Deliverable A.4.2

"Evaluation report on the applied restoration practices for each case study with restoration implemented"

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Executive summary

The present document represents the second Deliverable of Action A4 delivered on January, 2024. It reports the restoration practices and Nature-based Solutions (NBS) employed in the project's case studies by NewLife4Drylands and other related projects (e.g. LIFE PRIMED, LIFE GREEN LINK, etc.) that have been employed to test the project's assessment methodologies and approaches on hydrogeological, biodiversity, forestry and climate data (see Actions A.2, A.3, A.5).

A comprehensive analysis of applied restoration practices in different case studies, except Asterousia Mountain, across the Mediterranean region is presented (as per project design, the site does not have any past restoration action, and it will be the subject of a NewLife4Drylands restoration plan). The aim is to summarise the historical information on NBS delivered to help assess the effectiveness of these restoration initiatives, identify common trends, and propose recommendations for future endeavours.

The report drafts conclusions on the status of these restoration actions and highlights existing gaps case by case, defining a balance of success or unsuccess that will be useful to calibrate future restoration activities better and set intervention priorities.

The report is also linked with the "Report on ecosystem services assessment in the 6 case study areas" (Deliverable D4.3), which concludes and completes the evaluation process, giving indications on the ecosystem services provided by the case study areas. Ecosystem services are also crucial for assessing the effects of NBS implementation in the long term by comparing ex-ante and ex-post situations.

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1. Introduction

1.1 Project Overview

Background

NewLife4Drylands (NL4D) project deals with the specific need set by the "Life-Environment" subprogramme "Restoration of desertified land through nature-based solutions" to contrast the soil degradation causing landscape desertification by using Nature-Based Solutions (NBS). It aims to provide a framework and a protocol for identifying sustainable solutions that could be successfully implemented in degraded drylands, e.g. restoration land activities aiming to improve vegetation cover and productivity in those areas where desertification processes are undergoing (vulnerable areas). In addition, the project aims to develop specific techniques to monitor the successes or failures of restoration activities. The monitoring systems would allow obtaining long-term monitoring, instead of the usual short-term monitoring campaigns, to evaluate restoration activities' effectiveness and improve sustainable soil management. Using Earth Observation (EO) tools enables evaluation over time with lower costs than in-situ monitoring visits, overcoming possible difficulties in accessing areas under consideration.

This project focuses on developing a methodological approach for identifying dryland characteristics and for mid and long-term monitoring of restoration interventions of desertified lands through Remote Sensing (RS) techniques. RS can complement the lack of long-term, reliable, and homogeneous in situ information, usually rather timely and expensive. The protocol is based on high-resolution EO data and applies RS methodologies. Moreover, it provides a clear, specific, and costless assessment of the restoration process, which is useful for further intervention decision-making.

Objectives

The main objective of the project is to monitor the application, scalability and replication of the NBS for the restoration of degraded and desertified drylands by using satellite-based indicators, establishing an NBS-drylands protocol for the identification of drylands characteristics, designing NBS that could be successfully implemented in degraded drylands, and mid-term and long-term restoration monitoring.

NL4D's specific objectives are to:

• Provide a methodological and applicable approach in the form of a model for desertification monitoring of desertified areas based on remote sensing indicators

• Provide a specific protocol for NBS application for drylands restoration

Expected results

The NL4D's main expected result is the definition of a protocol for the identification of dryland characteristics and for monitoring restoration interventions of desertified land based on remote sensing methodologies. The following results will be achieved:

• one restoration protocol based on NBSs;

• one mid- and long-term monitoring model based on Remote Sensing;

• one monitoring report on 4 restored areas in Spain, Italy and Greece;
• one Restoration Plan to propose NBSs for Asterousia Mts, Greece.

Figure 1. Natura 2000 site "Bosco di Palo Laziale", Ladispoli, Rome, Italy. Tree mortality, water scarcity, and soil depletion are evident causes of land degradation triggered by forest dieback.

1.2 Action A.4 Monitoring restoration cases based on NBS

The success of the restoration actions (NBSs) in the case study areas was evaluated by NL4D on the basis of multi-disciplinary monitoring. The project integrates the available ground information to feed monitoring by new satellite data, allowing multi-parameter analysis and recalibration of ongoing and planned interventions for the long-term management of targeted ecosystems. Hence, the Action was devoted to collecting and providing data on desertification problems and effects on environmental quality, and NBS was adopted to feed Action A2, A3, and A5 to assess the effectiveness of the restoration practices put in place in the areas. In particular, biodiversity and forest data have been integrated with spatial and satellite data to better assess the conservation status of the considered habitats after the project interventions (e.g. reforestation programs) and at a wider geographical scale (e.g. regional level). Hydrogeological data (where available) have also been integrated with satellite measurements to verify the success of the water-related solutions (e.g. hydraulic systems) in increasing topsoil water availability over the years. Climate data have also been used to develop future scenarios for the impact of identified threats and provide input for shaping and planning further direct conservation actions.

The Action is devoted to aggregating specific information on restoration activities implemented in 4 case study areas, particularly by CREAF, HSPN and Sapienza University of Rome.

- ✓ El Bruc (Catalonia) and Tifaracás (Gran Canaria), Spain – project sites of LIFE The Green Link (LIFE15 CCA/ES/000125) and LIFE MONTSERRAT (LIFE13 BIO/ES/000094)
- ✓ Palo Laziale, Italy, and Nestos, Greece – project sites of LIFE PRIMED (LIFE17 NAT/GR/000511)

The land degradation processes of Alta Murgia, Italy, and Asterousia Mountain, Greece have never been addressed so far by any NBS or restoration action. In Alta, NBS restoration actions were launched by the NL4D project. The restoration plan for two Asterousia Mountain sites will be delivered by NewLIFE4Drylands NL4D by the end of the project (see Action A.5).

The Action also encompasses the ecosystem services assessment in the case study areas performed by IBE-CNR. Ecosystem services are crucial in assessing the effects of NBS implementation in the long term by comparing ex-ante and ex-post situations. The assessment of Ecosystem Services (ES) regards provisioning services (e.g. biomass production), regulatory services (e.g. soil carbon stock, water regulation), supporting services (e.g. biodiversity) of the ecosystems, and, when possible, cultural services in terms of recreation opportunity, attachment and aesthetic value. The ES assessment uses available ground data and land classification from satellite images. When possible, the assessment is expressed in quantitative biophysical units, represented as ES maps.

2. The NBSs' momentum

The concept of NBSs emerged in European policy agendas in the early 2010's (EC, 2013; 2015). With the introduction of the European Commission (EC) communication "Green Infrastructure (GI) – Enhancing Europe's Natural Capital" (COM/2013/0249), commonly known as 'EU Green Infrastructure Strategy' (EC, 2013), interest in 'Green Infrastructure (GI)' and 'Nature-based Solutions (NBS)', has progressively imbued ecological research and practice domains (Garmendia et al., 2016). This strategic document defined the Green Infrastructure as *"[...] a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, Green Infrastructure is present in rural and urban settings"*. Soon after, a marked orientation towards the need for practical actions saw the light in the EU report on 'Nature-Based Solutions and Re-Naturing Cities': *"NBS are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes"* (EC, 2015).

The strong relationship between GI and NBS is evident; "*GI can make a significant contribution to the effective implementation of all (EU) policies where some or all of the desired objectives can be achieved in whole or in part through Nature-Based Solutions*". Both concepts deliver vital resources also for achieving SDG's targets *"GI is a successfully tested tool for providing ecological, economic and social benefits through natural solutions"* and that *"the many benefits human society gets from nature, are consciously integrated into spatial planning and territorial development".* However, a primary difference between the two concepts can be outlined. NBS recalls an idea of a 'solution'. Unlike GI, it recognises a problem that needs to be solved or a benefit that humankind claims to receive. For example, forest habitats conceptually belong to the Green Infrastructure realm because they are ecosystems regulated by spontaneous ecological pattern processes, dynamics and functions ruled by nature. However, as soon as their design, conservation and management are intentionally converted into active control, their status of natural-based solutions becomes evident in the multiple ways they improve people's environmental, economic, and social conditions (service provisioning).

Green Infrastructure and NBSs have been initially brought closer to the urban environments. In the 'Urban Agenda for the EU' (EC, 2016), "*the multifunctional network of urban green spaces delivers among the most important drivers of Nature-Based Solutions in the cities".* The following actions boosted more acceptance of NBS approaches in rethinking existing urban landscapes and planning a new network of living systems for a better quality of life for the urban population (Defra and Natural England, 2013).

