IMPLEMENTATION OF AGROFORESTRY PRACTICES FOR THE RECOVERY OF DEGRADED SOILS IN SEMI-ARID AREAS OF SOUTHERN EUROPE: CASE STUDY OF LIFE OPERATION CO_2 PROJECT, AYOÓ DE VIDRIALES (SPAIN)

Franco K[1*], Kallen S[1], Gandía M[2], Sonneveld E[3], Alonso P[3]

(1) Transfer LBC, Barcelona, Spain; (2) Volterra Ecosystems, Barcelona, Spain; (3) Beral Ingeniería, Zamora, Spain.

* Correspondence author: life@transfer-lbc.com

Introduction

Tackling the impacts of climate change is not a matter of the future, as these are already being observed and their effects felt worldwide through changes in precipitation, temperature, extreme weather events and CO_2 emissions (Field et al., 2014) Nowadays, the current understanding of European climate trends leads to a projected overall temperature increase from 2º to 4º C and precipitation changes of 10 to 50% by the 2080s. These changes are unequally distributed across different regions or seasons and are likely to become more pronounced in **Southern Europe** with temperature increases reaching +5ºC and particularly, an increase of drought periods throughout the **Mediterranean area** (Garrote et al, 2015). Approx. 45% of the soil in Europe is in a state of vulnerability, 15% is even considered extremely vulnerable. This includes soils in some southern parts of the EU, such as Spain, Greece, Portugal, Italy and France (Joint, 2008).

Problems of soil degradation not only have environmental implications; in particular agricultural plots are facing degradation and their cultivation is rapidly becoming unprofitable, adding serious economic strains to rural areas that are already weak and suffer from land abandonment due to the rural-urban migration phenomenon.

The **LIFE11 ENV/ES/535 Operation CO_2** initiative arises therefore as a tool to demonstrate the feasibility of transforming abandoned areas in Spain into healthy and productive soils. This will create ecosystems that contribute to climate change resilience. The project has **implemented agroforestry systems in semi-arid areas** suffering from naturally degraded soils and abandoned lands in order to demonstrate the viability of these systems and to thus prove the green economy model as an alternative for future development. Meanwhile, it expects to increase crop productivity, improve soil quality and increase the potential for soil carbon sequestration.

One of the demonstration projects is located in the municipality of **Ayoó de Vidriales (Zamora, Spain).** The area consists of a **25 ha plot of rainfed land** with highly degraded soils, susceptible to wildfire due to the particularity of the climatic conditions of the region (sparse but very intense rainfall, maximum 400-500 mm per year), wind and sparse vegetation. The average altitude is 840 m.a.s.l. and soils are significantly acidic. This area has communal ownership and its use is fully controlled by the village council. According to neighbors, cereal production around the area used to be around 2,000 kg/ha, but because of incorrect management practices including excessive ploughing and monoculture, this figure has come down to 700 kg/ha despite the use of chemical fertilizers and pig manure. Given these calculations, the land object of our project was considered unprofitable and was left uncultivated for at least 15 years.

Material and methods

In order to transform this degraded area into an integral agroforestry ecosystem, several steps were taken:

1. <u>Agroforestry plan design</u>: During the first year (2012), an integral plan was developed according to each area's specific characteristics. Several plants were selected in order to address the following types of land use, i.e: a) timber, biomass trees, and fruit production trees (i.e. *Castanea sativa, Pistacia vera, Prunus dulcis, Pinus pinaster, Pinus pinea*); b) border protection, aromatic plants and bushes (*Quercus suber, Rosa canina, Prunus spinose, Crataegus monogyna*); c) cash crops and cover crops (*Secale cereale, Lupinus sp, Vicia sativa, Triticum spp, Vicia faba, Medicago sativa, Avena sp*) and other vegetation for soil improvement. Approx. 3,000 trees and shrubs were planted following a specific planting framework (i.e. *C. sativa* (10*6m), *P. vera* (10*10), *P. dulcis* (25*5), *P pinaster* (6*5), *Q. suber* (2*2). Some trees were

inoculated with ectomycorrhiza for future mushroom production, such as *P. pinea* with *Lactarius deliciosus, C. ladanifer* with *Boletus edulis* and *Q. suber* with *Pisolithus tinctorius.*

2. Division of plots: The demonstration area was divided in 3 plots in order to test production levels and root growth according to the products and mycorrhiza spores used. The plots were named Zone A (40% of the land with 100% product), B (40%:50%) and C (20%:0%). Tests were initiated in the fall of 2012 and will last until the summer of 2017 (**Figure 1**).

