the LENSES project

LEarning and action alliances for NexuS EnvironmentS

in an uncertain future

LENSES

WP8

D8.3 Application of NBS selection framework in pilots

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(CREA)

10/7/2023

Project partners

Project coordinator

Project Website:
www.prima-lenses.eu

This project is part of the PRIMA programme supported by the European Union.

GA n° [2041] [LENSES] [Call 2020 Section 1 Nexus IA]

Project no.	2041
Project acronym	LENSES
Project title:	Learning and action alliance for NEXUS environments in an uncertain future
Call:	PRIMA call Section 1 – Nexus 2020, Topic 1.4.1-2020 (AI)
Start date of the project:	01.05.2021
Duration:	36 months
Project Coordinator:	Stefano Fabiani, Council for Agricultural Research and Economic Analysis (CREA)
Deliverable title:	D8.3 – Application of NBS selection framework in pilots
Due date of deliverable:	30 April 2023
Organisation name of the lead contractor for this deliverable:	Council for Agricultural Research and Economic Analysis (CREA)
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Internal Reviewer 2	

Dissemination level		
PU	Public	PU
CO	Confidential, restriction under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

History			
Version	Date	Reason	Revised by
01	03/06/2023	Draft	Silvia Vanino (CREA)
02	22/06/2023	Revisions from all Pilot Leader	All Pilot Leader
03	03/07/2023	Review	Esteban Henao, M. Llanos López, Anna Osann (AgriSat)
04	10/07/2023	Final version	Silvia Vanino, Donato Ferrari (CREA)

Executive Summary

Nature-based solutions (NBS) are actions to protect, sustainably manage, or restore natural ecosystems, that address societal challenges such as climate change; one LENSES project's aim is to define some NBS to adopt in the pilot area to more sustainable agriculture.

This document presents a comprehensive assessment of Nature-Based Solutions implemented in various pilot areas: Pinios, Gediz, Deir Alla, Galilee, Tarquinia, Doñana, and Koiliaris. The primary objective is to establish sustainable landscapes that optimize the interactions between water, energy, and food systems while promoting socio-economic development.

In the Pinios pilot area, the focus is on adopting agroecological practices, improving soil quality, and enhancing water retention capacity to support sustainable agricultural practices. These NBS aim to address challenges related to food provisioning and water resource management.

Similarly, the Gediz pilot area emphasizes the importance of NBS for food provisioning, water provisioning, and water flow regulation. Recommendations for stakeholders and farmers are provided to promote sustainable practices and enhance the resilience of the ecosystem.

In the Deir Alla pilot area, the study explores potential NBS solutions to address food provisioning, water provisioning, and water flow regulation challenges. Although specific NBS implementations are not yet planned, the findings inform future decision-making processes.

The Galilee pilot area considers the implementation of agrovoltaic systems, which combine agricultural production with solar energy generation. This innovative approach not only contributes to food provisioning and water resource management but also promotes renewable energy generation.

In the Tarquinia pilot area, the focus is on water provisioning, water purification, water flow regulation, and erosion control. Although specific NBS have been identified, there is currently no experimental site for their implementation.

The Doñana pilot area prioritizes water purification, lifecycle maintenance, and ecosystem restoration. NBS implementations are aimed at restoring the ecosystem and optimizing resource use for agriculture while simultaneously promoting biodiversity conservation.

In the Koiliaris pilot area, the restoration of riparian forests is identified as a targeted NBS strategy. This approach addresses challenges related to moderating extreme events and regulating the climate through carbon sequestration.

The assessment considers various barriers to NBS implementation, including legislative, economic, technical, and social challenges. It highlights the importance of integrated approaches and stakeholder involvement in decision-making processes to overcome these barriers effectively.

Furthermore, the study incorporates socio-economic evaluation by valuing ecosystem services (ES) provided by the implemented NBS. The findings demonstrate positive socio-economic benefits derived from NBS implementation, emphasizing the significance of these solutions for sustainable development and resilience in the water, energy, and food sectors.

In conclusion, the assessment of NBS in diverse pilot areas underscores the importance of tailoring strategies to specific local contexts. By implementing NBS, these areas can achieve sustainable development goals while effectively managing their water, energy, and food systems.

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1 Introduction

In the context of the current global water crisis and the urgent need to preserve and sustainably manage the planet's water resources, projects that promote natural strategies for environmentally sustainable water use are of utmost importance. The LENSES project is based on the use of innovative solutions in agriculture that respect the environment by using natural methods for sustainable management of resources such as water.

A project that focuses on environmentally sustainable water use through natural strategies has several crucial objectives. These include water conservation through the adoption of efficient use practices, natural water purification through biological processes, and active community involvement in promoting sustainable practices. Implementing these goals will not only help conserve water resources, but also promote responsible water management for future generations. It is critical that natural strategies on the environmentally sustainable use of water become a priority for governments, organizations, and individuals around the world to ensure sustainable management of water resources and the preservation of our planet.

This analysis is tasked with identifying and providing the methodological and practical basis for selecting a set of solutions using NBS as the underlying principle of a Nexus approach.

In particular, proposals from the partners were collected and analysed, and they provided a suitable methodology for their study area, trying to bring out both the strengths and weaknesses of their proposals.

Each partner has devised and analysed the effects of an NBS that best suits its area in terms of geography, climate, soil composition, and other externalities. It is obvious that external factors influenced, and not a little, the choice of the best natural solution. The ultimate goals of each solution proposed by the partners will be explained below; going forward, all proposals will be explicitly analysed and explained with a cost-benefit analysis and a discussion of strengths and weaknesses.

The objective of the task 8.3 is to support pilot teams in applying the Natural Base Solution selection framework to choose sets of potential solutions that align with the specific context of the pilot. Next sections will present the several solutions defined and applied in the different LENSES pilot areas presenting positive impacts and possible barriers that can be overcome.

2 NBS implemented in “Pinios” Pilot Area (Greece)

2.1 Description of NBS selected

The main objectives of the WEF Nexus implementation in the Pinios Pilot area are (i) sustainable water resources management, (ii) an optimized WEF Nexus, and (iii) a focus on the sustainability of the agricultural sector and social-economic ecosystem development.

In deliverable 5.2, a primary list of appropriate NBS was developed (see Annex):

1) **NBS for irrigation practices improvement, both for the Agia sub-basin and the Pinios River Delta:**

Type 2—NBS for sustainability and multifunctionality of managed ecosystems, and specifically in the category of agricultural landscape management.

<u>NBS type</u>: Agroecological practices.

2) **NBS for agroecological practices improvement for Agia sub-basin:**

Type 2—NBS for sustainability and multifunctionality of managed ecosystems, and specifically in the category of agricultural landscape management.

<u>NBS types</u>:

- Increase soil water holding capacity and infiltration rates.
- Incorporating manure, compost, biosolids, or incorporating crop residues to enhance.
- Carbon storage.
- Mulching.
- Use of soil conservation measures – cover crops.

3) **NBS for agroecological practices improvement in the case of Pinios River Delta:**

Type 2—NBS for sustainability and multifunctionality of managed ecosystems, and specifically in the category of agricultural landscape management.

<u>NBS types</u>:

- Soil improvement and conservation measures.
- Incorporating manure, compost, biosolids, or incorporating crop residues to enhance.
- Carbon storage.
- Mulching.
- Use soil conservation measures – cover crops.

The following sections describe the NBS types experimented in Agia sub-basin: the mulching and the soil water management through irrigation scheduling.

2.1.1 Mulching

Mulching constitutes one of the most efficient weed management techniques and refers to the incorporation of the weeds left at the corridors of the cultivation (Figure 1).