The crucial role of GI and NBS in the restoration of degraded ecosystems was also shortly after recognised in the 'EU Biodiversity Strategy to 2030' (EC, 2020) and has been increasingly advanced through the positive policy and governance alignments of the 'European Green Deal' (EC, 2019) and EU Adaptation Strategy to Climate change (EC, 2021). The process has finally found substantial empowerment with the launch of the draft of the EU Nature Restoration Law. Under the framework of the EU Biodiversity Strategy, it now claims legally binding restoration targets for Member States, particularly for the habitats in Annex I of the EU Habitats Directive, as well as for ecosystems with the highest potential to capture and store carbon and reduce the impacts of extreme climate events, such as forests and peatland. NBS have a complete reflection at the global level in supporting the achievement of the global restoration targets and the UN Decade on Ecosystem Restoration 2021–2030.

While the enthusiasm for integrating NBS into ecosystem restoration goals is growing, a significant gap exists in documented experiences and evidence regarding effective assessment methodologies. The intricacies of evaluating the success of NBS projects for ecosystem restoration pose a considerable challenge, hindering the development of standardised frameworks and impeding the scalability of these solutions. Quantifying such impacts or potential impacts for multiple targets, such as those linked to biodiversity and climate change adaptation through replicable evaluation frameworks and monitoring mechanisms, remains challenging.

Without a comprehensive body of documented experiences, assessing NBS effectiveness encounters various obstacles. The multifaceted nature of ecosystems, the dynamic interplay of ecological processes, and the intricate relationship between natural and anthropogenic factors contribute to the complexity of evaluating restoration outcomes. Furthermore, the lack of standardised metrics and universally accepted evaluation methodologies hampers the ability to draw meaningful comparisons across diverse NBS initiatives.

The urgency of addressing global environmental challenges requires a concerted effort to bridge the existing gap in documented experiences and evidence related to NBS effectiveness. As the international community increasingly turns to nature-based approaches, there is a pressing need to develop standardised assessment frameworks that can be adapted to diverse ecological contexts. By doing so, we can enhance our understanding of the outcomes of NBS interventions and pave the way for the refinement and optimisation of restoration strategies on a global scale.

NL4D has risen to this challenge: exploring the challenges posed by the lack of documented valid methodologies in assessing the effectiveness of NBS for ecosystem restoration and underscoring the importance of concerted efforts to fill this crucial knowledge gap.

For more information on the methodologies and tools developed by the project, please refer to Actions A2, A3, A4 and A5, and to the relevant deliverables available on the project website https://www.newlife4drylands.eu/en/outcomes/

3. Case studies

The Mediterranean region, known for its ecological diversity, is constantly threatened by anthropogenic activities and natural processes. Restoration practices are pivotal in mitigating these impacts, aiming to enhance ecosystem resilience and support sustainable development.

In the project's case studies, a remarkable set of different NBS has been applied over the last two decades to face common-threatening challenges: landscape degradation, biodiversity loss, and climate change alteration. Many actors from different disciplines and organisations have participated, entirely or partially, in developing sound restoration, conservation and management solutions to halt such adverse processes against natural and semi-natural ecosystems.

A comprehensive list of these activities is conveyed in the form of an informative inventory report. These NBS and their impacts have been used to test the methodological approaches developed by NL4D. The spatiotemporal ground-truthing of project outputs is important to identify gaps and barriers and refine strategies for more adapted, need-oriented and cost-efficient future restoration actions.

Case Study	Location	Ecosystem Type	Restoration Actions	Outcomes and Challenges
 Nestos, East Macedonia	Northern Greece	Riparian/Alluvial Forest	- Remeandering, side-channel reconnection - Reforestation of native and non-native tree species - Creation of uptaking groundwater infrastructure - IAS experimental treatments and removal	- Unsuccessful regeneration of native trees - Emphasises the importance of adaptive multi-stakeholder management strategies
 Palo Laziale, Lazio	Central Italy	Planitial Oak Forest	- Forestry nursery and reforestation of native tree species - Selective shrub trimming and realisation of temporary ponds - Hydraulic interventions for habitat recovery and conservation	- Forest renovation of native seedlings - Enhanced ecosystem resilience - Improved forest and water management - Constraints in the authorisation process for hydraulic works due to a lack of

			- Sustainable Forest Strategic Management Plan - Management Plan for Water Resources - Ex situ conservation and propagation of keystone species of target habitats	dialogue among different competent authorities
 El Bruc, Cataluna	Northwestern Iberian Peninsula	Mediterranean Scrubland	- Native tree planting - Productive plan reintroduction - Fire risk management - Old agricultural land recuperation - Vegetation clearing with livestock	- Enhanced ecosystem resilience - Increased agro-biodiversity at the landscape level - Challenges with water scarcity, wildfire prevention and community involvement - Herbivorism by wild fauna (wild boars, roe deers)
 Tifaracas, Gran Canaria	Canary Islands	Canary Pine forest	- Native tree planting - Fauna control	- Enhanced ecosystem resilience - Increased encroachment of endemic species - Challenges with water scarcity, wildfire prevention and community involvement - Herbivorism by goats - Challenge with the eradication of naturalised alien species

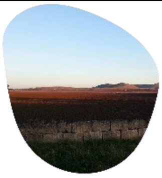
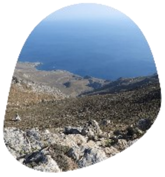
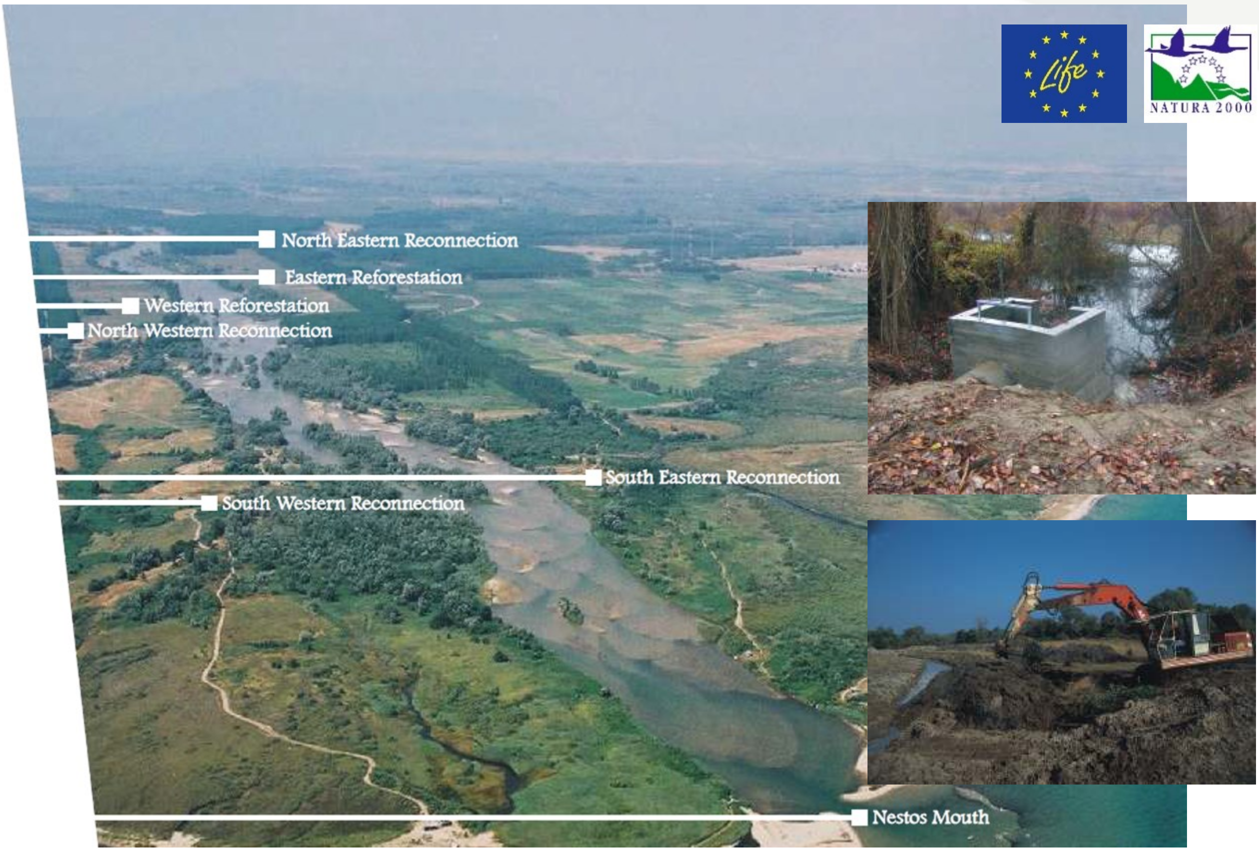
 Alta Murgia, Apulia	Southern Italy	Semi-natural dry grasslands	- Controlled grazing management - Invasive species control	- Increased native grass cover - Benefits to grazing livestock - Need for continued management efforts
 Asterousia, Crete*	Southern Greece	Mediterranean Scrub	NA	NA

Table 1. This table concisely overviews each case study, highlighting the location, ecosystem type, specific restoration actions implemented, and key outcomes and challenges observed. The information presented in the table can serve as a quick reference for understanding the diversity of restoration efforts in the different Mediterranean case study areas.