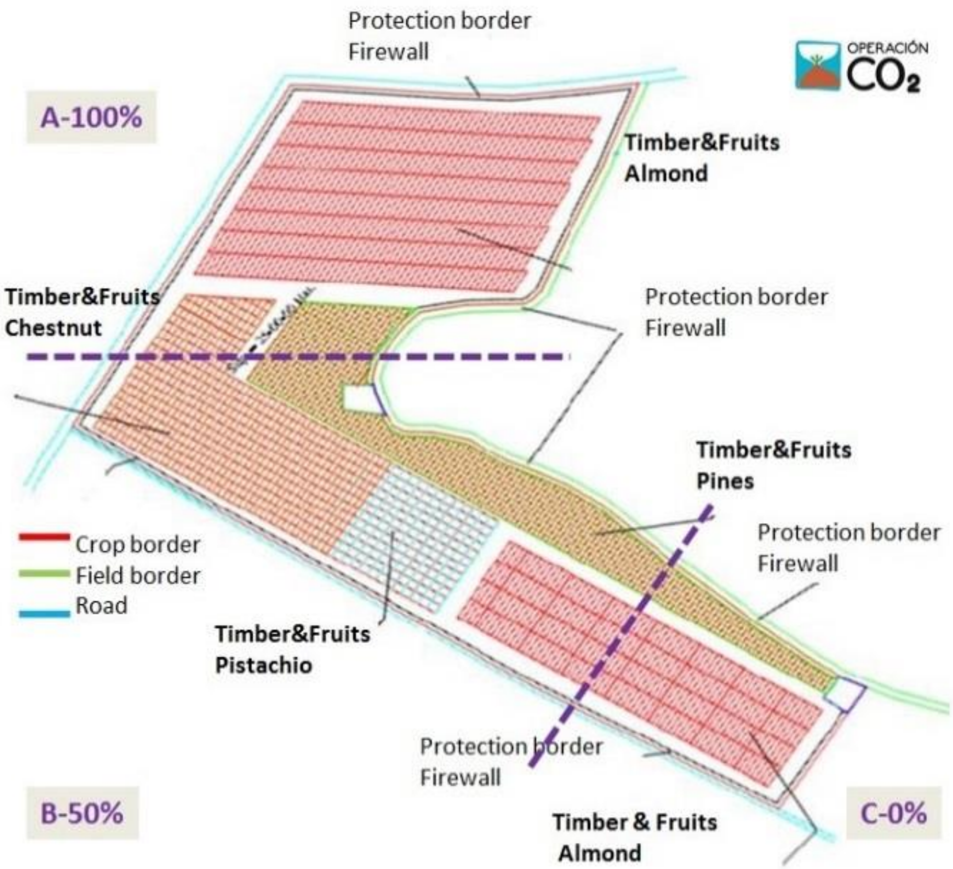

Figure 1. Agroforestry scheme and division of plots (Zones A, B & C)

3. Crop selection and implementation: First, a traditional pH corrector was applied. Afterwards, due to the lack of nutrients present, it was necessary to activate the soil microbiology before planting the new crops. A vertical land preparation with a chisel plow was applied to de-compact the soil, and sowing was done through cultivation on top of ridges. During the first year, the soil was inoculated with a mixed product, based on four types of endo-mycorrhizal spores, beneficial bacteria and humus. Mycorrhiza are symbiotic associations established between plants and soil fungi. It is probably the most widespread type of symbiosis in the biosphere, and around 90% of terrestrial plants are able to establish some kind of mycorrhiza (Smith & Read, 2010). They function as a soil enhancer to help prepare the land for planting during the following year. In this way, the biological recovery of soil was shortened in comparison to other land practices which can take many years. Furthermore, depending on the soil characteristics of the specific area, it was necessary to test with organic fertilizer composed of bacteria and humus to stimulate the reactions of mycorrhiza and create an interface between roots and soil nutrients.

