White Book of reforestation of degraded urban areas in Southern Europe

LIFE12/ENV/ES/000092

This White Book gathers the lessons learnt during the design and implementation of a demonstration project in the city of Valladolid regarding the reforestation of urban areas by testing and demonstrating the feasibility of combining forestation related techniques in degraded areas.

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Chapter 1. Introduction

The QUF (Quick Urban Forest) project is a European project, funded by the Life + Programme of the European Commission, which aims at contributing to the improvement of the living conditions and environment of European urban industrial areas by testing and demonstrating the feasibility of combining forestation related techniques in degraded areas. These techniques include the use of mycorrhiza and water retainers (both alone and combined).

A key demonstration project has been designed and developed in the Spanish city of Valladolid. The results and lessons learnt from the demonstration project have been gathered into this White Book with the objective of helping other Southern European cities develop more efficient and effective reforestation projects in urban areas.

The problem

There are 181 urban areas in Europe with over 200.000 inhabitants. 26 of these areas are located in the south of Europe, many of them as the result of a rapid immigration to cities in recent years. If we consider cities with more than 100.000 inhabitants the number multiplies by 10. Quick construction of industrial zones surrounding large capitals, rapid urban planning including very few green zones, and intensive agriculture landscapes now abandoned or industrial deteriorated soil, are configuring the typical landscape of these cities. The CO2 balance of these cities is one of the worst in Europe. Dry climates here (400-500 mm per year in the case of Valladolid), opposite to central and northern Europe, cause deterioration of the soil, air and water, that advances every day, and it is extremely difficult to counteract. The process of recovery is very slow, and in many cases it can't be taken back without human intervention, and desertification is the final result (Serpa et al., 2015). Even when there is human intervention biomass increases slowly, because launching the projects is difficult (planting failing, needs of continuous irrigation) and growing conditions are very slow (hard climate, bad soil) (Foley et al., 2005).

People of these cities, that once were living there as a temporary step because of high prices in the centre of the large capitals, travelling many kilometres, are tending to be established in these areas. New jobs, schools, hospitals, entertainment centres etc., are more and more placed there. But environmental conditions, slightly improved in the last years by placing gardens in the new areas (Salvati et al., 2017), are still far from being solved.

Large fields surrounding these cities are difficult to manage (FAO, 2016). Placing watering infrastructure is expensive, and sometimes these fields were previously waste landfills, before regulation was able to arrange correct waste processes in industrial cities.

This problem is not usually discussed in the public sphere and is more complex and deep than one may think. Air pollution, depending on the orography, may affect people's health. How can we help to drastically improve the restoration of conditions, the air, the social welfare, the CO2 absorption, the climate smoothing, the soil, etc. in urban areas like these?

The QUF Project aims at testing and proposing a set of solutions to enable cheaper and quicker reforestation applicable to these cities. For that reason, the QUF project is directly facing up some of the main environmental problems of European urban areas that, together with the waste treatment, are undoubtedly the major environmental challenges of our cities.

Problems that are common to all European cities - soil degradation, air pollution, deforestation, etc.- are worsen in the case of Southern European cities, due to their climate conditions, water availability, and economic problems (Sánchez-Salguero et al., 2012). This is even more critical due to the important fact that climate change is affecting first those places in the boundary of desertification.

Three of the main environmental problems that urban areas are facing in Europe (and worldwide) are:

- Air pollution.
- Soil sealing.
- Deforestation and climate change.

In the following paragraphs below, we discuss those problems in Europe and how QUF will try to contribute to their mitigation:

Air pollution

Air pollution in our cities has dramatically grown in recent decades due to the burning of fossils fuels, the rise of traffic and the rise of industrial and energy production.

The EU estimates that human exposure to fine particulate matter (PM2.5)[1] causes about 350.000 premature deaths each year.

The major air pollutants in urban areas are ozone and nitrogen oxides (NOX). These pollutants pose serious threats to human health, as they can be the cause of respiratory disorders, aggravated asthma, and impair development of lung function in children.

Measurements of air quality show that almost 90 % of the inhabitants of European cities where PM10 concentrations are measured are exposed to concentrations that exceed the WHO air quality guideline level of 20 µg/m3[2].

Indeed air quality in the European cities of the Mediterranean region is five times worse than the air in Northern European cities (Baldasano et al., 2003).

Reforestation of degraded areas in southern cities, especially in the Mediterranean area, will directly affect concentration of fine particulate matter, will also provide oxygen (a part to be transformed in ozone and also helping to transform CO into CO2), decreasing CO and CO2, and enabling to curb the NOX percentage. Urban forests can be regarded as management alternatives to minimize pollution in urban and peri-urban areas (Escobedo and Nowak, 2009).

[1] PM2.5 is particulate matter with an aerodynamic diameter of up to 2.5 µm and PM10 up to 10 µm The estimate is based on model calculations using anthropogenic primary PM and PM precursor emissions as an input (year 2000, EU-25) EU Clean Air for Europe (CAFÉ) programme http://europa.eu/scadplus/leg/en/lvb/l28026.htm.

[2] Ensuring quality of life in Europe's cities and towns. EEA Report No 5/2009

Soil sealing

Erosion, loss of organic matter, compaction, salinization, landslides, contamination, sealing… Soil degradation is accelerating, with negative effects on human health, natural ecosystems and climate change, as well as on our economy (Foley et al., 2005). At the moment, only nine EU Member States have specific legislation on soil protection (especially on contamination) (European Commission, Environment, 2011) and protecting soils remained an important objective for the Union, as shows the fact that a proposal for a Soil Framework Directive is still pending[3].

In 2006 the European Union's main land bore a sealing rate of 2.3% with an increasing trend. All regions along the Mediterranean coast, most other coastal regions, and almost all large urban agglomerations are affected by soil sealing (Montanarella, 2007).

Reforestation in southern cities will enable the creation of fertile soil, preventing erosion and enabling the arrival of new species, so augmenting biodiversity (Paul, 2016). The use of certain forestation techniques as the ones used in the QUF project might also improve some deterioration soils, typical in surrounding cities, eliminating or blocking part of the heavy metal pollution existing today. It is believed that the usage of mycorrhiza and water retainers together might facilitate a quick improvement of the floor, microbiological life, and organic materials in the first layouts of soil (Siles, 2010), that will be slowly be passed, through rain and living beings, to lower layouts. Proving to what extend this is truth is one of the objectives of the QUF Project.

Deforestation and Climate change

Carbon dioxide (CO2) is responsible for 63% of man-made global warming, and the most commonly produced by human activity greenhouse gas.

Since the Industrial Revolution, the concentration of CO_2 in the atmosphere has increased by around 37%, and it continues to rise. It is mainly produced by the combustion of fossil fuels.

Deforestation is responsible for approximately one quarter of global greenhouse gas emissions. When forests are cut down, the carbon stored in the trees is released into the atmosphere as CO2, adding to the greenhouse effect.

At the same time trees help to regulate the climate by taking up CO_2 from the atmosphere, they play a role in water cycles and reflectivity of the earth surface.

Consequences of climate change are already obvious all around Europe: temperatures are rising, rainfall patterns are shifting, glaciers are melting, sea levels are getting higher and extreme weather resulting in hazards such as floods and droughts is becoming more common leading to modify existing ecological dynamics.

Southern Europe and the Mediterranean basin are two of the more vulnerable areas to climate change, due to the rise of temperatures, extreme phenomena and droughts (Beniston et al., 2007).

To limit global warming it is essential to halt the rising trend in global greenhouse gas

[3] http://ec.europa.eu/environment/soil/process_en.htm

emissions before 2020.

Green urban spaces

Recent studies carried out at the University of Seville by Dr. Manuel Enrique Figueroa show that one hectare of urban forestry generates the oxygen used by six people and that a tree can absorb the CO2 produced by 100 cars in a day. Some species, like some types of pines, may absorb between 48.870 y 27.180 kilos of CO2 a year.

Green areas in the cities have more benefits. Studies show that children who live in areas with abundant green space are more active, 40% less likely to be obese (Ellaway et al., 2005) and show higher levels of attention than those without these benefits (Velarde et al., 2007). For these reasons, access to green urban areas has been proposed as an important indicator of urban sustainability and quality of life (Sanesi et al., 2011).

European cities of the Mediterranean region generally lack green areas, and most of the ones studies don't overpass the 20-30% of green areas in core cities. However, there is a trend towards increased areas of accessible green space in most European cities (EC, 2003).

Once again measures focused in those European areas with more need of green zones are possibly a priority for our continent.

Our approach

Approximately 75% of Europe's population lives in urban areas and by 2020 it is estimated that 80% of the population will. There are approximately 1.600 urban areas with more than 50.000 inhabitants, defined as functional urban areas, in the European Union.

Urban sprawl is affecting the environment as never before in human history and it is affecting people's quality of life and health.

We are convinced that forestation is a major concern in Europe to fight against most of these problems. But results of these forestations are much more important in those zones where arid conditions create special problems for population, especially in urban areas and its surroundings.

The QUF project is a European project, funded by the Life + Programme of the European Commission, which aims at contributing to the improvement of the life and environment of European urban industrial areas by testing and demonstrating the feasibility of combining forestation related techniques in degraded areas. These, techniques include the use of mycorrhiza and water retainers, with the objective of reducing watering requirements, increase biomass production and improve soil conditions. 30.000 plants of 6 Mediterranean native species have been planted, between 2014 and 2015, using three kinds of treatments (mycorrhizal, retainers and both together) in demonstration site in the city of Valladolid.

Chapter 2. The QUF Project

The objective of the project is to contribute to the improvement of the environment of European urban industrial areas by testing the feasibility of forestation related techniques in arid populated cities of South Europe, specifically with degraded soils due to industrial activity, where climate change is more aggressive, and high maintenance and water resources consumption are required. These techniques include the use of mycorrhiza and water retainers (both alone and combined), all monitored automatically through a network of sensors to create an extensive dataset of the environmental conditions and the results.

The following sections include a brief description of the objectives and how the project has been designed and implemented.

Objectives

Plantations such as the one carried out by the QUF project, on abandoned industrial areas next to the city (and connect to forestall areas), normally require previous restoration using specialized methods that compact, stabilize and prepare the soil. These expensive processes are adequate when the zones are small enough and in the middle of very urbanized areas that require quick acting.

However, the major efforts are now devoted to create forest areas in the surrounding zones of cities or those inside industrial polygons where infrastructure creation requires expensive preparation. The success of the operations may be determined the orientation of the land, the rain conditions of the first years, and summer temperatures. When conditions are bad, the percentage of failing is reaching 50%. Consequences in economic costs, water expenses, working hours, transport maintenance, CO2 generation, etc., are clear, and the results are not always satisfactory at achieving the expected final result. This also obliges the municipality to have several private maintenance companies that should be prepared for acting depending on conditions.

Despite all the efforts made by the City Council, the rate of survival of new tree in the first two year is very low, with loses around 40%.

Usually, there is not only one cause of a tree lost but two or more factors occur. These problems appear in most of European cities, particularly, in the Mediterranean cities.

The QUF Project was aimed at demonstrating that the combination of these techniques could help obtaining the following results:

- The achievement of at least 95% of successful trees planted without water infrastructure, and at least 30% more trees alive than when using no technology.
- The achievement of a 20% more in average tree biomass (measuring the dry mass of the aerial and terrestrial part of bushes and trees), compared with the reference population trees. The corresponding CO2 absorption increase will be also at least 20% of the reference population.
- Capture of at least 6 tons of CO2 during the first two years (much more during

following years, see following points for explanation).

- A decrease of 10% of noxious gases and particles in the atmosphere (CO, plumb, etc.).
- The achievement of an increasing curve of average air and soil humidity in those zones where trees have been planted, taking the five milestones (from H0 to H4).
- An increasing of at least 1% in soil organic matter after H4 from H0, as average measure in 30 cm. surrounding the trees, 10 cm. of first soil layout.

The experiment

The location

Valladolid City Council has granted for the project a plot with a surface of approximately 13 hectares. This plot is located in the city of Valladolid, at the Avda. de Santander bordering the Pisuerga River.

As a demonstrator, Valladolid is a perfect example of the cities the project is aimed at. Most of its characteristics may be directly applicable to other southern cities, including all Southern capital cities like Madrid or Rome, affecting millions of habitants.

It is located in the centre of the Castile and León region where the clime is semi-arid. The soil, mainly made from inceptisoiles and alfisoiles (according to the International Soil Taxonomy) has traditionally been used for agriculture purposes, (mainly dry cultivation), and the gradual installation of industrial settlements and urban areas. Currently industry is, together with services, the main economic drivers of the city.

At the end of the fifties Valladolid experienced a boost of industrial activities, mainly due to the automotive industry. As a consequence of the industrialization and the urban construction explosion of the nineties the environmental conditions have worsen.

Valladolid has doubled its population since 1960. The climate is Mediterranean mild, according to J. Papadakis methodology. The temperatures are quite extreme, with substantially significant differences between day and night, with an annual average of 12.3°C.

Winters are cold with frequent fogs and frosts (61 frost days on average) and 8 days of snow a year. The summers are hot and dry, with highs around 30°C, arriving to 42°C in some cases, but minimal fresh, slightly exceeding 13°C.

To fight against these conditions, Valladolid has joined the so-called “Pact of the Majors” to fight climate change and achieve the 20-20-20 objectives[4].

At the same time, the Province Council of Valladolid has carried out a reforestation project (part of which has been carried out with the support of the Life program in the frame of the Green Deserts project, although it has not included the surrenders of the city of Valladolid).

The location of the plantation has the following characteristics:

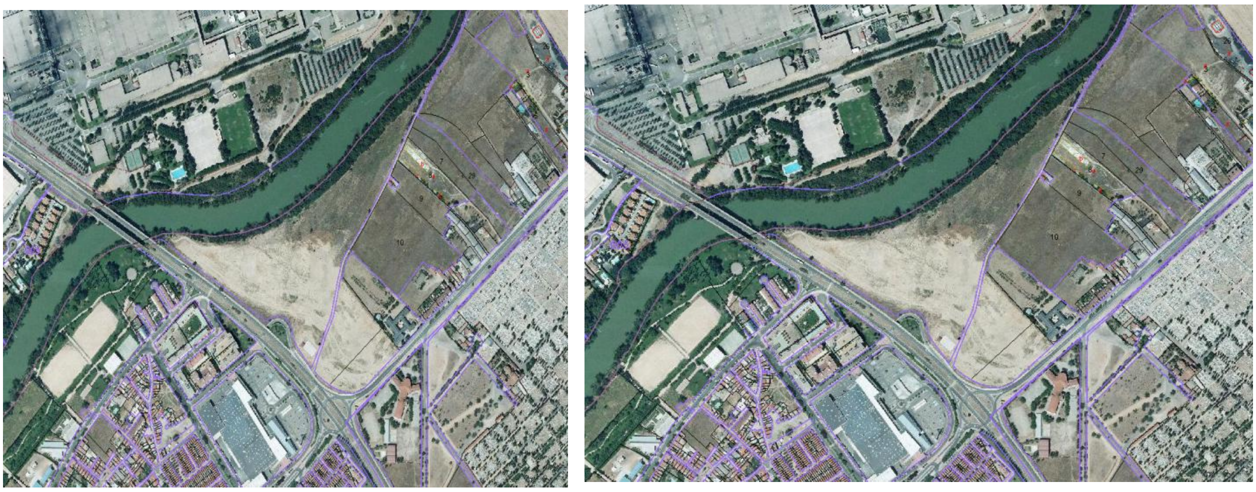
- It is located next to the Pisuerga River.
- The plot is not developable, and therefore the plantation will become a green area of

[4]http://www.valladolidagendalocal21.es/plandeaccionparalaenergiasostenible/tenemosunplan.html

the city for good.