**No restoration actions were ever implemented at the Asterousia site. The NL4D project will prepare a specific restoration plan for the site.*

The restoration actions investigated in this report represent good-practice examples in the Mediterranean region. They partly reflect the relatively long tradition of agro-forestry management in these countries. They comprise well-known "standard" types of forest restoration measures and innovative water delivery installations that enable recovery of various ecosystems (agro-forestry, riparian and Mediterranean habitats) and, simultaneously, initialise morphodynamic processes for more long-term resilience.

3.1 Nestos (Greece): combining hydraulic interventions and forestry practices to reestablish the ancient Delta of Nestos river and its alluvial ecosystems



Project(s)

- LIFE NESTOS - Habitat Management and Raptor Conservation in Nestos Delta and Gorge (LIFE02 NAT/GR/008489)
- LIFE PRIMED - Restoration, management and valorisation of PRIority habitats of MEDiterranean coastal areas (LIFE17 NAT/GR/000511)

Status

- Complete (2002-2006)
- Ongoing (2018-2024)

Contact Person

Christos Georgiadis, Hellenic Society for the Protection of Nature (HSPN)

Site description and ecological challenges addressed

The Nestos Delta, created by the alluvial deposits of the river that have extended the land into the sea, covers an area of about 55,000 ha and is of high ornithological value, hosting 307 different bird species, 34 of which are endangered. Because of its size and the variety of its habitats, the Nestos Delta is considered among the most important wetlands of Greece and Europe, protected within the National Park of Eastern Macedonia and Thrace. Its ecological significance is reflected by the establishment of two NATURA 2000 sites: The Birds Directive site

(SPA) GR1150001 "Delta Nestou Kai Limnothalasses Keramotis Kai Nisos Thasopoula" (14,783.79 ha) and the Habitats Directive Site (SCI) GR1150010 "Delta Nestou Kai Limnothalasses Keramotis - Evryteri Periochi Kai Paraktia Zoni" (23,043.86 ha).

The latter hosts the largest remaining riparian forest in the Mediterranean region, the so-called "Kotza Orman" (Great Forest), which has been severely reduced in size and functionality in past decades. Today, along with the 155 ha of the remains of the ancient forest, a dense secondary forest has grown along the artificial course, covering 1700 ha. The reduction was mainly due to tree cutting, land reclamation, and dam construction that forced the river into one central riverbed, altering the water discharge regime and reducing the sediment load (Xeidakis & Delimani, 2002; Mallinis et al. 2011). Habitats and species in both Natura 2000 sites face several serious threats, including shrub expansion and invasive species encroachment, eutrophication, expansion of agricultural activities and inappropriate forest and water management. These pressures are related to direct or indirect human actions that expose forest ecosystems to multiple stress factors.

Nature-based solutions evaluated/implemented

In the early 2000s, project LIFE NESTOS (LIFE02 NAT/GR/008489) implemented reforestation activities in public lands along the river with indigenous and exotic forest species to increase the size of the forest. In total, 60 ha of new natural riparian forests on former agricultural land on both riverbanks were created, converting large patches of grasslands to areas covered by broad-leaves deciduous (12,790 seedlings of willows, poplars, alder, ash, oak and *Robinia pseudocacia*). Irregular planting schemes and mixed plots with clearings in between were adapted to the local conditions and natural plant communities (especially the EU-priority habitats of alluvial and gallery forests). Parts of the reforested areas were fenced to prevent access, and vegetation has grown abundantly. The project also implemented hydraulic interventions to reconstitute four old branches with the mainstream of Nestos river to recover freshwater marshes and riparian forests and prevent saltwater intrusions into ground and surface waters.

Under the framework of LIFE PRIMED (LIFE17 NAT/GR/000511), a set of other environmental-friendly ecological restoration solutions, including pilot hydraulic interventions, experimental treatments of invasive species, and ex-situ in-situ plant propagation actions were implemented about twenty years later to deliver proper ecological conditions for the long-term conservation of target habitat types (i.e. Mediterranean temporary ponds, H3170*, and alluvial forest, H91E0*). These NBS were not evaluated because they were made too recently.

Main results

The impact of the replanting was very good and reached up to 85% with some trees already reaching up to 5 m in height by the end of the project. New forest stands created roosting and feeding areas for wildlife species, especially raptors like white-tailed eagles.

The project managed to reestablish old river tributaries to reintegrate sufficient amounts of fresh water into the riparian forest throughout the year to restore some of the ecological functions. Four old river branches were reconnected with the main river course - two on each side of Nestos, about 7 and 1 km from its mouth. Some positive effects of the action were visible soon after its implementation, with water periodically flowing again along a larger delta area and an expected decrease in soil salinity. However, the impact of the system needed long-time monitoring to be properly evaluated.

In the framework of LIFE PRIMED, four new ponds, with a total size of circa 0.1ha, were successfully established in three locations in the Lazaros area. Around the ponds, wooden sticks for fencing were placed. Three well points were constructed around the temporary ponds at a depth of 4 metres with an exploitable yield of 5 m^3/h and a pumping level of 2 meters. The uptake system is connected with a water nebulisation network (tubes, micro-sprinklers, water pumps, etc.) to provide an additional water source to the temporary ponds in case of need.

The project also established experimental plots applying different control treatments for invasive alien species, including artificial vegetation shading with the placement of ground plastic sheets, trimming of *Amorpha fruticosa* and simultaneous new plantings of *Alnus glutinosa* and *Populus alba* to enhance the abundance of native tree individuals, sheep grazing treatment in fenced areas.

Effectiveness of nature-based solutions using NL4D approaches

Contrary to the NBS implemented by LIFE PRIMED, the restoration actions of LIFE NESTOS provided a longer timescale for a reliable spatiotemporal analysis. According to the insights of Action A.2 (see deliverable A2.2), LIFE NESTOS activities have been unsuccessful due to a combination of direct and indirect anthropogenic causes.

- Many afforestated areas have declined due to water shortages at river flow and rainfall levels (except for poplar plantations). These areas maintained a good forest cover until the early 2010s, but towards 2017, they were progressively replaced by evergreen woodland species, grasslands and bare soil.
- Consequently, a large part of the reconstituted network of old river branches has been desiccated over time due to a water shortage caused by a lack of attention from dam management bodies for natural ecosystems.
- From 2017, an overall increase in wetter climatic conditions seems to have favoured an expansion of 91E0* cover in these areas. However, the limited analysis timeframe and unpredictable weather conditions from one year to another did not allow reliable considerations to be achieved.

Innovativeness

The hydraulic works implemented by LIFE PRIMED represent the most innovative devices built in the area. They also constitute a technological advancement of those made by LIFE NESTOS. Rather than exploiting water directly from the river, which is more susceptible to flood, sediment, and biogeochemical alteration, well-points are based on groundwater interception from the Nestos river subalve. They are constructed to create groundwater-surface water interaction in the area. During extended dry seasons, the well-point intake is activated, and water is released through a remotely controlled pumping system powered by solar panels onto a dispersing surface of approximately 0.1 hectares. The hydraulic system includes a network of well points, an irrigation system with dynamic micro-sprinklers, and an electronic 9V battery-electronic system that enables remote-control operation intended to last for at least 30 years.

Transferability of results

The After-LIFE plan of project LIFE NESTOS issued in July 2007 envisaged a firm commitment of the Forest Service of Kavala and Fisheries Research Institute to monitor the impacts of reforestation and river reconnections on target habitats and fauna. The long experience of the Forest Service in confronting threats - such as poaching, illegal woodcutting, sand reception, overgrazing and other human disturbances - combined with increasingly better qualified and more numerous personnel was claimed as the long-term medicine for securing and replicating the restoration efforts made in the area. However, in the years following the LIFE NESTOS activities, actions to restore, conserve and valorise the natural capital of the Nestos Delta were severely limited in number and extent. Finding information on the course and progress of these actions also remained a somewhat tricky exercise, severely limiting continuity and technical-scientific transfer from one project to the others that followed, such as LIFE PRIMED. The Greek economic crisis represented among the most important causes of this sharp contraction as it significantly impacted the national services, leading to budget cuts and reduced resources for crucial conservation and management efforts nationwide.