4. Planting the trees and bushes: During the 2013-2014 campaign, trees and shrubs were planted (**Figure 2**). A buffer zone along the entire border was included in order to serve as a windbreaker, fire buffer and also as a wildlife corridor. The execution of planting included the testing of different technologies offered in the market in order to support the growth of trees and bushes during the first year, especially in rough climate areas. For example, a 'water deposit' device was used, which consists of a water reservoir that slowly releases the moisture restoring the capillary function in the soil. Coconut fiber and wool carpets were also tested as soil cover around the newly planted trees. These solutions not only enhance the capillary function by preventing dehydration but also provide weed control near the growing tree.


Figure 2. Project area with the incorporation of the trees and shrubs.

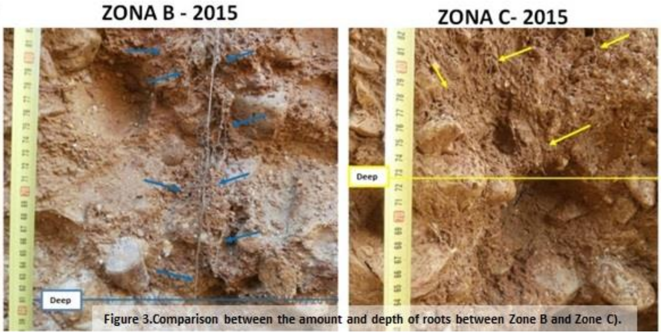

Figure 3.Comparison between the amount and depth of roots between Zone B and Zone C).

Figure 2. Project area with the incorporation of the trees and shrubs.
Figure 3. Comparison between the amount and depth of roots between Zone B and Zone C

In the same period once the trees were planted, cereals were sowed between the rows and a sustainable soil management plan was introduced; avoiding the use of moldboard plow, and any work that may damage the mycelium of mycorrhizal activity. Another well-known technique applied during this period was associating crops, in our case vetches with oats. The vetches are a nitrogen binder while the oats avoid layering of the vetches.

Results and Discussion

According to the studied **production**, **root growth** and **root mycorrhization levels**, it is safe to say that a positive transformation of the plot's soil has occurred, making it healthier and obtaining higher yields. Yearly observations have shown that root depth as well as quantity and density have increased, reaching even more than a meter and half depth (**Figure 3**). This allows the plant to explore a wider area of the land and thus extract a larger amount of nutrients to help its fertility and health. This benefit has been made possible due to the contribution that mycorrhiza, beneficial bacteria and humus offer to the soil creating symbiotic associations with the crop roots. The crops sowed in between tree lines have developed and have been harvested with improving performance each year, obviously determined by the limiting climatic factors of the area. During the first two years (2013-2014) wheat was cultivated, while vetch/oat was sown in 2015.

Physical changes in the soil were observed as well. Soil sponginess decreased when moving from Zone A to Zone C. Throughout the project, pits were dug in each of the 3 zones (A, B and C) in order to verify the differences in root development of each area. Digging the pits to observe root growth also became more difficult in the latter zone compared to the former. This can be explained by the fact that micro organisms change the structure of the soil gradually. These pits also showed that the moisture in the soil and root development was much higher in Zone A compared to the rest. The results were correlated with the yield rates (kg/ha) and the mycorrhizal colonization in the root system (M%) although the latter could only be measured during 2015.

As can be seen in **Figure 4**, it seems that there is a close correlation between root depth, root quantity, mycorrhizal intensity and yield. It shows that the best average results were obtained in Zone A where the largest amount of mycorrhizal inoculations occurred. An increase in yearly yields as well as a larger root depth was observed, most probably due to the presence of mycorrhiza in the roots from colonization. During 2015, samples of the roots were taken to verify the degree of mycorrhization at different soil depths and results showed that the inoculated Zones (A and B) had a much higher amount of roots between the 20-40 cm lines that Zone C, as well as higher percentages of mycorrhizal colonization compared to those obtained at the same depth in Zone C (control zone). However, in Zone C at 60 cm depth there is a significant percentage that may indicate the presence of natural mycorrhizal spores. This may offer a significant discovery- the biological balance in soil can be restored only if this soil has not been completely destroyed, and it is in our power to do so.