- It is located next to an industrial area but in the future it will become part of the forest park *Ribera de Castilla*.
- Communication facilities were suitable enough, both for reaching the pot and for telecommunication purposes. There is an air quality measuring station from the Council connected to the internal wireless network (fiber optic) near the plot.

Figure 1: View of the plantation plot



The plots limiting at the north are industrial land belonging to a polygon, and have disused degraded soils. Across the river, there is a factory (Michelin), one of the largest industries in the city. It presents an important gap over the river (from 5-7 meters).

Figure 2: Land before plantation

The plantation

During the project the effect of different treatments (mycorrhiza, retainers and mixed) in the improvement of the survival of six tree species has been tested.

The species tested have been:

- **Trees**: *Quercus ilex*, *Quercus faginea*, *Pinus pinea* and *Juniperus thurifera*.
  Shrubs: *Amigdalus communis* and *Acer campestre*.

There species have been inoculated with the following mycorrhiza:

1. Pisolithus tinctorius (Pers.) Coker & Couch (ectomycorrhiza).
2. Scleroderma polyrrhizum (JF Gmel.) Pers (ectomycorrhiza).
3. Glomus ssp. (Endomycorrhiza).

These mycorrhizal fungi used are fungi that are present naturally in Valladolid, they are able to mycorrhizal host species and young plants and are efficient by spore inoculation.

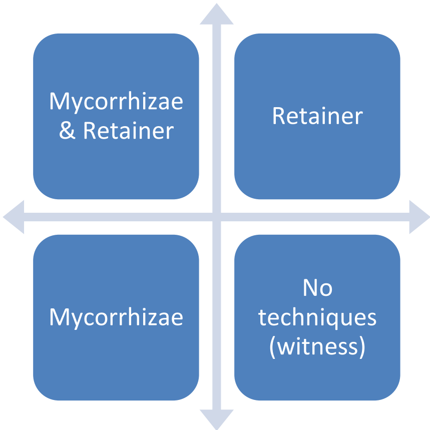
Each plant species of the project were mycorrhizal with the following fungi:

- *Pinus pinea* with Pisolithus tinctorius.
- *Almond*, *Juniperus* and *Acer* with Glomus.
- *Q. faginea* and *Q. ilex* with Pisolithus tinctorius + Scleroderma polyrrhizum

The retainer used was the Stockosorb retainer. This retainer is easy to use and has no added complementary products that could mask the comparison with the other treatments tested.

The plantation is designed as follows: 6 species are planted (4 shrubby tree and 2) in mixed masses, divided in four sectors per block, depending on planting techniques of the project, that is, if retainers and mycorrhizae are used or not. Therefore we have a sample for each soil/spice and treatment (main components of the project). The four sections are:

Figure 3: Scheme of the uses of reforestation techniques



The experimental is design in blocks in which the 4 treatments tested are repeated.

A total of 5 blocks with 4 sectors in each block, where the repopulation is made following techniques:

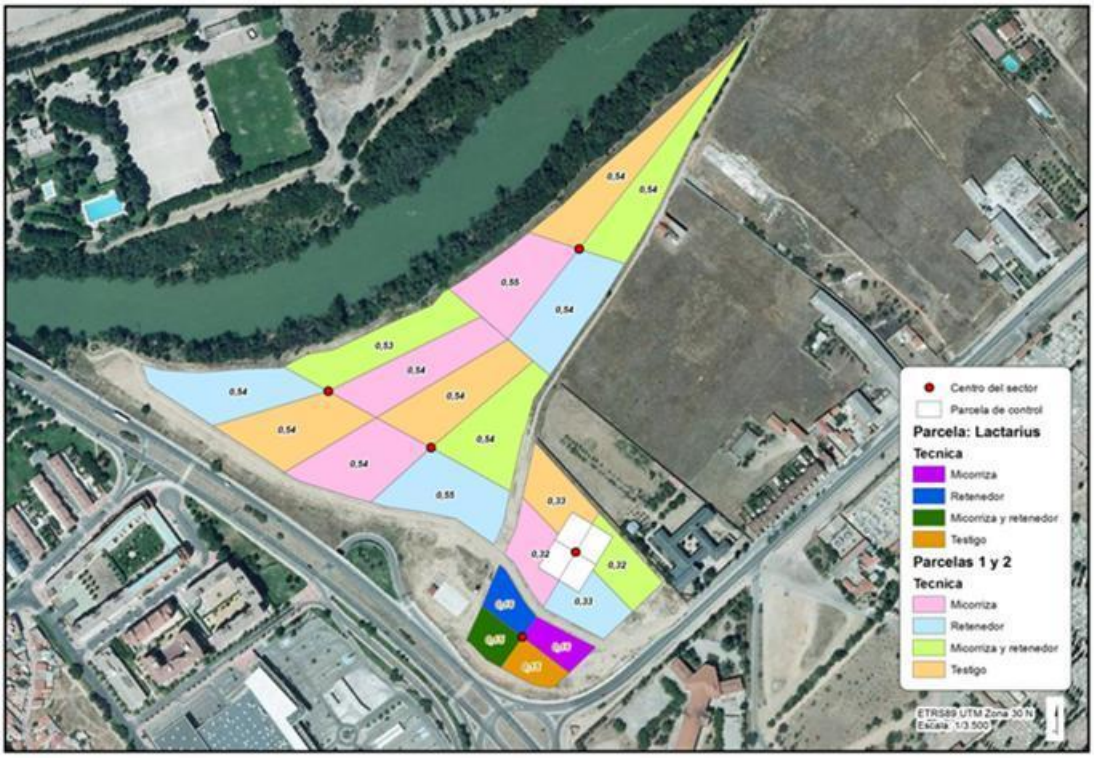
1. Witness: Plant in container.
2. Retainer: Plant in container planted with polymer retainer.
3. Mycorrhizae: Plant is inoculated with mycorrhizae.
4. Mycorrhizae plus retainer: inoculated plant is used and polymer retainer is incorporated into the planting hole.

3 of the blocks are approximately 2 hectares and each of its four sectors has 0.54 hectares. A fourth block is a little bit smaller, with a surface of 0.33 hectares per sector.

Finally a block of 0.6 hectares will be planted using plants with an edible mycological species, *Pinus pinea* mycorrhizal with Lactarius deliciosus. Four planting techniques are repeated in turn; witness, retainer, mycorrhizae and mycorrhizae with retainer.

In the following map shows the 5 different blocks and the 20 sectors where the various combinations of reforestation techniques applied:

Figure 4: Map of the plantation



The sensor network and data analysis

The experimental design of the project consisted in control plots and transepts - of the plantation - in which survival and growth dynamics at tree-level were measured periodically. Apart from field data, the impact of the different treatments has been tracked using automatic remote sensing techniques.

The analysis has been performed by using data from several sources:

1. A network of sensors that monitors temperature and humidity at 20 and 40 cm. of 64 plants of 2 species (*Pinus pinea* and *Quercus ilex*) in the 4 control plots along with climatic variables. The measures are obtained every 30 minutes during the entire duration of the project.
2. Observation of the survival of 1.436 trees of the 6 species in the 4 control plots at key moments of the project.
3. Measurement of the variables of biomass at the end of a project in a sample of plants.

The analysis has been performed in the full dataset and comparing the results by treatment, specie, and soil characteristics.

The results have been calculated at control plot level and transept level for i) each species, ii) each treatment and iii) specie-treatment to analyse the variability and interaction among hierarchical levels.

The analysis has been done by using different statistical methods (OSL and survival models) depending on the target of the analysis. The statistical tools used in the analysis is R.

The factors considered in the study: aimed to assess the role of degraded soils, adversity of abiotic factors and need to recover the forest trees are particularly relevant in urban environments, where to promote reforestation of arid and industrialized areas it is strongly advised to carefully evaluate and use techniques that promote the growth and survival of the plant. Our goal was to demonstrate the feasibility of creating green areas and, in this way, recover land in the cities without any major irrigation infrastructure. That has been the main motivation of our project.

Chapter 3. Urban soils restoring: foundations

The recovery of forest cover through the implementation of forest plantations had its boom during the XX century, particularly in arid and semi-arid zones (Master and Curtain, 2004).

Restoration is the process of recovery of an ecosystem that has been degraded, damaged or destroyed (Mansourian, 2005) so that the restoration of the original features, such as the composition, structure and function, that existed before degradation is achieved (Jordan et al., 1987; Hobbs and Norton, 1996; Higgs, 1997). It is clear that the restoration of land to its original form in degraded and polluted urban areas, located in completely artificial environments, is not entirely possible, but they can be improved, creating more environmentally favourable situations. The reforestation of these lands can improve soil conditions and the landscape in a relatively short period of time.

Natural regeneration of Mediterranean ecosystems is especially affected by the summer drought and water stress (Ruano et al., 2009) especially under edaphic conditions that impair the ability of plants to colonize these areas.

All restoration projects have, at least, four phases:

Preliminary analysis

A thorough preliminary analysis of the situation is required before initiating the design of the project. This analysis must include, at least:

- The location and the urban plans of the area.
- The soil.
- The weather conditions of the area.
- The purpose of the plantation (main use).

The **location** is a critical factor of any restoration project.

When facing a forestation project in an urban area the analysis of the present and future uses of the land is critical for the success of the project. Cities change very quickly, but trees take years to grow and a green area must be defined to last permanently.

It is important to consider that the area to be restored must have the appropriate qualification as green or rural area and that classification in the city plan should not be expected to change in the future.

For that reason, the urban planning of the city has to be consulted and future town plan considered.

The second element that has to be analysed is the **soil**. Soil testing is key to understand how the restoration should proceed. Soil has an important impact on the type of species to be planted, the density of the plantation, the type of soil preparation that has to be done, the type of mycorrhizae and even type of retainer to be applied.

To analyze soil trenches have to be done and a detailed analysis of the physicochemical structure, texture and components of the soil has to be developed. It is advisable to consult an expert in soils for this analysis. If chemical or heavy metal pollution is suspected, then a more comprehensive analysis must be done. In this regard, an expert in phytoremediation should consider the factors and the possibilities of carrying out the restoration of the land.

The third element that has to be taken into consideration is **weather**. Temperature and precipitations must be considered. The weather conditions influence species selection and treatments to be used.

Along with all these elements, a very important consideration that affects the design and planning of the work is **the goal of the project itself**. If the plantation is located within a city the project leaders must take into account what use will the new green area have.

For example, in the QUF Project, the plantation is located on the banks of a river, near a park. It is also opposite to a school and a shopping mall. For all that reasons, the plantation was conceived since the beginning as a park to be enjoyed by the citizens. That has conditioned both the selection of species and the design of the plantation itself, for example by incorporating paths that facilitate walking around the area and reaching the river.

Definition and design

Having analysed the initial situation the project has to be defined. This includes, in the first place, the selections of the techniques that will be tested. If the project includes both the use of mycorrhizae and or water retainers, the definition work start with a research on the three main elements of the design:

- Selection of species.
- Selection of mycorrhizae.
- Selection of retainers.

The research should be based on the location, soil and weather of the plantation plot, and would consist mainly on desk research and consultation with experts, if needed.

When choosing the **species** it is highly convenient to use native species of the area, as they have greater ability to adapt to climatic and soil conditions. The intended use of the plantation also need to be taken into consideration (vigour and aspect of the plants, insects and diseases problems, etc.). It is crucial to study existing literature on previous restoration works of the area and the current and past situation of species in the city.

Mycorrhizal plant is a guarantee of survival; especially in areas with highly degraded and infertile soils. Naturally 99% of plants form some kind of mycorrhiza (endomycorrhiza and ectomycorrhiza) that allows plants to improve the uptake of water and nutrients, achieve greater resistance to pathogens and boost their growth and survival. The type of symbiosis to be formed will depend on the plant species considered. It is therefore very important in controlled mycorrhizal associations, both in nursery and in field, to make an appropriate selection of species of fungi, depending on the host species and depending on the needs of the planting site (soil type, climate, pH, etc.).

Because this selection puts at stake the success of the plantation, advice from an expert is always advised in order to select the suitable autochthonous species along with the most suitable type and form of mycorrhizal inoculum.

Retainers are applied for water intake and nutrients in soils, improving water management and plant growth, acting as a water reservoir and releasing it to the needs of the plants. Usually they prolong the time until the plants reach the wilting point and help streamline rainwater, irrigation, fertilizers, adsorbing and storing for later release.

There are many different types of retainers but the most important is based on the use of polymers that are capable of absorbing water, increasing their volume about 300, 500 or even 600 times. They are able to expand and provide water between five to seven years (decreasing performance over time).

Most retainers' formulations are based on potassium and carbon, which has greater expandability. Sometimes, water retainers are mixed with other products, creating specific substrates that are suitable for increasing soil quality (i.e., including organic fertilizers). Some of the products that are available today include more than 20 different products, creating a complete product supply to the plant almost autonomously. This allows more intense natural cropping with chemical fertilizers that way, and avoid burnout soil. Other retainers are based on natural sources, such as algae, whose natural advantages are clear, although the capacity expansion in these cases is lower than in the polymer-based products.

The results of the QUF project will provide a guide for future projects on the real effects of the retainer used. However, the great amount of retainers and the continuous evolution of this technology will require an updated study of the solutions available at the market at each moment.

For all the components of the project, a cost benefit analysis is highly recommended. In Chapter 7 a cost-benefit of the QUF project has been included to help project leaders make informed decisions when designing their reforestation projects.

Implementation

After commissioning the two previous phases, analysis of the baseline and selection of species and treatments, the next phase is the implementation of the plantation. In this phase three main elements should be defined:

1. Design of the plantation: number of species, density (number plants/ha.), location (placement of each species within the framework of planting), type of land preparation (point or line, stroke or woods ...), number of treatments and their location in the field.
2. Distance between the lines or strokes.
3. A detailed work plan.