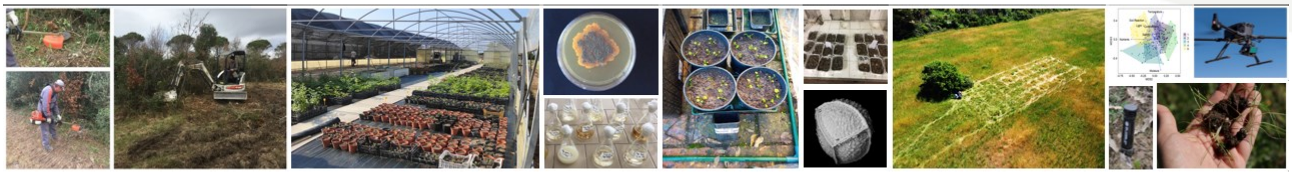
The situation improved in the early 2020s, coinciding with the end of the LIFE PRIMED project, allowing for a reinvigorated transferability of restoration actions. The experience and the contacts established during the project implementation succeeded in attracting the interest of nearby and other European partners for capitalising on the pilot hydraulic and IAS control systems with new jointly developed projects.

Lessons learned

Due to the aforementioned public service constraints, the project could not rely on existing initiatives. In addition, unexpected worldwide issues, such as the COVID-19 outbreak, exposed the project to further challenges of increasing complexity, which resulted in delays and complications. On the other hand, these barriers contributed to acquainting the involved experts with refined, improved and adapted technical, scientific and administrative know-how, enabling them to be among the most skilled teams in Greece in delivering practical restoration actions of riparian ecosystems and standing freshwater habitats.

Communication was pivotal in making the local communities and institutions closer and establishing a sense of responsibility for restoration devices and infrastructures (e.g., hydraulic systems, weather stations, and recreated temporary ponds). Regular briefings and producing and disseminating information material and publications were implemented to reach the scope.

3.2 Palo Laziale (Italy): interdisciplinary and evidence-based restoration techniques to promote ecological recovery of a Mediterranean floodplain woodland deployed by a severe case of forest dieback



Project(s)

LIFE PRIMED (LIFE17 NAT/GR/000511)

Status

Ongoing (2018-2024)

Contact Person

Vito Emanuele Cambria, Sapienza University of Rome

Site description and ecological challenges addressed

The Palo Laziale Wood is one of the last remaining patches of lowland forest along the coast of the Lazio Region that once covered the shoreline from the Tiber mouth to Capo Linaro. It is located about 40 km northwest of Rome, directly facing the Tyrrhenian Sea. It is a flat area of about 130 hectares, with an altitude between 3 and 10 metres above sea level. The woodland area of about 50 ha lies within a private property, entirely fenced in, and part of the SAC IT6030022 Bosco di Palo Laziale. The predominant vegetation is represented by a mixed forest of deciduous oaks, with a prevalence of *Quercus cerris* and rare individuals of *Q. petraea* and *Q. frainetto*. During rainy periods, the forest becomes completely swamped, with ponds in the depressed areas persisting until late summer and plant assemblages with species adapted to cope with such drastic changes (e.g. *Fraxinus angustifolia subsp. oxycarpa*) (La Montagna et al., 2023). However, over the last three decades, the area of Palo Laziale was affected by an increase in aridity due to a decrease in rainfall and a rise in temperatures, accompanied by extreme drought events (e.g. summer of 2003, 2007, 2020, 2022). This has limited the soil water content, also due to excessive plant evapotranspiration. Such abiotic stress has induced endophytic fungal agents hosted in the oak plants (e.g. *Biscogniauxia mediterranea, Discula quercina, Diplodia corticola*) to turn into a pathogenic stage, causing severe forest dieback with about 40% of the adult trees found dead and the forest canopy reduced by about 80% in 2004.
Unsustainable forestry practices and ineffective water management have caused severe forest dieback cases on the site, exacerbating climate change effects, shrub encroachment, inter and intra-specific competition among trees, pathogen vulnerability, and topsoil aridity.

Nature-based solutions evaluated/implemented

LIFE PRIMED has promoted on the site a set of traditional and innovative restoration actions, including selective trimming of encroaching shrub vegetation, creation of suitable biogeochemical conditions for the establishment of new temporary ponds, one free-pathogen forestry nursery and ex-situ and in-situ conservation practices of keystone plant populations, and a remote-controlled irrigation system to rebalance altered rainwater regimes in the forest stands. In particular, the hydraulic system aims to provide the target forest ecosystem with a supplementary water resource during the driest periods to ensure a proper water balance in the mixed deciduous forest. The water supply is essential to mitigate aridity and reduce excessive soil salinity and sodicity accumulation. To tailor and size these interventions, a team of experts from different disciplines have cooperated to assess and quantify the abiotic and biotic factors of the target habitat types.

Main results

The trimming interventions had an excellent result in Palo Laziale, with about 70% of the encroaching vegetation removed after the first stage. The activity has brought to light an affirmed renewal of trees from different ages ranging from 5 to 18 years old. This dense layer of seedlings comprises all the dominant tree species of Palo Laziale, including *Quercus cerris, Q. pubescens, Q. ilex, Fraxinus oxycarpa*. The shrub clearing also served to restore the fire-cut strips and access routes for fire-fighting and ground operations. The resulting material was used to produce organic fertiliser and mulch reused on-site.

Three ponds with different depths (from a few centimetres to 1 meter) were tailored to fit the habitat's ecological requirements (depth, soil composition and granulometry). Ponds no. 1 and no. 3 were designed with a "funnel" shape by digging at increasing depths from a few centimetres to a maximum of 1 metre but avoiding steep slopes so as not to impede the colonisation of aquatic fauna (e.g. *Emys orbicularis*). Pond no. 2 was created by only moving the topsoil (no digging required) to mainly welcome herbaceous species associated with habitat 3170*. Several uniform and shallow 5-15 cm depressions with some narrow, linear and slightly deeper furrows were obtained over almost the entire site. The three ponds have quite similar sizes, with diameters of about 40-50 meters each. In pond no. 2 were introduced typical species of the plant community *Isoëto-Nanojuncetea*, typically associated with habitat 3170* (*Ranunculus sardous, Lythrum tribracteaum, Mentha pulegium, Juncus bufonius, Isoetes spp*), which were propagated in a nursery.

In the same infrastructure were also cultivated woody species, including *Q. cerris, Q. pubescens, Q. ilex, Q. suber, Fraxinus spp.,* from seeds harvested from local donor sites, and afterwards planted in Palo Laziale for a total number of 2500. Only seeds that did not present signs of fungal presence/infection were propagated in the forest nursery, and resultant seedlings were monitored annually according to a phytopathological protocol.

A demonstrative hydraulic system was successfully implanted in the pilot site of Palo Laziale. Taking inspiration from agriculture, where it is typically used for irrigation purposes, this NBS was, for the first time, pioneered in restoring threatened and degraded forest ecosystems affected by climate regime alterations. The system is composed of three main components: a) a drainage trench to collect and deliver rainwater to the second component, b) this is an underground tank to store water during the wet period, c) a branched distribution network composed of draining trenches to provide the forest with a supplementary gravity-based amount of water during the hottest and driest period of the year.

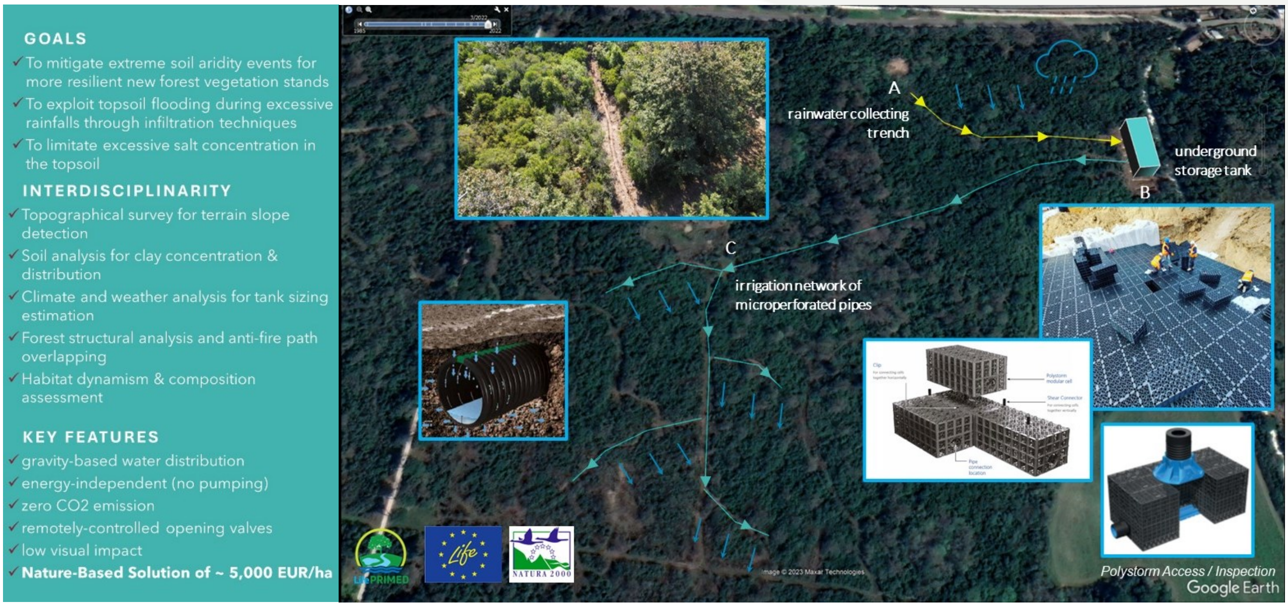


Figure 2. Infographic chart of the hydraulic system implemented in Palo Laziale.

