **the NbS concept is emerging and therefore immature**, at least as far as water management in agriculture is concerned. The ambiguity of the concept, the insufficiency of examples, the insufficiency of knowledge to put them into practice are challenges identified by the FG that respond to this perception. The second type of challenge is related to the implementation of NbS for water management in agriculture. Here is highlighted the **cost-benefit** relationship, the lack of **environmental awareness** (of farmers and consumers), the sharing of costs, the resistance to breaking down the **barriers to innovation**, the **loss of productive land** and the difficulty of **scaling up**.

However, the experts of the FG identified a range of opportunities to tackle and overcome these challenges. One set of opportunities linked to the first type of challenges lies within the objectives of the FG itself. These opportunities include the definition, criteria, and examples of NbS for agricultural water management as well as awareness raising. A second set of opportunities are linked to **EU policies**, programmes and strategies. The third set of opportunities included those related to the **cost of NbS**, that may require new mechanisms.
When FG members voted on the relevance of the previously identified opportunities, the most voted was "**mechanisms of reward for ecosystem services**", the second most voted was related to **knowledge generation** ("NbS engineering handbook"), and the third was "**showroom** with illustrative NbS for agricultural water management".

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4. What can we do? Recommendations

Ideas for Operational Groups

EIP-AGRI Operational Groups (OG) are projects composed of multiple actors such as farmers, researchers, advisers, businesses, NGOs to address a practical problem and innovate in the agricultural and forestry sectors. As a result of the individual reflections and group discussions, the FG came up with proposals for possible OGs or other innovative projects that took shape in the mini-papers. As the mini-papers were the result of work in subgroups, the proposed ideas for OGs projects had overlaps, different formats and different approaches. Table 3 summarises and synthesises the proposed OGs after an attempt at harmonisation and structuring, indicating the scale of their work and noting the type of actors that could be involved.

Table 3. Harmonised and structured list of ideas for Operational Group projects proposed by the FG during meetings or in mini-papers

Operational Group		Scale	Questions to be answered and activities	Actors
Farming practices with NbS	Applying straw on tracks between beds to reduce run-off. How to upscale?	Farm		Farmers, researchers, agricultural equipment manufacturers
	Enhance water storage availability via soil health improvement	Farm		Farmers, researchers
	Good practice for the transition from conventional to conservation agriculture	Farm	– What are the practices that facilitate the transition from conventional to conservation agriculture?	Farmers, farmers' associations, researchers
	Conservation agriculture without glyphosates	Farm, Industry	– What are the cropping practices that allow conservation agriculture without using glyphosate?	Farmers, researchers, agrochemical industry
	Maintenance of buffer strips of agricultural water courses	Farm		Farmers, researchers, agricultural equipment manufacturers
	Socioeconomic aspects of on-farm conservation practices	Farm/Local (watershed)/ Regional	– Establishment of Living Labs. – Development of techniques/tools for the spatial and temporal analysis of benefits. – Establishment and operation of local assessment ecosystems around pilot areas. – Quantification of benefits.	Cooperatives, farmers, research institutions, NGOs, farm advisors, companies related to agricultural sector

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	Quantifying water savings through soil and crop management practices	Farm	– How to quantify actual water savings? What water savings are relevant with each NbS?	Farmers, researchers
Managing green infrastructures	Monitoring and controlling water levels in constructed wetlands	Farm, Watershed		Watershed authorities, instrumentation manufacturers, researchers
	Monitoring and controlling water flow in earth channels	Farm, Watershed, Irrigation Districts		Watershed authority, water users' associations, instrumentation manufacturers, researchers
	Monitoring and controlling quality of subsurface water infiltration	Watershed, Irrigation Districts		Watershed authority, instrumentation manufacturers, researchers
	NBS for water management in mountain agricultural areas	Farm, Watershed, Irrigation Districts		Watershed authority, water users' associations, researchers
	NBS for agricultural water management in less favoured areas	Farm/Local (watershed)/ Regional	– Engagement of stakeholders and key local actors in the co-development and co-evaluation of pilot actions. – Technical guidelines of NbS implementation. – Participatory actions for the assessment of environmental and socioeconomic benefits. – Plans of action at watershed level (short, mid, long term).	Cooperatives, farmers, research institutions, decision/policy makers, governance schemes and authorities
	Constructed wetlands for agro-livestock industry pollution control	Farm, Watershed, Livestock industry		Public agencies, livestock industry, farmers' associations, researchers
	Spatial planning of constructed wetlands as NbS interventions for water resources management at small agricultural watersheds and maximisation of environmental and	Local (watershed)	– Establishment of social science labs for the development of customised solutions. Development of spatial analysis and decision support tools for the establishment of constructed wetlands. Demonstration actions/thematic parks. – Guidelines of implementation.	Cooperatives, farmers, research institutions, NGOs, decision/policy makers, engineers, governance schemes, local authorities