When defining the work plan and the plantation various aspects should be taken into consideration:

- Scenic value: the location of species within the plantation should take into consideration the esthetical aspects, such as the colour of the set.

- The logic of the plantation to make it feasible on a practical level.
- The quality of the plant is vital for the proper development and growth of the plantation. The root ball must have healthy roots and white tips. In no event should spoil or broken root balls without white tips are used. Using one or two plant sap is advised because it develops better and can survive more easily with the tested treatments.
- Planting should be done by expert practitioners.
- In the case of presence of herbivores, it is essential to use a protective mesh or continuous tubes with aeration holes on each of the plants.
- Check the competition from herbaceous vegetation around the plant is recommended for a suitable plantation establishment and development. To do this, one should conduct a harrowing plot and hand weeding around the plant once or twice a year, depending on the level of competition that exists. Special care should be taken to remove the herbaceous competition especially around the plants and in the moments of greatest growth and demand, spring and summer.

Monitoring and evaluation

Monitoring the evolution of the plantation is essential for its success, particularly if treatments are being used. Tracking the plantation helps to diagnose and assess the plantation since its inception and, with this information, make decisions about whether it is worth the treatments applied, if corrective actions are needed or whether to remove or add any new action into the work plan.

Plantation map

To make a correct assessment of the evolution of the plantation it is necessary to have a map of the planted area in order to define the number of sample plots that will help us evaluate the quality and the development of the plantation.

Stratification of the plantation

One of the first needs before monitoring the plantation is to stratify the plantation into more homogeneous units according to any of the following criteria: age differences of the plant nursery of origin, soil, slope, etc.

Sampling system

A sampling system has to be defined for the monitoring phase. The sampling system depends on the size of the plantation and the availability of data. Systematic, random or transect sampling can be done. In all cases the stratification previously made has to be taken into account.

The samples may have a frequency proportional to the level f control we want to have of the plantation, and the objectives of the reforestation project. Survival and growth (height and diameter) are the basic measurements that need to be done. For these variables twice a year would be enough (preferably before and after summer). However, it is recommended to conduct more sampling during the first two years after planting.

In the QUF Project, as we will see in along this White Book, a network of sensors has been installed and millions of data are being gathered, particularly on soil humidity and temperature. This exhaustive monitoring and data gathered is aimed at controlling, in meticulous way, the behaviour of the treatments and provide a comprehensive understanding of its effects at the plantation. The demonstration character of this experiment justifies our monitoring system, but once the results are analyzed and presented in this book future projects, it would not require such an important display.

Nº of plants sampled

It is advisable to carry out surveys with a significant number of plants per treatment. Studies with insufficient sample sizes are not able to detect differences between groups, leading to the erroneous conclusion that there is no such difference (Fuller, 2011). However if the sample number is excessive, the study becomes more expensive in economic and human terms. A balance between the objectives and the budget of the project should be reached when designing the sample. The same must be considered in terms of sampling area, aiming to hold as much variability as possible coping with budget and operational constraints.

Data collection and statistical study

For each plant general and specific data as a species, treatment, plant status, correct positioning of the guard, force and survival, should be assessed. As well as all data considered interesting for the evaluation of the plantation.

The volume of data collected will condition the statistical analysis to be performed.

Chapter 4. QUF Components and plantation

We have seen the main phases of a restoration project. This chapter summarizes the works carried out by the QUF Project in these various phases and the elections done, so it can guide future reforestation works in Southern European cities.

The project selected for testing the use of techniques that include the use of mycorrhizae and water retainers (both alone and combined). These techniques are meant, as we have already seen, to improve the results of the plantation and the quality of the soil in areas with arid conditions, surrounded by industrial zones or very poor soils.

By QUF Components we refer to the main elements that are part of plantation and that are being tested, namely:

- **Soils.**
- **Species (trees).**
- **Treatments:**
    - **Water retainers.**
    - **Mycorrhiza.**
    - **Combination of both.**

During the design phase the QUF components available in the market were assessed and the final components used were selected. The selection was made seeking to balance the budget and the objectives of the project, and took into account the following criteria:

- The weather in the area of the plantation (particularly average rain).
- The various types of soil of the land plot.
- The tree species.
- The price of the components to be purchased.
- Previous research and its results.

In the following sections we describe the analysis made and we explain why the selected components were chosen for the project.

Weather conditions

We carried out an analysis of the weather conditions. These conditions are critical for the selection of all components, but particularly for the selection of water retainers. In Annex 2 additional information of weather conditions in Valladolid is included.

This analysis concluded, in brief, that:

- The area has a **Continental Mediterranean weather**, characterized by cold winters (temperatures under 5°C) and hot summers (average temperature of 22°C).
- Average temperature is 12.4°C.
- Frosts are common, even during spring.
- Rain is usually steadily uniform during the year, with the exception of July and August. Average rain is 420 mm. annually.

This information was the base for QUF Components selection.

Soil conditions

Soil, as well as climate, is one of the most important factors for plant growth, along with water and nutrient supply. Processes such as erosion, salinization or contamination deteriorate the physical or chemical properties, causing soil degradation.

Urban soils are subject to many changes and aggressions: compaction, uncontrolled inputs, pollution, etc. Therefore, in this type of soil, it is necessary to know in detail and depth the characteristics of the soil, its depth, its good or poor quality, etc.

A good study allows us to detect aspects of the dynamics and history of the soil, such as the presence of an agricultural surface that impedes the good development of the plants, the depth of the soil that strongly influences the possibilities of the roots, the colour that can indicate Drainage, presence of lime or other compounds such as iron oxides, texture indicating water retention capacity for plants, etc. Definitely, the study of the soil allows us a better interpretation of the behaviour of plants in the future.

Figure 5: Trench for soil analysis

Previous to the selection of QUF Components, in February 2014, the soil of the plot was analysed. Two different trenches were done and soil analysis was performed at three different depths:

- From 0 to 20 cm.
- From 20 to 50 cm.
- From 50 to 120 cm.

The analysis of the soil shows that the plot has a soil poorly developed with recent alluvial materials in depositional profiles, with **sandy loam soil texture, with no saline alkaline at an 8.42 pH, with excessive release of nitrogen**.

However, and based on the findings of analysing the sensor data and survival data, we realised that there are 3 different soils corresponding to the control plots 1, 2 and 3, and 4 and that soil characteristics are playing a more relevant role than expected so we made another study in order to get more information.

Due to the low degree of development of these soils and the low presence of chemical elements, it is considered that one of the most important elements to understand the dynamics of water in the soil is texture, since its knowledge allows to infer about other important characteristics such as:

- Water retention capacity available for plants and supply.
- Installations for the circulation of water.
- Easy tillage.
- Risk of water and wind erosion.
- Ability to store nutrients.

Soil is not a simple mixture of particles. Soil behaviour is the combined response to the different fractions of sand, silt and clay that interact with each other and with organic matter. However, in soils with unbalanced textures and poor organic matter, the predominance of one of the fractions can be determinant, as in our case. In this sense, each of the soil fractions in each of the blocks has been analysed using the following table:

Table 1: Results from soil analysis

BLOCK	TASTINGS	DEPTH	% SAND	% SILT	% CLAY	TEXTURE
1	1	0 - 37	57	27	16	FRANK - SANDY
2 y 3	2	0 - 20	65	17	17	FRANK - SANDY
		20 - 50	73	17	9,6	SANDY - FRANK
4	4	0 - 30	43	30	27	LOAM
1	1	37 - 80	63	17	20	FRANK - SANDY
2 y 3	2	50 - 120	97	1,85	0,57	SANDY
4	4	30 - 90	43	25	32	LOAM

It can be observed that blocks 2 and 3 are more sandy in depth than block 1 and 4, the latter being the least sandy of the 4 blocks.

However, it is worth noting the low homogeneity of this soil due to the many uncontrolled contributions that have occurred over the years. This makes it really difficult to diagnose and interpret the result. Throughout the study plot there is a large quantity of coarse elements that can influence the behaviour of the soil and growth, especially when its proportion is large. A predominance of coarse elements in a soil causes it to act as a sieve against water, which it is not able to retain, and presents few possibilities for nutrient supply.

Selection of plant species

Two initial premises where considered regarding the selection of species for the plantation during the definition phase of the project:

White Book of reforestation of degraded urban areas in Southern Europe

1. Both tree and shrub species would be tested.
2. Species had to be autochthonous.
3. In tree species both hardwoods and softwoods species would be selected.

For the selection of species we made a preliminary research that included:

- Analysing the notebooks[5] elaborated by the Regional Government (Junta de Castile and León) to provide advice on reforestation works - Valladolid is included in Zone 11[6] -and technical guidelines[7] for reforestation also from the Regional Government.
- Consulting the Environmental services of Valladolid Council and the Regional Government.
- Revising the existing bibliography to identify the species that are most suitable for the soil class of the land plot.

The recommendations of the Regional Government regarding the type of species to use in Valladolid have been particularly useful, since these recommendations are being elaborated, and updated since 1994, being an accumulative, extensive and valuable experience in reforestation programs. These programs have been designed for agriculture lands, and nor urban areas, but have taken into consideration soil and weather conditions that are very similar to those of our project.

With this information, and the knowledge of our experts, the working team selected the following species:

- **Trees**: *Quercus ilex*, *Quercus faginea*, *Quercus pirenaica*, *Pinus pinea* and *Juniperus thurifera*.
- **Shrubs**: *Amigdalus communis* and *Acer campestre*.

The reasons for this selection were:

- *Quercus*: the choice of oaks is justified as being specie with frequent developmental problems in reforestation. On one hand, its implementation is difficult because it presents a considerable rate of first-stage mortality and it suffers a significant development delay comparing to other species, especially conifers. In many of the reforestation programs carried out in agricultural land, these species shows growth standstill. In many cases the aerial part dries but returns to sprout as trees are still alive but with an almost zero development of their aerial part during the first 5 years or more. For that reason we have decided to test if the QUF techniques can enhance the development of these species in reforestation projects.
- *Pinus pinea* is most often specie used in the reforestation programs in the province of Valladolid, presenting successful implementation and development for the reported

[5] Available here: http://www.medioambiente.jcyl.es/web/jcyl/MedioAmbiente/es/Plantilla100/1180952518454/_/_/_

[6] The notebook for Zone 11 is: http://www.medioambiente.jcyl.es/web/jcyl/binarios/97/918/Cuaderno%20Zona%20n%C2%BA%2011_Campos%20Centro%20-%202013.pdf?blobheader=application%2Fpdf%3Bcharset%3DUTF-8&blobheadername1=Cache-Control&blobheadername2=Expires&blobheadername3=Site&blobheadervalue1=no-store%2Cno-cache%2Cmust-revalidate&blobheadervalue2=0&blobheadervalue3=JCYL_MedioAmbiente&blobnocache=true

[7] Available here: http://www.medioambiente.jcyl.es/web/jcyl/MedioAmbiente/es/Plantilla100/1284455991422/_/_/_

cases.

- *Juniperus thurifera,* specie with a great ecological and ornamental value, but less used in reforestation due to the difficulties of its reproduction in nursery. The juniper is, however, a good choice to be implemented in arid limestone areas with reforestation problems.
- The *Amigdalus communis* is a spice that is well adapted to site terrain and it is widely used as an ornamental plant in Valladolid as a complementary species in reforestation of agricultural lands.
- *Acer campestris* was also included because it is a more demanding species, usually associated to Atlantic and mountainous forest areas. Although its landscape value is very valuable, the larger number of deaths in reforestation has reduced its implementation in restoration projects.

Selection of mycorrhiza

In order to meet the objectives of the project with respect to the implantation of sites with mycorrhizal plants, the following activities were performed:

1. Selection of mycorrhiza fungi with greater potential by selected species.
2. Preparation of inoculums and dose calculation.
3. Inoculation of plant in field.
4. Inoculation of plant in nursery.

Selection of mycorrhiza

To achieve the success of the mycorrhizal process it is very important that each species is inoculated with the right type of fungus.

Fungal species have been selected due to its mycorrhizal capacity and its antibiotic powers that will provide protection for reforestation seedlings against pathogenic organisms, as well as providing natural fertilizer nutrients to plants.

Literature and essays on prior tests were consulted, as well as experts from potential providers of the component.

Bibliography used includes the following (in its original language):

- J. Pera, J. Parladé (2005): Controlled inoculation of reforestation seedlings with ectomycorrhizal fungi: current knowledge in Spain. Forest System Vol 14 Nº 3 2005.
- Agerer, R. (2001). Exploration types of ectomycorrhizae: A proposal to classify ectomycorrhizal mycelial systems according to their patterns of differentiation and putative ecological importance, Mycorrhiza, 107–114.
- Ana, R., Javier, P., & Joan, P. (2007). Original article Influence of the fertilisation method in controlled ectomycorrhizal inoculation of two Mediterranean pines, Ann. For. Sci., 64, 577–583.
- Duponnois, R., Plenchette, C., Prin, Y., Ducousso, M., Kisa, M., Bâ, A. M., & Galiana, A. (2007). Use of mycorrhizal inoculation to improve reforestation process with Australian Acacia in Sahelian ecozones. Ecological Engineering, 29(1), 105–112.
- Nadeem, S. M., Ahmad, M., Zahir, Z. A., Javaid, A., & Ashraf, M. (2014). The role of

mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. Biotechnology Advances, 32(2), 429–48.

