LAYMAN'S REPORT

LIFE18 CCA/ES/001110

LIFE Mycorestore

Innovative use of mycological resources for resilient and productive mediterranean forests threatened by climate change.

1 What is LIFE MycoRestore?

LIFE MycoRestore is an innovative project that aims to enhance the resilience of Mediterranean forests in Spain, Italy and Portugal by harnessing the potential of mycological resources and implementing sustainable forest management practices to address the challenges imposed by climate change.

The project seeks to create wildfire and drought-resistance forests, promote green job opportunities that boost local economies and explore natural solutions for mitigating pests and pathogens.

Through these integrated efforts, LIFE MycoRestore plays a crucial role in safeguarding the long-term health and socio-economic well-being of Mediterranean forests, fostering a collective commitment to preserving these invaluable ecosystems for future generations.


of preserving our forests, increasing their
adaptability to climate change,

2 Project motivation

The motivation behind the LIFE MycoRestore project stems from the urgent need to address the multiple biotic and abiotic stressors currently threatening Mediterranean forests.

As climate change continues to unfold, droughts, the primary abiotic stressor in these ecosystems, are projected to become more frequent and severe, consequently amplifying the risk of forest fires. Furthermore, the increasing trend of rural abandonment has led to a decline in traditional silviculture practices that historically played a crucial role in mitigating fire outbreaks.

Extreme weather conditions can also weaken the health of the forest flora, and make it more vulnerable to pest and pathogens attacks. Rising temperatures contribute to an increase in the population of these biotic stressors, leading to the spread of disease among trees and causing significant tree mortality rates. Such impacts undermine the vitality of forest ecosystems and compromise their overall resilience.

LIFE MycoRestore's objective is to strengthen forest health in the Mediterranean region by utilising the inherent capabilities of fungi species to regulate forest humidity, provide natural pest control, and offer economic potential, in conjunction with the implementation of sustainable forestry practices that support local economies.

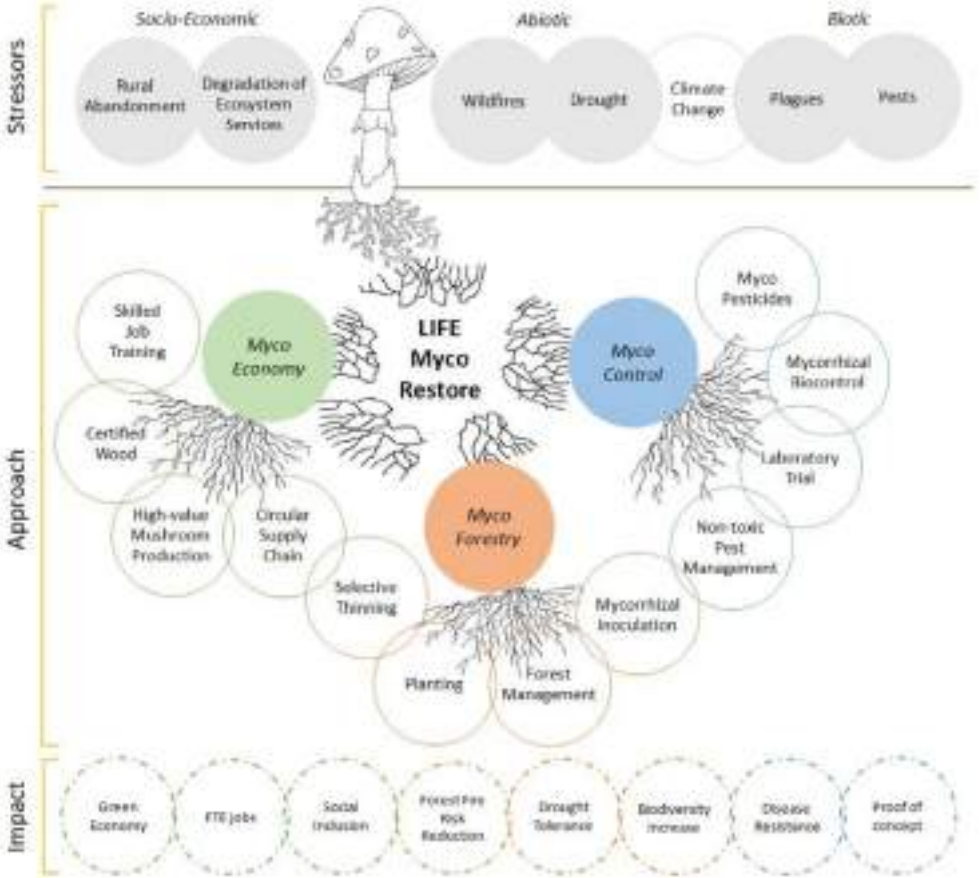
3 Project overview

LIFE MycoRestore operates in 3 interconnected fronts, each with its specific objective:

MycoForestry
Demonstrate sustainable mycological and forestry management practices for wildfire & drought-resistant forests.

MycoEconomy
Promote green jobs to stimulate rural economies and add value to products coming from forests managed in a sustainable way.

MycoControl
Provide proof of concept on the use of natural mycocontrol products and native fungal species for reduced pest/pathogen presence in forests.


Stressors
Socio-Economic
Rural Abandonment
Degradation of Ecosystem Services
Abiotic
Wildfires
Drought
Climate Change
Biotic
Plagues
Pests
Approach
LIFE Myco Restore
Myco Economy
Skilled Job Training
Certified Wood
High-value Mushroom Production
Circular Supply Chain
Myco Control
Myco Pesticides
Mycorrhizal Biocontrol
Laboratory Trial
Non-toxic Pest Management
Myco Forestry
Selective Thinning
Planting
Forest Management
Mycorrhizal Inoculation
Impact
Green Economy
FTE jobs
Social Inclusion
Forest Fire Risk Reduction
Drought Tolerance
Biodiversity Increase
Disease Resistance
Proof of concept

4 Where was the project carried out?

The project was carried out in several locations in Spain and Italy, each with unique forest ecosystems and specific challenges.

In **Spain**, four demonstration sites were selected: La Alamedilla, Linares de Riofrío, Cubo de Don Sancho, Valdelosa. These sites represented different Mediterranean forest types and faced various issues such as oak decline, pest infestation, and chestnut blight. The MycoEconomy activities took place in Tavertet, Catalonia at Mas Avenc and Mas Rajols

In **Italy**, the demonstration sites were San Godenzo and Vallombrosa. In San Godenzo, the project focused on a chestnut orchard affected by Ink disease and a chestnut coppice affected by chestnut blight. In Vallombrosa, a mature stand of silver fir was affected by root rot and wind damage.

In **Portugal**, activities took place in Cerdeira, an area where the native forest is under pressure from the presence of invasive species such as Acacia mimosa and Eucalyptus.

Overall, the project covered a range of forest types and phytopathologies, implementing targeted interventions to mitigate the impact of diseases and pests, enhance tree resilience, and promote sustainable forest management practices.

1. **La Alamedilla.** *Quercus ilex* - Holm oak
2. **Linares de Riofrío.** *Castanea sativa* - Chestnut
3. **Cubo de Don Sancho.** *Quercus pyrenaica* - Pyrenean oak
4. **Valdelosa.** *Quercus suber* - Cork oak
5. **Tavertert.** *Fagus sylvatica* - Beech tree
6. **San Godenzo.** *Castanea sativa* - Chestnut
7. **Vallombrosa.** *Abies alba* - Silver fir
8. **Cerdeira.** *Acacia dealbata* - Mimosa

5 How was the project carried out

5.1. Preparatory actions | 5.1.1. Mapping Forest Health

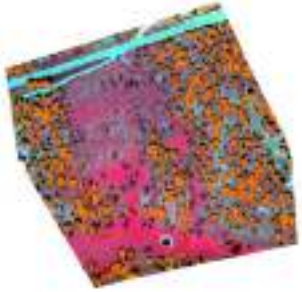
To assess the state of the forest before the initiation of the LIFE MycoRestore project, drone flights were conducted in various plots. The objective was to evaluate forest health, identify diseases, and detect pests such as chestnut canker, *Coraebus undatus*, and *Cerambyx welensii* insects.

The analysis was conducted in both Italy and Spain, focusing on the impact of diseases on the tree canopy. The drones were equipped with RGB and multispectral cameras, allowing the capture of orthophotos, digital elevation models, and vegetation indices such as NDVI, GreenNDVI, and NDRE. However, diseases affecting the roots were not evident in these maps, necessitating the development of in situ tests.