FIGURE 1- WEED MANAGEMENT BY MULCHING TECHNIQUE IMPLEMENTATION IN PILOT AREA.

To investigate the positive effects of mulching over the non-sustainable herbicides application, a field experiment was performed in the Agia sub-basin. In particular, a soil campaign was conducted in apple orchards in April 2022, just before the beginning of the growing season and is due to be expanded and repeated this year, including a more significant number of parcels, to improve the significance of the obtained results. Soil samples were collected at 12 points in 8 different orchard parcels; 96 soil samples, in total; half of them treated by mulching, and the rest by herbicides application (Figure 2). Samples were collected at 2 different depths, i.e., 0-10cm and 10-30cm from the soil surface.

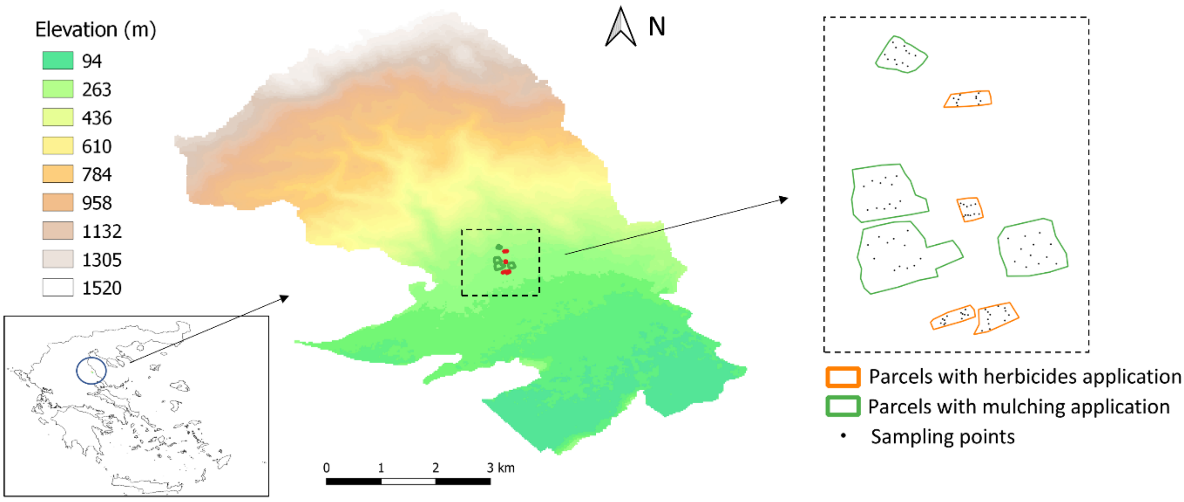


FIGURE 2 STUDY AREA AND LOCATION OF FIELD PARCELS UNDER STUDY (MALAMATARIS ET AL., 2023).

The area of parcels ranges from 0.18 to 1.91ha with an average value of 0.72ha. Soil texture in the study area is classified as loam (68.38%), sandy loam (24.86%), silt loam (5.00%), silty clay loam (1.15%), sandy clay loam (0.42%), and clay loam (0.18%). Soil also presents a pH of 6.94, 7.05, and 7.06; 42.66%, 42.97%, and 41.09% sand; 38.42%, 38.14%, and 37.16% silt; and 18.88%, 18.85%, and 21.70% clay, at 0–5 cm, 5–15 cm, and 15–30 cm depth, respectively, based on field measurements conducted in July 2020 along with data derived from the SoilGrids online database (SoilGrids, 2022).

2.1.2 Soil water management through irrigation scheduling

Soil water management through the application of well-developed and operational irrigation scheduling algorithms could significantly contribute to sustainable irrigation water use, avoiding over-exploitation of water resources. Moreover, it supports better use of green and blue water, avoiding excessive runoff and leaching of surplus which often is related to pollutants migration, whilst it strengthens preservation of soil organic matter and prevents soil compaction. In principle, irrigation scheduling opts at making better use of the soil water retention capacity and through this reduce the water abstracted for irrigation, whilst preserving soils at an optimal moisture status in order to avoid oxidation of organic carbon (at dried soils for prolonged time intervals), or soil erosion and nutrients runoff (at excessive irrigation events). The development of irrigation scheduling is strongly based on the operation of the Pinios Hydrologic Observatory (PHO) which was established in the Agia sub-basin in 2015. Heavily instrumented pilot fields have been established to develop the operationalisation of the management scheme that act as a demo to neighbouring farms in the region and beyond. Furthermore, data driven decisions on irrigation advising services, and therefore soil water management, are enabled with instruments installed throughout the basin and the soil classification maps compiled on the basis of extensive field surveys, along with the regional crop distribution inventory. Essentially, the infrastructure developed and the outcomes produced in the framework of H2020 ATLAS project are being utilised to complement the scopes of LENSES. On top of the above, through a dense telemetric groundwater level monitoring network a data driven platform informs stakeholders in near real time of the groundwater reserves status and in monthly intervals modelling predictions of the expected evolution. These tools along with the irrigation advice service are offering a solution to soil water management, water saving and in parallel reduction of energy footprint, through the reduced abstraction rates. The layout of the pilot fields and instrumentation installed may be depicted in Figure 3.

FIGURE 3 - INSTRUMENTED PILOT FIELDS IN AGIA SUB-BASIN.

PHO provides a high frequency and high spatial density monitoring of many meteorological and agro-hydrological parameters for the effective investigation of relevant processes in the pilot area. Taking advantage of the intensive monitoring data combined to hydrological modelling, weather forecast and data assimilation techniques initialized in the ATLAS project and further expanded in the LENSES project, sustainable water management of the pilot areas and soil protection could be achieved.

2.2 Assessment of the outcomes of the different NBS applied

First results of the aforementioned applied NBS seem to be more than encouraging in terms of enhancing the Water -Ecosystem -Food (WEF) Nexus security in pilot areas. Modelling processes are in progress and are expected to provide a coherent numerical validation of the preliminary assessments and expectations.

2.2.1 Mulching

Soil Organic Carbon (SOC) content was determined in the Laboratory of the Soil and Water Resources Institute, using a wet combustion technique, according to the Wakley–Black method. Soil samples were air-dried, and the fraction of fine earth (<2mm) was used for the analysis. In total, 1g of soil was transferred into a 500-mL wide-mouth Erlenmeyer flask; 10mL of 1N$K_2Cr_2O_7$ and 20mL of concentrated H_2SO_4 were added, and the flask was swirled until soil and reagents were mixed. After 30’ standing, 200mL of deionized water was added to the flask, while 3–4 drops of diphenylamine were used as an indicator for the titration with 0.5N $FeSO_4$.

SOC was found to present high in-field variability in terms of both weed removal practice and soil depth. Mulching was found to increase SOC content, minimizing carbon production due to burning biomass prevention, and thus, reducing greenhouse gas emissions and contributing to climate change mitigation. The difference between the mean SOC in fields applying mulching and herbicides was found to be statistically significant, as indicated using the student’s t-test method. For the upper soil profile (0-10cm depth), the results indicate that soil organic carbon in the fields applying mulching was higher by 31% compared to the fields applying herbicides. The corresponding difference for soil depth of 10-30 cm was 7%, thus demonstrating the effectiveness of mulching in increasing soil organic carbon (Figure 4). The results confirm the importance of mulching in SOC fractions, particularly in the upper soil layers.