- Oliveira, R. S., Franco, A. R., & Castro, P. M. L. (2012). Combined use of Pinus pinaster plus and inoculation with selected ectomycorrhizal fungi as an ecotechnology to improve plant performance. Ecological Engineering, 43, 95–103.
- Quoreshi, A. M., Piché, Y., & Khasa, D. P. (2007). Field performance of conifer and hardwood species 5 years after nursery inoculation in the Canadian Prairie Provinces. New Forests, 35(3), 235–253.
- Sousa, N. R., Franco, A. R., Oliveira, R. S., & Castro, P. M. L. (2012). Ectomycorrhizal fungi as an alternative to the use of chemical fertilisers in nursery production of Pinus pinaster. Journal of Environmental Management, 95 Suppl, S269–74.
- Antonio Díaz Espejo, A. Gutiérrez Abobal, Mario Honrubia García (2004): Utilización de mycorrhización controlada en la reforestación de un suelo agrícola con pino carrasco. Cuadernos de la Sociedad Española de Ciencias Forestales, ISSN 1575-2410, Nº. 17, 2004 (Ejemplar dedicado a: Actas de la III Reunión sobre Repoblaciones Forestales), págs. 151-156.
- Martín-Pinto, P. y Oria de Rueda, J.A.: Efecto de la mycorrhización de Pisolithus tinctorius y Rhizopogon roseolus sobre planta de Pinus nigra empleada en la restauración de un monte quemado. Andrés Arija,P. 1 , Hernández-Rodríguez, M. 1 , 1 1 Instituto de Gestión Forestal Sostenible. Escuela Técnica Superior de Ingenierías Agrarias. Universidad de Valladolid.
- J. Parladé, J. Pera (2005): Inoculación controlada con hongos ectomicorrícicos en la producción de planta destinada a repoblaciones forestales. Estado actual en España - Investigación agraria. Sistemas y recursos forestales, ISSN 1131-7965, Vol. 14, Nº 3, 2005, págs. 419-433.
- M. Honrubia,g. Díaz y a. Gutiérrez: Mycorrhización controlada de Pinus halepensis en vivero en función del tipo de inóculo y técnicas de cultivo. Depto. Biología vegetal. Fac. Biología. Univ. Murcia. Campus Espinardo, 30100 Murcia.
- J. Pera; I.F. Alvarez & X. Parladé (1993): Selección de hongos ectomicorricicos para Pinus pinaster ait. Departament de Pato logia Vegetal. Institut de Recerca i Tecnologia Agroalimentàries (IRTA). 08348-CABRILS (Barcelona). Congreso Forestal Español - Lourinzán 1.993. Ponencias y comunicaciones. Tomo III 391.
- E. Gómez-Sánchez; a.i. González-Ochoa; p. Torres (2); J. De las Heras & E. Simarro: Mycorrhización de plantas de Pinus halepensis, Pinus pinaster y Quercus ilex subsp. ballota para repoblación de zonas incendiadas de escasa regeneración natural. Departamento de Producción Vegetal y Tecnología Agraria. Universidad de Castilla-La Mancha. (2) Departamento de Biología Vegetal, Universidad Miguel Hernández. Facultad de Ciencias Ambientales. Elche (Alicante).

As a result the team decided to select the following species of mycorrhiza:

4. Pisolithus tinctorius (Pers.) Coker & Couch (ectomycorrhiza).
5. Scleroderma polyrrhizum (JF Gmel.) Pers (ectomycorrhiza).
6. Glomus ssp. (Endomycorrhiza).

These mycorrhizal fungi used are fungi that are present naturally in Valladolid, they are able to mycorrhizal host species and young plants and are efficient by spore inoculation.

Each plant species of the project were mycorrhizal with the following fungi:

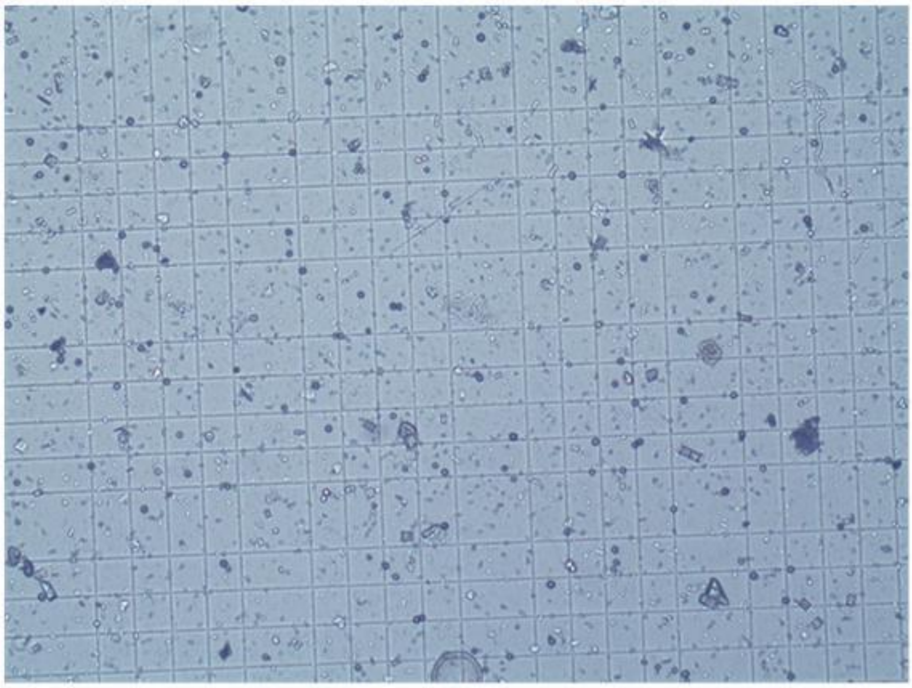
- *Pinus pinea* with Pisolithus tinctorius.
- *Almond*, *Juniperus* and *Arce* with Glomus.
- *Q. faginea* and *Q. ilex* with Pisolithus tinctorius + Scleroderma polyrrhizum.

Inoculum preparation and implementation

The case of ectomycorrhizas (Pisolithus and Scleroderma)

Organic field samples of fungi were collected, selecting those with similar characteristics of those of the plantation site. The hymenium was mashed to form a liquid mixture with sterile distilled water until a homogeneous spore suspension was stable.

Once the suspension was stable, the required concentration was fitted for plant inoculation. Usually, according to previous studies, a concentration between 5 $\cdot 10^5$ and 5$\cdot$ 10^6 spores/ml, depending of watering dose, is advised. To adjust the spores' concentration it was necessary to use a counting camera Thoma type or Neubauer type.



The case of endomycorrhiza (Glomus ssp.)

A commercial mixture of ready-to-use product was used. Several product suppliers were tested at the lab, finally selecting the highest quality one according to the tests. The dose was fitted to our treatment requirements of 0 -1 g/pl. following same suspension procedure as described before.

Inoculation inside the QUF Project was carried out in two separate periods of time and methodologies:

i) **Inoculation at field site**

April 30th 2014: (1st inoculation): 3103 plants.

May 14th 2014: (2nd inoculation): 720 plants.

ii) **Inoculation at nursery stage**

May 8th 2014: (1st inoculation): 3308 plants.

May 22nd 2014 (2nd inoculation): 3308 plants.

Overall, 10.439 plants were inoculated, considering that during spring 2015 death trees were planted again. After the first-stage study on climatic characteristics and soil properties on the study area, the following species were chosen for inoculation:

- Main species: *Pinus pinea, Quercus ilex* and *Quercus faginea.*
- Secondary species / shrub vegetation: *Celtis australis, Juniperus thurifera* and *Acer campestris.*

As shown below, the techniques to be carried out are divided quantitatively by specie.

Table 2: Species and number of plants to be inoculated

Plants to be micromised by ECM	*Celtis australis*	*Arce campestris*	*Juniperus thurifera*	*Pinus pinea*	*Quercus faginea*	*Quercus ilex*	Total
mycorrhiza	291	291	582	970	388	582	3103
mycorrhiza and retainer	291	291	582	969	388	582	3102
Total	**582**	**582**	**1163**	**1939**	**776**	**1163**	**6205**

i) **Inoculation at field site**

Mycorrhizal inoculation is supposed to be higher at nursery, where all steps of the inoculation chain can be controlled (e.g., seedlings, watering, soil). In our case, we conducted an experimental process, consisted on inoculating the plant at the field, just at the moment of plantation.

For ensuring the success of the process in this case, the dose of mycorrhizae used was higher compared to the usual doses used at nursery. Finally, the amount of dose inoculated on the field was:

Table 3: Dose of mycorrhizae per species in field inoculation

HOST	INOCULUM	NUMBER OF SPORES	DOSE
Juniperus oxycedrus	*Glomus spp.*	0,1gr/pl	10 ml
Pinus pinea	*Pisolithus tinctorius*	1*10^7 esp/ml	10 ml
Almond	*Glomus*	0,2gr/pl	10 ml
Acer campestris	*Glomus*	0,2gr/pl	10 ml
Quercus faginea	*Pisolithus + Scleroderma*	0,5*10^7 esp/ml + 0,5*10^7 esp/ml	10 ml
Quercus ilex	*Pisolithus + Scleroderma*	0,5*10^7 esp/ml + 0,5*10^7 esp/ml	10 ml

Two inoculations were done, with a time difference of 15 days to ensure a proper inoculation rate of plants. In this case, the way of procedure was directly by means of syringes. The following table shows the inoculated dose by plant and date:

Table 4: Inoculation at field: part 1

SPRING PLANTING 2014 DATE: 30-4-2014					
BLOCK	Block 1	Block 2	Block 3	Block 4	CP
SECTOR	4	6	12	16	CONTROL PLOTS
TREATMENT	Mycorrhiza	Mycorrhiza	Mycorrhiza	Mycorrhiza	CONTROL PLOTS
Almond	82	80	80	48	120
Acer campestris	82	80	80	48	120
Juniperus thurifera	164	161	161	97	120
Pinus pinea	273	268	268	161	120
Quercus faginea	109	107	107	64	120
Quercus ilex	164	161	161	97	120
	873	858	857	515	720

The lack of rain following the inoculation together with the poor soil condition and the numerous dead trees found at that time, made the project management team to interrupt the inoculation at study area level, deciding to focus on the 4 control plots where periodical watering were necessary to maintain plant survival rates at a reasonable level.

Table 5: Inoculation at field. Part 2.

SPRING PLANTING 2014	
DATE: 14-5-2014	
BLOCK	CP
SECTOR	CONTROL PLOTS
TREATMENT	CONTROL PLOTS
Almond	120
Acer campestris	120
Juniperus thurifera	120
Pinus pinea	120
Quercus faginea	120
Quercus ilex	120
	720

ii) **Inoculation at nursery stage**

According to the inoculation on the control plots and also the Project management plan (table 1); the remaining plants were inoculated at the nursery (table 6):

Table 6: Summary of plants inoculated at nursery

	Total to mycorrhizal	Control plots	Renedo nursery	Pending mycorrhization	10% increase over the total to mycorrhizal	Fuenteamarga nursery
Celtis australis	582	120	208	254	58	312
Acer campestris	582	120	301	161	58	219
Juniperus thurifera	1163	120	720	323	116	440
Pinus pinea	1939	120	1053	766	194	960
Quercus faginea	776	120	401	255	78	332
Quercus ilex	1163	120	625	418	116	535
TOTAL PLANT	6205	720	3308	2177	621	2798

Plants from two different nurseries were inoculated.

Imagen 6. Planta de *Quercus faginea* a inocular en viveros Fuenteamarga

Table 7: Dose of mycorrhizae at nursery inoculation

HOST	INOCULUM	NUMBER OF SPORES	DOSE
Juniperus oxycedrus	*Glomus*	0,1gr/pl	1 ml
Pinus pinea	*Pisolithus*	1*10^6 esp/ml	1 ml
Almond	*Glomus*	0,1gr/pl	1 ml
Acer campestris	*Glomus*	0,1gr/pl	1 ml
Quercus faginea	*Pisolithus + Scleroderma*	0,5*10^6 esp/ml + 0,5*10^6 esp/ml	1 ml
Quercus ilex	*Pisolithus + Scleroderma*	0,5*10^6 esp/ml + 0,5*10^6 esp/ml	1 ml

As described before in field inoculation, two inoculations in different times were done, to guarantee a better symbiosis between fungi and plant. The two steps inoculation was carried out in plants from the two different nurseries used, according to the following calendar:

Nursery I located in Renedo (Valladolid):

- 1st inoculation: May 8th 2014.
- 2nd inoculation: May 21st 2014.

Nursery II located in Fuenteamarga (Valladolid):

- 1st inoculation: June 17th 2014.
- 2nd inoculation: July 1st 2014.

After the inoculation process the project management team considered necessary to evaluate the achieved level of inoculation at plant level. To analyze that, a 22-plant sample was taken from the nursery on the way to the plantation site. The plants were analyzed at the lab by a third party, not participating in the inoculation process. The presence of ectomycorrhizal, both the count and the percentage of inoculated roots, were tested for *Pinus pinea* and *Quercus ilex.*

<u>*Pinus pinea*</u>

SAMPLE (customer code)	% of total mycorrhization	Number of morphotypes	Morphotypes	% of mycorrhization per morphotype	Observations
Sector 1 Pp	-	-	-	-	No enough light show
Sector 3 Pp	58,5	1	A	58,5	**X**
Sector 4 Pp	33,3	1	B	33,3	**X**
Sector 5 Pp	26,0	2	A - B	15,7 - 10,3	**X** -
Sector 6 Pp	-	-	-	-	No enough light show
Sector 7 Pp	30,2	2	A - B	1,4 - 28,8	
Sector 10 Pp	14,0	1	C	14,0	**X**
Sector 11 Pp	60,6	1	D	60,6	**X**
Sector 12 Pp	28,3	1	B	28,3	
Sector 13 Pp	12,7	2	A - D	5,1 - 7,6	- **X**
Sector 18 pine a	26,9	2	A - B	2,4 - 22,5	**X** -
Sector 18 pine b	3,9	1	B	3,9	
Sector 18 pine c	23,5	1	B	23,5	
Sector 20 pine d	33,1	1	A	33,1	**X**
Sector 20 pine e	37,0	2	A - B	16,0 - 21,0	**X** -

Quercus ilex

SAMPLE (customer code)	% of total mycorrhization	Number of morphotypes	Morphotypes	% of mycorrhization per morphotype	Observations
Sector 1 Qi	**0,9**	1	B	0,9	
Sector 3 Qi	**34,0**	1	B	34,0	The sample contains two plants together - **X**
Sector 4 Qi	**20,5**	1	B	20,5	The sample contains two plants (one cut) - **X**
Sector 5 Qi	**6,3**	1	B	6,3	
Sector 6 Qi	**11,2**	1	B	11,2	
Sector 7 Qi	**5,0**	1	B	5,0	Plants with two stems (one dry). Little root - **X**
Sector 10 Qi	**15,8**	1	B	15,8	**X**
Sector 11 Qi	**2,0**	1	B	2,0	**X**
Sector 12 Qi	**4,3**	1	B	4,3	**X**

Outcome of the independent validation analysis:

In regard of the presented results, it can be concluded that 22 out of the 24 analysed samples, the *Pinus pinea* trees from sectors 1 and 6, do not have enough root length to evaluate the amount of mycorrhizas.

All samples, both pine or oak samples, no root out of the container was observed (original prepared soil from the nursery) leading to considerer the development of root systems still sparse and limited.

Quercus ilex samples only present one morphological type of ectomycorrhizal (white-grey coloration and smooth appearance, simulating wax). There are six samples in which to proceed to identify fungi species, by means of DNA analysis.

On the other hand, pine samples show a greater morphological variety in terms of ectomycorrhizal: four cases comparing to the once for Spanish oak. The most frequent organism looks like cotton-texture at a white-grey coloration due to the presence of short hyphae emanating from the mycorrhiza) and mycelial (or rhizomorphs) white laces. Both morphological types are presented while in some plants.

