the LENSES project

## LEarning and action alliances for NexuS EnvironmentS in an uncertain future

# LENSES

## WP5

# D5.2 Roadmap to navigate the available catalogues of Nature-based Solutions and finalised list of candidate NBS

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# Table of Contents

# List of figures



# List of tables

# List of acronyms

***NBS:*** *Nature-Based Solutions*
***F:*** *Food, crops, wild foods and spices*
***W:*** *Water*
***P:*** *Pharmaceuticals, biochem. & industry. Products*
***E:*** *Energy*
***CS&R****: Carbon sequestration & climate regulation*
***WP:*** *Water purification*
***AQ:*** *Air quality regulation*
***EP:*** *Erosion prevention*
***FP:*** *Flood protection*
***MP&H:*** *Maintaining populations & habitats*
***P&DC:*** *Pest and disease control*
***CP:*** *Crop pollination*
***N:*** *Nutrient dispersal & cycling*
***R:*** *Recreation*
***I:*** *Intellectual and aesthetic appreciation*
***S:*** *Spiritual and symbolic appreciation*

# Roadmap to navigate the available catalogues of Nature-based Solutions and finalised list of candidate NBS

## Introduction

WP 5 aims to provide the methodological and practical foundations for the selection of a suite of solutions that use Nature-based Solutions (NBS) as an underlying principle to a Nexus approach. The objective of Task 5.1 was to undertake a critical review of existing frameworks for evaluating options for adaptation/building a resilient Water-Ecosystem-Food (WEF) Nexus for rural areas. The aim of the review was to identify commonalities and gaps in existing frameworks in relation to addressing the WEF Nexus, as well as their applicability at different spatial scales. Following the review of the framework landscape, a draft WEF-Nexus-appropriate framework for evaluating options for increasing resilience was developed. The LENSES WEF Nexus Evaluation framework presented in Deliverable 5.1 will be used for the development of the Nature-Based Solutions WEF Nexus Tool as part of Task 5.3.

The objective of Task 5.2 was to identify the potential role of NBS for addressing the challenges and opportunities for a resilient nexus, building on the challenges identified within the pilots (WP 2/8) and identifying the ecosystem services component of the challenge. A roadmap to help the pilots navigate the landscape was also developed. In this Task and the present Deliverable, the preliminary application of the LENSES WEF Nexus Evaluation framework to each pilot was conducted.

# Roadmap to navigate the available catalogues of NBS

The WEF Nexus-appropriate framework for evaluating options for increasing resilience was developed and presented in Deliverable 5.1 of the LENSES project. Figure 1 presents the conceptual design of the LENSES evaluation framework. For the design of the LENSES NBS WEF NEXUS Evaluation Framework, a list of NBS type (under each NBS category) that are appropriate for the use of the WEF Nexus was selected and is presented in the Annex of this report.

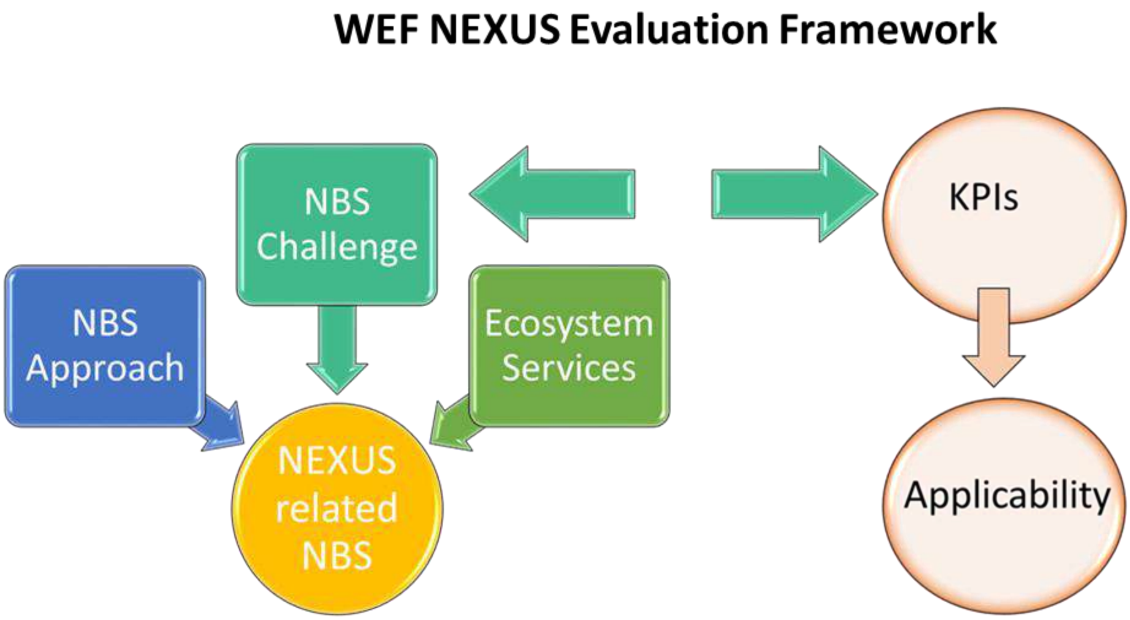



*Figure 1 Design of WEF NEXUS evaluation framework*

In this framework, the NBS practitioner has to follow a stepwise approach, which phases are described below and represented in Figure 2.

1. **Develop a vision for the landscape in consultation with the local stakeholders.** The first phase of the methodology is the development of a vision for the landscape. This vision drives the project and the potential local stakeholders to achieve consensus and overcome the many barriers that will rise from its implementation. To develop such a vision, it is important to identify the environmental and ecological problems of the area in order to define a holistic approach for solving them that would give added value to the region and enhance its resilience. This vision brings local stakeholders and the decision-makers on board in order to materialize the project (Lilli et al., 2020).
2. **Identify the challenges the area/basin under consideration is facing regarding the Water-Ecosystem-Food Nexus.** These challenges can be viewed at this stage separately for each component of the Nexus.
3. **Select WEF Nexus appropriate NBS bundles**. Use the list of Nexus appropriate NBS presented in the Annex and tables 4-10, developed in Deliverable 5.1 and select a primary list of appropriate NBS that address the vision for the landscape and the challenges.

4. **Apply the WEF NEXUS Evaluation Framework**. Identify the desired ecosystem services to obtain from the landscape as well the approaches needed to improve ecoystem services. These selections should be consistent with the vision identified in step 1.
5. **Evaluate the list of potentially applicable NBS** that contribute to more than one component of the WEF Nexus.
6. **Identify related Key Performance Indicators (KPIs)** for each NBS selected.
7. **Conduct stakeholder consultation** (focus groups) on the selected WEF optimized NBSs
8. Revise list and follow the same steps until the NBS list that **optimize the WEF Nexus** is finalized.

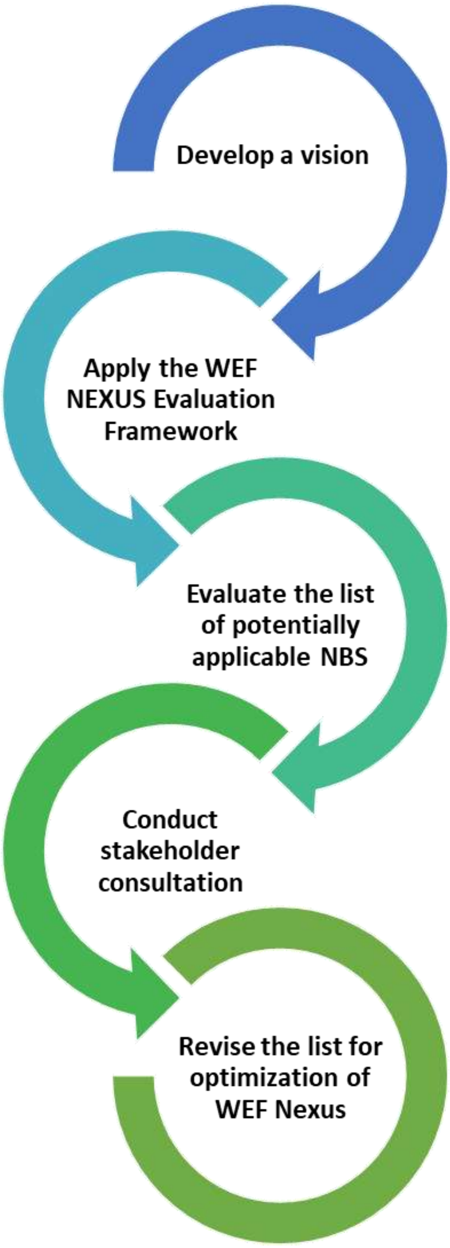



*Figure 2 Roadmap to help the pilots to navigate the landscape*

# Application to pilots

This section presents the preliminary application of the LENSES WEF Nexus Evaluation framework to each pilot. The detailed analysis of the components as well as the design of the Framework was presented in Deliverable 5.1.

## Pilot 1a: Koiliaris CZO, Chania, Greece

### *Vision*

The Koiliaris River watershed is a Critical Zone Observatory (CZO) (www.koiliaris-czo.tuc.gr) on the island of Crete and part of the European Long Term Ecological Research (eLTER) Network and the LTER-Greece Network, and has been extensively studied over the past 15 years. Research output from the Koiliaris CZO has been used to put together the scientific puzzle on the Mediterranean geo-environmental functions and develop the tools for sustainable water and land management. In addition, the active stakeholder involvement in the research and applied activities for water management and agricultural activities taking place in Koiliaris CZO has recognized the Technical University of Crete (TUC) and our research team as an "institution", accepted by the local people. TUC has been the "catalyst" for social consensus in solving local societal problems (Lilli et al., 2020).

The Koiliaris River watershed represents severely degraded soils due to heavy agricultural impacts, including grazing, over many centuries. It represents Mediterranean soils under imminent threat of desertification (i.e., soil carbon loss) due to climate change that is predicted by the UN IPCC for the region over the next century. The valley is prone to flooding of the riparian forest and agricultural area. Flash flooding is caused by high precipitation events that exceed the infiltration rate of the karst (Yu et al., 2019) and generate significant quantities of surface runoff. The main type of soil degradation in the basin is water erosion, which is due to the clearing of forests and natural vegetation for cropping and livestock grazing. De-vegetation and inappropriate cultivation practices induces soil organic matter losses making soils susceptible to erosion and desertification with global consequences for food security, climate change, biodiversity, water quality, and agricultural economy.

The main objectives of the WEF Nexus implementation in the Koiliaris River watershed are:

- Sustainable landscape
- Optimized WEF Nexus
- Focus on social-economic ecosystem development

### *Main sectoral challenges regarding the WEF Nexus*

Ultimate challenges along with the related important issues for each specific WEF Nexus component and water sub-basin are presented as follows.

**Water:** the ultimate challenge is to improve the water resources management of the watershed.

The important issues related to water in Koiliaris CZO are summarized as follows:

- Lack of one managing authority of water resources (Development Organization of Crete, Municipality of Apokoronas, Farmers Irrigation Cooperative, Water Authority of Crete).
- High fluctuation of the spring flow between winter and summer – prone to drought periods – cannot rely on groundwater wells from upgradient.

<u>Avocado Farmers:</u>
- Mostly drip irrigation.
- Mixing of spring water with high Cl concentrations – conflict between Development Organization of Crete and farmers.
- Lack of infrastructure – small reservoir with quality water.
- During drought periods it is difficult to satisfy irrigation requirements in part of the pilot area.

<u>Valley:</u>
- Irrigation with water of low quality because of high salinity.
- Competitive water uses between irrigation, tourism and local drinking water use – areas with insufficient water supply.

**Ecosystems:** the ultimate challenge is to improve ecosystem services.

The important issues related to ecosystems in Koiliaris CZO are summarized as follows:

- Significant livestock impacts especially in NATURA areas – Livestock capacity 1-2 animals/ha versus actual 10-14 animals/ha.
- Significant erosion due to soil management practices (tillage) even in areas with high slope.
- Urbanization impacts on the springs – villages without sewage system are built on the springs.
- Intensive agriculture with high amount of input used, such as fertilizers, pesticides and herbicides.
- Abandoned terraces – contribution to erosion and soil degradation.

It should be noted that local morphology, precipitation gradient, climatic gradient (with elevation) promotes above ground biodiversity.

**Food:** the ultimate challenge is Sustainable agricultural development.

The important issues related to food in Koiliaris basin are summarized as follows:

- Higher elevation – olive groves, vineyards.
- Low elevation, valley – olive groves, citrus, avocado (emerging), vegetables, animal feed.
- Small farm lots– no economy of scale.
- No profit for citrus and low for olive oil.
- Avocado is a dynamic new crop with good price.
- Farmers do not have formal training.
- Unsustainable agricultural practices – deep soil tillage.
- Farmers get information from agronomists who sell fertilizers and other farmers at the coffee shops

## *Primary list of appropriate Nature-Based Solutions*

The most appropriate NBS solutions for addressing the abovementioned challenges are listed below:

**NBS for erosion control and ecosystem restoration**

➢ NBS types dealing with the design and management of new ecosystems, and specifically in the category of the ecological restoration of degraded terrestrial ecosystems (Type 3):

- Systems for erosion control
- Soil and slope revegetation
- Strong slope revegatation
- Plant trees/ hedges/perennial grass strips to intercept surface run-off
- Use of pre-existing vegetation

➢ NBS types dealing with the design and management of new ecosystems, and specifically in the category of the restoration and creation of semi-natural water bodies and hydrographic networks (Type 3):

- Re-vegetation of riverbanks
- Floodplain restoration and management

**NBS for agricultural development**

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

- Agro-ecological practices
- Soil improvement and conservation measures
- Increase soil water holding capacity and infiltration rates
- Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage
- Enrichment planting in degraded and regenerating forests
- Hedge and planted fence

## *NBS approaches, challenges and ecosystem services identification*

Table 1 through Table 3 present the categorization of NBS selected for Koiliaris CZO according to the NBS approaches (Table 1), NBS challenge to be solved (Table 2) and ecosystem services provided by the NBS (Table 3). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 1 Categorization of NBS selected for Koiliaris CZO according to NBS approaches.*

| **NEXUS related NBS** | **NBS APPROACH (A2)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate adaptation approaches** | **Community based adaptation** | **Ecosystem based adaptation** | **Ecosystem based management** | **Ecosystem based mitigation** | **Ecosystem based disaster risk reduction** | **Ecological engineering** | **Ecological restoration** | **Infrastructure related approaches** | **Natural resources management** | **Sustainable agriculture/agro-forestry/aquaculture** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | |
| Agro-ecological practices | x | | | x | | x | | x | | | x |
| Soil improvement and conservation measures | x | | | x | | x | | | | | x |
| Increase soil water holding capacity and infiltration rates | x | x | x | x | | x | | x | | | x |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | x | | x | x | | x | | x | | | x |
| Enrichment planting in degraded and regenerating forests | x | | x | x | x | x | | x | | | x |
| Hedge and planted fence | | | | x | | | | | | | x |
| *Type 3 – Design and management of new ecosystems* | | | | | | | | | | | |
| ***Ecological restoration of degraded terrestrial ecosystems*** | | | | | | | | | | | |
| Systems for erosion control | x | | | | | x | x | x | | | |
| Soil and slope revegetation | x | | | | | x | x | x | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Strong slope revegetation | x | | | | | x | x | x | | | |
| Plant trees/ hedges/perennial grass strips to intercept surface run-off | x | | | | | x | x | x | | | |
| Use of pre-existing vegetation | x | | | | | x | | x | | | |
| ***Restoration and creation of semi-natural water bodies and hydrographic networks*** | | | | | | | | | | | |
| Re-vegetation of riverbanks | x | | x | x | x | x | x | x | | x | |
| Floodplain restoration and management | x | | x | x | x | x | x | x | | x | |