Effectiveness of nature-based solutions

Establishing a permanent ecological-based monitoring system was a crucial step to evaluate the restoration effort in Palo Laziale, and enable the proper management and long-term conservation of the target forest stands. A multi-level sensor system was designed and operationalised to track changes in the forest conditions and verify ecological responses to the irrigation work. It focuses:

- tree INDIVIDUALS through xylem flow measurements to evaluate the gas exchange performance of trees during the growing season;
- tree SPECIES through measurements of the carbon assimilation and plant transpiration;
- forest COMMUNITIES through structure and dynamics assessments;
- forest ECOSYSTEM through weather and soil measurements;
- LANDSCAPE through remote-sensing and drone-based assessments.

The following considerations can be made:

• after the early signs of ecological degradation in 2002 (forest dieback) and until 2014 vegetation showed clear stress symptoms (scarce renovation, tree depletion, low forest density, reduced canopy, etc.);

• from 2014, vegetation status improved, although the recovery remained lower in the area mainly affected by the fungal outbreak;

• in 2017, a portion of the forest was affected by a fire event, which is depictable from both ground and aerial evidence;

• in 2018, LIFE PRIMED started; a significant renewal of the woodland was detected, especially in the younger age classes (5-15 cm)

• despite extremely low rainfall regimes (less than 500 mm per year on average) registered in the site from 2020 onwards, the forest did not exhibit signs of disturbance. The recovery process is expected to continue with a progressive reaffirmation of the original mature layer of native oak species (*Q. cerris, Q. ilex, Q. pubescens, Fraxinus oxycarpa*), and the long-term maintenance of the habitats targeted by the project's restoration actions (91M0, 3170*, 5230*).

Innovativeness

LIFE PRIMED was one of the first ecological restoration projects in the Mediterranean region that harmonised the incorporation of ecosystem-based knowledge in the design process of practices for the restoration, conservation, and management of declined Mediterranean habitats. Determining the vegetation structure was one of the key tasks in the holistic and interdisciplinary decision units; the spatial distribution of plant communities and the peculiar ecological features of certain taxa or groups, including their conservation status and needs, were fundamental steps in the adaptative restoration and management of the site.

The hydraulic interventions had a strong interdisciplinary background. For the works' design and dimensioning, foresters, biologists, pedologists, geologists, botanists, zoologists, and environmental engineers cooperated to establish a common scientific baseline and operationalise the latest methodologies. (a) The ground slopes and the functioning of gravity were defined to predict the water distribution direction, flow, and speed. (b) The soil permeability was assessed to predict the draining network's water-spilling capacity towards the plant roots. (c) The area's climate trends were quantified to understand the forest's water stress accumulated over the last six decades.

The irrigation system was designed to mitigate the aridity that has affected the Palo Laziale site over the last decades. This system aims to ensure a proper water balance for the forest ecosystems, providing supplementary water during the driest periods. It intercepts surface waters, reducing rapid rainfall runoff and preserving precious water resources. Meteoric water and surface runoff are collected in a drainage trench during the rainy periods (November-February) and stored in an underground tank, which releases the water during drought periods. The system will remain in operation for a period of 30 years. It represents an innovative nature-based solution with a low environmental impact and high replication potential to promote ecological restoration and long-term conservation of Mediterranean natural forest ecosystems. The key assets of the system are the following:

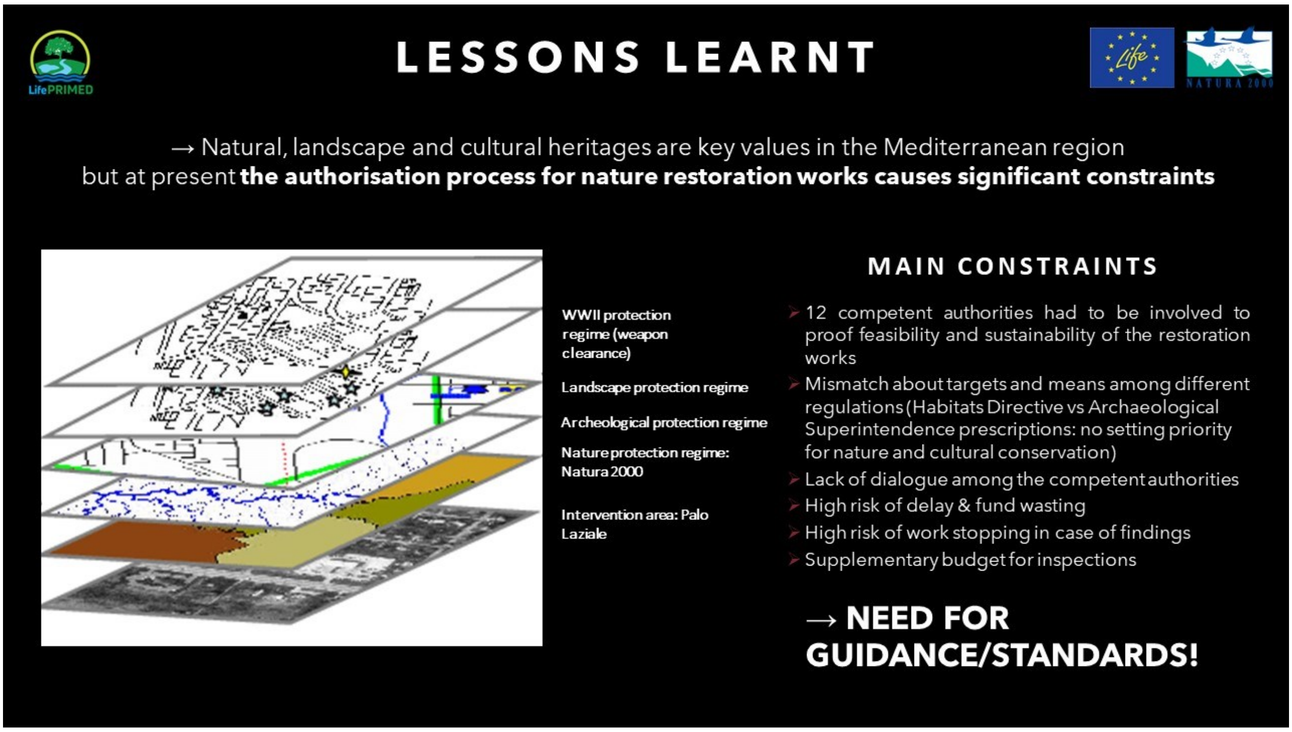
- the system works exclusively by gravity distributing water based on the natural slope of the ground;
- no fossil fuels are used to distribute accumulated water; photovoltaic panels power the pumping system;
- the water tank is wholly buried to exclude visual impact and disturb to wildlife;
- the excavation material is reused on-site, reducing landfill disposal.

Transferability of results

The interdisciplinary restoration approach and the NBS developed by LIFE PRIMED have been, in many cases, new and untried elsewhere, and results have been tested and evaluated in such a Mediterranean site for the first time. The project model was widely transferred through scientific conferences, networking events, and thematic events (e.g. Society for Ecological Restoration, Natura 2000 Biogeographical Seminars, and many other related platforms), and the best restoration techniques and solutions were replicated in other projects (e.g. NewLIFE4Drylands, TOPIO, LIFE SEEDFORCE, etc.).

Lessons learned

The NBS developed by PRIMED delivered a transnational, interdisciplinary, ecosystem-based holistic reference that can be replicated elsewhere to recover dysfunctional/deprived, poorly managed, or lacking natural and semi-natural forest areas. However, its pioneer ambition has highlighted the fragility of the existing administrative and bureaucratic machine responsible for the authorisation and execution of ecological restoration actions in Italy. Particularly, to implement field operations and construction works of the hydraulic system, it was necessary to get multiple authorisation certificates. Due to a peculiar overlap of several protection regimes in the wood of Palo Laziale (naturalist, landscape, archaeological, hydrogeological), the competent authorities to reach out to prove the feasibility and coherence of the restoration works were a remarkable number of twelve. Unfortunately, mismatches in targets and means among different regulations (e.g. there is not a clear and shared procedure to define conservation priorities in sites where both Habitats Directive vs Archaeological Superintendence prescriptions apply) and lack of dialogue and understanding among different competent authorities often caused dramatic delays and claimed supplementary financial sources to cover costs of unexpected needs (e.g. inspections, reports, etc.).