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	socioeconomic benefits		– Participatory plans of action at watershed level (short, mid, long term).	
	Optimising erosion mitigation and water infiltration at a small catchment scale	Farm, Watershed		Farmers, watershed authority, researchers
	Water users' associations for managing collective water green infrastructure	Farm, Watershed, Irrigation Districts		Water users' associations, engineering companies, researchers
	Water green infrastructure for preventing droughts	Farm, Watershed, Irrigation Districts		Watershed authority, engineering companies, researchers
	Agricultural water networks for Ecosystem protection and restoration - Interconnection with rivers/streams	River, Watershed, Irrigation District	– Gather the necessary competences and draft a first plan. – Design of the single NBS hotspot and of the network. – Facilitate adhesion to the overall plan by farmers, training for advisors, capacity building for decision makers. – Socio economic assessment and identification of trade-offs. – Improvement of the overall plan and carry out the (pilot) projects. – Engage existing water management bodies or promote and set up a new legal entity responsible of the management of the NBS Hotspots.	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Fund raising companies, Investment Banks, etc. NGOs. Academy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)
	Joint irrigated agriculture management and artificial NBS Hotspots	River, Watershed, Irrigation District	– Gather the needed competences and draft a first management plan. – Create consensus on shared goals. – Draft multipurpose management plans and governance rules. – Prevent and manage present and future possible conflicts	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. NGOs. Academy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)

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	Urban agglomerations interconnection with peri urban agriculture, treated water storage, recreative areas and its potential to incorporate artificial NBS Hotspots	Cities, River, Watershed, Irrigation District	– Integration with Wastewater Treatment Plants. – Planning and design of water reuse schemas (as for REG. 741/2020/EU) involving NBS Hotspots as additional barriers. – Assessment of water quality improvements standards, KPI and benchmarks set up. – Integration with novel on spot water treatment technologies (microfluidics, compact nano filters, regenerable disinfection/filtration devices, etc..). – Integration of continuous fluxes in water networks characterised by intermittent uses	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Water boards and Agencies (urban). Wastewater treatment plant managers. NGOs. Consumers' associations Civil society/citizens representatives Academy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)
	Market recognition of NbS for agricultural water management	Public agencies, Farmers' associations		Public agencies, private-public partnerships, farmers' associations, supermarket chains
Beyond field implementation	Showrooms for NbS agricultural water management	Public agencies, Farmers' associations		Public agency, farmers' association
	Establishing rural thematic networks of NbS for knowledge transfer and awareness	Regional/ National	– Establishment of targeted cooperation networks. – IT tools of knowledge transfer and networking beyond borders. – Digital registries of active actors. – Database of NbS. – Activities for cross-fertilisation of knowledge and innovation acceleration (e.g. innovation camps)	Cooperatives, farmers, research institutions, private IT and communication enterprises, farm advisors
	Strengthening rural communities' involvement in the assessment of environmental and socioeconomic benefits of NbS for agricultural water management	Local (watershed)/ Regional/ National Public agencies, Farmers' associations	– Establishment of Living Labs. – Public perception-attitude study – Deployment of awareness raising and capacity building activities. – Development and implementation of participatory assessment tools and techniques.	Cooperatives, farmers, research institutions, NGOs, governance schemes and social groups, Public agency, farmers' association