*Table 2 Categorization of NBS selected for Koiliaris CZO according to NBS challenge to be solved.*

| **NEXUS related NBS** | **NBS CHALLENGE (A3)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate resilience** | **Water management** | **Natural and Climate Hazards** | **Green space management** | **Biodiversity enhancement** | **Air quality** | **Place regeneration** | **Knowledge & Social Capacity Building for Sustainable Rural Transformation** | **Participatory planning and governance** | **Social justice and social cohesion** | **Health and well-being** | **New economic opportunities and green jobs** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | | |
| Agro-ecological practices | x | x | | | x | x | | | x | x | | x |
| Soil improvement and conservation measures | x | | | | x | | | | x | x | | x |
| Increase soil water holding capacity and infiltration rates | x | x | | | | | | | x | x | | x |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | x | | | | x | | | | | | | x |
| Enrichment planting in degraded and regenerating forests | x | x | x | | x | x | x | | x | x | x | |
| Hedge and planted fence | | | | | x | x | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Type 3 – Design and management of new ecosystems* | | | | | | | | | | | | |
| ***Ecological restoration of degraded terrestrial ecosystems*** | | | | | | | | | | | | |
| Systems for erosion control | **x** | | **x** | | **x** | | | | | | **x** | **x** |
| Soil and slope revegetation | **x** | | **x** | | **x** | **x** | **x** | | | | | **x** |
| Strong slope revegetation | **x** | | **x** | | **x** | **x** | | | | | | **x** |
| Plant trees/ hedges/perennial grass strips to intercept surface run-off | **x** | **x** | **x** | | **x** | **x** | **x** | | | | **x** | **x** |
| Use of pre-existing vegetation | **x** | | | | **x** | **x** | **x** | | | | **x** | **x** |
| ***Restoration and creation of semi-natural water bodies and hydrographic networks*** | | | | | | | | | | | | |
| Re-vegetation of riverbanks | **x** | **x** | **x** | | **x** | **x** | **x** | | **x** | | **x** | |
| Floodplain restoration and management | **x** | **x** | **x** | | | | **x** | | **x** | | **x** | |

*Table 3 Categorization of NBS selected for Koiliaris CZO according to ecosystem services.*

| **NEXUS related NBS** | **ECOSYSTEM SERVICES (A4)** | | |
|---|---|---|---|
| | **PROVISIONING SERVICES** | **REGULATION & MAINTENANCE** | **CULTURAL** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | |
| ***Agricultural landscape management*** | | | |
| Agro-ecological practices | **(W), (F)** | **(AQ), (WP), (FP), (CS&R), (N), (SFC), (P), (SD)** | **(R), (I)** |
| Soil improvement and conservation measures | **(W), (F)** | **(EP), (CS&R), (SFC), (N), (P)** | **(R)** |
| Increase soil water holding capacity and infiltration rates | **(W)** | **(FP), (EP), (CS&R)** | |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | **(W), (F)** | **(CS&R), (N), (SFC), (P), (SD)** | **(R)** |
| Enrichment planting in degraded and regenerating forests | **(W)** | **(MP&H), (CS&R), (EP), (FP), (CP)** | **(R), (I)** |
| Hedge and planted fence | **(W), (F)** | **(MP&H), (CS&R), (N), (P&DC)** | **(R), (I)** |
| *Type 3 – Design and management of new ecosystems* | | | |

| | | | |
|---|---|---|---|
| ***Ecological restoration of degraded terrestrial ecosystems*** | | | |
| Systems for erosion control | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H), (SFC), (P)** | **(R), (I)** |
| Soil and slope revegetation | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H), (CP),(SFC), (P), (N)** | **(R), (I)** |
| Strong slope revegetation | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H), (CP),(SFC), (P), (N)** | **(R), (I)** |
| Plant trees/ hedges/perennial grass strips to intercept surface run-off | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H), (CP),(SFC), (P), (N)** | **(R), (I)** |
| Use of pre-existing vegetation | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H), (CP), (SFC), (P), (N), (SD)** | **(R), (I)** |
| ***Restoration and creation of semi-natural water bodies and hydrographic networks*** | | | |
| Re-vegetation of riverbanks | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H),(SFC), (N), (SD), (AQ)** | **(R), (I)** |
| Floodplain restoration and management | **(W), (F)** | **(EP), FP), (MP&H)** | **(R), (I)** |

## NBS Preliminary Design for Koiliaris CZO

The main challenges that need to be addressed in Koiliaris CZO, focus on 3 geographic areas within the basin (depicted with yellow (1), red (2) and blue color (3) in Figure 3) and relate to different pressures derived from land management namely, intensive cultivation, soil degradation and livestock grazing. A detailed description of the challenge to be solved in each area follows:

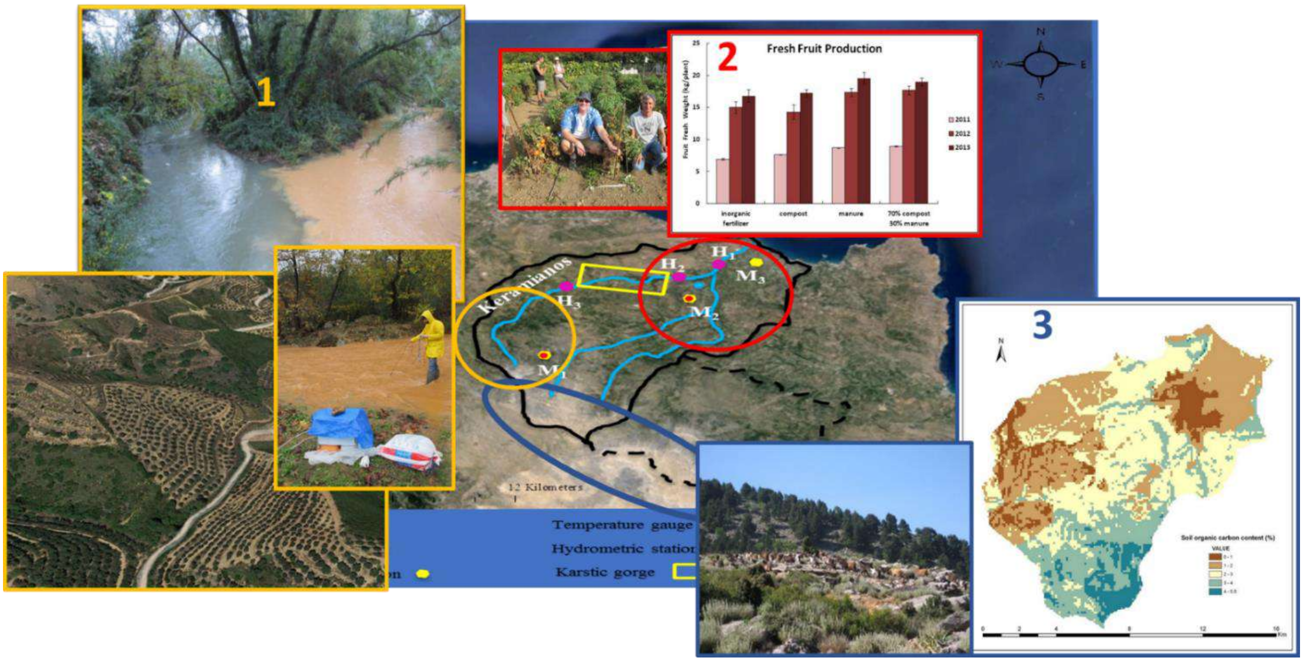


*Figure 3 Approximate extent of the areas of the watershed related to the main challenges to be addressed at the Koiliaris CZO*

**1) Intense soil degradation -** A temporary tributary (Keramianos) and a temporary spring (Anavreti), along with two episodic tributaries, contribute to the Stylos spring discharge to form the Koiliaris river. The two episodic tributaries drain the eastern part of the watershed, while the temporary tributary (Keramianos) flows over the western part.

The Keramianos tributary drains a small sub-catchment that generates surface runoff due to the schist geologic formation of the area. Keramianos stream flows along a karstic gorge (Diktamos gorge) and then over an alluvial plain before joining the Koiliaris river (Figure 3). Schist formations are quite friable and in combination with the steep slopes and the adaptation of intensive agricultural practices that are common in the area of Keramianos sub-basin, the top soil becomes extremely brittle and easily erodible. More specifically, due to the abandonment of traditional agricultural practices over the years, tractors now enter and plow the terraces, leading occasionally to their collapse, and exacerbating the erodibility of the soils. In addition, overgrazing leaves the top soil unprotected and vulnerable to surface runoff. Thus, Keramianos is the main tributary responsible for the bulk of the sediment transport in Koiliaris River (Sibetheros et al., 2013). On the other hand, waters derived from the karstic springs, have a relatively constant – low – concentration. Only two to four times a year, during flood conditions when daily precipitation at the meteorological station M1 (Figure 3) exceeds 120 mm (Kourgialas et al., 2010), the Keramianos tributary actually merges with the Stylos Springs flow, transferring significant loads of suspended sediment. For precipitation rates lower than this threshold, Keramianos disappears into the karstic gorge (Nerantzaki et al., 2015).

Significant areas of Keramianos sub-basin has intense soil degradation that is related to the cultivation of olive trees in steep slopes (see photo in Figure 3). The olives have been planted in terraces with out the associated stone walls, allowing in this way the soil to erode. Nerantzaki et al. (2015) have estimated that 63-70% of the sediment transport (wet and dry year respectively) is generated during flood events and originates from the Keramianos sub-basin. The annual erosion rate ranges between 0.55 to 1.6 ton/ha/yr for the sub-basin. This intense erosion rate is also causing land degradation and reduction of soil fertility.

**2) Agricultural practices and soil degradation -** During the first few years after conversion from forest or grassland to crop land, rapid loss of bio-available carbon and nitrogen and deterioration of soil stability has been observed, accompanied by a significant shift in soil fertility. The Cretan landscape has been transformed during the past 50-60 years from a low intensity agrarian landscape with low impact agricultural practices, and high bio-diversity, to a mechanized, high intensity agriculture and properties with monocultures. Agricultural practices have been the primary cause of land degradation (Soil tillage, no organic matter addition to soil, high pesticide and herbicide use). The map in Figure 3 shows that the soil organic carbon content is low in Koiliaris river basin, and primarily in areas 1 and 2 (0-2%), where the land is cultivated. Recycling of crop residue to soils and organic matter addition is the only way towards sustainable agriculture (graph in Figure 3). Soil fertility improves faster if in addition to bio-fertilization, farmers use traditional agricultural practices such as crop rotations and legume row plantings within olive trees and orchards (Nikolaidis, 2011).

**3) Biodiversity degradation due to free-grazing livestock -** The Koiliaris river basin offers a unique morphologic situation due to its karstic hydrogeology draining the upland grazing areas through karstic springs. Approximately 25000 sheep/goats are grazing in the karstic highlands of Koiliaris river (Figure 3), causing significant livestock impacts. Thus, sheep and goats' free grazing create environmental pressures and significant loss of biodiversity at the higher elevations of the basin.

**Proposed NBS Bundles**

As part of the modelling task of WP 5.4, we will use the following NBS bundles to these three areas in order to optimize the WEF Nexus. Below is the preliminary list of potentially applicable NBS that contribute to more than one component of the WEF Nexus and related challenges. The NBS can contribute to 1) erosion control, 2) biodiversity protection and 3) soil regeneration strategies that can be applicable in Koiliaris CZO. Table 4 presents recommended KPIs for each category of NBS proposed.

**1) NBS bundle for erosion control – Focus on olive groves**

- Vegetated stonewalls for terrace restoration and soil protection.
- Soil revegetation below the olive trees- terraces.
- Fertilization of olive groves with organic matter for soil structure regeneration.
- Plant trees and hedges at lower part (bufferzone) of the slope before river.

**2) NBS for high elevation biodiversity protection**

- Remove environmental pressures from sheep and goat free grazing
  - ➢ Move to lower elevation to animal house
  - ➢ Utilize manure
  - ➢ Let the system regenerate

**3) NBS bundles for soil regeneration**

- Adopt agro ecological practices.
- Use soil organic matter, organic fertilization and conservation measures for soil improvement.
- Incorporate manure, compost, biosolids, or crop residues to enhance carbon storage.
- Implement the riparian forest restoration project.

The selected NBS will enhance the Water-Ecosystem-Food Nexus of the watershed. The methodologies used to irrigate based on the demands of the tree and not on an aerial basis will reduce water consumption. In addition, soil organic matter incorporation in the soil will improve soil structure and increase soil water retention. The organized management of livestock will let the natural regeneration of biodiversity in high elevations while it will provide manure for the organic fertilization of the agricultural fields in the valley. Agroecological practices will also enhance the biodiversity in the valley. Finally, the regenerated soil will increase soil fertility and biomass production. These NBS will enhance the WEF Nexus and improve the life and well-being of the people in the area. A preliminary selection of KPIs is presented in Table 4. These KPIs should be monitored after the implementation of the NBS in order to evaluate their efficacy.

*Table 4 Preliminary selection of KPIs for each category of NBS in Koiliaris CZO*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS bundle for erosion control** | Carbon storage and sequestration in vegetation and soil | kg/ha/y |
| | Soil organic matter | % |
| | Infiltration rate and capacity | % or mm/h and mm/d |
| | Soil water available for plant uptake | mm/cm depth |
| | Total Predicted Soil Loss | t/ha/y |
| | Erosion risk | $m^3/y$ |
| **NBS for high elevation biodiversity protection** | Number of species within defined area | Number |
| | Biodiversity conservation | various |
| **NBS bundles for soil regeneration** | Carbon storage and sequestration in vegetation and soil | kg/ha/y |
| | Soil organic matter | % |

# Pilot 1b: Pinios River Basin Hydrologic Observatory, Greece

## *Vision*

Pinios River Basin (PRB) constitutes the most productive agricultural water basin of Greece, and the national Water Framework Directive pilot basin, covering more than 80% of the whole Water District of Thessaly (EL08). Agricultural sector is the dominant water user accounting for more than 90% of total water consumption, while the irrational surface and ground water over-abstraction has resulted in tremendous groundwater table decline, and seasonally preservation of ecological flow. The increasing risk of local water resources shortage and water quality deterioration, along with the presence of NATURA 2000 protected areas, the significant contribution of the local agricultural sector to national Gross Domestic Product, and the localized approach of the social structure, highly prioritize the need for adapting PRB to changing conditions.