There are available data also on mycorrhizal roots samples (nine in all) as in the previous case that might allow the identification of fungal species associated by DNA analysis. Both pine and oak based samples, presented high variability in the percentage of detected mycorrhizal colonization. The degree of mycorrhizal plants depends on both mycorrhizal its initial state (at the time of removal from the nursery and field establishment) and physicochemical and the biological soil characteristics of the different plots, characteristics which generally tend to be highly variable. Our field samples indicate high variability in the percentage of mycorrhizal roots, and therefore, it is recommended to work with several repetitions at lab analysis.

Selection of water retainers

Water retainers are the second element to be tested in the QUF Project. These hydrogels are applied for retaining water and nutrients in soil, improving water management and plant growth, acting as a water reservoir and releasing it to the needs of the plants.

Many different experiments have shown greatly the effectiveness of this technology, especially in poor soil conditions and climates where irrigation is difficult and the rain is concentrated in a few weeks.

To find the right retaining, an extensive search and analysis of existing studies carried out in Spain, Portugal, Australia and the United States was performed. The results of these tests and studies show that the Stockosorb retainer was the most suitable for our type of soil and species. This retainer is easy to use and has no added complementary products that could mask the comparison with the other treatments tested.

Table 8: Bibliography related to various tests with retainers in different parts of the world

Authors and year	**Reference**	**Country**	**Species**
Chirino et al 2011	Plant Soil 344: 99-110	Spain	*Quercus suber*
Chirino et al 2012	Plant Soil 344: 99-111	Spain	*Quercus suber*
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Olea europaea
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Olea europaea
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Retama spharaeocarpa
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Retama spharaeocarpa
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Pinus halepensis
Oliet et al. 2004	Manual de restauración forestal 2	Spain	Pinus halepensis
Oliveira et al 2011	Ecological Engineering 37: 255-259	Portugal	*Ceratonia siliqua*
Oliveira et al 2011	Ecological Engineering 37: 255-259	Portugal	*Pistaccia Lentiscus*
Oliveira et al 2011	Ecological Engineering 37: 255-259	Portugal	*Olea Europea*
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Artemisia ludoviciana
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Artemisia ludoviciana
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Artemisia ludoviciana
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Atriplex canescens
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Atriplex canescens
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Atriplex canescens
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Chrysothamnus nauseosus
Paschke et al., 2000	Restor Ecol 8: 276-282	USA	Chrysothamnus nauseosus
Ruthrof et al 2010	Australian Journal of Botany 58: 646-655	Australia	*Eucalyptusgomphocephala*
Ruthrof et al 2010	Australian Journal of Botany 58: 646-655	Australia	*Eucalyptusgomphocephala*
Ruthrof et al 2010	Australian Journal of Botany 58: 646-655	Australia	*Eucalyptusgomphocephala*
Seva-Gómez et al 2004	Cuad.Soc.Esp.Ccias.Forest 17: 233-238	Spain	*Quercus ilex*
Valdecantos et al. 2004	Technical report CEAM	Spain	*Quercus ilex*
Valdecantos et al. 2004	Technical report CEAM	Spain	*Quercus ilex*
Valdecantos et al. 2004	Technical report CEAM	Spain	*Quercus ilex*

The Stockosorb is a hydrogel formed by a polymer (cross linked as a potassium salt of acrylamide-acrylic acid) that increases the absorbing capacity of plants. It is a kind of super-absorbent polymer, high quality, due to its three-dimensional cross linked structure and to the ability of dehydration of its group's carboxylic acids. It increases soil capability to hold moisture and easily provide it to plants when they need it.

With this product in agriculture, a reduction of irrigation frequency of 50% is achieved because 1 kilogram of product retains 250 litres of water. In a study on a sandy soil as the QUF project, this reduction in frequency of irrigation was observed for the same amount of soil water after 80 days in this case.

It was applied in wet (8 parts of product per one of water): about 150-250 ml of homogeneous product in 1 litter of volume of the planting hole.

The use of components

Once the concrete components were selected, we defined the way in which they will be used and combined. As defined in the proposal, the components are used in two ways: alone, and in combination with others.

The plantation is designed as follows: 6 species are planted (4 shrubby tree and 2) in mixed masses, divided in four sectors, depending on planting techniques of the project, that is, if retainers and mycorrhizae are used or not. Therefore we have a sample for each soil/spice and treatment (main components of the project).

The experimental is design in blocks in which the 4 treatments tested are repeated.

A total of 5 blocks with 4 sectors in each block, where the repopulation is made following techniques:

1. Witness: Plant in container.
2. Retainer: Plant in container planted with polymer retainer.
3. Mycorrhizae: Plant is inoculated with mycorrhizae.
4. Mycorrhizae plus retainer: inoculated plant is used and polymer retainer is incorporated into the planting hole.

3 of the blocks are approximately 2 hectares and each of its four sectors has 0.54 hectares. A

fourth block is a little bit smaller, with a surface of 0.33 hectares per sector.

Finally a block of 0.6 hectares will be planted using plants with an edible mycological species, *Pinus pinea* mycorrhizal with *Lactarius deliciosus*. Four planting techniques are repeated in turn; witness, retainer, mycorrhizae and mycorrhizae with retainer.

In the following map shows the 5 different blocks and the 20 sectors where the various combinations of reforestation techniques applied:

- Block 1: sectors 1, 2, 3 and 4.
    - Sector 1: Witness.
    - Sector 2. Mycorrhiza and retainer.
    - Sector 3: Retainer.
    - Sector 4: Mycorrhiza.
- Block 2: sectors 5, 6, 7 and 8.
    - Sector 5: Mycorrhiza and retainer.
    - Sector 6. Mycorrhiza.
    - Sector 7: Witness.
    - Sector 8: Retainer.
- Block 3: sectors 9, 10, 11 and 12.
    - Sector 9: Witness.
    - Sector 10: Mycorrhiza and retainer.
    - Sector 11: Retainer.
    - Sector 12: Mycorrhiza.
- Block 4: sectors 13, 14, 15 and 16.
    - Sector 13: Witness.
    - Sector 14: Mycorrhiza and retainer.
    - Sector 15: Retainer.
    - Sector 16: Mycorrhiza.
- Block 5 or *Lactarius* Block: sectors 17, 18, 19 and 20.
    - Sector 17: Retainer.
    - Sector 18: Mycorrhiza.
    - Sector 19: Witness.
    - Sector 20: Mycorrhiza and retainer.

Chapter 5. Data analysis

The QUF Project is a demonstration project. For that reason, verifying and controlling the effects of the different tested techniques is an essential element of the project. Our intention is to make a rigorous and quantitative analysis of these effects to give greater validity to the conclusions. The analysis is performed comparing the results by treatment, specie, and soil characteristics. In particular, 5 analyses are done:

1. Analysis of the effect of the treatments on the water storage capacity of the soil after the rainfall.
2. Analysis of the effect of the treatments on average soil humidity.
3. Analysis of the effect of the treatments on average soil temperature.
4. Analysis of the effect of the treatments on the species survival.
5. Analysis of the effect of the treatments on plant biomass variables.

As it has already been mentioned in Chapter 2 when introducing the QUF Project, the analysis is performed by using data from three main sources:

- A network of sensors that monitors soil temperature and soil humidity every 30 minutes at a depth of 20 and 40 cm, in the rooting system of a total of 64 plants in 4 experimental blocks, along with a weather station that register local climatic variables (air temperature, precipitation and wind speed). To monitor soil characteristics two species (*Pinus pinea* and *Quercus ilex*) were selected, using two plants per specie in each treatment in each block (16 plants per block).
- Evaluation of the survival of 1.436 trees of 6 species at key moments of the project (7 observations so far).
- Measurement of biomass related information at the end of a project in a sample of plants.

The availability of a huge amount of data coming from the sensor network is an important feature of the QUF Project. Lack of high quality data continues to be one of the main constraints in agriculture particularly in forest plantations on degraded soils. The use of sensors expands the information available for decision making in terms of possible treatments (4 alternatives in the QUF) or the choice of the species (almond tree, oak, pine, gall oak, junipers and maple).

In the following sections we describe in detail the methodology used for gathering and analysis data, as well as the theoretical and the empirical models that has allow us to obtain relevant conclusions on the real effect of the techniques tested. All this information is expanded in Annex 1.

Methodology

The overall methodology we are using to make the data analysis is shown in Figure 5.

1. The sensors collect the data in real time and send the information to the server.
2. Data are downloaded from the server in a monthly basis.
3. Survival data are obtained in field conditions every few months.

4. Biomass data have been obtained at the end of the project.
5. The data are cleaned and the datasets used for the analysis are built.
6. Statistical analyses are performed and the results are discussed within the group and with external experts to obtain the main conclusions.
7. Based on the initial findings, the models of analysis are reviewed.
8. The preliminary findings are uploaded to the QUF site and a summary is included in the newsletter.

The following models of analysis have been applied: descriptive analysis, causal analysis of the treatments on soil moisture at 20 and 40 cm, soil temperature at 20 and 40 cm, and soil moisture gradient, moisture absorption analysis, survival analysis and analysis of biomass.

The overall methodology we are using to make the data analysis is shown in Figure 6.

Figure 6: Analysis methodology

Theoretical model

General model

The occurrence of isolated rainfall episodes in the Mediterranean area, are likely to take place during the drought periods of the summer. This makes difficult for soils to retain the scarce water, thus challenging the survival of the seedlings and further growth of plants.

The different treatments used in the project intend to improve the capacity of water absorption of the soil during these events of heavy rain by keeping higher levels of moisture for longer periods. It will yield higher average humidity in the soil that is likely to improve the survival chance of the plants and further growth.

Our model will explain the effect of the treatments: on water absorption of the soil after the rainfall; on the increase in average humidity, both at 20 and 40 cm; on the decrease in gradient humidity between 20 and 40 cm; and on the soil temperature at 20 and 40 cm. The analysis to assess whether the improvement of soil conditions is related to increasing the survival chance of the plants. Eventually, biomass measurement is carried out to verify that the absorption of carbon in the stem and root of plants, as well as the height and diameter of the plants, have improved due to the treatments.

The analysis is done by analysing the average effect of the treatments for the whole sample and depending on the period (vegetative and no vegetative), the specie and soil characteristic of the test blocks.

Changes in the moisture storage capacity of the soil after rainfall

Combining soil humidity data from sensors with weather incidents recorded by the station located in the plantation allow to analysing a very important phenomenon: the gradual infiltration of surface runoff resulting from a rainfall depending on the treatments.

The theoretical description of the phenomenon is the following:

Rain water infiltrates into the ground at a speed that depends on the characteristics of the soil, vegetation (Jiménez et al., 2006) and the percentage of soil saturation. The roots, and organic matter, increase the concentration of macro pores where the water can go away (Jarrett and Hoover, 1985) favouring its circulation and drainage to lower layers. Previous research has studied the effect of soil texture (Smith and Parlange, 1978) and vegetation (Johnson and Gordon, 1988) on the rate of infiltration of rainwater. It is expected that the treatments to seedlings in nurseries can also positively influence the retention of water in the topsoil, increasing water resources availability for plant growth. In fact, water resources have shown to have a relevant effect on the survival of seedlings in the arid Mediterranean area (Lopez et al., 1998).

Maximizing the use made by plants of a scarce resource like water is vital when rain events tend to be concentrated in short periods of time, both at daily and seasonal level. This is particularly relevant in the geographical area of the project, where summer storms play a decisive role in minimizing water stress of the plants during the long summer droughts.

In fact, the amount of rainfall recorded in the summer proved to be the variable that most influenced the natural regeneration of pine forests in the surrounding environment (Ruano et al., 2009) above rodent predation or the level of seeds produced.

Data from the weather station will be used to identify rainfall events, which will be characterized according to their intensity and time of the year. The evolution of the soil moisture after an event of rainfall (particularly during the summer) will yield valuable insights about the soil capacity to retain water depending on the treatments. By using measurements over time on two separate layers, one at a depth of 20 cm and other at 40 cm, will allow to test whether infiltrated water remains longer at the different horizons with one treatment or another.

Analysis of moisture in the soil in different strata

Using the data recorded by the sensors we want to analyse the soil moisture dynamic at two depths (20 and 40 cm). The objective is to determine the effect that treatments have on the soil water storage capacity of the species chosen for planting. The three applied treatments: mycorrhiza, retainers, and the combination of these two treatments (mixed) will be compared with a control - plants without treatment.

Soil water retention capacity is expected to increase through the use of retainers and also with the mycorrhization, although to a lesser extent. From a research point of view, there is little or no information about how the combination of both treatments will behave. Measuring ongoing values of soil moisture at two depths, we hope to satisfy the following research hypotheses:

i. The treatments will contribute to the increase of the soil moisture in the rooting system environment of the seedlings.
ii. The absolute difference of moisture between 20 and 40 cm layers will be reduced by the treatments.
iii. The effect will vary for each soil characteristics depending on the treatments.

From the theoretical point of view, increasing the amount of water in the soil over time has an associated best thermal conditions for the root development of plants (Burdett, 1990; Bowen, 1991), avoiding phenomena such as hardening of the post-nursery plants. There is an influence of soil temperature in the resistance to water stress (Arnott et al., 1993) and in the post-nursery (Franco et al., 2001) development of species. The specific heat of the soil increases, causing a delay effect in the change of the temperature at the seasonal and daily level. It is expected that the daily data will have very low climatic variability in the lower horizon (40-60 cm depth), but not in the upper horizon (Scheffer et al., 2002).

The consequences of this process is that the roots extend their period of development (Clarkson et al., 1986) and can go deeper into the ground (McMichael and Quisenberry, 1993). It is an indirect, although efficient, method to lengthen the period of root growth, especially useful in the phase of seedling establishment. Previous studies (Fullner, 2007) have shown that biomass production is increased in value as the gradient vertical temperature drops between the horizons.

Measurements of survival in field conditions along with the biomass data will allow to confirm/discuss this hypothesis of survival. In fact, it is advised to compare the results of moisture of the study with other factors that will be analysed over the life of the project such as survival models throughout the life of the plantation and development of root biomass at the end of the project.

Survival analysis

The targets of our forest plantation are multiple, from slowing soil erosion to the reintroduction of native species. These objectives are achievable, provided that the planting lasts over time and seedlings still survive in the field. South et al., (2000) suggested that the initial response in a plantation is affected, in order of importance, by environmental conditions, the management of the plant morphology and its physiology. Therefore, there are many factors to consider, particularly in Mediterranean environments. First, that there is enough rainfall to ensure the initial rooting of the plant and secondly by guarantying a sufficiently long vegetative period (Navarro et al., 2006).