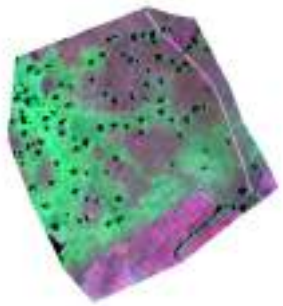
Also, a groundlevel baseline analysis was performed at the beginning of the project and at the end, to check for the forest health status and assess the improvement gained after the project strategies were implemented

This mapping exercise provided a detailed overview of the forest's overall health, highlighting areas susceptible to diseases, pests, or other stressors.

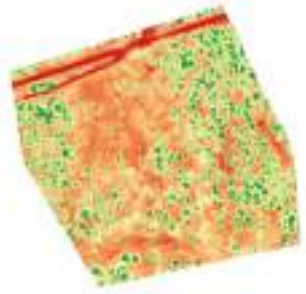
Ortofoto
Valdelosa 2019



Cartografía arbolado
Alamedilla 2019



Combinación Red/NIR/Verde
Cubo Don Sancho 2018



Normalized Difference Vegetation Index (NVDI)
Alamedilla 2018

| **5.1.2.** Plan & Design trial sites & training

The information obtained in the previous action served as a valuable resource for guiding management decisions and designing targeted interventions to restore and improve the health of these forests.

These results highlighted the challenges faced by the Spanish sites, including oak decline caused by *Phytophthora cinnamomi*, pathogenic fungi, bacterial infections, and pest diseases, as well as chestnut forests affected by chestnut blight disease. Inoculations with symbiotic fungi (mycorrhiza) and biocontrol agents like *Trichoderma sp.* were planned, as well as the planting of mycorrhizal vegetation to enhance tree resilience. The project also planned to introduce biodiversity boxes, with the purpose of attracting insectivorous birds, bats, and insect pollinators and predators, in order to control insect pests.

In Italy, soil inoculation with biocontrol agents was planned to treat the chestnut orchards affected by Ink disease and silver fir affected by annosum and arrmillaria root rot. Moreover, trunk inoculation with hypovirulent strains of the chestnut blight pathogen was also programmed.

| **5.1.3.** Preparing strategy for MycoEconomy

The partners of the LIFE MycoRestore project, including Mycelio, Volterra, Cerdeira, and Social Forest, collaborated to prepare a comprehensive strategy for the development of a sustainable MycoEconomy.

Through extensive market analysis, research, and partnerships, they identified opportunities in specialized forest products, services, and alternative revenue streams.

This strategic approach aimed to harness the potential of fungi-based solutions, such as substrate production, biomass utilization, and biochar, while promoting local economic growth, environmental sustainability, and social inclusion.

By combining their expertise, conducting training programs, and conducting research, the partners laid the foundation for a thriving MycoEconomy that benefits both the communities and the natural ecosystems.

Thinning

Thinning plays a crucial role in the LIFE Mycorestore project by selectively removing a portion of trees from overgrown forests, enhancing ecosystem health and promoting biodiversity. This practice allows for improved light penetration, air circulation, and nutrient availability, creating favorable conditions for the growth and development of target fungi and facilitating their ecological functions in the forest ecosystem.

Two selective thinnings were performed in Linares de Riofrio in 2021 to improve forest health. Mas Rajols also performed selective thinning to decrease the density of the forest in order to avoid forest fires. The wood obtain was later use for biochar production.

| 5.2.1. Mycoforestry

Planting

Planting mycorrhizal trees is of paramount importance in the LIFE Mycorestore project as these trees establish symbiotic relationships with beneficial fungi in the soil. Through mycorrhizal associations, the trees enhance nutrient uptake, improve soil structure, and increase resistance to environmental stresses. By incorporating mycorrhizal trees, the project aims to restore and improve forest ecosystems, promoting their resilience and long-term sustainability.

Planting took place in Cubo de Don Sancho and La Alamedilla in 2021, 2022, and 2023. In total, the project involved the planting of 232 mycorrhizal plants and 325 non-mycorrhizal plant.