A special research attention is paid to two watersheds of PRB, namely the Agia watershed which is the core of the Pinios Hydrologic Observatory (PHO) (Pisinaras et al., 2018), and the Pinios River Delta (PRD). Regarding the Agia watershed, apart from agriculture which is the dominant economic activity, food-processing industries, and tourism activities along the coastline of Agia and Tempi Municipalities constitute also significant economic activities. The main crops cultivated are orchards, while annual crops are also found. In PRD, agricultural along with touristic activities significantly support the local society. The dominant crop is corn, followed by wheat, sunflower, kiwi fruit, cotton, alfalfa, and olives.

The main objectives of the WEF Nexus implementation in the PRB are:

- Sustainable water resouces management
- Optimized WEF Nexus
- Focus on the sustainability of agricultural sector and social-economic ecosystem development

## *Main sectoral challenges regarding the WEF Nexus*

Land fragmentation, increased production costs, limited mechanization and modernization of agricultural production, and lack of well-organized cooperatives or groups facilitating integrated production to marketing operations threaten the viability of the farming sector, especially in the uncertainty of climate change and the limited access to investment capital.

Ultimate challenges along with the related important issues for each specific WEF Nexus component and water sub-basin are presented as follows.

> **Water:** The ultimate challenge is to improve the water resources management approach. The most important related issues per each sub-basin of interest are summarized as follows:
  - Agia watershed:
    - Uneven spatiotemporal distribution of groundwater resources.
    - Over-exploitation of groundwater resources for irrigation.

        - Limited efficiency of irrigated water networks and systems. Current practices assessment indicate cases with more than 40% excess irrigation water application. This is attributed to the fact that irrigation is practiced empirically, disregarding weather forecasts and often psychologically influenced by heat waves or droughts that not always impact severely on available soil water content.
        - Irrigation water needs are difficult to be satisfied in some areas during drought periods. Especially for the northern part of the aquifer, irrigation needs through groundwater exploitation are hardly satisfied after late July/early August

    - Pinios River Delta:
        - Medium to high sensitivity to droughts since crop water needs are satisfied through capillary rise in some areas. This is especially true for kiwi fruits which is the most dynamic agricultural product in the area.
        - Limited awareness of farmers regarding the significant contribution of capillary rise to crop water needs fulfillment. Previous studies (Pisinaras et al., 2021) indicate that capilary rise can contribute up to almost 300 mm to crop water requirements.

- **Ecosystems:** The ultimate challenge is to conserve, restore and maintain ecosystems along with their services at a good status. The most important related issues per each sub-basin of interest are summarized as follows:
    - Agia watershed:
        - Improper management of agricultural inputs.
        - Wide application of pesticides at a high percentage of the cultivated land affecting soil organic matter content.
        - Limited application of environmental friendly agricultural practices including cover crops, mulching and crop reidues’ incorporation.
    - Pinios River Delta:
        - Limited application of environmentally friendly agroecological practices, such as conservation tillage, cover crops and mulching.
        - High pressure to significant ecosystems, including NATURA 2000 areas, caused mainly by agricultural activities.

- **Food:** The ultimate challenge is to maintain or increase agricultural production, while reducing agricultural costs. The most important related issues per each sub-basin of interest are summarized as follows:
    - Agia watershed:
        - Fruit production such as apples, cherries and chestnuts, along with their exports to several countries inside and outside of EU should be maintained and improved.
        - High agricultural production cost, impacted by the significant increase in energy costs that in turn affect considerably the prices of agrochemicals (fertilizers, plant protection products, etc)
    - Pinios River Delta:

- High productivity of the plain area should be secured to further support the local economy.
- Kiwi-fruit production is rapidly expanded on the eastern part of the sub-basin, and constitutes a very dynamic and high water consuming activity that requires irrigation water of high quality.

## *Primarily list of appropriate NBS*

The most appropriate NBS for addressing the abovementioned challenges are listed below:

- **In the case of Agia watershed:**

  **NBS for irrigation practices improvement**

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

    NBS type:

    - Agroecological practices.

  **NBS for agroecological practices improvement**

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

    NBS types:

    - 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.

- **In the case of Pinios River Delta:**

  **NBS for irrigation practices improvement**

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

    NBS type:

    - Agroecological practices.

**NBS for agroecological practices improvement**

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

  NBS type:
  - Soil improvement and conservation measures.
  - Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage.
  - Mulching.
  - Use soil conservation measures – Cover crops.

## *NBS approaches, challenges and ecosystem services identification*

Table 5 through Table 7 present the categorization of NBS selected for PRB according to the NBS approaches (Table 5), NBS challenge to be solved (Table 6) and ecosystem services provided by the NBS (Table 7). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 5 Categorization of NBS selected for both watersheds (PRB pilot) according to NBS approaches.*

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate adaptation approaches** | **Community based adaptation** | **Ecosystem based adaptation** | **Ecosystem based management** | **Ecosystem based mitigation** | **Ecosystem based disaster risk reduction** | **Ecological engineering** | **Ecological restoration** | **Infrastructure related approaches** | **Natural resources management** | **Sustainable agriculture/agro-forestry/aquaculture** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | |
| Agro-ecological practices | x | | | x | | x | | x | | | x |
| Increase soil water holding capacity and infiltration rates | x | x | x | x | | x | | x | | | x |
| Soil improvement and conservation measures | x | | | x | | x | | | | | x |
| Incorporating manure, compost, biosolids, or | x | | x | x | | x | | x | | | x |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| incorporating crop residues to enhance carbon storage | | | | | | | | | | | |
| Mulching | x | | x | x | | x | | x | | | x |
| Use soil conservation measures – Cover crops | x | | | x | | x | | x | | | x |

*Table 6 Categorization of NBS selected for both watersheds (PRB pilot) according to NBS challenge to be solved.*

| **NEXUS related NBS** | **NBS CHALLENGE (A3)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate resilience** | **Water management** | **Natural and Climate Hazards** | **Green space management** | **Biodiversity enhancement** | **Air quality** | **Place regeneration** | **Knowledge & Social Capacity Building for Sustainable Rural Transformation** | **Participatory planning and governance** | **Social justice and social cohesion** | **Health and well-being** | **New economic opportunities and green jobs** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | | |
| Agro-ecological practices | x | x | | | x | x | | | x | x | | x |
| Increase soil water holding capacity and infiltration rates | x | x | | | | | | | x | x | | x |
| Soil improvement and conservation measures | x | | | | x | | | | x | x | | x |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | x | | | | x | | | | | | | x |
| Mulching | x | | | | x | | | | | | | x |
| Use soil conservation measures – Cover crops | x | | x | | x | x | | | | | | |

*Table 7 Categorization of NBS selected for both watersheds (PRB pilot) according to ecosystem services.*

| NEXUS related NBS | ECOSYSTEM SERVICES (A4) | | |
|---|---|---|---|
| | PROVISIONING SERVICES | REGULATION & MAINTENANCE | CULTURAL |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | |
| ***Agricultural landscape management*** | | | |
| Agro-ecological practices | **(W), (F)** | **(AQ), (WP), (FP), (CS&R), (N), (SFC), (P), (SD)** | **(R), (I)** |
| Increase soil water holding capacity and infiltration rates | **(W)** | **(FP), (EP), (CS&R)** | |
| Soil improvement and conservation measures | **(W), (F)** | **(EP), (CS&R), (SFC), (N), (P)** | **(R)** |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | **(W), (F)** | **(CS&R), (N), (SFC), (P), (SD)** | **(R)** |
| Mulching | **(W), (F)** | **(CS&R), (N), (SFC), (P), (SD)** | **(R)** |
| Use soil conservation measures – Cover crops | **(W), (F)** | **(MP&H), (CS&R), (EP), (CP), (SFC)** | **(R), (I)** |

## *NBS Preliminary Design for Pinios River Basin Hydrologic Observatory*

The main challenges that need to be addressed in Agia watershed and Pinios River Delta are represented in Figure 4, depicted respectively in yellow and green.

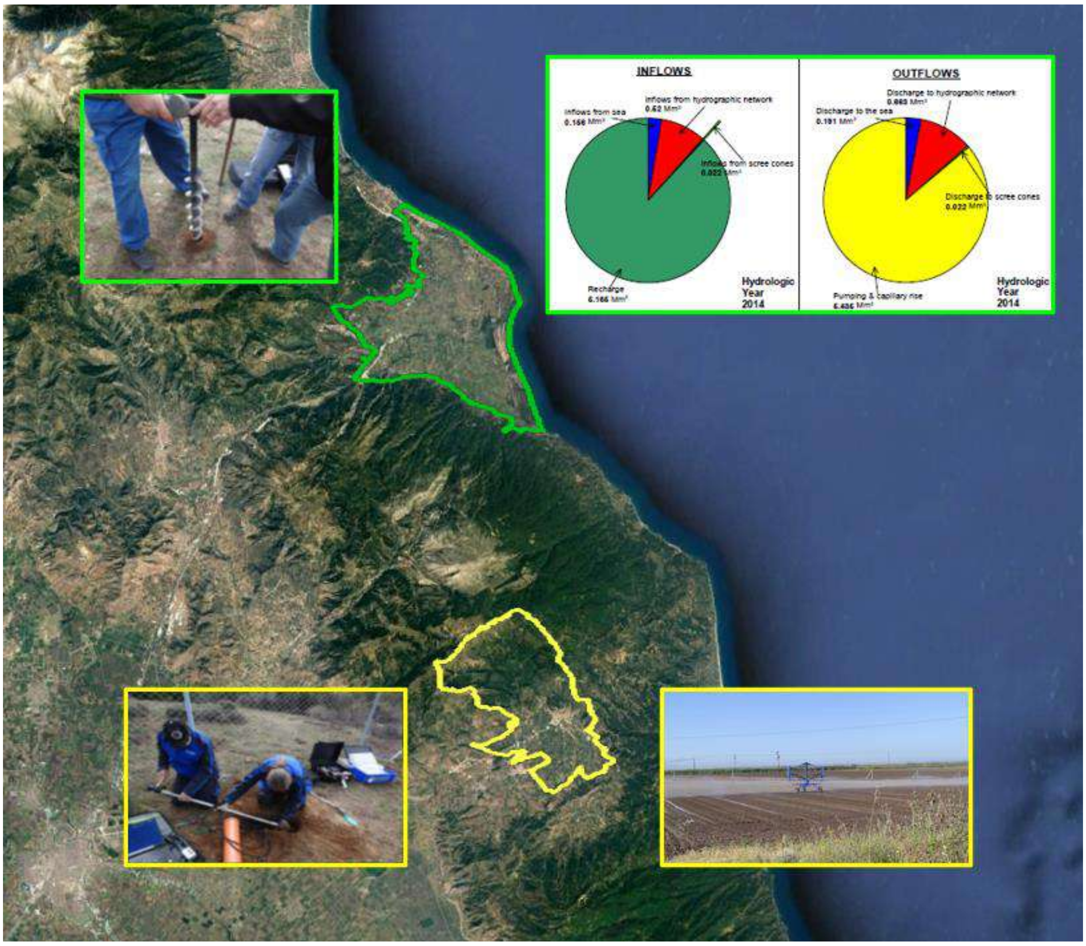



*Figure 4 Main challenges in Pinios River Basin*

The main challenges that need to be addressed in the pilot areas include:

**1) Over-exploitation and irrational management of surface and groundwater resources** – In Agia watershed, intensification of irrigation accompanied by the extensive development of the agricultural sector, started since the 1970s. Excessive groundwater abstractions to sustain expanding irrigated agriculture triggered decline of groundwater level, and quality deterioration. Artesianism that used to be a characteristic of the central and southern plain area sustaining surface flow, is now only apparent in limited parts and at limited months of wet hydrologic years. Uneven spatio-temporal distribution of groundwater resources and even partial water insufficiency during peak irrigation periods is amongst the crucial issues for the basin. Many wells were drilled on the alluvial aquifer situated at the plain southern part of the watershed. On the other hand, a major part of irrigation water for Pinios Delta comes from surface water directly abstracted from Pinios River with ephemeral small dams. This water is further distributed not only with piped networks, but also with open channels that were originally constructed to serve for drainage and therefore water losses are very high. Moreover, water availability for irrigation is directly connected to river water availability, thus indicating the risk for reduced irrigation water availability during drought periods.

**2) Low implementation of agroecological practices for increasing soil organic matter and enhancing soil hydraulic properties** – In both Agia watershed and Pinios River Delta, agroecological practices such as cover crops, mulching and crop residues incorporation to increase soil organic matter are applied at only small agricultural areas in favor of pesticides utilization. This often leads to soil compaction, reduced soil infiltrability and soil organic matter content. Farmers have limited awareness of agroecological practices, such as conservation tillage, mulching and cover crops application that can efficiently enhance not only nutrients' management and increase soil organic matter in the soil, but they can also enhance the hydraulic behavior of soil. Especially for the Pinios River Delta, capillary rise from the shallow aquifer can partially contribute, at about 300mm/y, to meet crop water needs. However, farmers are not aware of the potential of capillary rise even though this leads to reduced irrigation. In parallel, lack of knowledge of the importance of the phreatic aquifer relates to neglecting agrochemicals' management thus adding to the pollution load leaching to the saturated zone.

**Proposed NBS Bundles**

NBS bundles will be applied under a mathematical modeling concept to Agia watershed and Pinios River Delta in order to optimize the WEF Nexus, and contribute to more than one component of the WEF Nexus and related challenges. Moreover, soil organic matter will be monitored in selected fields in Agia watershed that apply agroecological practices and will be compared to others that do not follow such practices. NBS bundles can contribute to 1) improving water resources management, thus avoiding irrational use often reaching over-exploitation, through the application of well-developed and operational irrigation scheduling algorithms; 2) increasing soil organic matter and enhancing soil hydraulic properties through the quantified results produced both by modelling and monitoring awareness on agroecological practices. Recommended KPIs for each category of NBS proposed in Agia watershed and Pinios River Delta are presented in Tables 8.

*Table 8 Preliminary selection of KPIs for each category of NBS in Agia watershed and Pinios River delta*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS for groundwater resources quantitative restoration** | Depth to groundwater | m |
| | Groundwater exploitation index (GEI) | % |
| | Groundwater level | m below ground surface |
| **NBS for increasing soil organic matter and enhancing soil hydraulic properties** | Measured soil carbon content (only for monitored fields) | ton/ha |
| | Calculated infiltration rate and capacity | % or mm/h and mm/d |
| | Plant-available water | mm/cm depth |
| | Soil water retention capacity | $m^3/m^3$ |

# Pilot 2: Gediz Basin & Delta, Turkey

## *Vision*

The Gediz basin is among the most important agricultural production areas of Turkey. Agricultural areas usually consist of irrigated arable land, but also include forests, pastures wetlands and residential areas. In terms of production capacity, cotton and corn silage are among the main field products in Menemen plain, which is one of the important part of the Gediz basin. In addition, the development of cattle breeding in the basin has also improved the cultivation of forage crops. There is a bird sanctuary and a RAMSAR area in the coastal part of the delta.

The region is facing drought and water shortages due to climate change. One of the most important problems of the Gediz delta is drainage and flooding/ponding in rainy seasons. Agricultural areas are under pressure due to urbanization and industrialization in the region. Competitive (agricultural, urban and industrial) use of water resources causes water scarcity. The most important problem in agricultural areas at the outlet of the delta is soil salinity. Moreover, soil degradation and pollution due to intensive agriculture will threaten agricultural lands in the future.