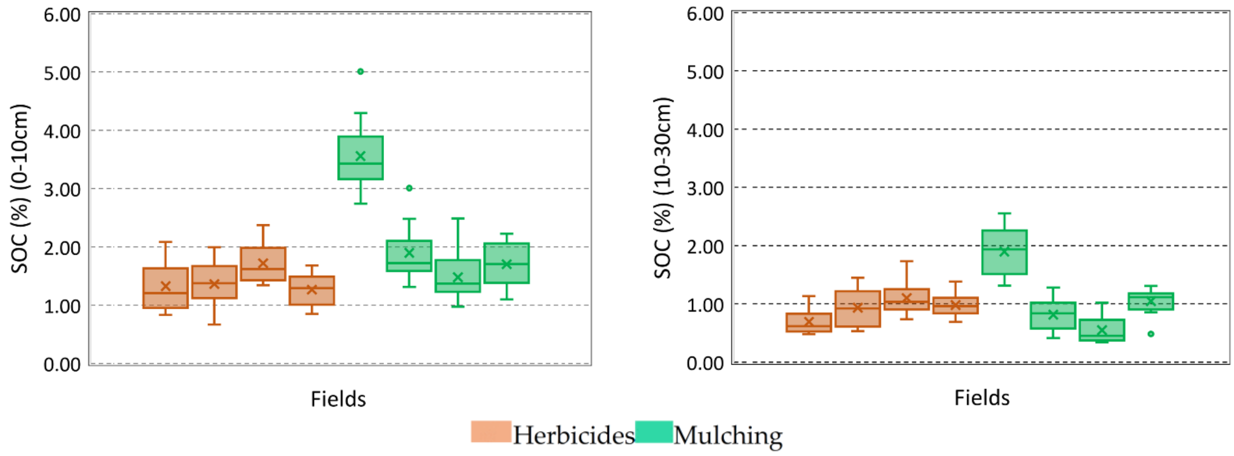


FIGURE 4 - SOIL ORGANIC CARBON (%) FOR THE TWO DIFFERENT WEED REMOVAL PRACTICES AT TWO DIFFERENT SOIL DEPTHS (MALAMATARIS ET AL., 2023).

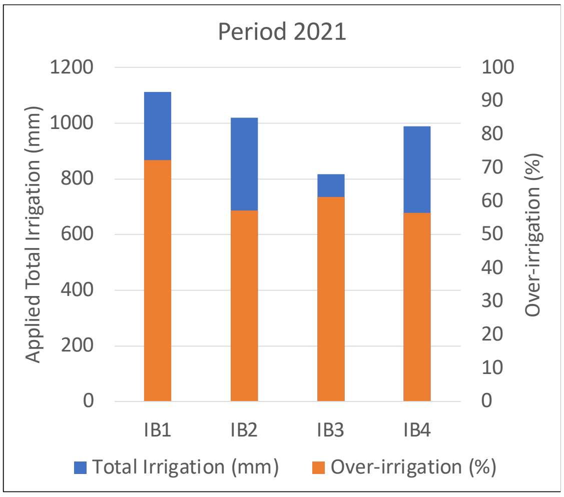
Furthermore, the increased SOC documented in the fields where mulching was applied could provide additional multiple indirect assets to the farmers that have adopted it. Soil erosion risk may be reduced, and soil fertility could be significantly improved, especially when SOC increase relates to crop residue retention. Soil water holding capacity could be also positively affected, despite the fact that the latest literature suggests that actual improvement is rather limited. Moreover, the weeds preservation along with the reduced use of herbicides and elimination of nutrients' washout to aquatic receptors could also contribute to biodiversity conditions improvement, whilst on the long run soil health is improved through the reduction of erosion risk. The above collateral benefits are expected to decrease agricultural production cost, and thus promote economic viability and social cohesion of the local societies.

A possible barrier refers to the difficulty of perceiving farmers to adopt mulching technique instead of time-saving herbicides application. For that reason, mulching demonstration accompanied by educational seminars aiming at further promoting the environmental and economic benefits for farmers along with possible funding of the NBS, could significantly contribute to mulching promotion among farmers.

2.2.2 Soil water management through irrigation scheduling

Soil water management through irrigation scheduling provides answers to several scientific and societal questions raised in the pilot areas. State-of-the-art and data-driven irrigation scheduling algorithms and methodologies for irrigation optimization, including both ideal duration and frequency of irrigation, are currently developing. Irrigation scheduling is based on data from the pilot orchards, covering a wide range of setups from fields without instrumentation to intensively monitored fields. Soil water retention is expected to be kept at optimal level, thus reducing water usage and maintaining soil moisture at optimal conditions at all times, i.e., near field capacity. Preliminary results confirm the optimal use of soil water and reveal a water consumption reduction potential ranging from 15% to over 50%. The above positive effects are expected to decrease agricultural production cost, thus promoting economic viability and social cohesion of the local societies. The irrigation advice services will soon become available free of charge for all farmers in the pilot area, at the generic (non-instrumented) version. The positive effects of the soil water management through irrigation scheduling is therefore laying on several aspects: (1) reduction of actual volumes of water abstracted for irrigation, (2) avoidance of runoff which relates to soil erosion and pollutants migration, (3) control of soil surface and air humidity thus reducing the risk of moisture-born plant diseases that require expensive treatments, (4) preservation of optimal soil moisture conditions making use of soil water retention capacity and avoiding carbon oxidation.

A possible barrier is mainly associated to the need to invest in the necessary equipment to provide more detailed and accurate irrigation schedule to the wider pilot area (render fields instrumented) and the modification of the calculation algorithm to incorporate all existing crops, plus the maintenance cost of the service. Incurring costs for high precision implementation of the NBS may be covered through national or European financial aid, such as Hellenic National Strategic Reference Framework 2021-2027, new EU CAP, and EU Green Deal. However, the sufficient application of the current form of developed irrigation services seems not to require any additional capital investment. Essentially, it is strongly believed that farmers will progressively convert to such technologies should these be promoted by institutional stakeholders and direct financial assets are realized due to the substantial reduction of energy bills in parallel to establishing optimal soil and air moisture conditions that in turn translate to reduction of required spraying with chemical plant protection agents to protect from moisture born infections (such as fungicides etc.). A characteristic improvement of the farmer's performance in terms of overirrigation is illustrated in Figure 5, where a considerable reduction in water consumption can be seen in two consecutive crop seasons, which however has a large potential to be further improved.



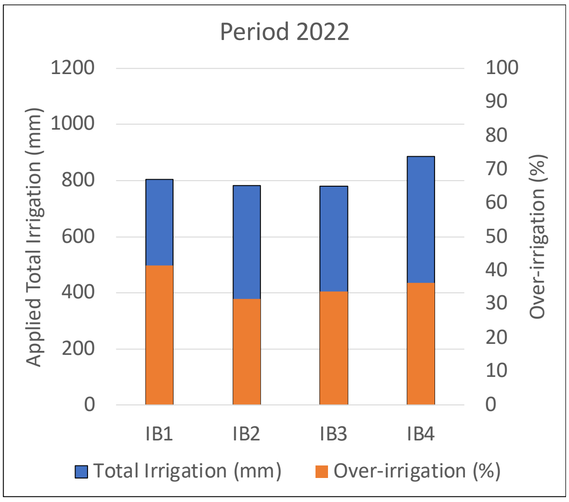


FIGURE 5- IMPROVEMNET OF IRRIGATION PERFORMANCE AT A PILOTING FIELD OF AGIA BASIN (PHO), CENTRAL GREECE (TSAKMAKIS ET AL., 2023). IB=IRRIGATION BLOCK, THE OPERATIONAL UNIT WITH REGARDS TO IRRIGATION APPLICATION WITHIN THE PILOT FIELD

Both tried NBS are progressively becoming widely known and to an extent accepted in the conscious of farmers in the region, however there is still a long way to systematically adopt and implement them. In any case, the two approaches are seen as a bundle of methods that should be encouraged together as standard farming practice.