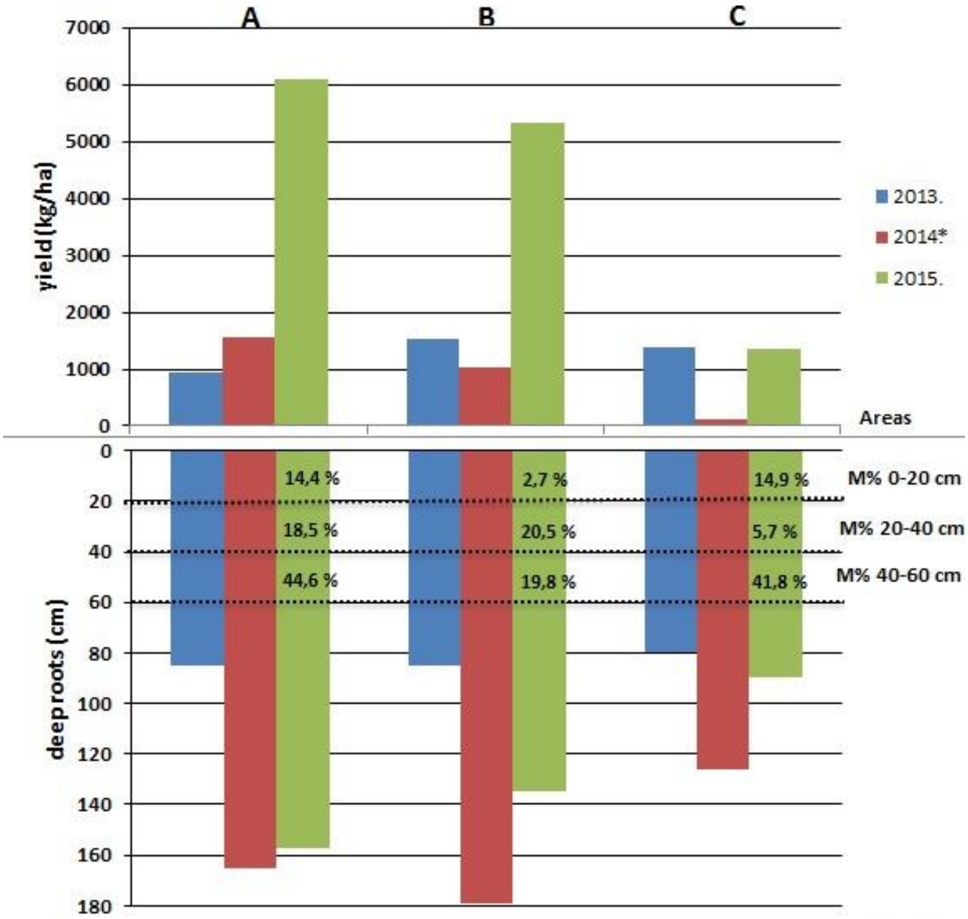

Figure 4. Relationship between harvest yield, root depth and mycorrhizal colonization in the root system (M%) in Zones A, B and C in the 25 ha. Plot (2013-wheat, 2014-wheat, and 2015-vetch/oat). *2014 had an exceptionally dry spring compared to the common average, so harvest yields were thus negatively affected.

The main ambition of the LIFE Operation CO_2 project is to convert this degraded land into healthy soil and demonstrate that the agroforestry system approach is also economically viable. The establishment of trees and shrubs may have helped to reduce the vulnerability of this particular ecosystem and acted as an adaptation measure to combat climate change. Additionally, when biomass on the land and in the soil is increased, the potential for carbon sequestration can also be analyzed. This model can be **replicated** in other areas that are also classified as arid and semi-arid land throughout Spain and other Mediterranean countries with similar dry, hot summers. This model could give an **impulse to the Greening strategy** within the CAP payment system as it clearly helps to making soil & ecosystems more resilient due to the greater variety of crops, improving biodiversity and protecting water & habitats.

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References:

Field, CB, Barros, VR, Dokken, DJ, Mach, KJ, Mastrandrea, MD, Bilir, TE, & Girma, B (2014) IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Garrote, L, Iglesias, A, Granados, A, Mediero, L, Martin-Carrasco, F (2015) Quantitative assessment of climate change vulnerability of irrigation demands in Mediterranean Europe. Water Resources Management, 29(2), pp 325-338

Joint, E. E. A. J. R. C. W. H. Report (2008). Impacts of Europe's changing climate—2008 indicator-based assessment. EEA Report No 4/2008 JRC Reference Report No JRC47756

Smith, SE, Read, DJ (2010) Mycorrhizal symbiosis. Academic press