3.3 El Bruc (Catalonia, Spain): restoring agrosilvopastoral landscape planting with the Cocoon ecotechnology

Project(s)

- LIFE MONSERRAT - Integrated silvopastoral management plan: An innovative tool to preserve biodiversity and prevent wildfires (LIFE13 BIO/ES/000094)
- LIFE The Green Link - Restore desertified areas with an innovative tree-growing method across the Mediterranean border to increase resilience (LIFE15 CCA/ES/000125)

Status

- Complete (2014-2019)
- Complete (2016-2020)

Contact Person

Vicenç Carabassa, CREAF

Site description and ecological challenges addressed

El Bruc site is 700 ha wide and located at a 450-800 m elevation, corresponding mainly to private properties. Its climate is Mediterranean, with an average precipitation of 666 mm/y, 46 days of rain, and more than 3 dry months. This area went under a natural fire in 2015, which burnt 1000 ha, that were partially affected by a previous forest fire in 1986. Thus, it presents a high level of degradation: soil erosion and land abandonment. However, it represents a protection and connection corridor for the Montserrat-Roques Blanques-riu Llobregat SCI (code ES5110012), an emblematic area with a high touristic, aesthetic and ecological value.

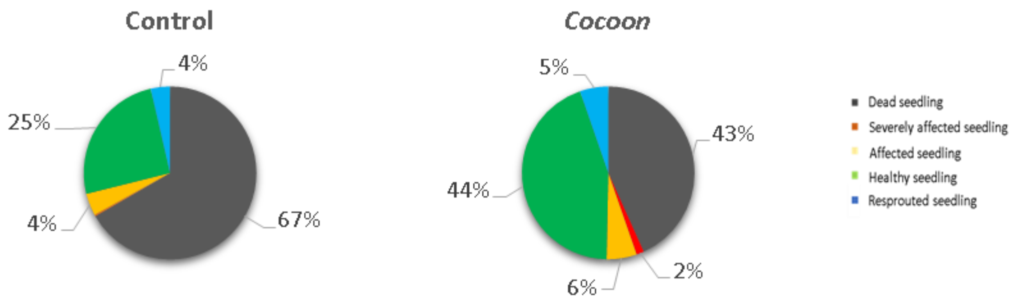
Nature-based solutions evaluated/implemented

LIFE Montserrat project was developed between 2014 and 2019 in 14 municipalities around Montserrat. This project promoted the implementation of livestock projects based on extensive forest grazing with the aim of maintaining, in the long term, a territory with high levels of biodiversity, less vulnerable to the spread of large forest fires, and better adapted to climate change scenarios. Additionally, the use of prescribed burning as a tool for habitat management and fire risk reduction was evaluated.

In the framework of LIFE The Green Link project a restoration plan that included the afforestation with a mosaic of agricultural and forest species was applied. This restoration plan had the specificity of the tool used for planting, the Cocoon, an innovative technology for tree and shrub plantation. (), The restoration plan was adopted and implemented during autumn 2016 and spring 2017, planting 4150 trees in 24 ha.

Main results

Regarding Cocoon planting system, this technology increased seedling survival in new plantations in El Bruc. Mortality ratio in control seedlings was 67%, higher than in Cocoon seedlings, where it was reduced to 43%. On the contrary, the percentage of healthy plants increased in individuals with Cocoon up to 44%, while in control seedlings it only reached 25% of the total. The best results were obtained in the two subspecies of *Quercus ilex* (spp ilex and spp ballota), *Quercus faginea*, *Olea europaea* var. Cornicabra and *Juglans regia,* where Cocoons had survival rates well above their respective controls.



Global distribution of the monitored seedlings planted in El Bruc (Catalonia), according to their physiological state in May-June 2019.

Regarding forest grazing the results confirmed the capability of the livestock used (cattle, goats, and donkeys) to effectively control forest phytomass, despite the low nutritional value of the most common species. The results on vegetation indicate progress in habitat management with grazing. However, in some Pastoral Management Units, the results were limited due to the short time since the start of grazing and the herds being too small for the area they need to manage.

Another notable finding from the monitoring conducted was that with more years of grazing in an area, less livestock density is required to achieve good results in terms of vegetation control. Therefore, the continuity and stability of pastoral projects are key to the adequate provision of environmental services.

The LIFE Montserrat project facilitated the integration of 10 new livestock farmers, which is quite a challenge considering the complex natural configuration of the environment and its relatively urban character within the metropolitan area of Barcelona, along with the pressures that entails. This integration was organized through the Catalan Shepherds' School, thereby highlighting the importance of this institution established in 2009.

Innovativeness

Regarding Cocoon use, a new planting system was designed to optimise the plantations in the context of restoration projects. This incorporates significant innovations compared to other existing planting tools: made from agri-food wastes contributes to circular economy and reduces prices; its biodegradability reduces maintenance costs and soil pollution; a natural substance that acts as repellent was added into the wax that goes on the external layer of the Cocoon, reducing herbivory problems; the transmittance system improves the water transport efficiency to the soil; an improved lid reduces premature collapse better-retaining water inside the bowl; an improved shelter design makes it more resistant to the elements. In El Bruc, a new planting system was designed using a drill installed on a tractor that increased the planting efficiency, reducing the time needed to make the holes, especially on steep slopes.

Regarding forest management, the main innovativeness that introduced LIFE Montserrat in the action area was related to governance management and payment for ecosystem services schemes. The people of each territory are the ones who manage it, but if they do not work towards a collective commitment to the territory, any action will always depend on investments and top-down directives from the authorities. That is why implementing a long-term management model in the territory requires the involvement and support of the participating entities, as well as the local entities and population. Managing complex projects that integrate diverse areas of action requires governance structures that facilitate effective coordination among the involved sectors.

Continuous work with landowners and livestock farmers has fostered mutual understanding, allowing for the reconciliation of interests and reaching agreements on long-term land stewardship that benefit all parties involved, as well as the conservation and biodiversity of the territory. These agreements can set a new precedent for relationships between stakeholders and sustainable management practices for the future.

Transferability of results

Originally, LIFE The Green Link consortium estimated to replicate the planting experience in 6 locations with 6.000 Cocoons. But already in 2016, many interested parties contacted the consortium with demand for replication activities. Thanks to the continuous development of the Cocoon and its lower cost price due to improved production capacity (FTI Cocoon project), the consortium decided to advance and expand the replication activities. Both Land Life Company and Volterra Ecosystems committed to offering an additional 1.500 Cocoons, and 50+ locations in Spain, Italy, Greece, and Portugal have now incorporated this innovative reforestation technique. LIFE Terra (www.lifeterra.eu) project uses this for planting activities.

Private companies and public administrations use the Cocoon in plantations in forest and agricultural scenarios.

The LIFE Montserrat project is necessarily replicable throughout the entire Mediterranean region. In Mediterranean Europe, the socioeconomic evolution discourages forest management and, along with the loss of the traditional agro-silvo-pastoral mosaic landscape, creates a scenario conducive to the development of large forest fires, a trend that is exacerbated by the current context of climate change. Fire prevention is clearly cost-effective compared to extinction measures and is therefore a strategy to be favoured. Additionally, the agro-silvo-pastoral mosaic that has traditionally shaped the Mediterranean mountain landscape holds the highest levels of biodiversity in this biogeographical environment and simultaneously offers conditions of high resilience to fires.

Maintaining ecosystem functionality and providing environmental services exceed the capacities of national and EU budgets alone. Only by incorporating payment for ecosystem services to viable small and medium-sized agricultural operations can major challenges like biodiversity loss or climate change be effectively addressed. Conservation policies and natural hazard prevention must be based on, and will only be viable in the long term, through the effective engagement of the main local socioeconomic stakeholders. Therefore, framework policies like the Common Agricultural Policy (CAP) need to be modified and adapted to support and favour small and medium-sized enterprises, balancing their influence with industrial agriculture. Real cross-sectoral cooperation between policies and administrations is necessary, capable of adapting to the different geographic realities across Europe, from Mediterranean to Central European agriculture.

Lessons learned

Prescribed burning

- Planning prescribed burns in spaces with softer topography allows for the reduction of the danger of fire escape and improves the outputs.
- Planning larger burn spaces simplifies management efforts and reduces costs.
- Starting from planning that includes a variety of structures to be treated in different locations allows for better use of prescription windows.
- The use of prescribed burns for the maintenance of adult tree structures with an herbaceous stratum for grazing seems to be an interesting and easy to execute option, both in populations of *Pinus halepensis* and *Pinus nigra.*
- The use of fire in regenerated *Pinus halepensis* treated with clearing without elimination of remains generates high mortality rates.
- The use of fire for the recovery of open spaces in bush structures on land not much suitable for other traditional means, due to slope limitations or owing to stony conditions is an interesting and viable option.

Forest grazing

- Livestock farming is recognized as a valid management tool by the involved stakeholders and it is perceived as a positive activity for the local population.