3 NBS selected in “Gediz Pilot” (Turkey)

The most appropriate NBS solutions defined in Menemen Plain listed below:

1) **Better use of protected/natural ecosystems**

Type 1 - *Protection and conservation strategies in terrestrial (e.g., Natura2000), marine (e.g., MPA), and coastal areas (e.g., mangroves) ecosystems*

- Limit or prevent specific uses and practices.
- Maintain and enhance natural wetlands.
- Natural Protected Area network structure.

2) **NBS for sustainability and multifunctionality of managed ecosystems**

Type 2 - *Agricultural landscape management*

- Agro-ecological practices.
- Change crop rotations.
- Soil improvement and conservation measures.
- Agro-ecological network structure.
- Increase soil water holding capacity and infiltration rates.
- Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage.
- Use soil conservation measures - Deep-rooted plants and minimum or conservation tillage.

Type 2 - *Coastal landscape management*

- Integrated coastal zone management.

The following sectors show the description of the NBS types experimented in the pilot: the intercropping, the microbial fertilizer, and the Holistic Regenerative Practices.

3.1 Description of NBS selected

3.1.1 Intercropping Implementation in Pilot Area:

Intercropping is characterized as the simultaneous production of two or more different types of crops on the same piece of land. Intercropping is one of the most effective methods in agricultural production with a long history.

It is known as the achievement of a high and stable production that not only raises complementary products in the area but also reduces the harmful effects of diseases and pests, prevents pollution and effectively uses resources. In the pilot area, vetch is widely intercropped with fruit trees as a fodder plant.

3.1.2 Microbial Fertilizer Implementation in Pilot Area:

Microbial fertilizers play a role in the natural uptake of plant nutrients. Soil microbial activity increases plant nutrient availability and soil fertility.

It contributes to the protection of natural resources and sustainability in agriculture by improving soil quality. Microbial fertilizers containing rhizobium bacteria are used to provide biological nitrogen fixation in legume agriculture in the pilot area.

In order to increase the biological nitrogen fixation (BNF), training, demonstration and field days are organized for producers to raise awareness and extend the use of microbial fertilizers in legume plants grown in the pilot area.

3.1.3 Holistic Regenerative Practices in Pilot Area:

Holistic regenerative practices applications emerge as a solution to reduce adverse effects in the soil due to traditional agricultural habits such as; soil pollution, degradation, salinity, etc.

This practice is applied demonstratively in UTAEM[1] lands in order to set an example for the producers in the region.

In order to raise awareness among the stakeholders: trials have been designed to restore the natural balance of the project area in Menemen. Producing organic cotton with holistic regenerative practices, such as cover cultivation, mulching and no-till farming, in addition to organic production principles, are ongoing.

3.2 Assessment of the outcomes of the different NBS applied

3.2.1 Results of intercropping implementation in Pilot area:

Given the examples applied in the pilot area, the vetch plant, intercropped with fruit trees is mainly mixed with the soil after the harvest and used as green fertilization (Figure 6). Thus, it reduces the need for chemical fertilizers and provides soil improvement and plant nutrients that the soil needs. Some producers also obtain income by using intercropped plants as animal feed.

[1] LENSES project partner - International Agricultural Research And Training Center

FIGURE 6 - VETCH PLANT INTERCROPPED WITH FRUIT TREES IN GEDIZ PILOT AREA

However, some farmer areas' size and land fragmentation make this practice difficult. On the other hand, the region´s producers hold on to traditional production methods and do not prefer intercropping agriculture because of their current tillage habits (excessive tillage). It is aimed to disseminate the intercropped agriculture practice by explaining the benefits and gains of these practices in the pilot region.

3.2.2 Results of microbial fertilizer implementation in Pilot area:

It is aimed to improve soil quality by reducing the use of chemical nitrogen fertilizers with microbial fertilizer applications in the region. Moreover, with the dissemination use of microbial fertilizers in legumes, it is possible to increase quality and efficiency, reduce production costs, and protect natural resources.

Due to the inadequate production planning of the producers, they face difficulties in reaching the microbial fertilizer when needed.

For this reason, on May 15, 2023, a field day was held with the participation of local farmers (Figure 7) to demonstrate the application of microbial fertilizers. In this event, which was organized with around 30 farmers, the producers' awareness was increased especially about this NBS. Detailed information was given to farmers about LENSES Project. In addition, a presentation was made to the farmers about the use, application and benefits of microbial fertilizers. At the end of the day, the demonstration of microbial fertilizer applications in the trail area of UTAEM was visited.

FIGURE 7 - STAKEHOLDER PARTICIPATION AT THE FIELD DAY IN GEDIZ PILOT, WHERE A DEMONSTRATION OF THE APPLICATION OF MICROBIAL FERTILIZER WAS DONE.

4 NBS selected in “Deir Alla” Pilot area (Jordan)

4.1 Description of NBS selected

The NBS that contribute to **Soil salinization and land degradation,** can be applicable in Deir Alla Pilot area.

1) NBS bundle for Soil salinization and land degradation – Focus on forage

- Crop rotation
- Irrigation water Management
- Forage and silage quality

2) NBS bundles for soil regeneration

- Follow agro ecological practices.
- Use soil organic matter, organic fertilization, and conservation measures for soil improvement.
- Incorporate manure and compost.

The selected NBS will enhance the Water-Ecosystem-Food (WEF) Nexus of the watershed. The methodologies used to irrigate are based on the demands of the crop which will reduce water consumption and improve water productivity. In addition, incorporation of manure (soil organic matter) in the soil will improve soil structure and increase soil water retention. The organized management of livestock will reduce feeding cost by using the best utilization method by implementation of ensiling techniques. Finally, the regenerated soil will increase soil fertility and forage production. These NBS will enhance the WEF Nexus and improve the livelihood and food security of the people in the area.

The silage quality was analysed and reported as:

Crop-Alfalfa & Sorghum-Analysis: Forage quality

Feed Analysis							
Crop	Moisture	Crude Protein	Crude Fiber	Ether Extract	NDF	ADF	ASH
Sorgham	80.822	11.264	33.446	3.178	63.824	25.542	13.198
Sesbania	65.72	14.722	24.868	8.946	33.86	27.036	6.818
Alfalfa	53.146	17.928	-	-	-	-	-
Silage	Moisture	Crude Protein	Crude Fiber	Ether Extract	NDF	ADF	ASH
Sorgham 100	80.64	11.18	32.95	3.09	63.52	25.25	13.17
Sorgham 75	76.8	11.96	31.28	4.67	56.26	25.89	11.43
Sorgham 50	73.17	12.88	28.91	5.9	48.74	26.09	9.9
Sorgham 25	69.36	13.76	26.94	7.46	41.3	26.61	8.143
Sorgham 0	65.69	14.65	24.56	8.92	33.82	26.98	6.79

This project is part of the PRIMA programme supported by the European Union.
GA n° [2041] [LENSES] [Call 2020 Section 1 Nexus IA]

FIGURE 8 SILAGE QUALITY DATA COLLECTED IN MIDDLE JORDAN VALLEY.

NARC Team is working to collect other data for the yield and irrigation amount used to calculate other parameters like the productivity.

5 NBS selected in “Galilee – Hula Valley” Pilot area (Israel)

5.1 Description of NBS selected

The most appropriate NBS for addressing the challenges of the “Galilee -Hula Valley” pilot area defined in the Del.5.2 are listed below:

1) **NBS for agricultural development**

Type 1 – Better use of agricultural ecosystems and specifically in the category of Monitoring
NBS type:

- Assessment of NBS benefits.