## *Main sectoral challenges regarding the WEF Nexus*

Ultimate challenges along with the related important issues for each specific WEF Nexus component and water sub-basin are presented as follows.

**Water,** major challenge is to improve the water resources management of the basin.

Essential challenges related to water in the Gediz delta are summarized as follows:

- Difficulties in reaching quality water due to administrative deficiencies in water distribution.
- In the coastal parts of the Gediz Pilot area, the salt concentration of the groundwater has increased due to the sea water intrusion.
- Widespread use of surface irrigation methods, since the irrigation network in the Menemen Plain section of the pilot area is not suitable for pressurized irrigation systems.
- Fluctuation in water reserve and water scarcity due to drought.
- Use of low quality water (drainage water), for agricultural irrigation in dry periods.
- Increasing stress on underground water resources due to excessive water losses in the irrigation network.
- Since the Menemen plain is located at the outlet of Gediz, the water pollution load is high.
- Lack of knowledge of farmers about irrigation management.

**Ecosystem:** preserve and develop/improve the ecosystem.

Essential challenges related to Gediz Delta and ecosystems are summarized as follows:

- Soil degradation in agricultural lands due to incorrect agricultural practices (excessive tillage, fertilization, pesticide and herbicide applications, etc.).
- Urbanization effects/pressures on agricultural lands.

- Increase in groundwater level and salinity due seawater intrusion.
- Protected areas (RAMSAR, Bird Paradise) are subject to shrinkage due to water scarcity.

**Food:** the ultimate challenge is sustainable agricultural development.

Important food-related challenges in the Gediz Delta are summarized as follows:

- Instability in product prices reduce producer profit and product diversity.
- Agricultural lands  are not cultivated due to inadequate land consolidation.
- The regional farmers stick to their production pattern (Cotton, Maize).
- Decreases in product variety and yield due to drought, water scarcity and input costs.

## *Primarily list of appropriate NBS*

The most appropriate NBS solutions for addressing the abovementioned challenges are listed below:

### 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.

### 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

## *NBS approaches, challenges and ecosystem services identification*

Table 9 presents the categorization of NBS selected for Gediz delta according to the NBS approaches. This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 9 Categorization of NBS selected for Gediz Basin according to NBS approaches.*

| **NEXUS related NBS** | **NBS APPROACH (A2)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate adaptation approaches** | **Community based adaptation** | **Ecosystem based adaptation** | **Ecosystem based management** | **Ecosystem based mitigation** | **Ecosystem based disaster risk reduction** | **Ecological engineering** | **Ecological restoration** | **Infrastructure related approaches** | **Natural resources management** | **Sustainable agriculture/agro-forestry/aquaculture** |
| *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 | | | | X | | | | | | X | |
| Maintain and enhance natural wetlands | X | X | X | X | X | | | X | | | |
| Natural Protected Area network structure | | | X | X | X | X | | X | X | | |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | |
| Agro-ecological practices | X | | | X | | X | | X | | | X |
| Change crop rotations | | | | X | | | | | | | X |
| Soil improvement and conservation measures | X | | | X | | X | | | | | X |
| Agro-ecological network structure | X | | | X | | X | | X | | | X |
| Increase soil water holding capacity and infiltration rates | X | X | X | X | | X | | X | | | X |
| Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage | X | | X | X | | X | | X | | | X |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Use soil conservation measures - Deep-rooted plants and minimum or conservation tillage | X | | X | X | X | X | | | X | | X |
| ***Coastal landscape management*** | | | | | | | | | | | |
| Integrated coastal zone management | X | | | X | | X | | X | | | |

## *NBS Preliminary Design for Gediz Basin & Delta*

Main challenges that need to be addressed in Gediz Basin & Delta (Figure 5) are focused on 4 areas within the basin.

**Agricultural practices and soil degradation:** Due to intensive agriculture, soils are exposed to excessive fertilizers, pesticides and tillage. Over irrigation and insufficient drainage combined with surface irrigation cause soil salinity. In addition, crop rotation is not preferred in the region, therefore causing soil exhaustion. Moreover, wastes from urbanization and industrialization create significant pollution. In the Menemen pilot area, before and after the irrigation water table measurements indicate that the water table depths vary between 83-158 cm in agricultural lands and between 51 and 150 cm in coastal areas. The groundwater salinity (EC) in these areas varies between 1.64-2.42 in the inland and 6.66-7.69 in the coastal regions. Also, high sodium concertation are observed in Tuzçullu subregion.

**Natural protected area and growing pressure of urbanization on farmland:**

Rapidly increasing population and industrialization in the region cause continuous the loss of agricultural lands. Natural protected areas (RAMSAR, Bird Paradise) are subject to shrinkage due to water scarcity. Another issue in regard of urbanization is private gardens which use significant amount of water at the expense of agricultural uses.

**Water management:**

Menemen plain is located on the downstream side of Gediz basin. Irrigation of Menemen plain is managed by two irrigation unions, Right Bank and Left Bank. Irrigation water for the Menemen left bank irrigation land (which is pilot area) is supplied from Emiralem Regulator. The length of the main canal is 10 km, 5 secondary canals is 304 km and the tertiary canals are 145 km in total. Also, there is a drainage channel length of 256 km. In addition to all these, total irrigation area of the Menemen plain is 16500 ha. In dry periods, there is a problem in the supply of irrigation water occasionally. Annual water distribution planning is carried out by the Irrigation Association according to water availability data received from DSI.

*Figure 5 Main WEF related challenges in Gediz Basin & Delta*

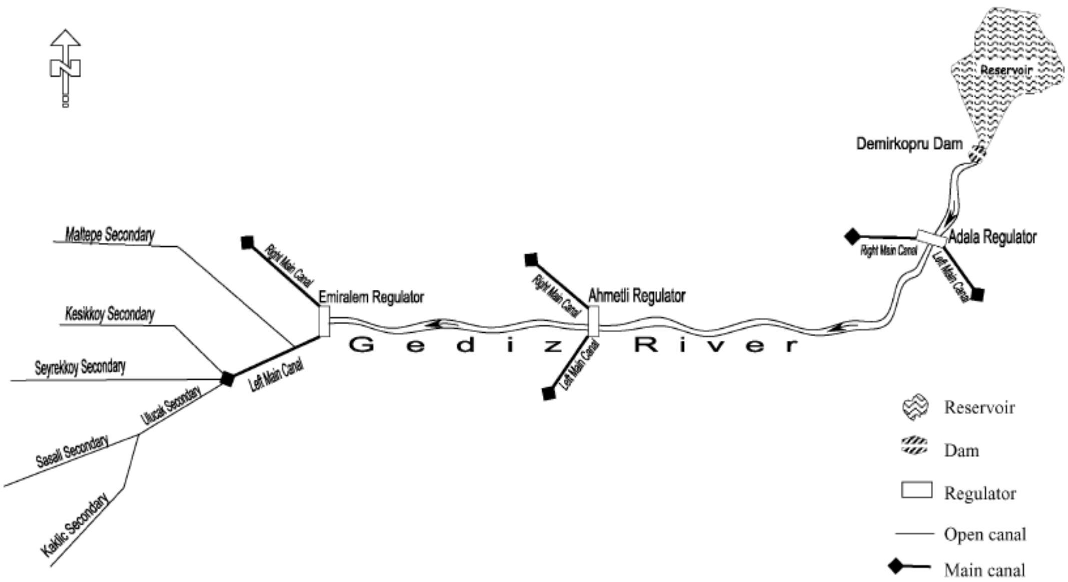



*Figure 6 Gediz River Irrigation Network*

Water losses are quite high due to the inadequate infrastructure of irrigation systems. Surface irrigation methods are commonly used because infrastructures of the agricultural irrigation network are not suitable for modern irrigation methods. The scarcity of water experienced during the irrigation season also causes problems in water quality. Administrative problems and inadequacy of water distribution infrastructure cause yield losses due to water scarcity in the periods when the plant needs water the most. Further to that in areas where adequate irrigation water cannot be provided therefore producers are forced to use poor quality drainage water.

If the available water volume is less than the total water demand in the region, challenges arise in water distribution planning. Apart from the planned water distribution of the network, there are also uncontrolled water wells.

**Climate Change and drought:**

Yield losses are experienced due to the decrease in irrigation water and drought. Climate change forces farmers to change their production pattern and this leads income losses. According to the drought study conducted with 63 years of data, 32 years of drought were found in different degrees in the region (Kayam Y. et.al, 2017). Further issue related the effective drought measure is lack of practices aimed for the preservation of soil moisture in the Menemen Plain.

## *Preliminary design of NBS bundles*

We will apply NBS Bundles to these four areas in order to optimize the WEF Nexus. Below is the preliminary list of potentially applicable NBS that contribute to more than one component of the WEF Nexus and related challenges. The NBS can contribute to 1) soil regeneration, 2) biodiversity protection and 3) water management 4) climate change & drought can be applicable in Menemen Pilot area. Table 10 presents recommended KPIs for each category of NBS proposed.

**NBS bundle for sustainability and soil regeneration by Agricultural practices- Focus on Soil and Water Management**

- Increase of crop rotation practices.
- Use of soil organic matter, organic fertilization and conservation measures for soil improvement.
- Avoiding excessive irrigation causing salinity.
- Dissemination of conservation agricultural practices (adequate and balanced fertilization, reduced tillage).
- Planning the disposal of soil pollutants.

**NBS bundle for Sustainability of agricultural land and protected natural ecosystem**

- Mitigation and monitoring of possible environmental stress.
- Providing adequate water for the sustainable life in natural protected land.

**NBS bundle for Water management**

- Developing planning and recommendations for the improvement of irrigation infrastructure.
- Promoting modern irrigation methods.

- Crop pattern planning according to available irrigation water.
- Nitrate and pollution monitoring in drain water.
- All stakeholders related to water management would take a more active role in the decision mechanism.

**NBS bundle for Climate Change and Drought**

- Dissemination of drought resistant plant selection.
- Measures to conserve soil moisture.
- Developing existing basin-based drought action plans.

The selected NBS will contribute to the protection of the ecosystem, efficient use of water and ensuring sustainable food supply, especially in the part of the basin that includes the Menemen Plain. In particular, the use of modern irrigation methods instead of excessive and uninformed irrigation will increase the effective use of water and will also help to solve the problem of salinity caused by excessive irrigation.

In the long term, selected NBS will increase the amount and quality of groundwater through other environmental practices, reducing the chemical utilization, increasing soil organic matter, and ultimately improving the sustainability of soil and water.

The selected NBS will also provide continuity in water supply to the Bird Sanctuary, which is the protected ecological area of the basin. Thus, it is aimed to protect population of the region and increase biodiversity. Moreover, it will be determined whether there are other elements that threaten this protected area in the Region, and recommendations for necessary precautions will be developed.

It will be possible to develop existing action plans against climate change and drought, which have been increased their impact in the region in recent years.

A preliminary selection of KPIs is presented in Table 10.

*Table 10 Preliminary selection of KPIs for each category of NBS in Gediz Basin*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **Sustainability and soil regeneration by Agricultural practices** | 2.1.5 Measured soil carbon content | ton/ha |
| | 6.29 Soil Type | unitless |
| | 7.3 Soil organic matter | % |
| **Sustainability of agricultural land and protected natural ecosystem** | 2.6 Total surface area of wetlands | ha |
| | 6.13.1 Urban/residential areas | ha |
| | 6.13.2 Productive areas | ha |
| | 6.14 Natural areas, sites of community importance and special protection areas | ha |
| | 6.15.1 Inhabitants | No/ha |
| | 6.57 Water availability for irrigation purposes | $m^3/y$ |
| | 9.2 Number of native species | Number |

| | | |
|---|---|---|
| | 10.7 Proportion of protected areas | % |
| **Water management** | 3.14 Water Quality – general urban | various |
| | 3.16 Nitrogen and phosphorus concentration or load | % |
| | 3.17 Metal concentration or load | % |
| | 4.15 Evapotranspiration rate | mm/day |
| | 4.31 Water availability for irrigation purposes | $m^3/y$ |
| **Climate Change and Drought** | 1.3 TXx, Monthly mean value of daily maximum temperature | °C |
| | 1.4 TNn, Monthly mean value of daily minimum temperature | °C |
| | 2.5 Soil Temperature | °C |
| | 2.13.1 Mean or peak daytime temperature - Direct temperature measurement | °C |
| | 2.17 Rate of evapotranspiration | mm/day |
| | 2.18 Land surface temperature | °C |
| | 6.50 Standardized Precipitation Index | unitless |

# Pilot 3: Tarquinia plain, Italy

## *Vision*

The Tarquinia Plain has been declared as vulnerable area due the high concentration of nitrates in the groundwater. The availability of water resources for irrigation – mainly surface water from the Marta River – and the soil fertility provoked a fast intensification of the agricultural practices in the area. Due to the current interactions between the local producers and the food market companies, and the current food products prices, farmers seem to be forced to increase the quantity of products, using even more fertilizers. This loop is leading to an even increasing degradation of the soil and groundwater quality.

Two phenomena are activated. On the one hand, the soil degradation process is causing water erosion along the hillslopes, which is somehow exacerbated by the farmers' tillage practices. Former grazeland are often transformed in cultivated land, with tillage operations that do not account for the natural morphology of the territory. The increased sediment transportation in the Marta River is partially caused by the soil erosion. This is having an impact on the riverbed and, consequently, on the flood mitigation. On the other hand, the distributed pollution of the groundwater and the presence of punctual pollution sources – i.e. malfunctioning wastewater treatment plants and irregular wastewater discharges – are affecting the river ecosystem.

The main objectives of the WEF Nexus implementation in the Tarquinia plain are:

- Enhance the sustainability of agricultural practices.
- Protect the local biodiversity.
- Mitigate the flood risk and the soil erosion processes.

## *Main sectoral challenges regarding the WEF Nexus*

In the Tarquinia Plain, the interconnections among the different WEF Nexus sectors are stronger than in the other pilots. I.e. the main issues related to the water cannot be dealt with separately from those related to the food production. As already explain, the main Nexus challenge here is to enhance the sustainability of the local development by reducing the environmental impacts of agricultural practices. Specifically, the main challenge is related to the reduction of the pressures on the water resources – i.e. Marta River and the groundwater body – due to the unsustainable use of chemical products in agriculture.

Regarding the ecosystem, the main challenge is to protect the landscape from the rapid transformation due to the agricultural use of the territory. Protecting the landscape could have a positive impacts on the local biodiversity, and specifically on the wild birds' population.

## *Primarily list of appropriate NBS*

In Tarquinia plain pilot, we are not planning to apply NBS Bundles to identified challenges within the scope of LENSES. Our commitment is to make a design of these bundles and discuss and assess their feasibility with the larger group of stakeholders. Also, NBS will be considered as a core element of the System Dynamic Model and included as part of the construction of the desired visions (i.e. visioning exercise).