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			– Drawing roadmaps of actions and governance schemes of social innovation to support communities of action.	
	NbS for agriculture waste management for the achievement of the Sustainable Development Goals	Regional/ National Policy, Farmers communities	– Development of documentation tools and benefits assessment techniques using Sustainable Development Goals relevant indicators. – Documentation of effectiveness through pilot actions. – Thematic parks, Demonstration areas. – Participatory assessment of benefits and sustainability.	Public agency, farmers' association, researchers
	Assessing the benefits of NbS at farm and small agricultural catchment levels	Farmers, Public agencies	– Q: How to apply multi-criteria analysis to assess the various benefits of NbS?	Public agency, farmers' association, researchers
	Creating and assessing social benefits from NbS for agricultural water management	Farmers, Public agencies		Public agency, farmers' association, researchers
	Creating and assessing ecosystem services from NbS for agricultural water management: stream and ground-water regulation, biodiversity, C sequestration, GHG emission mitigation. 1) Farming practices; 2) Green water infrastructure	Farmers, Public agencies		Public agency, farmers' association, researchers
	Developing tools for maximising the socioeconomic impact and co-benefits of NbS for water resources management at farm level	Farm/Local (watershed)	– Developing tools and techniques of integrated analysis and assessment of benefits (environmental and socioeconomic at both spatial and temporal level). – Impact monitoring technologies across scales – Participatory evaluation and documentation of	Cooperatives, farmers, research institutions, professional and socioeconomic chambers, farm advisors, water related agencies and IT companies

			tools/techniques in pilot areas. – Development and evaluation of state-of-the-art decision support systems to maximise benefits (using artificial intelligence, machine learning, big data etc).	
	Farmers direct and indirect benefits and trade off: implementing artificial NBS hotspots as a way out from water conflicts		– Standards/guidelines for Cost/Benefit Analysis (CBA) – Standards/guidelines for ecosystem services socio-economic assessment. – Identification of drawbacks, according to each of the NBS Hotspot purposes. – Standards/guidelines for trade-offs economic assessment. – Guidelines for conflict prevention and management, rules for conflict resolution.	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Water boards and Agencies (urban). Wastewater treatment plant managers. NGOs. Academy (socioeconomic, conflict management specialists)
	Mechanisms of reward for NbS ecosystem services	Private-public partnerships, Farmers' associations		Public agencies, private-public partnerships, farmers' associations, supermarket chains
	Towards Land Degradation Neutrality through NbS in rural landscapes	Local (watershed)/ Regional/ National	– Development of monitoring tools using Land Degradation Neutrality relevant indicators. – Documentation of effectiveness through pilot actions. – Thematic parks, Demonstration areas. – Land-use planning tools and guidelines for addressing LDN challenges through the establishment of NbS.	Cooperatives, farmers, research institutions, NGOs, decision/policy makers, governance schemes and authorities
	Selecting, planning and designing appropriate NbS for AWM agricultural water management: 1) Farming practices, 2) Green water infrastructure	Farmers, Water users' associations, Public agencies		Farmers, engineering companies, researchers

Research needs from practice

Assessment of effectiveness of NbS for agricultural water management requires deep understanding of the natural and artificial physical processes that are involved. Given the multidimensionality of NbS, the innovation process should be embedded in the research on the physical processes. Moreover, policy actions that incentivise participation in the innovation process and adoption of NbS are necessary to ensure progress in the adoption process. These actions may be part of the EU Common Agricultural Policy (i.e., conditionality measures or voluntary agri-environmental measures), River Basin Water Plans, Flood Risk Plans, Natura 2000. Education at all levels, from university to the farm, passing by agricultural practitioners, should ensure that NbS for agricultural water management are funded and justify as alternative or complementary to conventional solutions. Therefore, we advocate for Participatory Action Research to respond to research needs of NbS for agricultural water management.

The research needs identified in the FG are broken down and developed below. Most of them are generic, therefore applicable to soil management, constructed wetlands, recharge ditches, terraces, river "hotspots", or any other NbS or green infrastructure for agricultural water management.

Understanding physical processes

The physical processes involved in NbS are characterised by their complexity and interlinks. Therefore, state-of-the-art site-specific research (at farm, watershed or river scale depending on the NbS) is imperative before promoting their adoption.

Spatially distributed modelling of the eco-hydrological processes should precede the development of procedures for the design, assessment and management of NbS for agricultural water management. On-site monitoring of natural or managed processes is the basis for analytical research and essential for model development. Monitoring techniques are therefore key components of the required research. Living-Labs (i.e., full-scale demo sites) are probably the most appropriate research infrastructure for this purpose. Fundamental research of specific processes may be also necessary. In this case, laboratory or field-controlled experiments might be needed. Water accounting methods applicable at nested scales should be one outcome of the research on physical process in order to support NbS assessment and decision-making.

Assessment criteria, models and indicators

The NbS concept is still maturing. Several of the research needs identified are related to standardisation and evaluation criteria and indicators.