Type 2 – NBS for sustainability and multifunctionality of managed ecosystems and specifically in the category of Agricultural landscape management

NBS type:

- Increase soil water holding capacity and infiltration rates.

Agrovoltaics is the NBS-selected solution to water scarcity and natural resource utilization chosen by the Galilee pilot. The pilot works on the technology´s agronomic and practical farming application under simulated panel shading. Assortment of soil, water and atmospheric instrumentation and manual methods are applied to evaluate the impact of partial shading by solar panels on the crop water relations, and factors determining final yield and fruit quality.

In the Hula Valley pilot, harvesting the sun was the obvious NBS solution putting to work the stable summertime sunshine from one side and using the shading to alleviate the water shortage from the other side. Inter-row space of row plantations present unused sun radiation ready to install photovoltaic panels referred as Agro-voltaic (APV). The potential benefits to the grower are reduced evapotranspiration (ET), saving water and providing reduced plant stress, and steady, risk-free income all year around. Drawback for the growers are potential yield or quality loss caused by the partial shading and microclimate change. Power company benefits come from freeing additional land use for PV deployment, providing power over short conduits close to the end users. As the technology is in the infant stage, many questions regarding agro-technology and crop care must be answered before the growers can evaluate the risks and benefits and accept APV in their orchard. The aim of the Hula pilot of LENSES is to monitor and analyse the effect of partial shading by PV panels on the performance of the crops (Figure 9, Figure 10).

In the first season (2021), the effect of partial shading by simulated PV panels (bureaucracy and regulation, etc…) of a plum orchard at Ayelet Hashahar was monitored. While water saving and plant stress relief was observed, considerable yield loss was recorded, mainly because of a chain effect where chilling-units deficiency delayed fruit set by two weeks, right into a hot spell, caused by sort of a "greenhouse effect" of the panels, ending with less fruit per tree.

In the second season (2022), the experiment was moved to a nectarine orchard at Yiftah, awaiting promised permits for deployment of the panels, which never came, relegating to simulation again. A differential irrigation experiment was laid out with more extensive instrumentation. Basically, the results were similar: Partial shading provided reduced plant stress and water use, however despite favoured growth conditions, ended with 15% yield loss and two weeks delay of harvest.

One of the conclusions of those two seasons is that many other factors are to take in account than simply energy balance, water use or plant stress. Crops have specific response to shading and for blocking part of the sky to energy and airflow, for the good and for the bad.

As for stakeholders, both growers said that they are ready to install APV panels despite of yield loss to ensure the steady and riskless income streams of power generation. This is probably one of the reasons of reluctance of the regulators to permit APV in orchards: Growers might abandon the trees in case of adverse market conditions and global warming, leaving the land bare.

FIGURE 9 - AERIAL VIEW IN GALILEE PILOT AREA

FIGURE 10 - CROSS ROW RADIOMETER IN GALILEE PILOT AREA

5.2 Assessment of the outcomes of the different NBS selected

Main positive results of partial shading in two fruit crops – Japanese pear at Ayelet Hashahar and nectarines at Yiftah – were reduced water use, however that was accompanied by yield loss and adverse physiological effects such as delay in getting into and coming out of dormancy. Some of those effects are cause by the shading, others are caused by the physical obstruction of the inter row of air flow and radiation to clear skies.

6 NBS selected in “Tarquinia” Pilot area (Italy)

6.1 Description of NBS selected

In the Tarquinia plain pilot, the main objective is to develop a design for NBS bundles and engage in discussions with a broader group of stakeholders to evaluate their feasibility. We will incorporate NBS as a fundamental component of the System Dynamic Model and integrate it into the process of constructing the desired visions, which will be achieved through a visioning exercise. However, NBS Bundles will not be directly implemented to address the identified challenges within the LENSES scope From the catalogue of Nexus related NBS to be evaluated in light of local context were identified the following several types, specific to the study area:

- Type 1 – Better use of protected/natural ecosystems
- Type 2 – NBS for sustainability and multi-functionality of managed ecosystems
- Type 3 – Design and management of new ecosystems

The identified potential NBS to address challenges are the following:

Type 1- Protection and conservation strategies in terrestrial, marine, and coastal areas ecosystems

- Limit or prevent specific uses and practices
- Ensure continuity with ecological network (protection from fragmentation)
- Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction
- Maintain and enhance natural wetlands

Monitoring

- Assessment of NBS benefits
- Ecosystem services evaluation methods
- Regular monitoring of bio-indicators

Type 2 - Agro-ecological practices

- Soil improvement and conservation measures
- Change crop rotations
- Agro-ecological network structure
- Mulching
- Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage
- Produce and integrate biochar into agricultural soils

- Use soil conservation measures: Cover crops; Deep-rooted plants and minimum or conservation tillage; Agroforestry; Wind breaks
- Enrichment planting in degraded and regenerating forests
- Forest patches

Type 3 - Ecological restoration of degraded terrestrial ecosystems

- Systems for erosion control
- Soil and slope revegetation
- Strong slope revegetation
- Plant trees/ hedges/perennial grass strips to intercept surface run-off
- Re-vegetation of riverbanks
- Floodplain restoration and management
- Hedge and planted fence
- Flower strips

6.2 Assessment of the outcomes of the different NBS selected

In the Tarquinia pilot area, researchers have undertaken a comprehensive assessment to identify suitable NBS for addressing the environmental challenges specific to the region. Through an extensive evaluation process, a range of NBS options has been compiled, taking into account the unique characteristics of the area, such as water provisioning, water purification, erosion control, and water flow regulation.

However, the selection and implementation of NBS cannot be carried out in isolation. Recognizing the importance of local knowledge and engagement, a participatory approach has been emphasized to ensure that the chosen NBS align with the needs and aspirations of the Tarquinia community. By involving local stakeholders, such as farmers, landowners, and residents, in the decision-making process, a collaborative environment is fostered, promoting a sense of ownership and shared responsibility for the successful implementation of NBS.

A crucial element in the success of an environmentally sustainable water use project is community awareness and involvement. Goals in this area include educating people about global water issues, promoting responsible water use practices, and actively involving people in planning and implementing sustainable strategies. Through education programs, awareness campaigns and public participation initiatives, it aims to create widespread awareness of the importance of water and the actions needed to preserve it.

7 NBS selected in "Doñana" Pilot area (Spain)

7.1 Description of NBS selected

In order to achieve sustainable management of natural resources in the Doñana region, it is imperative to prioritize the optimization of the WEF Nexus. As part of a research effort, NBS have emerged as a pivotal tool for promoting landscape sustainability, facilitating re-naturalization efforts, enhancing water use efficiency in agriculture, and driving socio-economic development. However, it is important to note that the implementation of NBS in the pilot area does not currently have practical intentions.

The following NBS solutions are highly suitable for addressing the challenges faced in the area:

NBS for ecosystem restoration:

Type 3—**design and management of new ecosystems, and specifically in the category of the Restoration and creation of semi-natural water bodies and hydrographic networks.**

NBS types:

1 **Restore wetlands in areas of groundwater recharge:**

- Objective: Restore and enhance wetland ecosystems in regions where groundwater recharge occurs.
- Approach: This involves the restoration and conservation of wetland habitats, such as marshes, swamps, and bogs, which act as natural sponges and help replenish groundwater reserves. By restoring these wetlands, it enhances their capacity to absorb and retain water, thus contributing to groundwater recharge and maintaining sustainable water resources.