**NBS for erosion control and ecosystem restoration**

**Type 1** – Better use of protected/natural ecosystems

*Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems*

NBS types:

- Limit or prevent specific land uses and practices
- Natural Protected Area network structure

*Monitoring*

- Assessment of NBS benefits

**Type 3** – Design and management of new ecosystems

*Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems*

NBS types:

- Systems for erosion control
- Soil and slope revegetation

*Restoration and creation of semi-natural water bodies and hydrographic networks*

- Ecological restoration of degraded coastal and marine ecosystems

**NBS for agricultural development**

**Type 2** – NBS for sustainability and multifunctionality of managed ecosystems

*Agricultural landscape management*

NBS types:

- Agro-ecological practices
- Change crop rotations
- Soil improvement and conservation measures
- Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage
- Agro-ecological network structure

**NBS for flood risk reduction**

*Restoration and creation of semi-natural water bodies and hydrographic networks*

- Re-vegetation of riverbanks

## NBS approaches, challenges and ecosystem services identification

Table 11 through Table 13 present the categorization of NBS selected for Tarquinia Plain according to the NBS approaches (Table 11), NBS challenge to be solved (Table 12) and ecosystem services provided by the NBS (Table 13). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 11 Categorization of NBS selected for Tarquinia Plain according to NBS approaches.*

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate adaptation approaches | Community based adaptation | Ecosystem based adaptation | Ecosystem based management | Ecosystem based mitigation | Ecosystem based disaster risk reduction | Ecological engineering | Ecological restoration | Infrastructure related approaches | Natural resources management | Sustainable agriculture/agro-forestry/aquaculture |
| *Type 1– Better use of protected/natural ecosystems* | | | | | | | | | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | | | | | | | | | |
| Limit or prevent specific land uses and practices | | x | x | x | | | | x | | x | x |
| Natural Protected Area network structure | x | x | x | x | | | | | | x | |
| *Monitoring* | | | | | | | | | | | |
| Assessment of NBS benefits | | x | x | | | x | | | | | x |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| *Agricultural landscape management* | | | | | | | | | | | |
| Agro-ecological practices | x | | x | x | | x | | | | | x |
| Change crop rotations | x | x | x | x | | x | | | | | x |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil improvement and conservation measures | x | | x | x | | | | | | | x |
| Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage | | x | | | | | | | | | x |
| Agro-ecological network structure | x | x | x | x | x | | x | x | | | x |
| ***Restoration and creation of semi-natural water bodies and hydrographic networks*** | | | | | | | | | | | |
| Re-vegetation of riverbanks | x | | x | x | x | x | x | x | | x | |
| *Type 3 – Design and management of new ecosystems* | | | | | | | | | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | | | | | | | | | |
| Systems for erosion control | | | | | | x | | x | | | |
| Soil and slope revegetation | | | | | | x | | x | | | x |
| *Restoration and creation of semi-natural water bodies and hydrographic networks* | | | | | | | | | | | |
| Ecological restoration of degraded coastal and marine ecosystems | | | | | | | | x | | | x |

*Table 12 Categorization of NBS selected for Tarquinia plain according to NBS challenge to be solved.*

| **NEXUS related NBS** | **NBS CHALLENGE (A3)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate resilience** | **Water management** | **Natural and Climate Hazards** | **Green space management** | **Biodiversity enhancement** | **Air quality** | **Place regeneration** | **Knowledge & Social Capacity Building for Sustainable Rural Transformation** | **Participatory planning and governance** | **Social justice and social cohesion** | **Health and well-being** | **New economic opportunities and green jobs** |
| *Type 1– Better use of protected/natural ecosystems* | | | | | | | | | | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | | | | | | | | | | |
| Limit or prevent specific land uses and practices | | | | | | | | x | | | | |
| Natural Protected Area network structure | | | | x | x | | x | | | | | x |
| *Monitoring* | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Assessment of NBS benefits | | | | | | | | x | x | x | x | x |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | | |
| *Agricultural landscape management* | | | | | | | | | | | | |
| Agro-ecological practices | x | | | | | | | x | | | | x |
| Change crop rotations | x | | | | | | | x | | | | x |
| Soil improvement and conservation measures | x | | x | | x | | | x | | | | x |
| Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage | x | | x | | x | | | x | | | | x |
| Agro-ecological network structure | x | | x | | x | | | x | | | x | |
| ***Restoration and creation of semi-natural water bodies and hydrographic networks*** | | | | | | | | | | | | |
| Re-vegetation of riverbanks | | | | | x | | x | | | | | |
| *Type 3 – Design and management of new ecosystems* | | | | | | | | | | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | | | | | | | | | | |
| Systems for erosion control | | | x | | | | | | | | | |
| Soil and slope revegetation | | | x | | | | | | | | | |
| *Restoration and creation of semi-natural water bodies and hydrographic networks* | | | | | | | | | | | | |
| Ecological restoration of degraded coastal and marine ecosystems | x | | x | | x | | x | | | | | |

*Table 13 Categorization of NBS selected for Tarquinia Plain according to ecosystem services.*

| NEXUS related NBS | ECOSYSTEM SERVICES (A4) | | |
|---|---|---|---|
| | PROVISIONING SERVICES | REGULATION & MAINTENANCE | CULTURAL |
| *Type 1– Better use of protected/natural ecosystems* | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | |
| Limit or prevent specific land uses and practices | | **EP, FP, MP&H, N** | |
| Natural Protected Area network structure | **F** | **WP, EP, FP, MP&H, CP** | **R** |
| *Monitoring* | | | |
| Assessment of NBS benefits | | | **I** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | |
| *Agricultural landscape management* | | | |
| Agro-ecological practices | **F** | **EP, MP&H, CP, N** | |
| Change crop rotations | **F** | **EP, MP&H, CP, N** | |
| Soil improvement and conservation measures | **F** | **EP, MP&H, CP, N** | |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | **F** | **EP, MP&H, CP, N** | |
| Agro-ecological network structure | **F** | **WP, EP, MP&H, CP, N** | **R** |
| *Type 3 – Design and management of new ecosystems* | | | |
| *Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems* | | | |
| Systems for erosion control | | **EP, FP, N** | |
| Soil and slope revegetation | | **EP, FP, N** | |
| *Restoration and creation of semi-natural water bodies and hydrographic networks* | | | |
| Ecological restoration of degraded coastal and marine ecosystems | **F, W** | **CS&R, WP, EP, MP&H, CP, N** | **R** |

A preliminary selection of KPIs suitable to monitor the efficacy of NBS, in Italian pilot area, are reported in Table 14.

*Table 14 Preliminary selection of KPIs for each category of NBS in Tarquinia (IT)*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS for erosion control and ecosystem restoration** | Changes in land cover | ha/y |
| | Changes from annual to permanent crop | ha/y |
| | % soil cover | % |
| | Establishment of wind breaks and hedges | Meter or ha |
| | Total Predicted Soil Loss | t/ha/y |
| | Erosion risk | m3/y |
| | Area affected by severe erosion rate (severe soil loss, E > 10 t/ha/y) (source: JRC) | $km^2$ |
| **NBS for agricultural development** | Crop diversification: Number of different crops cultivated in an area | Num/y |
| | Number of farms that use agro-ecological practices | Num/y or ha/y |
| **NBS for flood risk reduction** | Change in surface covered by vegetation near riverbanks | ha/y |
| | Flooded area caused by a 10-years return period flood | $Km^2$ |
| | Flood prevention practices included in riverbanks management strategies at municipality level | Num |

# Pilot 4: Doñana region, Spain

## *Vision*

The Doñana area is located in Southwest Spain within the region of Andalucía and in the Guadalquivir river basin. The core area is the Doñana National Park which occupies the right bank of the Guadalquivir river at its estuary on the Atlantic Ocean, and that is surrounded by a dynamic territory where intensive agriculture has largely expanded in the last 60 years.

The system can be defined as a fluvial–littoral ecosystem whose structure and functions are shaped by the interactions of the Guadiamar and Guadalquivir rivers and the Atlantic Ocean, with four main ecosystem units: marshes, sand dunes, coastal systems, and the estuary (Zorrilla-Miras *et al*., 2014). Through centuries, the human use of these ecosystems (e.g., free-range livestock breeding, hunting, snail harvesting, fishing, and grass cropping for soap and glass making) produced cultural landscapes where multifunctional ecosystems delivered a diverse range of services to society and exceptional ecological values (Gómez-Baggethun et al., 2010; Ojeda, 1987). In this way, one century ago, the hydrological situation of the Doñana region could be considered as almost pristine, with a minimum impact from human activities. However, in this period a number of actions have increased the pressure on the hydrological system, ordered in a chronological order as:

- Eucalyptus planting in large areas where agricultural activity was low (since 1920).
- The drainage of large areas of marshlands to convert them to agriculture, the biggest and most successful effort being the Almonte-Marismas Plan. The full implementation of this plan (promoted by FAO to alleviate hunger in Spain) would have made disappear all the Doñana marshlands. International pressure was crucial to preserve part of the natural area (i.e. WWF international was created as part of this initiative) (since 1910 but since 1950 more intensively).
- Coastal touristic development near the marshlands, in the coastal systems (Matalascañas area) increasing the need of ground-water abstraction for human consumption (since the 1960 decade).
- Berry cultivation in the Rocina stream basin, decreasing groundwater contributions to the marshlands and increasing habitat fragmentation (since the 1980 decade).

The optimization of the WEF nexus is a core issue for a sustainable management of the natural resources in the region. NBSs can play a large role in facilitating this optimization (e.g. increasing sustainability and re-naturalization of the landscape, increasing the efficiency of water use in agriculture or promoting the socio-economic development).

## *Main sectoral challenges regarding the WEF Nexus*

In this section, we aim to provide an initial characterization of the current situation (including developments in the last decades) of water, agriculture, ecosystems, and climate aspects. Ultimate challenges along with the related important issues for each specific WEF Nexus component and water sub-basin are presented as follows.

**Water:** the main uses are crops irrigation and environmental use. There is some use for drinking and energy generation. Data on available water resources and existing water demands is provided in the Guadalquivir river basin Management Plan. A new version of this Plan covering the 2021-2027 period is about to enter into force (being currently under public consultation phase).

Irrigation is the largest water use in the area, and is a conflicting use with the required contribution of water to the Doñana wetlands. In July 2020, the Guadalquivir river basin authority (Confederación Hidrográfica del Guadalquivir – CHG) declared as over-exploited three out of the five groundwater bodies in the Almonte-Marismas aquifer (i.e. Almonte, Marismas and Rocina groundwater bodies) because of the large water abstractions for irrigation, which is the main cause of the deepening of the groundwater levels in a continuous way in the last two decades. The designation of over-exploited aquifer involves the annual approval of water use plans to ensure the sustainable use of groundwater: the CHG defines a maximum quantity of water to be used by land unit.

As a consequence of this over-exploitation, many temporal lagoons and wetlands near the marshlands, which are very dependent on groundwater contribution, are facing serious deterioration in the last years. Also, groundwater discharges into the marshlands (e.g. through the Rocina stream) have largely decreased because of the disconnection between surface water bodies and the aquifer.

Beyond this, the use of fertilizers and pesticides in intensive agriculture is producing a significative impact on the water quality of some water bodies, e.g. Rocina groundwater body.

In this situation, some major challenges are the enforcement of the annual water use plans (whose fulfilment can be strongly supported through more effcient irrigation) as well as a strengthened control of illegal use of water.

**Ecosystems:** Doñana is widely considered as a hotspot in terms of biodiversity and one of the most important wetlands across Europe. It is located in the crossroad of three large biogeographical regions (i.e. European-Atlantic / Mediterranean / African) and is a natural area of paramount importance for migratory birds and several endangered species (e.g. Iberian Lynx). It is included in the UNESCO's Heritage list because of "the great diversity of its biotopes, especially lagoons, marshlands, fixed and mobile dunes, scrub woodland and maquis", as well as for being "one of the largest heronries in the Mediterranean region and is the wintering site for more than 500 000 water fowl each year" (https://whc.unesco.org/en/list/685/), e.g. census from January 2021 estimated 530 000 birds wintering in Doñana.

However, the conservation status of Doñana cannot be considered as good. For example, the Doñana marshlands is included in the RAMSAR list of wetlands of International importance but the area is also enlisted in the Montreux Record; this is a List of Wetlands of International Importance where changes in ecological character have occurred, are occurring, or are likely to occur as a result of technological developments, pollution or other human interferences.

In the last years, the Spanish government has received warnings from the European Union and UNESCO about the Doñana conservation status. Recently (June 2021), the European Union Court of Justice condemned Spain for not being in compliance with the Habitats and Water Directives because of groundwater over-abstraction in the Doñana region.

The main challenge is the conservation and protection of Doñana Natural Space (Doñana National Park plus Doñana Natural Park covering 122 500 ha), threatened by a reduction in water contribution.

**Food:** the ultimate challenge is Sustainable agricultural development.

Agriculture is a key economic activity in this region, providing jobs and income to a large part of the rural population. In terms of crops distribution, we can make a distinction between three areas:

1) the area where the berry production is mainly located. Berry crops (strawberry, blueberry, raspberry and blackberry) have largely extended since the 1980's decade, creating a new industry which has been crucial for the socio-economic development of this area. Berries are grown in greenhouses or under plastic covers and are irrigated with high water doses. This resource-intensive process of berry cultivation has created several environmental problems, in particular deforestation, habitat fragmentation, illegal use of water, and over-abstraction of groundwater resources. There is a Special Plan into force (a land use Plan) which aims to tackle some of these problems and reduce their impact on the good ecological status of the natural habitats in the Doñana region.

2) the "Marismas" groundwater body where rice and other vegetables with high irrigation needs are grown. Crops in this area are partly irrigated with surface water diverted from Guadalquivir river (most of rice farming area) and with groundwater pumped out from the aquifer.

3) Other areas in the Guadiamar basin, where woody crops -mainly olive trees and to a lesser extent fruit trees- are irrigated.

The main challenge for agriculture is to guarantee a sustainable high-value agricultural activity in a context of water scarcity exacerbated by climate change.

Finally, Doñana is broadly considered as a very threatened area **by climate change**. Several recent studies and scientific publications warns of the big climatic threats for Doñana, e.g. desertification, sea level rise, changes in climatic conditions affecting endangered species, etc. Therefore, climate change is a strong stressor for the three domains of water (reduction of rainfall and available resources), agriculture (very dependent on irrigation) and ecosystems (facing serious problems to adapt to the pace of the changes).

Main challenges are to develop proper climate change risk assessments, awareness raising on the existing and expected problems, and the implementation of specific measures for adaptation to climate change.

## *Primary list of appropriate NBS*

The most appropriate NBS solutions for addressing the abovementioned challenges are listed below:

**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:

- Restore wetlands in areas of groundwater recharge.
- Reconnect rivers with floodplains to enhance natural water storage.
- Rivers or streams, including remeandering, re-opening Blue corridors.
- Floodplain restoration and management.

➢ Type 1—better use of protected/natural ecosystems: monitoring

NBS types:

- Assessment of NBS benefits.
- Ecosystem services valuation methods.

**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:

- Agro-ecological practices.
- 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.