The first need is therefore for a common framework for qualification and assessment of NbS that are specific to agricultural water management. This framework could result from the adaptation of one of the existing generic frameworks for solutions to societal challenges, or from a development from scratch.

The basic characteristics of the solutions that this framework should have to consider are the effectiveness and the magnitude of the primary effect that the solution seeks (water savings, increased availability). The assessment of its resilience is important as it is a nature-based solution. The nature-based qualification should be based on objective criteria, depending on the extent to which it reproduces natural processes or uses elements from outside the natural environment.

Next is the assessment of benefits, internal and external. On the one hand there are the economic benefits, which ideally should be valued monetarily, on the other hand there are the social benefits and ecosystem services. The necessary research should adapt cost-benefit, cost-effectiveness and market-based analyses, using multi-criteria techniques, to the specific case of agricultural water management solutions.

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Three issues must not be forgotten in these analyses:

- solutions involve trade-offs
- the effects must be assessed in the medium and long term, which implies selecting appropriate monitoring mechanisms
- the effects must reach beyond the area where the solution is applied, i.e., territorial, social and environmental scaling-up assessment methods are needed.

Governance

Water governance implications are particularly important and intangible when the scope of the NbS is fluvial ecosystems, shared watersheds or irrigation districts. Different communities and institutions are then involved, requiring particular governance models that are not yet sufficiently framed. Proposing new models of water governance adapted to the NbS is the role of interdisciplinary research.

Other recommendations, including improving take up

The outcomes of research must be used by practitioners, consultants and decision-makers to inform their activities. This requires transforming research results into:

- decision support systems for policy-makers
- manuals with design procedures and management guidelines for practitioners
- surveys on social perception and awareness of the NbS for agricultural water management
- means of dissemination of NbS for agricultural water management
- catalogues of NbS for agricultural water management that collect evidence of their advantages and benchmarks and show their complementarity and synergies with conventional solutions
- mapping pedo-climatic and socio-economic conditions that favour the success of specific solutions (e.g. soil conservation practices)
- techniques and sensors (e.g. soil water sensors, gauging devices) adapted to the needs and constraints of their on-farm application

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Annex A: List of experts and facilitation team

Focus Group Expert	Profession	Country
María Almagro Bonmatí	Researcher	Spain
Gottlieb María Basch	Researcher	Portugal
Adriano Battilani	Researcher	Italy
Christoffer Bonthron	Working at an NGO	Sweden
Peter Čaky	Farmer	France
Nadia Carluer	Researcher	France
Mateusz Ciasnocha	Farmer	Poland
Martin Crowe	Adviser	Ireland
Jeroen De Waegemaeker	Researcher	Belgium
Rossano Filippini	Farmer	Portugal
Sophie Gendre	Other	France
Twan Gielen	Adviser	The Netherlands
Sławomir Gromadzki	Farmer	Poland
Eva Hernández	Working at an NGO	Spain
Airi Kulmala	Working at an NGO	Finland
Sergio Martos-Rosillo	Researcher	Spain
Eleanna Pana	Innovation broker	Greece
Elisabeth Schulz	Civil Servant	Germany
Vasileios Takavakoglou	Researcher	Greece
Attilio Toscano	Researcher	Italy

Facilitation team	
Mateos Luciano	Coordinating expert
Céline Karasinski	Task manager
Antanas Maziliauskas	Co-task manager
Aniko Seregelyi	European Commission – DG AGRI
Marta Iglesias	European Commission – DG AGRI

You can contact Focus Group members through the online EIP-AGRI Network.
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Annex B. List of mini-papers

Number	Tittle	Coordinator	Contributors
1	Nature based Solution at a field scale	Gendre	Basch, Čaky, Almagro-Bonmatí, Gielen, Kulmala, Filippini
2	Nature based solutions as green infrastructures for agricultural water retention, treatment and availability	Carluer	Bonthron, Kulmala, Marto-Rosillo, Mateos, Pana, Schulz, Toscano
3	Agricultural NbS for river ecosystems resilience	Battilani	De Waegemaeker
4	Assessing the socioeconomic and environmental benefits of NbS. Challenges and future perspectives	Takavakoglou	Almagro-Bonmatí, Basch, Pana

The mini-papers can be found on the Focus Group webpage

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AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

An EIP AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf

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servicepoint@eip-agri.eu | +32 2 543 73 48 | Koning Albert II laan 15 | Conscience Building | 1210 Brussels | Belgium