Fungal inoculation

Fungal inoculation, particularly with Trichoderma and ectomycorrhizal fungi, was a key aspect of the project's Mycoforestry activities. Trichoderma fungi, known for their biocontrol properties, were introduced through airborne and soil inoculation. These fungi produce enzymes and metabolites with antifungal and antibiotic properties, helping to prevent the colonization of harmful microorganisms in plant roots.

In addition to Trichoderma, ectomycorrhizal fungi were inoculated in all demo sites. These fungi formed beneficial associations with plant roots, enhancing water and nutrient absorption, improving plant nutrition, and increasing tolerance to stress. Pisolithus tinctorius, in particular, mitigated the effects of water stress and provided resilience to drought conditions, making it valuable for tree health in the context of climate change.

Liming

Furthermore, the project focused on liming, which involved the amendment of acid soils with calcium carbonate or calcium sulfate. The primary objective was to correct the soil pH and make calcium ions available. This correction promoted the development of biocontrol species like Tuber borchii and Tuber aestivum (truffles) and created an antagonistic environment against the phytopathogenic Phytophthora cinnamomi, as calcium ions inhibited its growth.

The amendments were applied annually, with the doses determined based on initial soil pH and texture. It was important to avoid abrupt increases in pH to prevent the release of other toxic elements in the soil. The execution of liming was recommended before the spring rains or in September-October, and regular soil pH evaluation ensured the desired levels were maintained.

*Through these practices, the LIFE MycoRestore project aimed to establish **resilient and healthy ecosystems** in forests, promoting biodiversity, supporting natural regeneration, providing protection against pathogens, enhancing plant nutrition and stress tolerance, and promoting the growth of valuable species like truffles.*

5.2.2. MycoEconomy

In the MycoEconomy component of the LIFE Mycorestore project, the focus was on promoting sustainable practices and developing a thriving mycorelated industry. The project engaged in various activities to achieve these goals, benefiting both the environment and the local economy.

One crucial aspect was the implementation of a comprehensive training program. This program aimed to equip individuals with the necessary skills in sustainable forestry management and mushroom cultivation. Participants received training on topics such as sustainable forest management techniques, wood processing, chainsaw use, mushroom and substrate production, and biochar production. The successful completion of the program allowed participants to obtain the prestigious European Chainsaw Certificate, highlighting their expertise and knowledge.

| **5.2.2.** MycoEconomy

To strengthen the supply chain and reduce dependence on external factors, a facility for producing mushroom substrates was succesfully established by one of the partners. The substrates are derived from the wood obtained from sustainably managed surrounding forests as part of the MycoEconomy action. The project overcame challenges in refining the production setup and obtained organic certification for both mushroom cultivation and substrate production, highlighting the commitment to sustainable practices .

In addition to substrate production, experiments were conducted to create high-value compost by combining spent mushroom substrate, cow manure, biochar, and effective microorganisms. The resulting compost received positive feedback from farms and. The project also focused on biochar production, ensuring its consistency and quality.

The project also ventured into the world of truffles. We focused on inoculating and producing truffles, contributing to the development of the mycorelated industry.

These activities highlight the project's contribution to the development of sustainable mycoEconomy practices, emphasizing the potential for local, small-scale and circular forestry management approaches.

5.2.3. Mycocontrol

The LIFE Mycorestore project incorporated a promising approach called mycocontrol to manage plant diseases and pests in a sustainable manner. Mycocontrol involves utilizing beneficial fungi as natural biocontrol agents to suppress harmful organisms and promote plant health. By harnessing the power of specific fungal species, the project aims to reduce the reliance on conventional chemical pesticides, which can have detrimental effects on the environment and human health.

Through extensive research and experimentation, the project has identified several key fungal species that exhibit strong biocontrol properties against various plant pathogens and pests. These fungi are selected based on their ability to outcompete and antagonize harmful organisms, effectively suppressing their growth and minimizing damage to crops. The project team has developed innovative formulations and delivery systems to optimize the application of these beneficial fungi. These formulations ensure the survival and efficacy of the fungi while allowing for easy and practical deployment in agricultural and forestry settings. Also, the project has analysed bacterial microbiome of holm oak tree in order to check for bacteria involved in the oak decline disease and to establish basis for future biocontrol schemes of the disease.