2 Reconnect rivers with floodplains to enhance natural water storage:

- Objective: Reestablish the connection between rivers and their floodplains to promote natural water storage.
- Approach: This strategy focuses on restoring the natural hydrological connectivity between rivers and adjacent floodplains. By allowing rivers to naturally overflow onto floodplains during high-water periods, it enhances water storage capacity, reduces the risk of downstream flooding, and promotes the natural filtration and purification of water through the floodplain vegetation.

3 Remaindering rivers or streams and re-opening blue corridors:

- Objective: Restore natural meandering patterns to rivers or streams and create "Blue corridors" for ecological connectivity.
- Approach: Remaindering involves recreating the original sinuous course of a river or stream, which enhances its ecological functionality by improving water flow, promoting sediment transport, and creating diverse habitats. Re-opening Blue corridors refers to restoring and connecting fragmented aquatic habitats to form continuous corridors for aquatic species, facilitating migration, genetic exchange, and overall ecosystem health.

4 Floodplain restoration and management:

- Objective: Restore and manage floodplain areas to improve their ecological and hydrological functions.
- Approach: This strategy involves restoring and conserving floodplain ecosystems, including wetlands, marshes, and riparian vegetation. Floodplain restoration aims to maintain the natural dynamics of

flooding, allowing the floodplain to act as a temporary storage area during high-water events. Proper management practices consider floodplain vegetation, floodwater diversion, and sediment deposition, helping mitigate flood risks, support biodiversity, and enhance water quality.

These NBS approaches contribute to sustainable water management by utilizing natural processes and ecosystem services to restore and enhance the functionality of aquatic ecosystems, benefiting water resources, biodiversity, and overall environmental well-being.

NBS for optimization in the use of resources for agriculture and increase of biodiversity.

Type 2 – **NBS for sustainability and multifunctionality of managed ecosystems and specifically in the category of Agricultural landscape management**

NBS types:

1 **Agro-ecological practices:**
- Objective: Promote sustainable agricultural practices that work in harmony with the environment.
- Approach: Agro-ecological practices focus on the integration of ecological principles into agricultural systems. This includes techniques such as organic farming, crop rotation, agroforestry, and integrated pest management. These practices aim to enhance soil health, biodiversity, and ecosystem resilience while minimizing the use of synthetic fertilizers and pesticides.

2 **Soil improvement and conservation measures:**
- Objective: Enhance soil quality and prevent soil erosion.
- Approach: This involves adopting various measures to improve and conserve soil, such as terracing, contour plowing, and strip cropping. These techniques help reduce soil erosion caused by water runoff and wind, which helps maintain the integrity of agricultural land and prevents sedimentation in water bodies.

3 **Increase soil water holding capacity and infiltration rates:**
- Objective: Improve the ability of soil to retain water and allow for efficient water infiltration.
- Approach: Methods to increase soil water holding capacity and infiltration rates include adding organic matter (such as compost or manure) to improve soil structure, reducing compaction through proper land management practices, and implementing techniques like cover cropping. These practices help retain more water in the soil, reducing water runoff and enhancing water availability for crops.

4 **Agro-ecological network structure:**
- Objective: Establish interconnected ecological networks within agricultural landscapes.
- Approach: Creating an agro-ecological network structure involves designating areas within agricultural landscapes for habitat restoration, biodiversity conservation, and ecological connectivity. This can include the establishment of wildlife corridors, native plant buffers, and protected areas that support beneficial organisms and promote ecosystem services.

5 **Mulching:**
- Objective: Preserve soil moisture, reduce weed growth, and enhance soil health.
- Approach: Mulching involves applying a layer of organic or inorganic material (such as straw, wood chips, or plastic sheets) to the soil surface around plants. Mulch helps retain moisture, suppresses weed growth, moderates soil temperature, and improves soil structure by increasing organic matter content.

6 **Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage:**

- Objective: Improve soil fertility and increase carbon sequestration in agricultural systems.
- Approach: By incorporating organic materials such as manure, compost, biosolids, or crop residues into the soil, carbon-rich organic matter is added. This enhances soil fertility, improves nutrient cycling, and promotes the long-term storage of carbon in the soil, contributing to climate change mitigation efforts.

Type 1—better use of protected/natural ecosystems: protection and conservation strategies in terrestrial, marine, and coastal areas ecosystems

NBS types:

- Ensure of continuity of ecological networks (protection from fragmentation)

7.2 Engaging Stakeholders and Assessing NBS Feasibility in the Doñana Pilot Area

The NBS outlined in the document will serve as a valuable foundation for the discussions with the stakeholders. By presenting the NBS approaches, their benefits, and the proposed bundling options, the aim is to foster a comprehensive understanding among the stakeholders of the potential advantages and challenges associated with each solution. This participatory approach will allow for a thorough examination of the technical, environmental, social, and economic aspects, ensuring that the final decisions align with the specific needs and aspirations of the pilot area.

Furthermore, the inclusion of NBS solutions as a core element of the System Dynamic Model underscores their significance in shaping the desired visions for the pilot area. By integrating NBS into the visioning exercise, a holistic and forward-thinking approach is adopted to address the complex challenges at hand. The visioning process will facilitate the identification of synergies, trade-offs, and innovative opportunities that can arise from the strategic implementation of NBS solutions.

The engagement of stakeholders ensures that their perspectives, expertise, and local knowledge are integrated into the design and implementation of NBS strategies. Through this collaborative process, the pilot area can develop a robust and context-specific framework that maximizes the potential benefits of NBS while addressing the unique challenges and opportunities present in the area.

By fostering a sense of ownership and shared responsibility among the stakeholders, the aim is to create a long-lasting impact that goes beyond the pilot area. The insights gained from this collaborative process can serve as a valuable learning experience, informing future NBS initiatives in other regions and fostering a culture of sustainable development and environmental stewardship.

8 NBS selected in "Koiliaris" Pilot area (Greece)

8.1 Description of NBS selected

The main objectives of implementing the WEF Nexus approach in the Koiliaris River watershed are to establish a sustainable landscape, optimize the interactions between water, energy, and food systems, and focus on the socio-economic development of the ecosystem. This approach aims to integrate and manage the interdependencies between water, energy, and food sectors, considering their interactions and impacts on social and economic aspects.

Strategies for NBS in the Koiliaris River watershed include:

1. NBS for erosion control and ecosystem restoration:
    - Implementation of erosion control systems.
    - Revegetation of soil and slopes.
    - Strong revegetation measures for steep slopes.
    - Planting trees, hedges, or perennial grass strips to intercept surface run-off.
    - Utilization of pre-existing vegetation.
2. NBS for the restoration and creation of semi-natural water bodies and hydrographic networks:
    - Re-vegetation of riverbanks.
    - Restoration and management of floodplains.
3. NBS for agricultural development:
    - Adoption of agro-ecological practices.
    - Implementation of soil improvement and conservation measures.
    - Enhancement of soil water holding capacity and infiltration rates.
    - Incorporation of manure, compost, biosolids, or crop residues to enhance carbon storage.
    - Enrichment planting in degraded and regenerating forests.
    - Implementation of hedges and planted fences.

These strategies aim to address the challenges of soil erosion, ecosystem degradation, and the need for sustainable agricultural practices.

8.2 Assessment of the different NBS selected

The assessment of the NBS implementation will be done using mathematical models (Deliverable 5.4). It will be used the Karst-SWAT model in order to quantify the impacts of erosion control NBS measures to sediment loads and sediment export from the basin and the impact of livestock free grazing on the water quality of the river as well as the 1D-ICZ (Integrated Critical Zone) model to access the impacts of agro-ecological practices on ecosystem services.