➢ 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)

## *NBS approaches, challenges and ecosystem services identification*

Table 15 through Table 17 present the categorization of NBS selected for Doñana region according to the NBS approaches (Table 15), NBS challenge to be solved (Table 16) and ecosystem services provided by the NBS (Table 17). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 15 Categorization of NBS selected for Doñana region according to NBS approaches.*

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate adaptation approaches | Community based adaptation | Ecosystem based adaptation | Ecosystem based management | Ecosystem based mitigation | Ecosystem based disaster risk reduction | Ecological engineering | Ecological restoration | Infrastructure related approaches | Natural resources management | Sustainable agriculture/agro-forestry/aquaculture |
| ***Type 1 – Better use of protected/natural ecosystems*** | | | | | | | | | | | |
| Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems | | | | | | | | | | | |
| Ensure of continuity of ecological networks (protection from fragmentation) | | x | x | x | x | x | | | | | |
| Monitoring | | | | | | | | | | | |
| Assessment of NBS benefits | | | | x | | | | | x | x | |
| Ecosystem services valuation methods | | | | x | | | | | x | x | |
| ***Type 2 – NBS for sustainability and multifunctionality of managed ecosystems*** | | | | | | | | | | | |
| Agricultural landscape management | | | | | | | | | | | |
| Agro-ecological practices | x | | | x | | x | | x | | | x |
| Soil improvement and conservation measures | x | | | x | | x | | | | | x |
| Increase soil water holding capacity and infiltration rates | x | x | x | x | | x | | x | | | x |
| Agro-ecological network structure | x | | | x | | x | | x | | | x |
| Mulching | x | | x | x | | x | | x | | | x |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | x | | x | x | | x | | x | | | x |
| Use soil conservation measures - cover crops | x | | | x | | x | | x | | | x |
| ***Type 3 – Design and management of new ecosystems*** | | | | | | | | | | | |
| Restoration and creation of semi-natural water bodies and hydrographic networks | | | | | | | | | | | |

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate adaptation approaches | Community based adaptation | Ecosystem based adaptation | Ecosystem based management | Ecosystem based mitigation | Ecosystem based disaster risk reduction | Ecological engineering | Ecological restoration | Infrastructure related approaches | Natural resources management | Sustainable agriculture/agro-forestry/aquaculture |
| Restore wetlands in areas of groundwater recharge | x | | x | x | x | x | x | x | | x | |
| Reconnect rivers with floodplains to enhance natural water storage | x | | x | x | x | x | x | x | | x | |
| Rivers or streams, including remeandering, re-opening Blue corridors | x | | x | x | x | x | x | x | | x | |
| Floodplain restoration and management | x | | x | x | x | x | x | x | | x | |

*Table 16 Categorization of NBS selected for Doñana according to NBS challenge to be solved.*

| NEXUS related NBS | NBS CHALLENGE (A3) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate resilience | Water management | Natural and Climate Hazards | Green space management | Biodiversity enhancement | Air quality | Place regeneration | Capacity Building for Sustainable Urban Transformation | Participatory planning and governance | Social justice and social cohesion | Health and well-being | New economic opportunities and green jobs |
| ***Type 1 – Better use of protected/natural ecosystems*** | | | | | | | | | | | | |
| Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems | | | | | | | | | | | | |
| Ensure of continuity of ecological networks (protection from fragmentation) | | | | | | | | | x | | x | |
| Monitoring | | | | | | | | | | | | |
| Assessment of NBS benefits | | | | | | | | | x | x | | x |
| Ecosystem services valuation methods | | | | | | | | | x | x | | x |
| ***Type 2 – NBS for sustainability and multifunctionality of managed ecosystems*** | | | | | | | | | | | | |

| NEXUS related NBS | NBS CHALLENGE (A3) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate resilience | Water management | Natural and Climate Hazards | Green space management | Biodiversity enhancement | Air quality | Place regeneration | Capacity Building for Sustainable Urban Transformation | Participatory planning and governance | Social justice and social cohesion | Health and well-being | New economic opportunities and green jobs |
| Agricultural landscape management | | | | | | | | | | | | |
| Agro-ecological practices | x | x | | | x | x | | | x | x | | x |
| Soil improvement and conservation measures | x | | | | x | | | | x | x | | x |
| Increase soil water holding capacity and infiltration rates | x | x | | | | | | | x | x | | x |
| Agro-ecological network structure | x | | | | x | x | | | x | x | | x |
| Mulching | x | | | | x | | | | | | | x |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | x | | | | x | | | | | | | x |
| Use soil conservation measures - cover crops | x | | x | | x | x | | | | | | |
| ***Type 3 – Design and management of new ecosystems*** | | | | | | | | | | | | |
| Restoration and creation of semi-natural water bodies and hydrographic networks | | | | | | | | | | | | |
| Restore wetlands in areas of groundwater recharge | x | x | x | | x | | x | | | | x | |
| Reconnect rivers with floodplains to enhance natural water storage | x | x | x | | | | | | x | | x | |
| Rivers or streams, including remeandering, re-opening Blue corridors | x | x | x | | | | x | | | | x | |
| Floodplain restoration and management | x | x | x | | | | x | | x | | x | |

*Table 17 Categorization of NBS selected for Doñana according to ecosystem services.*

| NEXUS related NBS | ECOSYSTEM SERVICES (A4) | | |
|---|---|---|---|
| | PROVISIONING SERVICES | REGULATION & MAINTENANCE | CULTURAL |
| ***Type 1 – Better use of protected/natural ecosystems*** | | | |
| Protection and conservation strategies in terrestrial, marine and coastal areas ecosystems | | | |
| Ensure of continuity of ecological networks (protection from fragmentation) | | **(MP&H)** | **(R), (I), (S)** |
| Monitoring | | | |
| Assessment of NBS benefits | | | **(S)** |
| Ecosystem services valuation methods | | | **(S)** |
| ***Type 2 – NBS for sustainability and multifunctionality of managed ecosystems*** | | | |
| Agricultural landscape management | | | |
| Agro-ecological practices | **(W), (F)** | **(AQ), (WP), (FP), (CS&R), (N), (SFC), (P), (SD)** | **(R), (I)** |
| Soil improvement and conservation measures | **(W) , (F)** | **(EP), (CS&R), (SFC), (N), (P)** | **(R)** |
| Increase soil water holding capacity and infiltration rates | **(W)** | **(FP), (EP), (CS&R)** | |
| Agro-ecological network structure | **(W), (F)** | **(AQ), (WP), (FP), (CS&R), (N), (SFC), (P), (SD)** | **(R), (I)** |
| Mulching | **(W), (F)** | **(CS&R), (N), (SFC), (P), (SD)** | **(R)** |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | **(W), (F)** | **(CS&R), (N), (SFC), (P), (SD)** | **(R)** |
| Use soil conservation measures - cover crops | **(W), (F)** | **(MP&H), (CS&R) (EP), (CP), (SFC), (P), (AQ)** | **(R), (I)** |
| ***Type 3 – Design and management of new ecosystems*** | | | |
| Restoration and creation of semi-natural water bodies and hydrographic networks | | | |
| Restore wetlands in areas of groundwater recharge | **(W), (F)** | **(CS&R), (EP), (FP), (MP&H),(SFC), (P), (N), (SD)** | **(R), (I)** |
| Reconnect rivers with floodplains to enhance natural water storage | **(W), (F)** | **(EP), (FP), (MP&H)** | **(R), (I)** |
| Rivers or streams, including remeandering, re-opening Blue corridors | **(W), (F)** | **(EP), FP)** | **(R), (I)** |
| Floodplain restoration and management | **(W), (F)** | **(EP), FP), (MP&H)** | **(R), (I)** |

## NBS Preliminary Design for Doñana region

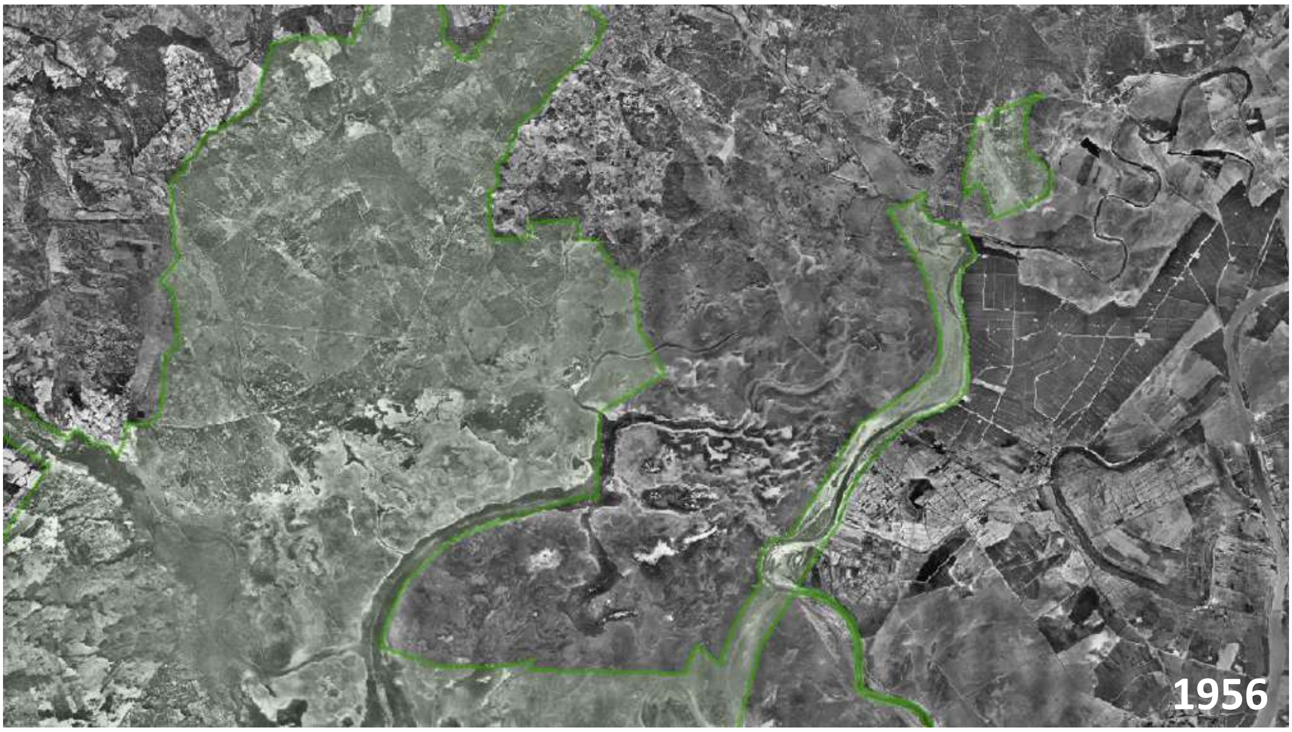
The main challenges that can be addressed through NBS in Doñana region are:

a) *An improved hydrological connection between the Guadiamar river basin and the Doñana marshlands.*

In the 1950s-1970s period, there were several intense transformations in the Guadiamar basin that seriously affected the hydraulic behaviour of the system before the Doñana wetlands were designated as a protected area. A considerable part of the Guadiamar was channelled through a new riverbed (known as “Entremuros” – which can be translated as “between walls”) and water resources were diverted to the Guadalquivir estuary and mainly assigned to crop irrigation. A large marshland area was transformed into arable lands. After this modification, the freshwater inflow to the Doñana wetlands got limited to 30% of the original flow.

In 1998, the breakdown of a dam storing mining waste was the start of the known as “Aznalcollar disaster”, when the dumping of toxic sludge slowly moving through the Guadiamar river almost reached Doñana National Park. Some emergency measures were taken, creating a larger disconnection between the Guadiamar river and the marshlands.

A number of restoration actions were implemented within the frame of the Doñana2005 program (2005-2015) to recover the connection between the Guadiamar river basin and the marshlands under conditions of regular outflow (over 10 $m^3/s$). However, the flooded area from the Guadiamar river has not shown significant increases in the last few years, and several actors are claiming for more ambitious measures.



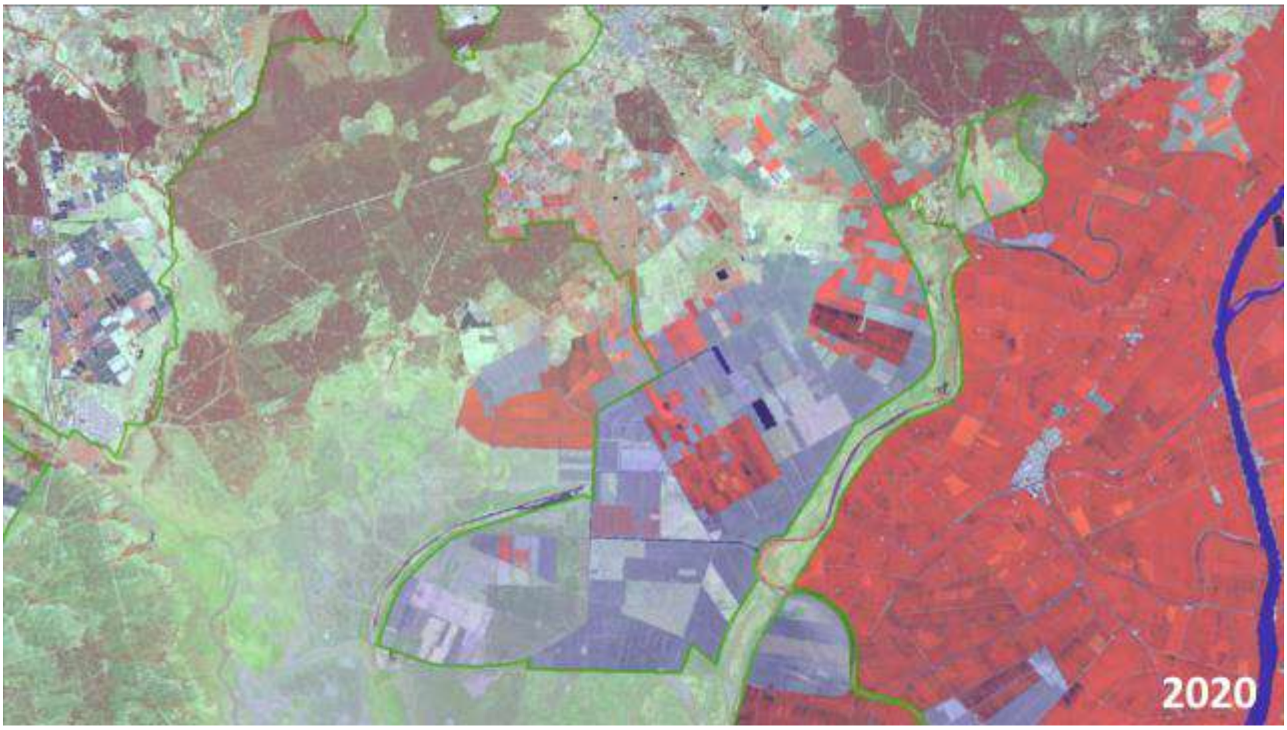



*Figure 7. Marshland transformation in the Guadiamar basin that is currently limiting the hydrological connection between the Guadiamar river basin and Doñana marshlands. The figure above is an ortophoto from 1956 whereas the image below is an infrared color composition derived from a SENTINEL 2 satellite (where irrigated crops are shown in red colour). The Doñana protected area is depicted in transparent green and a green outline.*

*b) Reduction in water use by agriculture and maintenance of agricultural production.*

After the official declaration of some groundwater bodies as over-exploited in 2020, there is a pressing need for reducing the total water use in agriculture. However, this is an area that produces high-value agricultural outputs, e.g. vegetables, citrus, almonds and rice, generating high economic revenues and employment. Moreover, developing a sustainable agricultural system in the boundaries of a widely known protected area is a big challenge that can also be turned into a great opportunity. In this line, increasing biodiversity of the agricultural landscapes and increasing the connectivity of Doñana with other habitats can pay important dividends to the whole socioecological system, in particular if this is paired with relevant economic incentives.