- The infrastructures and basic conditions to enable the start of grazing activities (livestock, land access, livestock infrastructures) are a necessary but not sufficient step to consolidate livestock farms in the long term.
- The provision of productive infrastructures, support for commercialization, and structuring of alternative income sources to production are needed.

Cocoon plantations

- The Cocoon device has worked well in the planned period when installed correctly.
- Shallow (<30 cm) or stony soils are not appropriate for installing this device. However, it can be used on soils with gravel or boulders that do not pierce the wall of the Cocoon.
- The main functionalities of the Cocoons last for at least a year, pending environmental conditions.
- The bottom of the bowl may continue to function as an anti-evaporation screen, thus increasing soil moisture availability to the tree seedling.
- As Cocoon becomes degraded, some fragments remain outside, which slows down its decomposition. In some areas, it may be advisable to remove the parts that remain on the surface, as well as the remains of the protectors.
- Besides rainfall regime, species type, the quality of the seedling, the planting process, and the soil quality play an important role in seedling development. Cocoons are less competitive than common techniques for plantations in soils with high water retention capacity in Mediterranean sub-humid climates, or when water drought-tolerant species are planted. Small differences in survival and growth, combined with higher planting costs with Cocoons, make this eco-technology less interesting in these situations.
- Cocoon is less efficient than traditional techniques when planting species tolerant to drought (e.g., *Pinus halepensis, Tetraclinis articulata, Prunus dulcis, Rosmarinus officinalis*).
- In general, Cocoon works better on tree species than in shrubs.
- Using good quality seedlings with well-developed roots without spiralling or J-rooting is very important.
- The use of the Cocoon has given good results for the plantation of olive trees by means of the traditional system of cutting, in comparison with the respective control.

3.4 Tifaracás (Gran Canaria, Spain): preintroducing endemic species in areas with high risk of desertification

Project(s)

LIFE The Green Link - Restore desertified areas with an innovative tree-growing method across the Mediterranean border to increase resilience (LIFE15 CCA/ES/000125)

Status

Complete (2016-2020)

Contact Person

Gustavo Viera (GESPLAN) and Vicenç Carabassa (CREAF)

Site description and ecological challenges addressed

Tifaracás is situated in the Gran Canaria Biosphere Reserve. It is an arid area inside El Nublo II, a Site of Community Importance (SCI) and a Special Area for Conservation (SAC), code ES7010039 (Natura 2000 network code). It is an arid area where the average rainfall is less than 200 mm, affected by desertification, wildfires and severe herbivorism (wild goats).

Nature-based solutions evaluated/implemented

The ecological restoration of the area included traditional plantation of different shrubs and tree species, all endemic from the Canary Islands. All the plantations were made using individual fencing against the wild goats. Innovative restoration improvements and trial areas were also planted using the Cocoon ecotechnology. Main plantations were carried out during November-December 2018 and October 2019 (3209 trees for 10,7 ha).

Main results

Cocoon technology increased seedling survival in new plantations. In Tifaracás, the site remained stable, with no significant changes in plant biodiversity. This could be attributed to the harsh environmental conditions of the area, characterised by an arid climate and the presence of wild goats (GESPLAN, 2019), which might hinder the development of more vegetation.

Individual fencing showed a high efficiency in protecting seedlings from wild goats. Moreover, those individual fences showed the potential to capture and harvest water from fog, which increased the water availability from the plant.

Innovativeness

The planting system was designed to optimise the plantations in the context of restoration projects. In this area previous plantations presented high mortality ratios, sometimes reaching 100%. Cocoon incorporates significant innovations compared to other existing planting tools: made from agri-food wastes contributes to circular economy and reduces prices; its biodegradability reduces maintenance costs and soil pollution; a natural substance that acts as repellent was added into the wax that goes on the external layer of the Cocoon, reducing herbivory problems; the transmittance system improves the water transport efficiency to the soil; an improved lid reduces premature collapse better-retaining water inside the bowl; an improved shelter design makes it more resistant to the elements.

Transferability of results

LIFE Nieblas (www.lifenieblas.com) project, mainly executed on Gran Canaria island, incorporates the use of cocoon and fencing systems used in LIFE The Green Link. In fact, the fencing system used in LIFE The Green Link constitutes the first prototype for Individual Fog Water Collectors (IFWC) that are being implemented with impressive results in Gran Canaria plantations.

Lessons learned

- Degradation rate is slower at sites in climates with higher aridity, which would prolong the device's usefulness and improve its influence on the plant. This is especially important in Tifaracás plantations, where seedlings must be watered at least once per drought season during the first year due to the high aridity.
- Heavier textured soil, characterised by higher water retention, may support survival and growth in lower rainfall regimes (and reduce the need for refilling(s) in arid regions).
- *Olea europaea var. guanchica* had high implantation ratios. All the seedlings of these species for the control group have died, but all the seedlings with Cocoon survived. Therefore, using these species on restoration projects is recommended in areas with similar climatic and edaphic conditions, using the Cocoon technology as a measure helping climate change adaptation.

3.5 Alta Murgia (Italy): testing ecological restoration techniques to promote dry grassland habitat recovery in degraded agricultural surface

Project(s)

NewLIFE4Drylands

Status

Ongoing

2021-2024

Contact Person

Rocco Labadessa, National Research Council

Site description and ecological challenges addressed

Alta Murgia is a SCI and Special Protection Area (SPA), code IT9120007. The site includes the Italian "Alta Murgia" National Park (2004) and is characterised by the presence of highly diverse unique ecosystems and endemic and threatened grassland species. However, over the years, it has been exposed to a tremendously fast process of habitat fragmentation and contamination due to combined pressures. The Common Agricultural Policy (CAP) drove the widespread transformation of calcareous grassland pastures into croplands by rock shattering, which also induced soil erosion and sediment deposition in aquifer. Such process had caused an extensive loss of semi-natural vegetation and ecosystem functions. Further threats locally belong to contamination of soils and aquifer systems caused by illegal waste and toxic mud dumping, as well as increasing traditional legal and illegal mining activities, wind farm infrastructures, and below-average precipitation for many years.

Nature-based solutions evaluated/implemented

The activities have been oriented at implementing a set of NBSs regarding ecological restoration techniques, addressing the need to counteract the effects of land degradation processes. Within an experimental site of 9000 m2, NL4D has promoted a set of sustainable techniques for restoring protected dry grassland types that naturally occur in Alta Murgia. 42 experimental plots of 20x10m areas (14 treatments with 3 replicates) were selected in either recently ploughed or unploughed surfaces. For each soil type, a set of restoration techniques was tested, including different combinations of soil processing (i.e. harrowing, topsoil inversion, sod cutting, soil compression), transfer of plant material (i.e. dry hay, seed-enriched hay, shrub seeds) and soil cover (jute bionet). Unmanaged surfaces were selected as control plots for each soil type. Full description of the implemented method and the results of the soil analysis are in the annex A4.2_TEC_20240301 "Scientific Report on recovery activities in Alta Murgia".

Main results

The effects of restoration actions have been monitored in terms of ongoing changes in plant community and soil features compared to initial conditions. Due to the initial stage of the restoration process, monitoring results could not provide a comprehensive evaluation of the experimented approach. However, early-stage vegetation dynamics still show a higher influence of the previous soil management (ploughed vs. unploughed) rather than of the tested treatments, with higher plant diversity and occurrence of grassland specialist species in the previously unploughed plots, especially in case of no treatments. At this stage, every type of disturbance due to soil processing seems to cause an increase in ruderal species, while no effect can be currently found with regard to seed sowing technique. As a preliminary result, with reference to the considered vegetation types, active restoration efforts do not have positive effects on previously undisturbed soils, though their effects may become significant in the subsequent seasons and more effective in facilitating the colonisation of previously disturbed agricultural surfaces. Based on field data collected during spring 2023 and 2024, detailed results of the early-stage vegetation dynamics observed in the restoration site will be detailed in the final report of the project.

Effectiveness of NBSs

The experimented approaches address the need to counteract the effects of a set of land degradation processes, i.e., landscape modification and habitat loss, decline in vegetation cover and ecosystem functioning, and soil erosion. Besides the activity has been mainly focused on testing ecological restoration techniques, the experimental site based in a farm fits with the approaches of NBSs regarding agro-ecology and organic farming, along with testing the feasibility of planning green infrastructures and ecosystem-based management at the larger scale of the National Park.

Innovativeness

The case study allowed for the first implementation of a comprehensive set of restoration techniques to recover semi-natural grasslands in Alta Murgia. By testing the effectiveness of the experimented NBSs, this activity can provide a documented framework to initiate and spread grassland restoration actions in the protected area and other sites in the Mediterranean region.

Transferability of results

The assessment of restoration effectiveness and feasibility will provide useful information to guide the users to the identification of the most suitable NBSs for the restoration of degraded lands. Within the aims of the NL4D project, the results of this experiment have been used to validate protocols and monitoring tools for environmental management and planning at local and regional scale based on the use of RS techniques.