In addition, TUC has conducted field measurements on biological and non-biological avocado farms to illustrate how agro-ecological practices (NBS – carbon addition) improve soil aggregation and soil structure, decrease bulk density, increase soil porosity and the water holding capacity, improve soil fertility and soil biodiversity. In other words, this field experiment illustrates how the NBS of agro-ecological practices improves the WEF Nexus of agricultural systems.

As part of a project funded by the Region of Crete, TUC has conducted the design of a riparian forest restoration and flood protection (Lilli et al., 2020) that has been used by LENSES to conduct a techno-economic analysis and business model that are presented in other WPs.

The main barriers to implementation of the NBS in this pilot area are legislative, economic, technical and social (Lilli et al., 2020).

As far as the legislative barriers, there is a lengthy approval process for the preliminary study that involves multiple institutions with conflicting objectives and for the technical approval process for implement the NBS solutions.

The identification of funding mechanisms for both financing the study as well as the restoration work is a major barrier especially under conditions of economic austerity. Technical barriers to implementing NBS can manifest both from the perspective of the remediation company (i.e., lack of knowledge to design the restoration of riparian forest) as well as from the governmental agency that issues the permits (i.e., lack of knowledge to approve the design resulting in potential delays in permitting). A significant social barrier is the acceptance of local stakeholders and farmers, for example to reclaim agricultural area and restore the riparian forest.

The development of a global vision for agricultural development of the area and its linking with the environmental benefits, and also the creation of a decision-making approach to designing and implementing NBS are the drivers to overcome the barriers and enhance the social acceptability of the NBS implementation.

9 Socio-economic evaluation

The adoption of NBS has high importance because it allows for managing ecosystems providing a broad range of services benefitted by humans, and that improve ecosystem resilience to disturbances. These services are referred to as "Ecosystem Services" (ES). One relevant aspect of ES is that most of them, above all many regulating and cultural ES, do not have an explicit economic value. A lack of, or inadequate, ES valuation can lead to the overexploitation of resource stocks, result in poorly informed decisions in the design of policies, projects or investments, and finally lead to an unfair spreading of the benefits proceeding from ES. For this reason, implementing a socio-economic valuation of ES is essential in considering and developing NBS.

To operationalize an ES-based approach to the WEF Nexus and assess socio-economic benefits deriving from the adoption of NBS, a general methodological framework was developed, presented to the pilots and then tested for the Koiliaris river area in north-western Crete (Greece).

The methodological framework developed and reported in Work Package 6 (Bottaro et al., 2022) has been summarized hereafter.

The first step has involved an in-depth literature review about ES definitions, classification systems, and ES-based approaches to define the conceptual background of the framework. Local experts and managers have identified the multiple challenges faced within each pilot in relation to the WEF Nexus. The challenges were linked to one or more ES and/or non-ES strategies. The latter consists of consumption and management options, policies, or governance of natural resources. For each identified ES, tailored socio-economic indicators were selected to assess ES supply and related economic value.

The focus on the ES allows us to associate those NBS that can better address the pilot' challenges, with the ES they provide. Moreover, being capable of assessing ES a comparison among NBS is possible.

Finally, a cost-benefit analysis (CBA) related to ES benefits via-a-vis the NBS implementation and maintenance costs has been structured in order to identify among a basket of selected NBS the ones which offer larger amount of ES (and related economic benefits) suited to mitigate the challenges.

The framework has been presented to the pilot leaders within the monthly participative activities of February 2023 promoted by Working Package 2 and during the plenary meeting of March 2023 in Israel and Jordan. Through these, a first list of ES to be evaluated and some NBS suggestions were obtained. The information reported in Table 2 shows the ES prioritization and NBS suggested at the current stage of the framework implementation in all the project's pilots.

TABLE 1 - STATE OF ART OF PILOTS' ES PRIORITISATION AND NBS CONSIDERATION.

Pilot	Prioritised ES	NBS
Doñana (ES)	water purification, lifecycle maintenance	NBS for ecosystem restoration; NBS for optimization in the use of resources for agriculture and increase of biodiversity
Koiliaris (GR)	moderation of extreme events (flood protection), climate regulation,	Riparian forest
Pinions (GR)	food provisioning, water provisioning, climate regulation, water flow	Agroecological practices; increase soil water holding capacity and infiltration rates; soil improvement and conservation measures; incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon

	regulation, lifecycle maintenance	storage; mulching; use of soil conservation measures (cover crops)
Gediz (TK)	food provisioning, water provisioning, water flow regulation	We don't implement NBS in our study area. However, we will suggest possible NBS recommendations to stakeholders and farmers.
Narc (JO)	Reduce soil salinization and land degradation	Application of crop rotation, improve irrigation management and improvement of forage and silage quality.
Tarquinia (IT)	water provisioning, water purification, water flow regulation, erosion control	We don't implement NBS in our study area. We identified the NBS, but we don't have experimental site in the area.
Hula (IS)	food provisioning, water provisioning, water flow regulation	Thinking of agrovoltaic (not NBS)

As can be seen, each pilot is at a different stage of the work and consequently the socio-economic assessment also reached different steps for the different pilots.

For Koiliaris pilot it was possible to implement the whole framework including the cost-benefit analysis due to clarity in the definition of NBS and data availability.

Therefore, the framework was tested for the case study of Koiliaris river, assuming the restoration of a riparian forest as the targeted NBS. Due to the explorative nature of the study, the benefits associated to the selected NBS focused on a subset of ES, namely moderation of extreme events and climate regulation via carbon sequestration. ES supply was assessed via InVEST 3.9.1 models. As for the economic valuation, the replacement cost method was used for the moderation of extreme events, and the market price method for climate regulation. Costs considered included implementation and maintenance costs (assumed to be equal to 5% of the implementation costs) of the selected NBS. A 3.5% discount rate was considered (Dicks et al. 2020) over a 20 year-long period.

Table 3 reports the outcomes of the biophysical evaluation of ES supply and economic value, while table 5 summarizes the outcomes of the CBA. ES have been evaluated according to a "*with and without*" approach, i.e., as a difference between values accounted under the NBS scenario and the baseline conditions.

To calculate the economic value of the moderation of extreme events a lamination basin has been used as substitute good, assuming an average unit cost of 400€/m3. The economic value for climate regulation has been calculated considering an average market price per ton of CO2 (7.70€ per tCO2eq).

TABLE 2 - MODERATION OF EXTREME EVENTS AND CLIMATE REGULATION ASSESSMENT UNDER THE BASELINE AND NBS SCENARIO.

	1. **Baseline (without NBS scenario)**	2. **With NBS scenario**	**B-A**	**€**
Retained runoff volume (m^3)	17,931.96	20,620.84	2,688.88	1,075,554.07.
Carbon storage (tons of CO_2)	5,977.32	5,819.71	21,358.35	164,459.32

TABLE 3 - OUTCOMES OF THE COST-BENEFIT ANALYSIS.

Net present value (€)	Benefit/cost ratio	Internal rate of return	Payback period (years)
11,364,940.45	7.67	40.49%	5

A more detailed description of the CBA can be found in Project's Deliverable 6.1 (Bottaro et al., 2022).

The test allowed validating and calibrating the framework, confirming it can be effectively run at the pilot scale, though being strongly tied to data availability. Since this study is a preliminary implementation of the framework and further refinements might occur, results should be considered with caution. A precautionary approach might consist in lowering – according to a given buffer – the expected benefits to consider possible adverse events – either naturally occurring or human-induced – that might affect ES supply and value over time. Nonetheless, though considering only two out of the many possible ES delivered as co-benefits by the selected NBS, the CBA shows that socioeconomic benefits exceed the costs.