A clear inspiration is the ZITRUS project, developed by EDEKA (one of the largest food retailers in Germany) together with WWF (environmental NGO and an important actor in Doñana) and Iberhanse (one of the largest citrus producers in Andalusia region). The project is working on several farming areas across Spain (some of them located quite close to the LENSES pilot area) and promoting a holistic transformation through several axes: ensuring a legal and more responsible use of water, optimising irrigation systems, drastically reducing the use of agrochemicals, recovering soil fertility and increasing biodiversity in the farming areas. As a final goal, the project aims to reduce/avoid the footprint of agriculture on the environment while producing outputs with a high-demand by consumers.

There is a large amount of woody crops in the Guadiamar basin near Doñana (more than 3 400 ha of citrus, fruit-trees, almond trees and olive trees) in an area that is of crucial importance for the ecological connectivity of Doñana with other natural areas (see figure 8). This is also the area where water table levels of the aquifer have decreased the most. Therefore, the potential implementation of a program focusing on the same aspects highlighted by the ZITRUS project (e.g. increase in biodiversity, reduction of agricultural footprint, reduction in total water use) through the implementation of a bundle of NBS and a supportive business model can help to tackle the existing challenges.

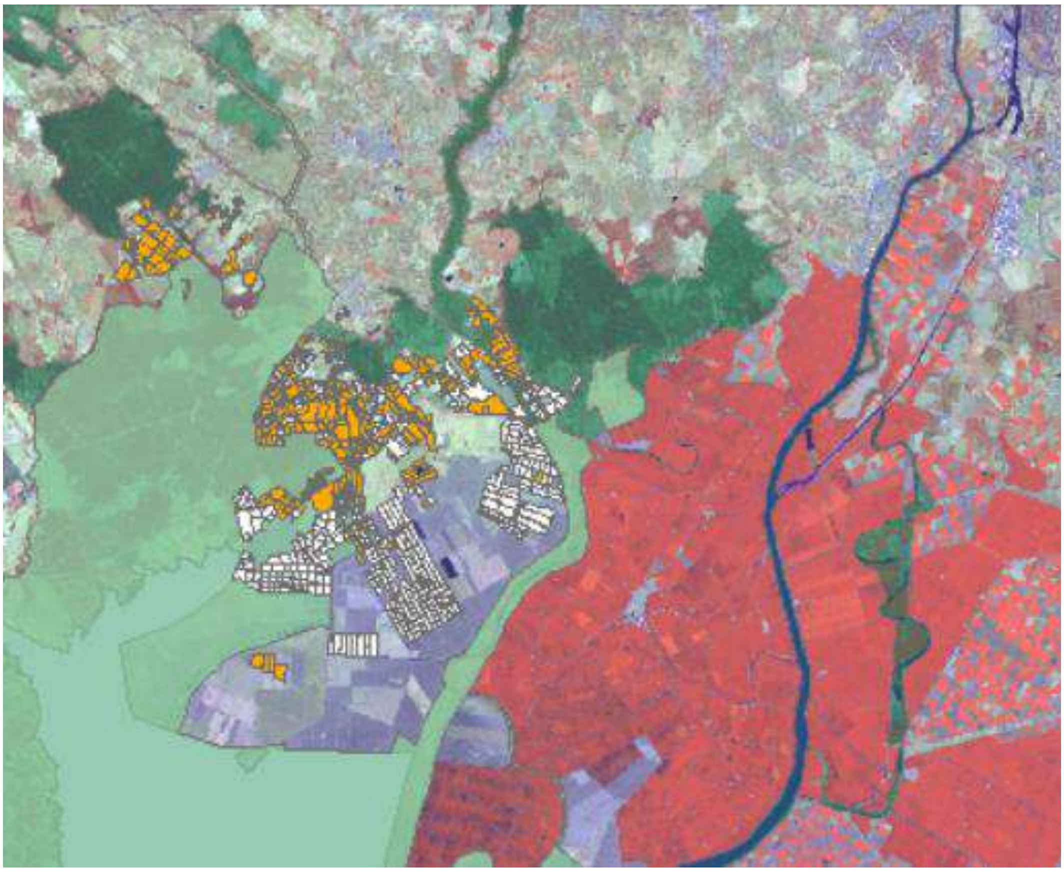


*Figure 8. Woody crops (coloured in orange) in the boundaries of Doñana protected area (coloured in pale green). Other protected areas are depicted in dark green.*

**Proposed NBS Bundles**

In Doñana pilot, we are not planning to apply NBS Bundles to these challenges within the scope of LENSES. Our commitment is to make a design of these bundles and discuss and assess their feasibility with the larger group of stakeholders. Also, NBS solutions will be considered as a core element of the System Dynamic Model and included as part of the construction of the desired visions (i.e. visioning exercise).

**1) NBS bundle for increasing hydrologic connection between Guadiamar river and Doñana marshlands**

- Assessment of NBS benefits.
- Ecosystem services valuation methods.
- Restore wetlands in areas of groundwater recharge.
- Reconnect rivers with floodplains to enhance natural water storage.
- Rivers or streams, including remeandering, re-opening Blue corridors.

- Floodplain restoration and management.

**2) NBS bundle for optimization in the use of resources for agriculture and increase of biodiversity**

- Ensure of continuity of ecological networks (protection from fragmentation).
- Agro-ecological practices.
- 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.

A preliminary selection of KPIs is presented in Table 18. These KPIs should be monitored after the implementation of the NBS in order to evaluate their efficacy.

*Table 18 Preliminary selection of KPIs for each category of NBS in Doñana.*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS bundle for increasing hydrologic connection** | Net surface water availability | $m^3/y$ |
| | Surface area of restored and/or created wetlands | ha |
| | Social learning regarding ecosystems and their functions | Qualitative data (dimensionless) |
| **NBS for optimization in the use of resources for agriculture and increase of biodiversity** | Trend in piezometric levels (TPL) | $m^3/y$ |
| | Groundwater exploitation index (GEI) | % |
| | Soil water retention capacity | $m^3/m^3$ |
| | Infiltration rate and capacity | % or mm/h and mm/d |
| | Species diversity within defined area | Number |

# Pilot 5: Middle Jordan Valley, JO

## *Vision*

The total annual water supply in Jordan from the Jordan Valley has been approximately 300 M $m^3$ per year. It should be noted that the water supply includes conveyance of 60 M $m^3$ of water per year from the King Abdullah Canal to Amman through the Deir Alla Diversion, leading to an essential water supply within the valley of 150 M $m^3$ per year, compared to 300 M $m^3$ of total water demands within the valley. This implies that approximately 70 % of the actual water demands are supplied. The real Jordanian water demands in the study area have been assessed at 298 M $m^3$ /year, of which 268 M $m^3$ is provided through the various sources described above. Particularly the agricultural sector suffers from shortages, whereas these shortages become more severe along the southernmost stretches of the King Abdullah Canal. These shortages are closely linked to the overall water balance in Jordan, and the increasing demands from other parts of the country, particularly the urban area of Amman. Currently, Amman already receives 60 M $m^3$ of water per year from the sources of the Jordan Valley. This situation puts a clear cap on future agricultural and economic aspirations in the Jordan Valley. Finding solutions that need less water or reduce unaccounted water percentages against higher benefits per production unit will be required.

The Jordan Valley extends from Lake Tiberias, at an elevation of -212 meters above sea level (m ASL), southward to the Dead Sea at a present height of about -429 m ASL (2016). Its width at the north of the Dead Sea is around 20 km, whereas to Lake Tiberias, it is approximately 10 km with a minimum width in its central part of 4 km.

## *Main sectoral challenges regarding the WEF Nexus*

Ultimate challenges along with the related important issues for each specific WEF Nexus component are presented as follows.

**Water:** the ultimate challenge is to improve the water use efficiency and management at farm level.

The important issues related to water in Jordan Valley are summarized as follows:

- High fluctuation of water quality and quantity effluent for diffrent season of winter and summer due to competitive on water resources diffrent sectors with agricultural sector. Irrigation water salinity used range from 2 to 3 dS/m.
- Ground water quality in Jordan Valey is saline, so farmers cannot rely on it for irrigation before desalinization.

<u>Forage producers:</u>
- Mostly farmers used conventional surface irrigation.
- During drought periods it is difficult to satisfy irrigation requirements.

<u>Jordan Valley:</u>
- Irrigation with water of low quality because using mixed water moderately saline.

- High fluctuation of water quality and quantity effluent over the  diffemt seasons of  the year  due to shortage and scarcity which affect the water allowance for agriculture.

**Ecosystems:** the ultimate challenge is to improve ecosystem services.

The important issues related to ecosystems in Jordan Valley are summarized as follows:

- Significant livestock concentated in Jordan Valley that cause pressure on feeddstuff and water resources.
- Significant soil degredation and deterioration soil productivity due to salinity build up and intensive agriculture. As well as over fertilization, pesticide and herbicide applications.

**With regard to food,** the ultimate challenge is sustainable agricultural development.

The important issues related to food in Jordan Valley are summarized as follows:

- The Unique ecosystem of Jordan Valley that is below sea level (range from -200 to -400 meter) gave it privillage as an agricultural enviromnet to produce vegetables, fruits and forages out of season.
- Farmers in Jordan Valley do not have good enough capacity for forage production.
- Reduce food waste (mange good post-harvest practices).
- Increase cost efficiency.

## *Primarily list of appropriate NBS*

The most appropriate NBS solutions for addressing the abovementioned challenges are listed below:

**NBS for Soil salinization and degradation**

**Type 1 –** Better use of protected/ natural ecosystems and specifically in the category of the Monitoring

NBS types:

- Assessment of NBS benefits

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

NBS types:

- 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.
- Incorporating manure, and compost  to enhance carbon storage.
- Use soil conservation measures - Deep-rooted plants and adoption of minimum or conservation tillage.

## *NBS approaches, challenges and ecosystem services identification*

Table 19 through Table 21 present the categorization of NBS selected for Jordan Valley according to the NBS approaches (Table 19), NBS challenge to be solved (Table 20) and ecosystem services provided by the NBS (Table 21). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 19 Categorization of NBS selected for Deir Alla according to NBS approaches.*

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate adaptation approaches | Community based adaptation | Ecosystem based adaptation | Ecosystem based management | Ecosystem based mitigation | Ecosystem based disaster risk reduction | Ecological engineering | Ecological restoration | Infrastructure related approaches | Natural resources management | Sustainable agriculture/agro-forestry/aquaculture |
| *Type 1 – Better use of protected/natural ecosystems* | | | | | | | | | | | |
| ***Monitoring*** | | | | | | | | | | | |
| Assessment of NBS benefits | | | | **X** | | | | | **X** | X | |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | |
| Agro-ecological practices | **x** | | | **x** | | **x** | | **x** | | | **x** |
| Use grazing management and animal impact as farm and ecosystem development tools | | | **x** | **x** | **x** | | | | | | **x** |
| Change crop rotations | | | | **x** | | | | | | | **x** |
| Soil improvement and conservation measures | **x** | | | **x** | | **x** | | | | | **x** |
| Increase soil water holding capacity and infiltration rates | **x** | **x** | **x** | **x** | | **x** | | **x** | | | **x** |
| Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage | **x** | | **x** | **x** | | **x** | | **x** | | | **x** |

*Table 20 Categorization of NBS selected for Deir Alla according to NBS challenge to be solved.*

| NEXUS related NBS | NBS CHALLENGE (A3) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate resilience | Water management | Natural and Climate Hazards | Green space management | Biodiversity enhancement | Air quality | Place regeneration | Knowledge & Social Capacity Building for Sustainable Rural Transformation | Participatory planning and governance | Social justice and social cohesion | Health and well-being | New economic opportunities and green jobs |
| *Type 1 – Better use of protected/natural ecosystems* | | | | | | | | | | | | |
| ***Monitoring*** | | | | | | | | | | | | |
| Assessment of NBS benefits | | | | | | | | | x | x | | x |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | | |
| Agro-ecological practices | x | x | | | x | x | | | x | x | | x |
| Use grazing management and animal impact as farm and ecosystem development tools | | | | | | | | | x | x | | x |
| Change crop rotations | x | | | | x | | | | x | | | x |
| Soil improvement and conservation measures | x | | | | x | | | | x | x | | x |
| Increase soil water holding capacity and infiltration rates | x | x | | | | | | | x | x | | x |
| Incorporating manure, compost, biosolids, or crop residues to enhance carbon storage | x | | | | x | | | | | | | x |

*Table 21 Categorization of NBS selected for Deir All according to ecosystem services.*

| NEXUS related NBS | ECOSYSTEM SERVICES (A4) | | |
|---|---|---|---|
| | PROVISIONING SERVICES | REGULATION & MAINTENANCE | CULTURAL |
| *Type 1 – Better use of protected/natural ecosystems* | | | |
| ***Monitoring*** | | | |
| Assessment of NBS benefits | | | (S) |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | |
| ***Agricultural landscape management*** | | | |
| Agro-ecological practices | (W), (F) | (AQ), (WP), (FP), (CS&R), (N), (SFC), (P), (SD) | (R), (I) |
| Use grazing management and animal impact as farm and ecosystem development tools | (F) | (MP&H), (SFC) | |
| Change crop rotations | (W) , (F) | (SD), (SFC), (P), (CP) | |
| Soil improvement and conservation measures | (W) , (F) | (EP), (CS&R), (SFC), (N), (P) | (R) |
| Increase soil water holding capacity and infiltration rates | (W) | (FP), (EP), (CS&R) | |
| Incorporating manure, compost, biosolids, or incorporating crop residues to enhance carbon storage | (W), (F) | (CS&R), (N), (SFC), (P), (SD) | (R) |

## *NBS Preliminary Design for Deir Alla/Jordan Valley*

The main challenges that need to be addressed in Deir Alla Jordan Valley (JV), are focused on Middle Jordan Valley representative by Deir Alla Agricultural Regional Research station in Figure 9 mention below as follows:

1) **Water-scarcity:** Water for irrigation is deteriorated water quality due to using mixed water quality available from Khirbit Asmra treated wastewater plant as well as the King Talal dam that collected water from rain harvesting beside to treated wastewater, other dams, aquifers, and artesian wells. These two facts make the Jordan valley the vital source for agriculture in Jordan.

2) **Agricultural practices and soil degradation:** Due to using mixed water and high chemical fertlization by farmer lead to salinization of soil. During the last decade farmer directed to use chemical fertilizer instead of organic fertilizer decline the bio-available carbon in agricultural soil that lead to deterioration of soil stability and productivity performance accompanied by a significant shift in soil fertility.