Irrigation at the time of executing the plantation is advised (Siles et al., 2010) to ensure an optimum plant survival rate, especially in the Mediterranean area (Castro et al., 2005). In Spain, irrigating forest plantations under water stress conditions is an established practice (Serrada et al., 2005). But nowadays, there is a contradiction in the literature since it has been shown by various authors that the survival and growth of plants greatly improves with an initial (or successive) irrigation (Jiménez et al., 2004), while other authors advise against the initial irrigation because it induces the plants to be less tolerant to summer drought and therefore, adversely affecting the economic performance of the plantation (King et al., 2009). Due to the extraordinary weather conditions during the plantation, we decided to perform a first irrigation in much of the surface repopulated.

Once the plant is arranged in the field, the first step in assessing the degree of success of a plantation in semi-arid conditions is to quantify the survival of seedlings and subsequently identify growth rates (Maestre and Cortina, 2004).

In the QUF project, through the monitoring of abiotic conditions of the plantation and through precise measurement of the temperature and humidity in individuals planting, we intend to monitor (accurately and continuously during the establishment phase) those factors that are most likely to influence seedling survival (McKay, 1997).

Indicators such as net response rate (NRR) (Armas et al., 2004) have been used to measure survival in controlled trials. Periodic measurements to control the survival rate along different stages of the project, and for different factors, namely i) soil characteristics ii) species and iii) treatment will be made in the project. This information will be related to the soil humidity data registered in the plants monitored.

The methods most frequently used to model the survival of the trees are statistical, using a flexible non-linear function with values between 0 and 1, and using maximum likelihood estimates (MLE). In general, it is assumed that there is a risk base function that is proportionally affected by different covariates on what are called proportional hazard models. The most common distribution function is the log-logistic, although semi-parametric models are also widely used if the shape of the hazard function is not the main goal of the analysis, as proposed by Cox & Oakes (1984). It is also frequently used nonparametric estimators of survival function as proposed by Kaplan & Meier (1958) using intervals of width equal to the observation intervals. Recursive portioning methods and neural networks have been also use without yielding clear improvements over conventional statistical models (Monserud & Sterba, 1999).

Analysis of variables related to biomass

Analysing the root development in the project is intrinsically linked with previous analyses of humidity, temperature and survival. In a new plantation, the flow of biometric data from the radical part of the plants is of greater importance, by providing greater inference capacity to better understand and correlate the different processes:

1. Root elongation of each individual is closely correlated with the temperature in the ground to reach the optimum for each species (Stone et al., 1983).
2. The survival of not-taproot plants is favoured by lateral root development (Stone and Taylor, 1983).
3. Foliar biomass production increases until reaching the optimum for each specie (De-Lucia et al., 1992) which varies depending on the geographic origin (Lyr, 1996).

Given the relatively short time horizon of the project QUF, measuring biometric indicators (see section 4) of the radical part is the cornerstone that relates survivability, plant physiology and abiotic factors. The challenge is to determine which morphological attributes are the most appropriate to measure these parameters considering their autocorrelation. It has been proposed measuring root attributes that may better predict the survival and growth of the plant in the field (Louis et al., 2004) while being simple to measure (Scagel et al., 1993). By modelling these processes we will be able to test hypotheses and expected results at the species level, species-treatment, soil and treatment. Some of these hypotheses are:

1. In relation to the production of root biomass, treating seedlings at the nursery with retainers, mycorrhiza or the combination of both (mixed) will yield better results compared to seedlings without treatment.
2. The effect will vary for each specie depending on the treatments.
3. The effect will vary for each soil characteristics depending on the treatments.
4. There is a correlation between the effect of the treatments on survival rates and the effect of the treatments on root biometrics.

Unlike moisture, temperature and survival data, biomass data will be taken outside the control blocks (through longitudinal transects) because of being destructive (the plant is extracted from the ground).

The following procedure has been performed in order to determine the amount of carbon present in the plants:

- The plants were removed from the ground and were kept in plastic bags with their rootballs.
- Once in the laboratory, the plants are divided into aerial and subterranean parts (cutting in the root collar). Both parts are labelled with the name of the plant and the sector where they come from.
- Both parts are cleaned carefully, removing traces of soil (careful cleaning not to lose roots, they might be flushed whenever a large strainer or sieve is placed where all parts of the plant are collected).
- Both aerial and subterranean parts are weighed in a precision scale (in decigrams). For the aerial parts, the diameter at the bottom and the total height are measured. Data of every plant are collected in spreadsheets.
- Each aerial and subterranean part of the plants is placed in separate trays with their labels and they are introduced in a laboratory oven for the drying. The temperature of

the oven must be 60°C.

- Once in the oven, the content of the trays must be weighed every 24h. When the weight loss in those 24h is lower than the 10% of the previous weight, the plant is considered dried and has to be taken out of the oven.
- Once dried, every plant part (aerial and subterranean) has to be weighed. This weight will be added to the spreadsheet as dry weight (aerial and subterranean).
- Carbon content can be obtained from the dry weight of every part and a coefficient that depends on the species.

Data

Survival data in control plots in different times

Survival data are obtained using periodic observations on the control blocks established specifically for evaluating survival.

Measurement of plant survival will be made on 1.436 trees of 6 species in the following times:

- 1 month after the start of planting (June 2014).
- 4 months after initial planting (August 2014).
- Five months after the start of the planting (September 2014).
- After the first winter (March 2015).
- At the end of the second summer (September 2015).
- At the end of spring of the third year (June 2016).
- At the end of the third year (November 2016).

The number of trees measured by specie, treatment, and block (4 replicates for the combination of species and treatment) is shown in Table 1.

Collection of the survival data has been made in field conditions, surveying the status of the tree plant (live=1/dead=0). A survival data set with the observations will be created with the statistical package R.

Table 9: Sample of trees for survival analysis in control plots by treatment and specie

Plot 1								
	Al	Ar	Jt	Pp	Qf	Qi	Qp	Total
No treatment	14	15	15	14	8	13	7	86
Mixed	16	14	14	16	13	13	4	90
Micorize	15	15	16	15	8	15	6	90
Retainer	15	15	15	15	14	15	1	90
Total	60	59	60	60	43	56	18	356

Plot 2								
	Al	Ar	Jt	Pp	Qf	Qi	Qp	Total
No treatment	16	15	14	16	6	16	7	90
Mixed	15	12	15	15	12	16	5	90
Micorize	15	13	15	15	7	15	10	90
Retainer	15	17	17	14	11	15	1	90
Total	61	57	61	60	36	62	23	360

Plot 3								
	Al	Ar	Jt	Pp	Qf	Qi	Qp	Total
No treatment	16	15	15	15	5	15	9	90
Mixed	15	15	15	15	3	15	12	90
Micorize	16	15	16	14	2	15	12	90
Retainer	15	15	15	15	4	15	11	90
Total	62	60	61	59	14	60	44	360

Plot 4								
	Al	Ar	Jt	Pp	Qf	Qi	Qp	Total
No treatment	15	15	15	15	3	15	12	90
Mixed	15	15	16	15	13	14	2	90
Micorize	15	15	15	15	3	15	12	90
Retainer	15	15	15	15	8	16	6	90
Total	60	60	61	60	27	60	32	360

All plots								
	Al	Ar	Jt	Pp	Qf	Qi	Qp	Total
No treatment	61	60	59	60	22	59	35	356
Mixed	61	56	60	61	41	58	23	360
Micorize	61	58	62	59	20	60	40	360
Retainer	60	62	62	59	37	61	19	360
Total	243	236	243	239	120	238	117	1436

There are 78 trees that show a different specie depending on the year of observation (2014, 2015 and 2016), mainly in the Quercus faginea and pirenaica (under certain circumstances it is difficult to differentiate both species). We have decided not to include in the analysis those species due to the high uncertainty of the true specie.

Data provided by the sensors each 30 minutes (humidity, temperature and climate)

The humidity and temperature data are obtained through sensors installed in 64 plants. The sensors are of 2 types:

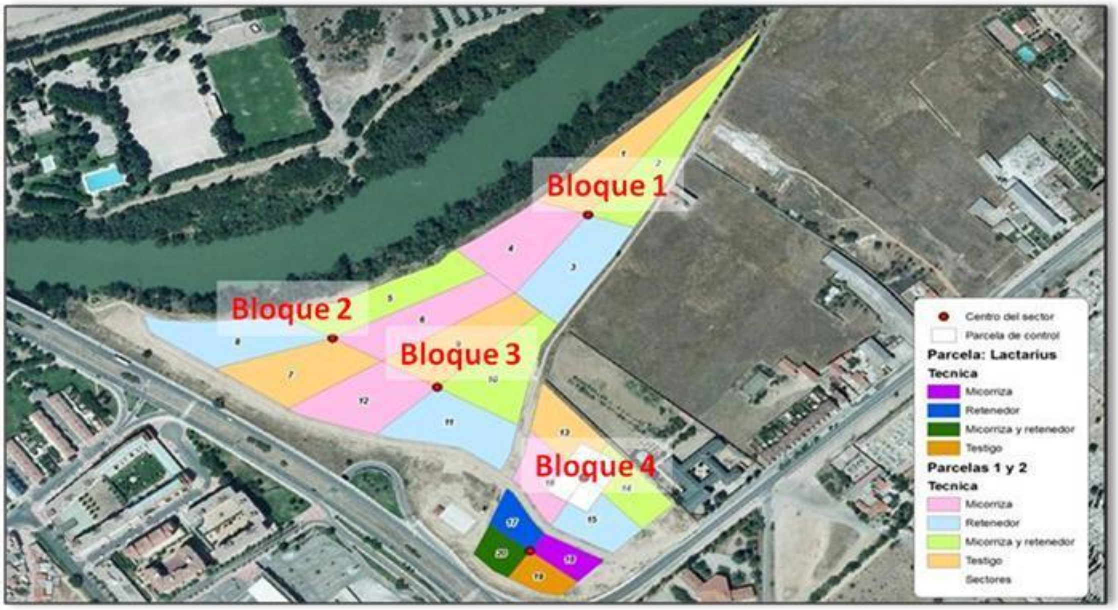
- Aquacheck: is a capacitance sensor that measures the frequency units (SFU) of the capacitance circuit generated by the electrodes of the probe. The sensor contains a pair of electrodes that act as a capacitator and the soil medium act as a dielectric of the capacitator and completes and oscillating circuit. The output of the capacitance probes are associated to the scaled frequency hat is related to the soil moisture. The scale frequency is converted to volume percent of water in the soil through a calibration process.

- Soil Temperature: measured in a range of -10 to +60 ° Celsius with accuracy of + / - 1 º Celsius.

For each plant two set of sensors are installed at 20 cm. and 40 cm. depth.

There are 4 treatments (mycorrhiza, retainer, mycorrhiza + retainer, no treatment) repeated in 4 blocks. The blocks are divided into control plots per treatment. Each block of control treatment is a randomized design with six species.

Figure 7: Scheme of the plantation by blocks and control plots



Two out of the six species are monitored with sensors 2: *Pinus pinea* (Pp) and *Quercus ilex* (Qi). Therefore 8 plants for treatment of each species are measured, 2 in each control block. Appendix 1 includes a list of the plants under observation, indicating the block to which they belong, species and treatment.

To collect the information we use addit S4 dataloggers, each with 6 sensors of soil moisture and temperature, making a total of 12 dataloggers. The dataloggers are connected to a hub of communications (addit) that collects and sends the information. There is one of these devices installed on each of the galvanized steel poles, about 5 m high and at least 1 meter buried. The posts are coated wooden to go unnoticed.

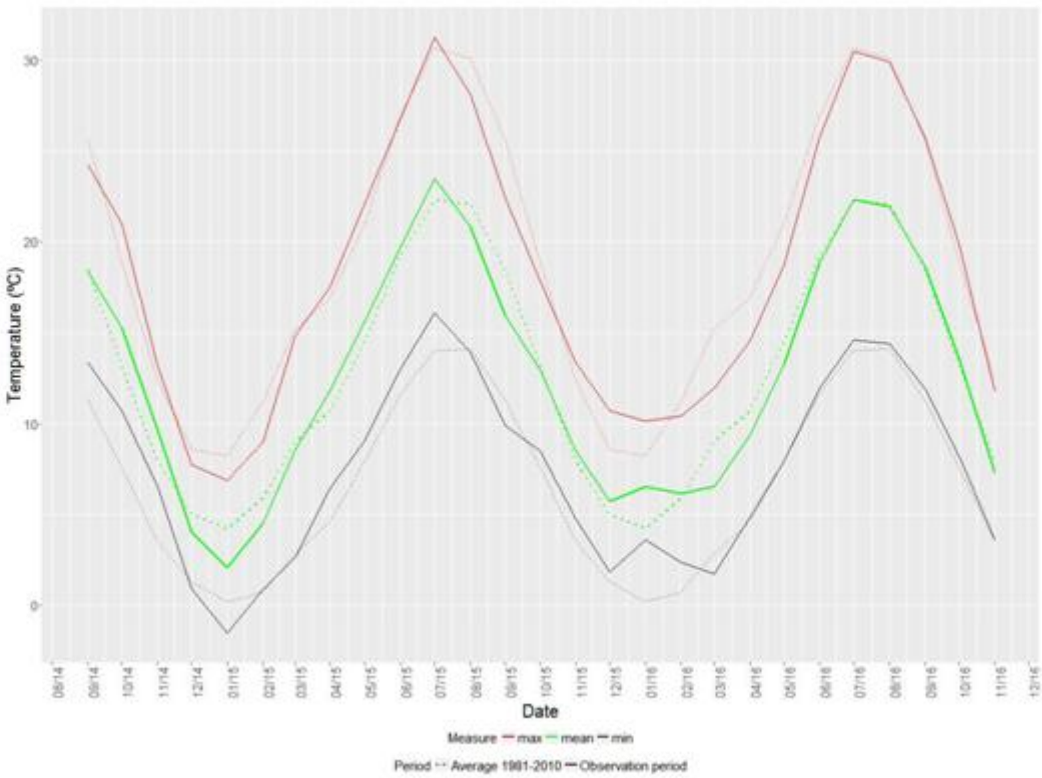
As mentioned, each plant has 4 sensors: humidity at 20 to 40 cm. and temperature at 20 and 40 cm. and the data is collected every half hour.

The moisture measure provided by the probes is an indirect measure of the real moisture of the soil. We are using Aquacheck probes that are capacitance sensor measuring the frequency units (SFU) of the capacitance circuit generated by the electrodes of the probe. The sensor contains a pair of electrodes that act as a capacitator and the soil medium act as a dielectric of the capacitator and completes and oscillating circuit. The output of the capacitance probes are associated to the scaled frequency hat is related to the soil moisture. The scale frequency is converted to volume percent of water in the soil through a calibration process.