The proposed framework and the methodology described represent a practical solution to support decision making and to guide the selection of NBS, however they should not be considered as stand-alone tools, rather they should be integrated with other approaches, including participatory ones to include stakeholders' needs and preferences when planning, designing, and implementing NBS solutions.

10 Conclusions

This document provides a summary of the assessment of Nature-Based Solutions (NBS) implemented in LENSES pilot areas. The primary objective of these NBS is to establish sustainable landscapes that optimize the interactions between water, energy, and food systems while promoting socio-economic development. The assessment highlights the importance of tailoring strategies to specific local contexts and addresses challenges related to food provisioning, water resource management, and ecosystem restoration.

In the Pinios pilot area, the focus is on adopting agroecological practices, improving soil quality, and enhancing water retention capacity. The Gediz pilot area emphasizes NBS for food provisioning, water provisioning, and water flow regulation. The Deir Alla pilot area explores potential NBS solutions for food provisioning and water resource management. The Galilee pilot area considers the implementation of agrovoltaic systems, combining agricultural production with solar energy generation. The Tarquinia pilot area focuses on water provisioning, purification, flow regulation, and erosion control. The Doñana pilot area prioritizes water purification, lifecycle maintenance, and ecosystem restoration. The Koiliaris pilot area targets riparian forest restoration for moderating extreme events and regulating climate.

The assessment identifies barriers to NBS implementation, such as legislative, economic, technical, and social challenges. It emphasizes the importance of integrated approaches and stakeholder involvement to overcome these barriers effectively. The study also incorporates socio-economic evaluation by valuing ecosystem services provided by the implemented NBS, demonstrating their positive socio-economic benefits for sustainable development and resilience in the water, energy, and food sectors.

Overall, by implementing NBS tailored to their specific contexts, these pilot areas can achieve sustainable development goals while effectively managing their water, energy, and food systems.

11 References

Bottaro, G., Righetti, C., Masiero, M., Pettenella, D. (2022). Socio-economic indicators and framework for Nexus-relevant NBS. Project6.1. PRIMA LENSES project.

Dicks J, Dellaccio O, Stenning J (2020) Economic costs and benefits of nature-based solutions to mitigate climate change. Final Report. Cambridge Econometric, UK.

European Commission (2015) Nature-Based Solutions & Re-naturing Cities. Final Report of the Horizon 2020 Expert Group on ‘Nature-Based Solutions and Re- Naturing Cities’. Directorate-General for Research and Innovation–Climate Action, Environment, Resource Efficiency and Raw Materials.

Hoff J (2011) Understanding the nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus, Bonn, Germany, 16–18 November 2011, Stockholm Environment Institute (SEI): Stockholm, Sweden.

Lilli, M.A.; Nerantzaki, S.D.; Riziotis, C.; Kotronakis, M.; Efstathiou, D.; Kontakos, D.; Lymberakis, P.; Avramakis, M.; Tsakirakis, A.; Protopapadakis, K.; et al. (2020). Vision-Based Decision-Making Methodology for Riparian Forest Restoration and Flood Protection Using Nature-Based Solutions. Sustainability 2020, 12, 3305. https://doi.org/10.3390/su12083305

Malamataris, D., Pisinaras, V., Babakos, K., Chatzi, A., Hatzigiannakis, E., Kinigopoulou, V., Hatzispiroglou, I. & Panagopoulos, A. (2023). Effects of Weed Removal Practices on Soil Organic Carbon in Apple Orchards Fields. *Environmental Sciences Proceedings*, 25(1), 25.

Scott CA, Crootof A, Kelly-Richards S (2016) The urban water-energy nexus: drivers and responses to global change in the ‘urban century. Environmental Resource Management and the Nexus Approach: Managing Water, Soil, and Waste in the Context of Global Change. Hettiarachchi H, Ardakanian R (eds) (Berlin: Springer), pp 113–40

SoilGrids – Global Gridded Soil Information. Available from: https://soilgrids.org/ (accessed 15 December 2022).

Tsakmakis, I., Babakos, K., Chatzi, A., Pisinaras, V., Brogi, C., Bogena, H., Dombrowski, O. & Panagopoulos, A. (2023). Precision Irrigation Scheduling through High Frequency Data Monitoring. Implementation in Apple Orchard Cultivations – central Greece. EGU General Assembly 2023, Vienna, Austria.

Annex I: List of candidate NBS that can be used for optimizing the WEF Nexus, defined in deliverable 5.2

Type 1 – Better use of protected/natural ecosystems

Protection and conservation strategies in terrestrial (e.g. Natura2000), marine (e.g. MPA), and coastal areas (e.g. mangroves) ecosystems
Limit or prevent specific uses and practices
Ensure continuity with ecological network (protection from fragmentation)
Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction
Maintain and enhance natural wetlands
Protect remaining intertidal muds, saltmarshes and mangrove communities, seagrass beds, and vegetated dunes from further degradation, fragmentation, and loss.
Natural Protected Area network structure
Mangrove forests protected area MPA network structure
Monitoring
Assessment of NBS benefits
Ecosystem services valuation methods
Regular monitoring of bio-indicators

Type 2 – NBS for sustainability and multifunctionality of managed ecosystems

Agricultural landscape management
Agro-ecological practices
Use grazing management and animal impact as farm and ecosystem development tools
Change crop rotations
Soil improvement and conservation measures
Increase soil water holding capacity and infiltration rates
Agro-ecological network structure
Mulching
Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage
Produce and integrate biochar into agricultural soils
Enrichment planting in degraded and regenerating forests
Forest patches
Hedge and planted fence
Flower strips
Use soil conservation measures - Cover crops
Use soil conservation measures - Wind breaks
Use soil conservation measures - Deep-rooted plants and minimum or conservation tillage
Promote agroforestry
Coastal landscape management

Encourage development of early successional sand dune habitats (dry dunes and wet slacks) where carbon sequestration rates are high. Enhance or facilitate habitat expansion, including the facilitated range expansion of mangroves, as warming conditions and changes in storm occurrence permit. Integrated coastal zone management

Type 3 – Design and management of new ecosystems

Ecological restoration of degraded terrestrial ecosystems
Quarry restoration Phytoremediation Systems for erosion control Soil and slope revegetation Strong slope revegetation Replace hard engineered river stabilisation with softer alternatives (e.g. willow-based) Plant trees/ hedges/perennial grass strips to intercept surface run-off Use of pre-existing vegetation
Restoration and creation of semi-natural water bodies and hydrographic networks
Restore wetlands in areas of groundwater recharge Reconnect rivers with floodplains to enhance natural water storage Re-vegetation of riverbanks Re-meander rivers (where they have been artificially straightened) to help reduce speed and height of flood peaks Restore grassland/low input arable in drinking water catchments Use engineered reedbeds/wetlands for tertiary treatment of effluent Target ponds/wetland creation to trap sediment/pollution runoff in farmed landscape Constructed wetlands and built structures for water management Rivers or streams, including remeandering, re-opening Blue corridors Floodplain restoration and management
Ecological restoration of degraded coastal and marine ecosystems
Create new intertidal habitat through afforestation, or planting of saltmarsh or seagrass at appropriate elevations in the tidal frame Restore micro-topography, creek networks, sediment inputs, and nutrient exchange in abandoned aquaculture ponds. Re-establish and restore previous intertidal habitat by de-poldering or coastal realignment Ecological restoration of degraded coastal and marine ecosystems Coastal sand engine Dune replenishment