3) **Energy-poor and home to a rapidly growing population:** About 20 % of the poor in Jordan live in rural areas depending primarily on agriculture; they are livestock keepers, smallholders of farm households, and landless former agriculturalists. Despite the lack of motivation for rural youth, agriculture is still an essential source of employment in rural communities (IFAD 2010).

4) **Overgrazing practices due to free-grazing livestock:** Sheep and goats free grazing system will cause ecosystem deterioration and damage of vegetative cover and plant biodiversity in the Jordan Valley.

5) **Abandoned of Agricultural Units:** Due to immigration of land owner to major cities in Jordan


*Figure 9. Deir Alla Agricultural Regional Research station*

**Proposed NBS Bundles**

We will apply NBS Bundle to the experimental site in order to optimize the WEF Nexus. Below is the preliminary potentially applicable NBS that contribute to more than one component of the WEF Nexus and related challenges. The NBS can contribute to **Soil salinization and land degradation** that can be applicable Deir Alla. Table 22 presents recommended KPIs for each category of NBS proposed.

**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, compost.

The selected NBS will enhance the Water-Ecosystem-Food Nexus of the watershed. The methodologies used to irrigate, which are based on the demands of the tree, 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 e.g. implementing 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. A preliminary selection of KPIs is presented in Table 22. These KPIs should be monitored after the implementation of the NBS in order to evaluate their efficacy.

*Table 22 Preliminary selection of KPIs for each category of NBS in Deir Alla*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS bundle for Soil salinization and land degradation – Focus on forage (food)** | Water productivity | $Kg/m^3$ or $JOD/m^3$ |
| | Forage and Silage quality | Kg N/t, Crude Fiber and digestibility % |
| **NBS bundles for soil regeneration** | Soil carbon/organic matter | % |
| | Soil Fertility | ppm |

# Pilot 6: Galilee, Hula Valley, Israel

## *Vision*

The surge in water prices in the last years is induced by the massive and growing dependancy of the Israeli economy on continuous supply of desalinated seawater. Though the desalination plants sucssesfuly helped Israel tackle the aggrevating climate-change-induced water crisis, it generated some side effects. Rising water prices, put farm production, especially in the Hula Valley peripheral region, on the verge of profitability, and the farming economy to the verge of sustainability. Collapse of the local farming economy will have tremendous social consequences, and will reduce the resources for financing public services to treat and maintain, among others, environmentally important services.

Activities in the Galilee pilot, located at the Hula Valley in the North of Israel, will tackle the nexus interactions between Water-Ecosystem-Food-Energy (WEFE) from various aspects. Harvesting the sun energy is a nature-based solution to our understanding. It follows the request to increase alternative energy production.

Turning wasted sun-radiating energy not assimilated by photosynthesis to electric power by photovoltaic panels (PV), generates a novel bi-usage which promotes a new ecosystem service, as well as a steady additional income for the grower. The partial sky cover may provide additional benefits, like crop protection and reduced energy input for evapotranspiration (ET) as well as reduce uses of eater for irrigation. Basic condition for the success of the new method is minimal or at least bearable damage to yields and incomes from the crop. The aim of the of the Galilee pilot is to evaluate the main factors effecting the crop under partial shading of the PV panels and the yield results.

Potential combination of additional income and reduced water input will pave a way to prevent and reduce the foreseen damages to the farm economy.

## *Main sectoral challenges regarding the Water-Ecosystem-Food-Energy Nexus*

Ultimate challenges along with the related important issues for each specific WEF Nexus component are presented as follows.

**Water,** the ultimate challenge is to provide the farmers with a sustainable solution for the surging water prices.
The important issues related to water in the Hula Valley are summarized as follows:

- The discharge of the Jordan River - the primary water source of the Sea of Galilee that flows through the Hula Valley, is expected to decrease by up to 22% in the 21st Century. It is a dramatic trend for the region in terms of water availability and water scarcity.
- From 2012 to 2018, the precipitation amount in the Galilee was lower than the long-term average for this region. This figure reflects a local decrease in the replenishment of water resources.
- Water pricing is a political and societal issue which will bear the desalination costs.

- Agro-Voltaic solution reducing water use and generating solar power will have their inherent economic and environmental benefits.

**Ecosystems:** the ultimate challenge is to improve ecosystem services by modifying the provisioning services provided by the agricultural ecosysytem.

The important issues related to ecosystems in Hula Valley are summarized as follows:

- Reducing carbon footprint from agriculture
- Reducing $CO_2$ emissions from agricultural crops

**Energy** the ultimate challenge is to develop a feasible, stable and profitable novel energy source at the field scale, to be integrated with the agricultural crops. Such spatial bi-usage of the agricultural plot will increase the plot's profitability and the overall sustainability of the local agriculture.

The important issues related to energy in the Hula Valley are summarized as follows:

- Ground-level solar systems were and are due to be erected in the Hula Valley. However, these are land consuming and deprive agriculture use.
- Panels above the trees' level will require high investment, which must be economic viable, and will not "replace" the crops, as ground-level systems.
- Panels are creating shade over the trees, and the effect on fruit production must be evaluated.
- Panels may have also an effect on the biodiversity at the orchards.

**Food,** the ultimate challenge is to minimise yield loss and preserve crop quality and quantity.

The important issues related to food in the Hula Valley are summarized as follows:

- Agriculture in the Hula Valley was always dependent on the effective use and control of water resources.
- Agricultural crops include a large variety of winter crops, summer crops, crops for the food industry and perennial crops.
- The Galilee is the "fruit barn" of Israel and also fruits are exported to Europe, and therefore the effect on the crops is important.

## *Primarily list of appropriate NBS*

The most appropriate NBS for addressing the abovementioned challenges are listed below:

**NBS for agricultural development**

**Type 1 –** Better use of agricultural ecosystems and specifically in the category of Monitoring

NBS types:

Assessment of NBS benefits

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

NBS types:

Increase soil water holding capacity and infiltration rates

## *NBS approaches, challenges and ecosystem services identification*

Table 23 through Table 25 present the categorization of NBS selected for Hula valley according to the NBS approaches (Table 23), NBS challenge to be solved (Table 24) and ecosystem services provided by the NBS (Table 25). This information is related to the WEF Nexus and can be used for the ultimate selection of NBS.

*Table 23 Categorization of NBS selected for Hula Valley according to NBS approaches.*

| NEXUS related NBS | NBS APPROACH (A2) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Climate adaptation approaches | Community based adaptation | Ecosystem based adaptation | Ecosystem based management | Ecosystem based mitigation | Ecosystem based disaster risk reduction | Ecological engineering | Ecological restoration | Infrastructure related approaches | Natural resources management | Sustainable agriculture/agro-forestry/aquaculture |
| *Type 1 – Better use of Agricultural ecosystems* | | | | | | | | | | | |
| ***Monitoring*** | | | | | | | | | | | |
| Assessment of NBS benefits | X | | | X | | | | | X | X | X |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | |
| Increase soil water holding capacity and infiltration rates | | | X | X | | | | | X | X | X |

*Table 24 Categorization of NBS selected for Hula Valley according to NBS challenge to be solved.*

| NEXUS related NBS | NBS CHALLENGE (A3) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate resilience** | **Water management** | **Natural and Climate Hazards** | **Green space** | **Biodiversity enhancement** | **Air quality** | **Place regeneration** | **Knowledge & Social Capacity Building for Sustainable Rural Transformation** | **Participatory planning and governance** | **Social justice and social cohesion** | **Health and well-being** | **New economic opportunities and green jobs** |
| *Type 1 – Better use of Agricultural ecosystems* | | | | | | | | | | | | |
| ***Monitoring*** | | | | | | | | | | | | |
| Assessment of NBS benefits | | **X** | | | | | | **X** | | | | **X** |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | | | | | | | | | | |
| ***Agricultural landscape management*** | | | | | | | | | | | | |
| Increase soil water holding capacity and infiltration rates | **X** | **X** | | | | | | | | | | |

*Table 25 Categorization of NBS selected for Hula Valley according to ecosystem services.*

| NEXUS related NBS | ECOSYSTEM SERVICES (A4) | | |
|---|---|---|---|
| | **PROVISIONING SERVICES** | **REGULATION & MAINTENANCE** | **CULTURAL** |
| *Type 1 – Better use of Agricultural ecosystems* | | | |
| ***Monitoring*** | | | |
| Assessment of NBS benefits | **(W), (F)** | | |
| *Type 2 – NBS for sustainability and multifunctionality of managed ecosystems* | | | |
| ***Agricultural landscape management*** | | | |
| Increase soil water holding capacity and infiltration rates | **(W), (F)** | | |

## NBS Preliminary Design for Hula Valley

The main challenges that need to be addressed in Hula Valley, are focused on the field-scale as follows:

1) **Water-scarcity:** Water for irrigation is dependent on regional water availability and water scarcity. Reduction of overall quantaties of irrigation water due to the reduction in evapotranspiration can change dramatically the field-scale water status.
2) **Agricultural practices:** Application of APV at the field-level can impact the supporting functions in agriculture to integrating new methodologies into farming practices and incentives for better irrigation methods and disease control. It may also refer to reducing the uses of fertilizers, pesticides, and herbicides, leading to better management of crops.

**Proposed NBS Bundles**

We will apply NBS Bundle to the experimental site in order to optimize the WEFE Nexus. Below is the applicable NBS that contribute to more than one component of the WEFE Nexus and related challenges.

**NBS bundle for Bi-usage application of agricultural plots – focus on orchards**

- Increase soil water holding capacity.
- Irrigation water Management.
- Harnessing solar radiation for the production of a novel ecosystem service – the agricultural plot as an energy source.

The selected NBS will enhance the Water-Ecosystem-Food-Energy Nexus of the watershed. Spatio-temporal properties of irrigation will be based, and adapted to the new water demands of the fruit trees. Installation of APV will transfer the agricultural practice to a bi-usage practice, preserving crop yield while generating a new perspective of ecosystem services (energy-wise) at the field-scale. A preliminary selection of KPIs is presented in Table 26. These KPIs should be monitored after the implementation of the NBS in order to evaluate their efficacy.

*Table 26 Preliminary selection of KPIs for each category of NBS in Hula Valley*

| Category of NBS | Recommended indicators | Units |
|---|---|---|
| **NBS bundle for Bi-usage application of agricultural plots – focus on orchards** | Water productivity | $m^3 /m^2$ |
| | Crop yield | Kg /0.1 ha |
| | Carbon storage and sequestration in vegetation and soil | kg/ha/y |
| | Energy Production | $KW/m^2$ |

# Final remarks

The objective of Task 5.2 was to identify the potential role of Nature-Based Solutions (NBS) for addressing the challenges and opportunities for a resilient nexus, building on the challenges identified within the pilots and identifying the ecosystem services component of the challenge. A roadmap to help the pilots navigate the landscape was developed and a preliminary application of the LENSES WEF Nexus Evaluation framework to each pilot was conducted.

Table 27 presents a summary of the NBS bundles and recommended indicators resulted from the application of the LENSES WEF Nexus Evaluation framework to pilots. Summarizing the information resulted from the application of the LENSES WEF Nexus Evaluation framework, the vision of all pilots is common and threefold:

- Increasing sustainability and re-naturalization of the landscape;
- Focusing on the sustainability of agricultural sector; and
- Promoting the socio-economic development.

The optimization of the WEF nexus is a core issue for a sustainable management of the natural resources and agricultural development. NBSs can play a key role in facilitating this optimization.

*Table 27 Summary of the application of LENSES WEF Nexus Evaluation framework in the pilots. NBS bundles and recommended indicators*

| Pilot | Category of NBS | Recommended indicators |
|---|---|---|
| **Koiliaris CZO, Greece** | **NBS bundle for erosion control** | Carbon storage and sequestration in vegetation and soil<br>Soil organic matter<br>Infiltration rate and capacity<br>Soil water available for plant uptake<br>Total Predicted Soil Loss<br>Erosion risk |
| | **NBS for high elevation biodiversity protection** | Number of species within defined area<br>Biodiversity conservation |
| | **NBS bundles for soil regeneration** | Carbon storage and sequestration in vegetation and soil<br>Soil organic matter |
| **Pinios River Basin Hydrologic Observatory, Greece** | **NBS for groundwater resources quantitative restoration** | Depth to groundwater<br>Groundwater exploitation index (GEI)<br>Groundwater level |
| | **NBS for increasing soil organic matter and enhancing soil hydraulic properties** | Measured soil carbon content (only for monitored fields)<br>Calculated infiltration rate and capacity<br>Plant-available water<br>Soil water retention capacity |
| **Gediz Basin & Delta, Turkey** | **Sustainability and soil regeneration by agricultural practices** | Measured soil carbon content<br>Soil Type<br>Soil organic matter |

<table>
<tr><th>Pilot</th><th>Category of NBS</th><th>Recommended indicators</th></tr>
<tr><td></td><td>Sustainability of agricultural land and protected natural ecosystem</td><td>Total surface area of wetlands<br>Urban/residential areas<br>Productive areas<br>Natural areas, sites of community importance and special protection areas<br>Inhabitants<br>Water availability for irrigation purposes<br>Number of native species<br>Proportion of protected areas</td></tr>
<tr><td rowspan="3">Tarquinia plain, Italy</td><td>NBS for erosion control and ecosystem restoration</td><td>Changes in land cover<br>Changes from annual to permanent crop<br>% soil cover<br>Establishment of wind breaks and hedges<br>Total Predicted Soil Loss<br>Erosion risk<br>Area affected by severe erosion rate</td></tr>
<tr><td>NBS for agricultural development</td><td>Crop diversification: Number of different crops cultivated in an area<br>Number of farms that use agro-ecological practices</td></tr>
<tr><td>NBS for flood risk reduction</td><td>Change in surface covered by vegetation near riverbanks<br>Flooded area caused by a 10-years return period flood<br>Flood prevention practices included in riverbanks management strategies at municipality level</td></tr>
<tr><td rowspan="2">Doñana region, Spain</td><td>NBS bundle for increasing hydrologic connection</td><td>Net surface water availability<br>Surface area of restored and/or created wetlands<br>Social learning regarding ecosystems and their functions</td></tr>
<tr><td>NBS for optimization in the use of resources for agriculture and increase of biodiversity</td><td>Trend in piezometric levels (TPL)<br>Groundwater exploitation index (GEI)<br>Soil water retention capacity<br>Infiltration rate and capacity<br>Species diversity within defined area</td></tr>
<tr><td rowspan="2">Deir Alla, Jordan valley</td><td>NBS bundle for Soil salinization and land degradation – Focus on forage (food)</td><td>Water productivity<br>Forage and Silage quality</td></tr>
<tr><td>NBS bundles for soil regeneration</td><td>Soil carbon/organic matter<br>Soil Fertility</td></tr>
<tr><td>Hula Valley, Israel</td><td>NBS bundle for Bi-usage application of agricultural plots – focus on orchards</td><td>Water productivity<br>Crop yield<br>Carbon storage and sequestration in vegetation and soil<br>Energy Production</td></tr>
</table>

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# Annex I: Finalized list of candidate NBS that can be used for optimizing the WEF Nexus

### 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.<br>Enhance or facilitate habitat expansion, including the facilitated range expansion of mangroves, as warming conditions and changes in storm occurrence permit.<br>Integrated coastal zone management |

## Type 3 – Design and management of new ecosystems

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

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