However the calibration process has been more challenging than expected and eventually, it has been impossible for us to find a suitable transformation function due to the strong variability, both in the field data and in the samples collected for the calibration. Therefore the results are based on the raw data provided by the probes.

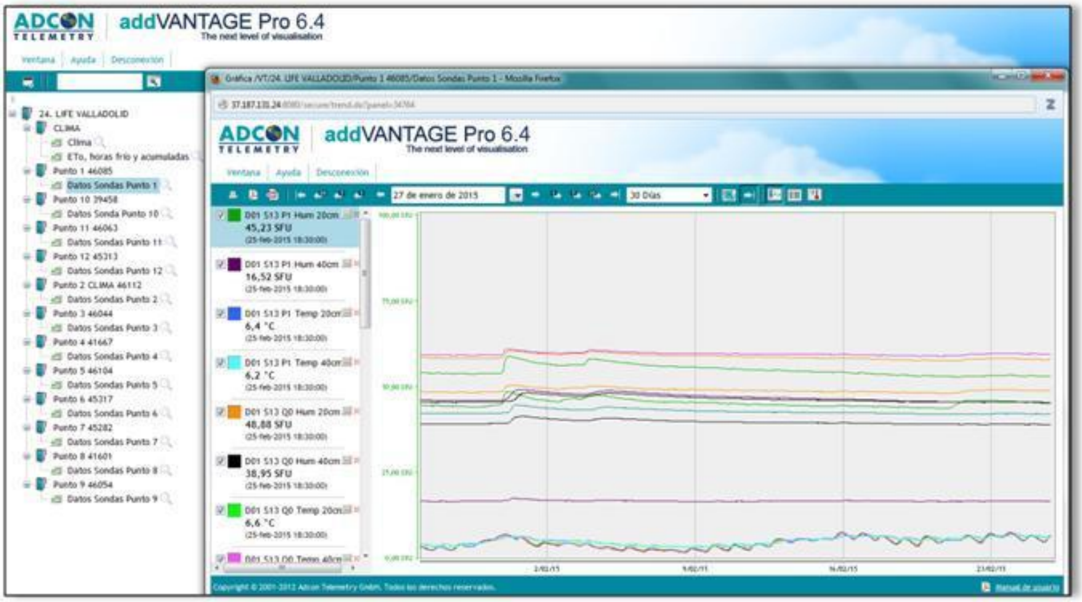
Meteorological data are also obtained every half hour. In particular, the temperature (in ° C), precipitation (in mm.), relative humidity (in% RH) and the wind speed (km / h). As an example, Figure 7 compared to the historical data.

Figure 8: Daily temperature evolution (mean, max, and min)



The raw data is dumped periodically from the data collection application and processed. Figure 9 shows the data collection application.

Figure 9: Screenshot of the data collection application "addVANTAGE Pro 6.4"



Once the raw data are downloaded, they are processed to generate an observation for each of the plants and time of observation. Humidity and temperature observed in each plant at 20 and 40 cm and data provided by the weather station: precipitation, temperature, wind speed and humidity are included in each observation. Due to the small intra-day variation of the data the information is averaged in a daily basis. Therefore, we have two datasets, one including all the observations and other including the daily average observations. The former is used in the moisture absorption analysis where having hourly data is mandatory while the latter is used for the soil humidity analysis.

Final data of biomass

We have carried out an analysis of biomass in the different species at the end of the project. Different information has been obtained from each tree: diameter, height, sector, soil, specie, and treatment.

Samples of different varieties (*Amigdalus communis*, *Arce campestre*, *Juniperus thurifera*, *Pinus pinea* and *Quercus ilex*) located in two blocks (3, 4) have been collected. Several treatments have been applied to these species namely: the absence of them, retainer, mycorrhiza and mixed.

The variables measured in the study are as follows:

- Biomass: Diameter and height and weight of roots and stem. The variables are highly correlated so we have constructed a compound variable using a linear transformation through an analysis of many components for the data set obtained from the diameter and height of the species, as well as carbon absorption in roots and stems of the trees (dependent variables).
- Treatment: application of treatments (absence of them, retainer, mycorrhiza and mixed) in the tree: we found 28 samples to which no treatments is applied; 31 with

retainer; 29 with mycorrhiza, and finally, 31 mixed (independent variable).

- Block: block where the tree is located (3 or 4). In Block 3 there are 58 samples per 61 of Block 4 (control variable).
- Specie: name of each species of tree in the sample. 25 samples of *Amigdalus communis*; 23 of *Arce campestre*; 23 of *Juniperus thurifera*; 23 of *Pinus pinea* and 25 of *Quercus ilex*.

The averages and deviations table are shown in the following table:

Table 10: Means and typical deviations of biomass

Spice	*Treatment*	*Samples of Biomass*	*Mean Biomass*	*Sd Biomass*
Al	No	6	1,3208	0,7386
Al	Retainer	6	1,3188	0,5305
Al	Mycorrhiza	7	1,2486	0,8136
Al	Mixed	6	0,3178	1,2859
Ac	No	5	-0,0471	0,3362
Ac	Retainer	7	-0,1914	0,7047
Ac	Mycorrhiza	5	-0,1909	0,8625
Ac	Mixed	6	0,1498	0,4092
Jt	No	4	-1,1069	0,9887
Jt	Retainer	6	-0,4525	0,7034
Jt	Mycorrhiza	7	-0,8938	0,5821
Jt	Mixed	6	-0,5769	0,4380
Pp	No	7	-0,1257	0,7107
Pp	Retainer	5	-0,0201	0,4280
Pp	Mycorrhiza	5	-0,6249	0,2054
Pp	Mixed	6	0,3939	0,3178
Qi	No	6	-0,3473	0,5110
Qi	Retainer	7	-0,6460	0,3837
Qi	Mycorrhiza	5	-0,3755	0,4724
Qi	Mixed	7	-0,2986	0,4103

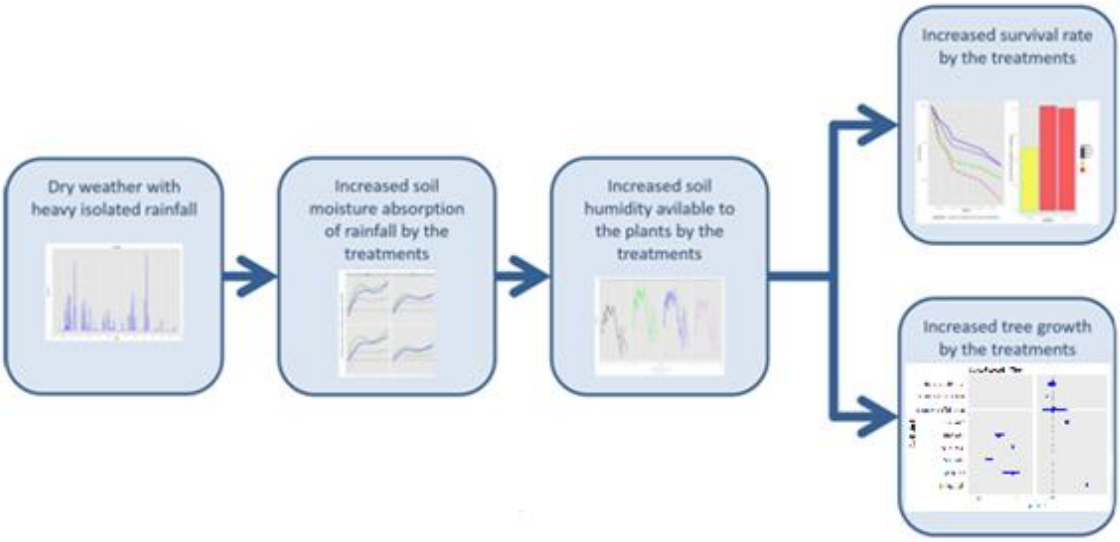
Chapter 6. Results

For this White Book data gathered until the end of November 2016 has been analysed. A full description of the empirical model and the detailed results of the analysis are included in Annex 1. The next sections summarize the main findings and conclusions obtained from that analysis.

A general model based on challenging climate conditions

The model posed in the analysis is shown in Figure 10. Dry weather conditions with isolated heavy rainfall and extended periods of drought decreases the survival rates of trees under low watering conditions. In fact we have seen that the weather conditions during the 2 years experiment have being challenging specially because of the higher dispersion of the monthly rainfalls. The treatments are expected to improve the moisture absorption capacity of the soils and therefore to increase the water available for the seedlings. Higher levels of water available for the trees will yield higher survival rates while increasing the growth. Thus, we also expect the treatments to affect an increase in plant biomass.

Figure 10: General model of the study



The treatments are likely to increase water absorption of the soil after the rainfall

By using a simple model of water absorption of the soil in the 24 hours after a rainfall we have seen that the treatments are related to an increase of the water absorption, particularly when the soil is dry. For each litre of rainfall per hour the soil humidity after 24 hours increases between 0.15 and 0.2 points when using the treatments and the results are statistically significant. The effect at 40 cm. Depth is much lower, probably because it takes longer for the water to affect deeper layers in the soil.

The strong differences between the blocks are also relevant although it is difficult to get reliable conclusions. May be that the differences are due to the smaller samples when analysing the blocks separately combined with the high dispersion of the measurements provided by the probes.

The treatments slightly increase the average soil moisture at 20 and 40 cm

The moisture of the soil increases when using the treatments but the magnitude of the change is very small and the effect is only significant for the treatment mycorrhiza. The effect at 40 cm. depth is slightly lower. May be that the results are not significant because of the high dispersion of the measures provided by the probes.

The reason for no getting significant results may be due to measurement errors, to the small sample size (64 trees), the big number of factors being considered (treatments, species, and blocks), the high dispersion of the measures, and other unobserved factors not being considered in the model such as local characteristics of the soil surrounding the tree or individual characteristics of the tree.

The main conclusion is that, although the effect is small it seems that using the treatments is related to a slight increase of the soil moisture. Whether this increase is relevant for the survival and growth of the trees will be assessed through the survival and biomass analysis.

We have also analysed the effect of the treatments on the temperature to find that the temperature at 20 and 40 cm. slightly increases when using retainers (alone or combined with mycorrhizas), in the no vegetative period and very slightly decreases in the vegetative period, although the effect is so small (always less than 1 ºC) that it is likely to not make any difference.

The treatments decrease the absolute value of the difference of moisture between 20 and 40 cm

In block 1 and block 4 there is a high gradient of average soil moisture between the 2 layers and therefore, we thought that it could be interesting to analyse whether the treatments have an effect on decreasing the gradient of humidity between the different layers.

We have seen that the gradient moisture of the soil decreases significantly when using the treatments (around 4 points). But we found worthy to analyse how the effect varies depending on the blocks.

The effect of the treatments on soil moisture depends on the soil characteristics

There are 4 experimental blocks in the plantation and we have used the different characteristics of the blocks to analyse the effect of the treatments depending on different soil characteristics. On the one hand, blocks 2 and 3 show a similar behaviour with both the humidity at 20 cm. and 40 cm. having similar levels, suggesting a uniform soil along the strata, and with the treatments substantially improving the capacity of the soil to retain moisture after a rainfall. On the other hand, block 1 and block 4 show very different behaviours. In block 1 the humidity at 20 cm. level is much lower than at 40 cm. level and the changes are much smoother after a rainfall, suggesting a soil with sand at the higher levels and clay at the lower levels. Conversely, humidity in the block 4 is higher at the 20 cm. level compared at the 40 cm. level and the changes at the 20 cm. level are also substantial after the rainfall and lower at the 40 cm. level. It suggests than the 20 cm. level show higher level of clays.

Analysing the results by block adds up new challenges to the study. As the number of factors growth, the possibilities increase geometrically making more difficult to reach accurate conclusions. Therefore we have made a general analysis of the effect of the different soils in order to provide reliable recommendations.

Regarding soil moisture, there are strong differences among the experimental blocks but only the effects in block 3 for most of the treatments are statistically significant at both layers. It suggest that the big dispersion in the measurements hinder getting conclusions when the sample gets smaller.

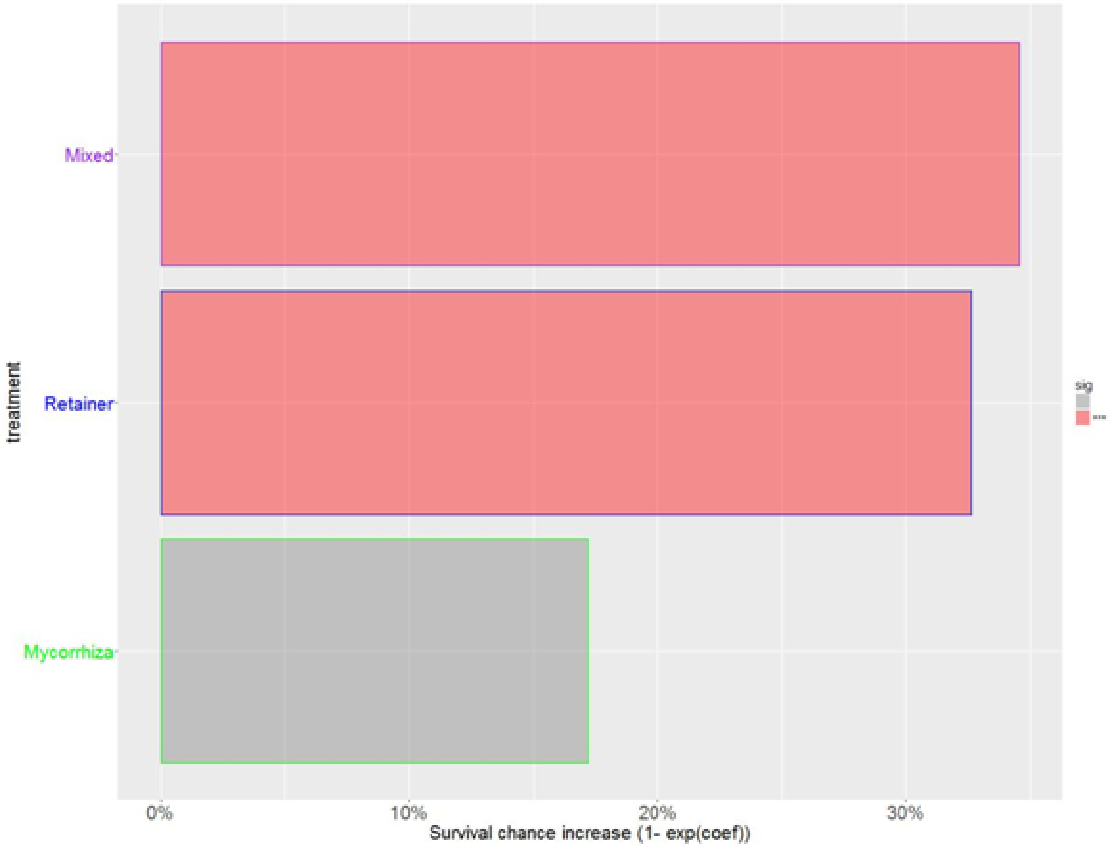
However, we find significant effects of the treatments on the gradient moisture depending on the block. The treatments in block 1 almost half the gradient of moisture.