In addition to its efficacy in disease and pest control, mycocontrol offers additional benefits such as improved soil health and biodiversity conservation. The beneficial fungi employed in the project not only protect plants but also contribute to the overall ecological balance by enhancing soil quality, promoting nutrient cycling, and fostering a favorable environment for beneficial microorganisms.

1 **Identification of Pathogens**
Field surveys
Sample collection

2 **Laboratory Analysis**
Pathogen characteristics
Life cycle study
Weakness identification

3 **Forest Trials**
Testing mycocontrol techniques
Application of beneficial fungi
Assessing effectiveness

If you want to learn more, consult the Guide for the identification and control of some common diseases of Mediterranean forest.

5.2.3. Mycocontrol

For pests control, the project installed pheromone traps to monitor and control the populations of pest beetles in Spanish demo sites of El Cubo and La Alamedilla.

In addition to the planned mycocontrol methods, a second natural control approach using **biodiversity boxes** was implemented in Spanish sites 3 and 4 of the project. This innovative method, inspired by successful implementations in other projects, involves installing specially designed boxes in trees. These boxes attract birds, bats, and insect pollinators and predators that help control pests such as Coraebus and Cerambyx beetles.

*By promoting sustainable pest management practices, the **LIFE Mycorestore** project contributes to the preservation of agricultural productivity, environmental conservation, and safeguarding of human health.*

6 Conclusions of the project

The LIFE MycoRestore project has reached its conclusion, marking a significant milestone in the advancement of mycoforestry techniques and their application in forest restoration and management. Throughout the project's duration, a wide range of activities and research initiatives were undertaken, yielding valuable insights and outcomes.

The project successfully demonstrated the potential of fungal inoculation, mycocontrol, and other mycoforestry practices in improving forest health, combating tree diseases, and enhancing ecosystem resilience.

Moreover, the project explored the economic prospects of mycoeconomy, recognizing the value of specialized forest products, including substrates, mushrooms, and biochar. By establishing partnerships, conducting market analyses, and developing business plans, the project showcased the potential for sustainable, circular economic models that leverage fungi as a renewable resource and create employment opportunities within local communities.
The successful collaboration between project partners, stakeholders, and local communities has been instrumental in achieving all the project's objectives. Through knowledge sharing, capacity building, and community engagement, the project fostered a sense of ownership and created a network of actors dedicated to advancing mycoforestry practices.

As the project concludes, its legacy will continue to inspire future research, forest management approaches, and policy development. The LIFE MycoRestore project has laid a solid foundation for further exploration of mycoforestry, offering a sustainable and innovative solution for forest restoration, biodiversity conservation, and the promotion of thriving rural communities.

7 EU policies synergies

The LIFE MycoRestore project strongly supports key European Union policies and initiatives, showcasing its alignment with the New Forest Strategy 2030, the European Green Deal and the Biodiversity Strategy to 2030. The project's contributions are multifaceted and impactful.

In terms of the **New EU Forest Strategy for 2030**, LIFE MycoRestore ensures the sustainable and balanced management of EU forests, enabling their multifunctional potential to thrive. By implementing innovative mycoforestry techniques, the project enhances the ecosystem services provided by forests, addressing the growing demand for raw materials, such as mycelium-based and wood-based products, as well as renewable energy sources like biomass. Additionally, MycoRestore responds to the challenges faced by forest-based industries by promoting innovation, training, skills development and effective information exchange.

The project directly supports the **EU's Biodiversity Strategy for 2030**. By leveraging the ecological role of fungi, the project aims to enhance biodiversity and ecosystem services within forestry systems. It focuses on conserving and restoring fungal diversity, which is critical for the functioning and resilience of ecosystems. As climate change intensifies, the project's efforts play a crucial role in safeguarding forests against the escalating threats of fires, droughts, pests, and diseases.

Through these actions, LIFE MycoRestore not only fosters forest resilience but also paves the way for a more resilient economy.
By involving local stakeholders, such as forest owners, farmers, and residents, the project fosters community engagement and participation. It provides opportunities for capacity building, knowledge transfer, and the creation of green jobs, thus supporting **rural community development.**

Lastly, the **Circular Economy Action Plan**, a key component of the **European Green Deal**, finds strong relevance in the MycoEconomy aspect of the LIFE MycoRestore project. The project's integral approach to various forestry activities aligns with the principles of the circular economy. By harnessing the potential of fungi and adopting sustainable practices, MycoRestore exemplifies how waste materials can be transformed into valuable products, reducing waste generation and promoting resource efficiency.