Lessons learned

The ongoing activity proves the complexity of the implementation steps in the field. The problems encountered raise the need for a stable network of farmers and institutions, especially oriented at securing the follow-up and durability of restoration processes. Having to deal with the authorisation of land-transformation activities in a protected area, although oriented at ecological restoration, also highlighted the need for specific agreements with public administrations that could help facilitating the implementation of good practices.

3.6 Asterousia Mountains (Crete, Greece): Restoration Plan with proposed NBS on land and soil management



Project(s)

NewLIFE4Drylands

Status

Ongoing

2021-2024

Contact Person

Michalis Probonas, University of Crete – Natural History Museum of Crete (UoC – NHMC)

Site description and ecological challenges addressed

The Asterousia mountain is located in the Heraklion Prefecture of Crete. The area's climate is characterised as sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers. The soils are highly degraded due to erosion with exposed bedrock in several places. Vegetation consists mainly of phrygana and maquis; olive groves are present in areas with relatively deep soils. Although the natural vegetation in the Asterousia Mts shows a capacity for succession to higher forms, the area is overgrazed during the winter months, which prevents such succession. In addition, climate, with long and dry summer and high evapo-transpiration rates, favour desertification due to water scarcity and droughts. The resulting loss of productive, arable land from soil erosion and salination and the over-pumping of aquifers to compensate for water losses are among the key factors posing a desertification risk for the site, which is further intensified by rising global warming effects.

Nature-based solutions evaluated/implemented

At the time this report was being drafted, NL4D was developing the Restoration Plan for Asterousia. The proposed NBS techniques, based on the results of the Protocol and Monitoring Model of NL4D, include:

• Afforestation/reforestation

• Agroforestry by integrating trees with crop and/or livestock systems

• Changing the direction of plowing and cultivating along the lines

• Implementing soil erosion control structures, such as traditional dry-rock walls

• Adopting reduced or eliminated tillage practices

• Employing soil management practices like compost application and mulching.

The Restoration Plan of Asterousia area will not be binding but will serve as an advisory and scientific tool for local authorities and governmental agencies to deal more effectively with desertification and enhance the resilience of ecosystems, the environment and local communities. The expected results from its voluntary implementation of these NBS techniques by competent authorities could be observed from the years 2024/2025 and onwards. Parts of its prescriptions will be operationalised in the project MONALISA ‘MONitoring and Assessing prevention and restoration solutions to combat desertification in LIving labs for achieving Soil heAlth’ (HORIZON-MISS-2023-SOIL-01-04), which started in 2024.

Main results

NA

Effectiveness of nature-based solutions

NA

Innovativeness

NA

Transferability of results

NA

Lessons learned

NA

4. Limitations/gaps in assessing NBS applied in the case studies and recommendations for more appropriate monitoring and evaluation schemes

1. Overlook of Long-Term Monitoring

Many NBS initiatives lack long-term monitoring strategies, making assessing sustained impacts many years beyond their implementation challenging. Few but easy-to-use and easy-to-monitor parameters have to be identified and scheduled well before the end of the projects to enable ex-post longitudinal studies to be carried out for the time being. They are essential for understanding how ecosystems evolve over time and how their benefits may change.

2. Lack of Interdisciplinary Integration

In most of the case studies, the solutions for ecological restoration were often implemented in a mono-sectorial way. For a more holistic NBS, there is a need for more comprehensive interdisciplinary approaches that integrate ecological, economic, and social dimensions, each one with its own strengths and gaps.

3. Constraints of Existing Technology

Satellite Remote Sensing cannot represent useful support in case of small areas less than 50 ha in size, as discussed in deliverable A2.2. RS primarily captures surface-level information, and monitoring below-ground processes associated with Nature-Based Solutions, such as root system dynamics, remains a significant challenge. Furthermore, some indices extracted by satellite RS data are not reliable in the case of the presence of high vegetation as those related to soil conditions (e.g., Soil Salinity, Soil Organic Carbon). Moreover, RS may face challenges in accurately characterising intricate vegetation processes.

4. Lack of Standardised Metrics

The absence of well-defined standardised metrics hinders comparability across these different NBS projects. Developing universally accepted metrics and assessment frameworks can enhance consistency and facilitate cross-case comparisons. For example, those developed by NL4D and reported in Action A.5.

5. Exclusion of Local Knowledge

Although many of these NbS were implemented in the framework of EU-funded projects, which usually promote engaging local communities, indigenous knowledge and perspectives were often unincluded in NBS design and implementation schemes. Incorporating traditional ecological knowledge can provide a more holistic understanding of the effective need for NBS and facilitate monitoring the impact of NBS on local communities and ecosystems on a long-term basis.

6. Uncertain Feedback Loops

Understanding the complex feedback loops within ecosystems is challenging. Assessments should consider the potential unintended consequences of NBS, such as altered hydrological patterns or shifts in species interactions.

5. Conclusion

NBSs have emerged as promising strategies for addressing a myriad of environmental challenges, ranging from climate change mitigation to biodiversity conservation and ecosystem restoration. These approaches leverage the inherent power of nature to provide sustainable and cost-effective solutions. NL4D outlined how assessing the impact of NBSs is essential for effectively maximising NBS benefits and addressing environmental challenges.

Restoration practices in the Mediterranean case study areas demonstrated successes and challenges. From the information gathered from these 6 six case studies is evident that the assessment of NBS effectiveness encounters various obstacles and gaps. This report underscored the need for collaborative, adaptive, and well-planned restoration strategies to address environmental degradation effectively. While current methodologies provide valuable insights, addressing the identified gaps is crucial for a more comprehensive understanding. Long-term monitoring, interdisciplinary collaboration, standardised metrics, the inclusion of indigenous knowledge, and consideration of feedback loops are key areas that require attention to advance the field of NBS impact assessment.

This dearth of documented experiences and evidence is particularly evident in the realm of long-term monitoring and assessment. Many NBS projects designed to restore ecosystems and enhance their resilience face challenges in establishing robust monitoring mechanisms that can capture changes over extended periods. Consequently, the paucity of longitudinal data limits our understanding of the sustained impacts of NBS on ecosystems, hindering the development of evidence-based best practices. The lack of standardised metrics and universally accepted evaluation methodologies hampers the ability to draw meaningful comparisons across diverse NBS initiatives. Current RS assessments must focus on multiple aspects to prevent a fragmented understanding of NBS impacts. Addressing these limitations through advanced sensor technologies, improved spectral capabilities, and integration with ground-based monitoring approaches is crucial for enhancing the utility of remote sensing in effectively monitoring Nature-Based Solutions.

As we strive for a sustainable future, refining assessment methodologies will contribute to the success of nature-based approaches in addressing global environmental challenges. By learning from the experiences of these case studies, stakeholders can refine future restoration initiatives, contributing to the overall sustainability and resilience of the Mediterranean ecosystems.

6. Bibliography

- European Commission, 2013. Green Infrastructure (GI) - Enhancing Europe's Natural Capital. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (GI). Brussels, (COM (2013) 249 final). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0249:FIN:EN:PDF
- European Commission, 2015. Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. Final report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'. Directorate-General for Research and Innovation, Brussels.
- European Commission, 2016. Establishing Urban Agenda for the EU 'Pact of Amsterdam' - Agreed at the Informal Meeting of EU Ministers Responsible for Urban Matters on 30 May 2016 in Amsterdam, The Netherlands.
- European Commission, 2019. The European Green Deal.
- European Commission, 2020. EU Biodiversity Strategy for 2030. Bringing nature back into our lives. Brussels, 20.5.2020 COM(2020) 380 final.
- European Commission, 2021. Forging a climate-resilient Europe – the new EU Strategy of Adaptation to Climate Change, COM(2021) 82 final.
- Garmendia, E., Apostolopoulou, E., Adams, W.M., Bormpoudakis, D., 2016. Biodiversity and green infrastructure in Europe: boundary object or ecological trap? Land Use Policy. http://dx.doi.org/10.1016/j.landusepol.2016.04.003
- La Montagna, D., Cambria, V. E., Attorre, F., De Sanctis, M., & Fanelli, G. (2023). Temporal changes of vascular plant diversity in response to tree dieback in a mediterranean lowland forest. ANNALI DI BOTANICA.
- Mallinis G., Emmanoloudis D., Giannakopoulos V., Maris F., Koutsias N., 2011. Mapping and interpreting historical land cover/land use changes in a Natura 2000 site using earth observational data: The case of the Nestos delta, Greece. Applied Geography 31: 312 – 320.
- Xeidakis, G. S., & Delimani, P. (2002). Coastal erosion problems in Northern Aegean coastline, Greece. The case of the Rhodope Prefecture coasts. Environmental. Studies, 8, 151e158