8 Dissemination activities

The work and achievements of the LIFE MycoRestore project have been effectively disseminated to increase awareness and knowledge about its objectives. A wide audience has been reached, estimated at approximately **27,500 individuals**, who engaged with the project through the website, social media channels and participation in both online and on-site events.

Events:

- 13 Networking events with 21 LIFE Projects. Audience: 400 individuals.
- 10 Local Awareness events. Audience: 350 people.
- 4 Commercial events held by Mycelio, with a highlight in Biocultura 2021 where around 1000 visitors knew about MycoRestore visiting Mycelio's stand.
- 10 National and international conferences. Audience: 800 attendees.
- 18 presentations to different stakeholders. Audience: 449 individuals.
- 3 Technical Seminars

7,469 *visitors*
492 *news articles*

197 *followers*

42 *videos*
10,348 *views*
102 *subscribers*

486 *posts*
#lifemycorestore

303 *followers*

30 *Press mentions*

Examples of press mentions

Mycelio at Biocultura BCN 2021

Networking con LIFE Esc360 in Italy

The MycoRestore Good practices Guide set to policy makers

9 The LIFE project

LIFE is the EU´s financial instrument supporting environmental and nature conservation projects throughout the EU. Since 1992, LIFE has co-financed more than 5,500 projects, contributing approximately 5,000 million euros to the protection of the environment.

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This Project is co-financed by the European Union through the LIFE Programme.

Total budget:
€3,045,717

% EU contribution:
€1,575135

Duration:
01/07/2019 – 30/06/2023

Contact:
https://mycorestore.eu/en/contact/

10 Partners

Project leader.

The Institute of Natural Resources and Agrobiology of Salamanca (IRNASA) is part of the Spanish National Research Council (CSIC), and it conducts multidisciplinary research to provide scientific solutions for the sustainability of agroecosystems, including strategies for ecological conservation and resilience of forest and agriculture ecosystems facing the climate change challenges"

Collaborating with universities and research institutions, IRNASA-CSIC has extensive experience in managing research projects.

The University of Valladolid is one of the most important centers of Higher Education in Spain.

Its "Cátedra de Micología" includes various public, private and scientific actors that promote fungi as a source of social, scientific, ecological and economic wealth.

This group of experts is responsible for conducting numerous research investigations related to the world of fungi, including and extensive research on the biocontrol of forest diseases using local fungi strains.

Cerdeira - Home for Creativity is dedicated to revitalizing the abandoned village of Cerdeira in Serra da Lousã, preserving its architecture and cultural landscape with a creative and ecological approach.

Cerdeira also prioritizes the conservation of the forests surrounding the village and the promotion of a sustainable economy that highlights the value of local resources.

IDForest is a technology-based company specialised in fungal biotechnology that develops cultivation methods of edible mycorrhizal mushrooms such as truffles, saprotrophic mushrooms such as Shiitake and mycorrhizal fungi that can act as biological control of plant disease.

The company's team has more than 15 years of experience studying pathogenic fungi and their biological control.

Partners

The Institute for Sustainable Plant Protection (IPSP-CNR), a part of the Italian National Research Council (CNR), focuses on studying plant responses to biotic and abiotic stress factors.

Their research aims to identify mechanisms of resistance and adaptation to enhance plant health in agriculture and forestry, promoting the use of beneficial microorganisms to improve plant health and employ natural enemies in integrated pest management, identifying bio-molecules of agricultural or industrial interest, and promoting a sustainable and environmentally friendly growth.

Mycelio is a company dedicated to produce certified organic mushrooms and substrate for mushroom cultivation, made from wood removed from the surrounding forests to prevent the risk of fires.

When the mushroom production process is completed, the spent substrate is transformed into a high-value compost, closing the loop of a fully circular economic model.

Volterra aims to restore ecosystems in Spain through innovative agro and forestry techniques such as the planting of trees inoculated with mycorrhizal fungi to enhance their resilience to drought.

The company also contributes to the development of sustainable rural economies by promoting the transformation of forest pruning into biochar, a highly valuable product with many applications that is also added to the compost produced by Mycelio.

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