Therefore the results suggest that the treatments are likely to decrease the gradient of moisture between layers in those soils with a high difference between the moisture, particularly when the moisture is lower at depths closed to the surface. It could have an effect on the seedlings that have a rooting system that depends more heavily on the moisture at levels close to the surface.

The treatments increase the survival rate of the trees

Considering all the species, the treatments show to be effective, particularly when including retainers, increasing the chance of survival rate more than 30% and the results are very statistically significant. The effect is lower (17%) when using only mycorrhizas and the result is not significant. The summary of the increase of the chance of surviving for all species depending on the treatments is shown in Figure 11.

Figure 11: Effect of the treatments for all species



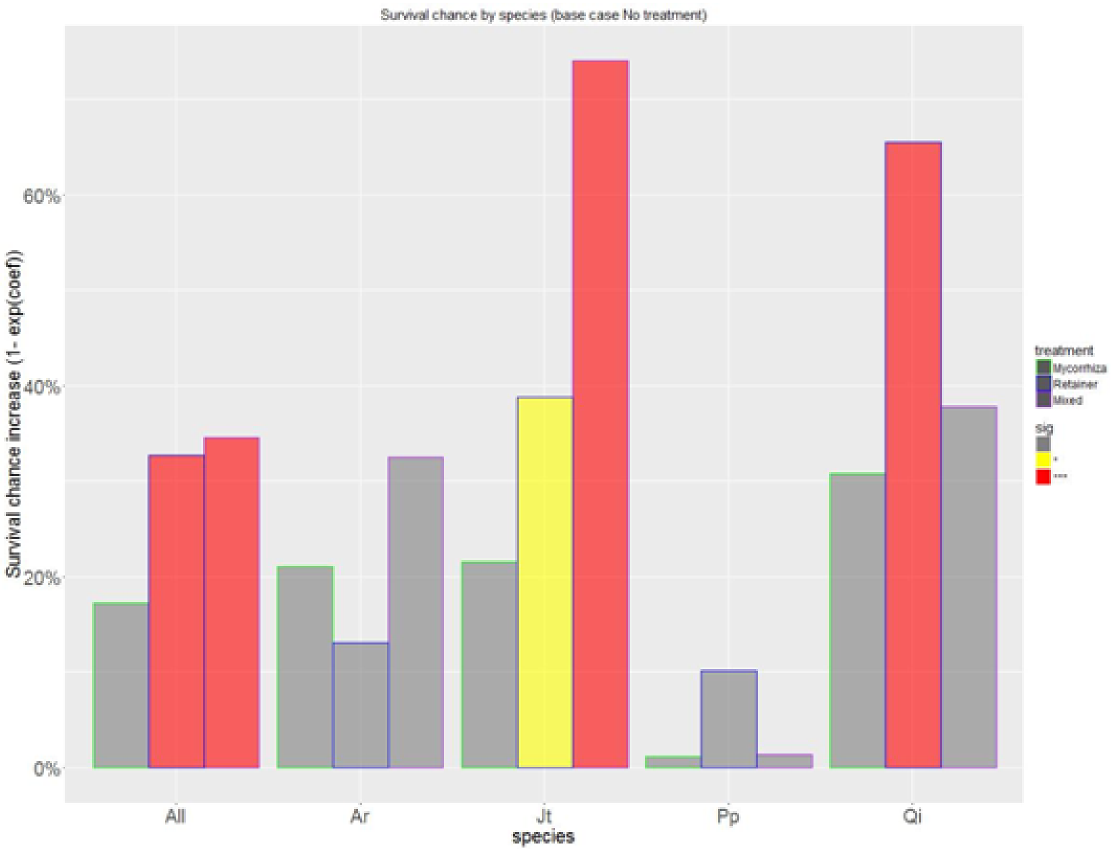
When analysing the effect for the different species in all blocks, the *Quercus ilex* seem to increase the chance of surviving by using retainers. The other specie that substantially improves when using retainers is the *Juniperus thurifera*, particularly when combined with mycorrhizas.

There is no effect of the treatments on the other species.

When considering the whole plantation the summary of the findings of the survival rate analysis is as follows:

- Well adapted species such as the *Pine* and the *Almond* do no benefit from using treatments.
- The *Maple*, a more demanding specie, neither benefit from the treatments.
- *Quercus ilex* are likely to benefit from using retainers substantially increasing the survival rate (up to 66%).
- The *Junipers* also benefit from using retainers up to 74% on average when combined with mycorrhiza. This result is a particularly interesting because Junipers are supposed to be well adapted to the Valladolid climate.

Figure 12: Survival chance increase by specie depending on treatment

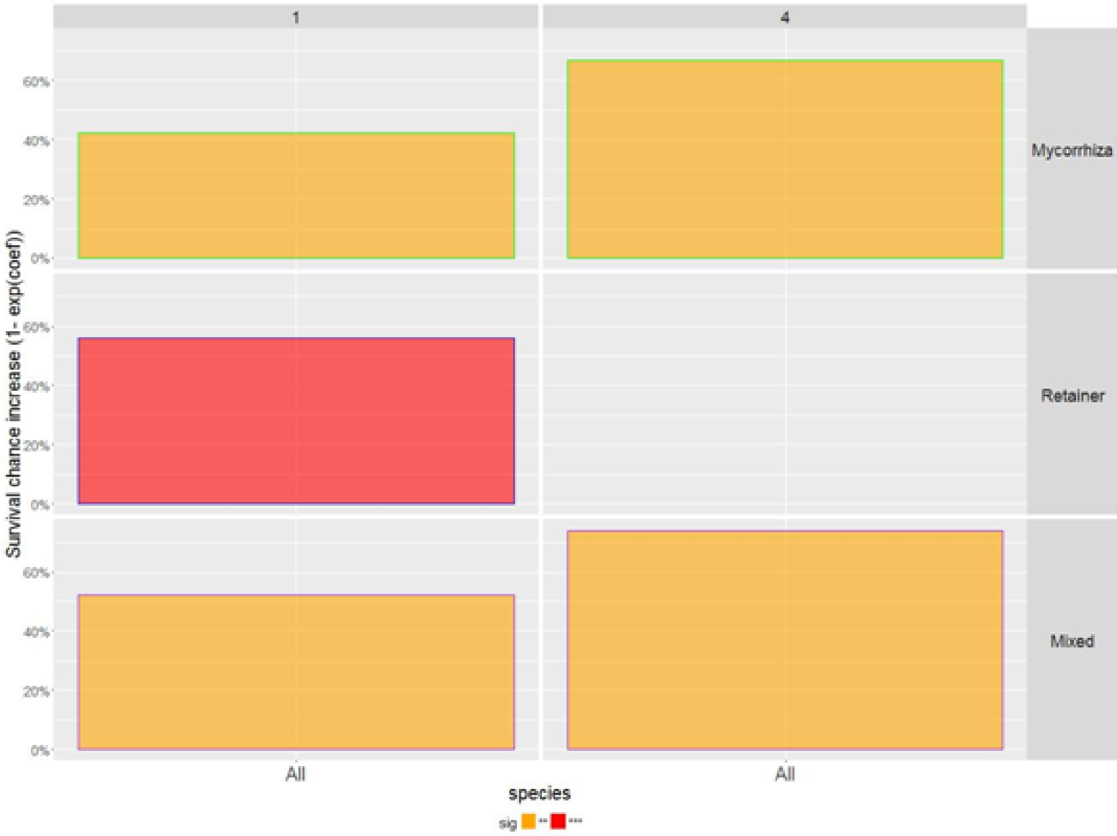


Therefore, we can conclude that treatments are having a positive effect, particularly those including retainers, although the effect strongly depends on the specie. The effect of mycorrhizas seem to be smaller. That is surprising if considering that the soil with the mycorrhiza treatment shows the higher level of increase in soil humidity. There may be several reasons to explain that fact: (i) low level of effective mycorrhization in the plants with the mycorrhiza treatment as shown in Annex 1; (ii) it takes time for the mycorrhizas to have an effect on the plant; (iii) there is natural mycorrhization among the plants without the mycorrhiza treatment, thus hindering the true effect; and (iv) there is competition for the water between the plant and the mycorrhiza. Further research could investigate these points.

The effects of the treatments on the survival rate of the trees depends on the soil characteristics

We think that it is particularly interesting the effect depending on the blocks. The different soil characteristics seem to strongly affect the survival rate of the trees depending on the treatments. When considering all the species only blocks 1 and 4 seem to be improved by the use of treatments. When there is a strong gradient between the strata (block 1 and 4) the treatments based on retainers substantially increase the survival rates of *Juniperus* and *Quercus*. However when the gradient is small (blocks 2 and 3) the effect of the treatments seems to be very marginal, although we have seen that the increase of humidity due to the treatments in these blocks are higher than in blocks 1 and 4.

Figure 13: Summary of the survival analysis by block (base case No Treatment)



The effect is particularly significant for the *Quercus* and the *Juniperus*.

In analysing the effect of the treatments on the survival rate of the different species the findings are summarized in Table 1. We mainly find significant effects on the Junipers and Oaks and the results are usually higher when using retainers (alone or combined with mycorrhizas).

Table 11: Summary of increase in survival rate by specie, block and treatment

Block	Specie	Mycorrhiza	Retainer	Mixed
1	*Al*	100%		
	Ar			
	Jt		66%	82%
	Pp			
	Qi	72%	72%	
2	*Al*		100%	
	Ar			
	Jt			
	Pp			
	Qi			
3	*Al*		100%	
	Ar			
	Jt			85%
	Pp			
	Qi			
4	*Al*			
	Ar			84%
	Jt	100%		100%
	Pp			
	Qi	83%		100%
All	*Al*			
	Ar			
	Jt		39%	74%
	Pp			
	Qi		66%	

It is also very relevant how different are the effects depending on the blocks.

The increase tree biomass

Taking into account the presence of all species and both sampled blocks, the treatments does not seem to have a statistically significant effect on biomass at this stage of the plantation (2.5 years after plantation).

When analysing the effect of the treatments for the different species in both blocks, we find some significant isolated results in the *Juniperus thurifera* and *Pinus pinea* although with contradictory signs. There is no effect of the treatments on the other species. We think that the reason is the high dispersion of the values and the small size of the trees.

Conclusions

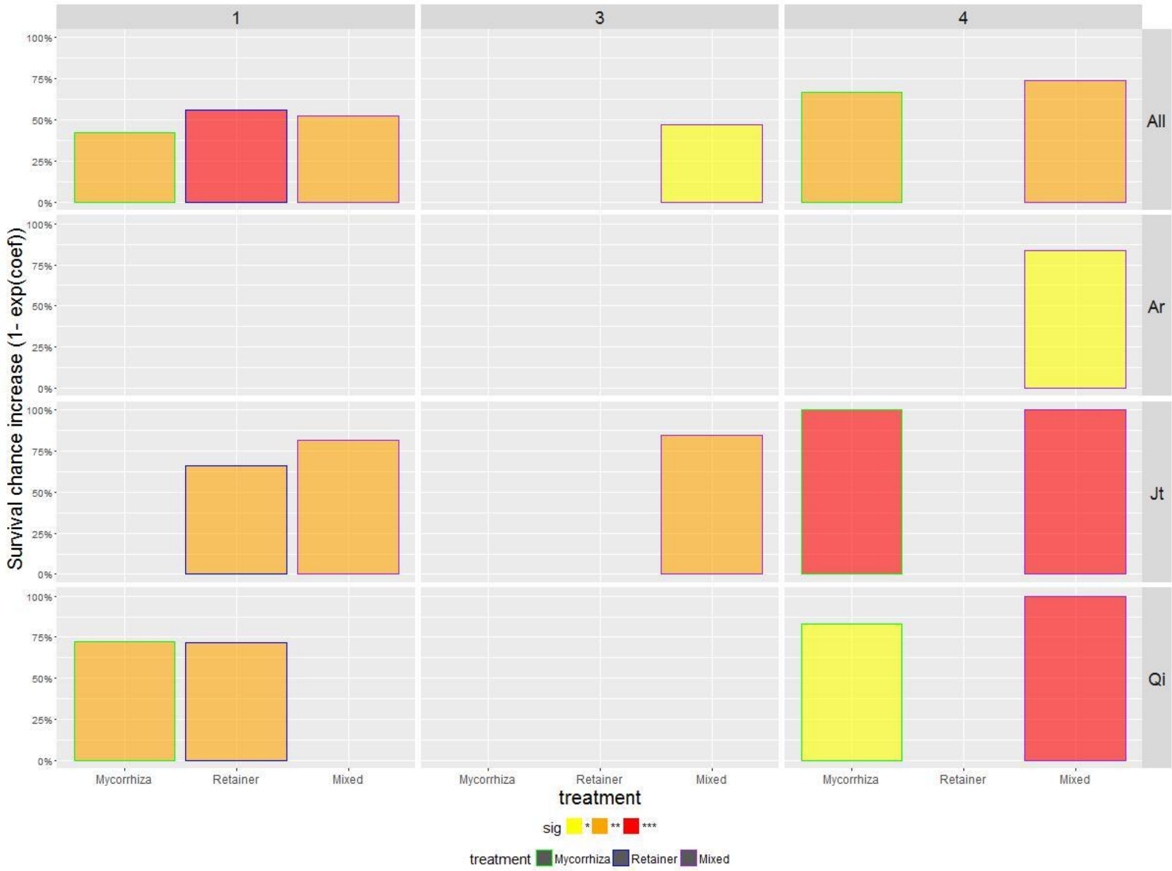
We find that the treatments might have a substantial effect on increasing the survival rate of the seedlings but only when some conditions hold:

- Trees are partially adapted to tough weather conditions such as the *Quercus* or *Junipers*. There is an insignificant effect when working with species very well adapted to the dry climate (such as the *Almond* or the *Pine*) or very demanding (*Maple*).

- The treatment is easy to apply and yields short term benefits. We see a higher effect of the treatments including retainers compared to the mycorrhizas, where reaching an effective level of mycorrhization may be challenging or the effects can happen in the medium term. Previous research has shown that the mycorrhizas can improve the survival rates and therefore the conclusions of this project regarding the mycorrhiza should be taken carefully.
- The results depend strongly on soil characteristics. We have observed that the effect is much higher in Blocks 1 (frank sandy soil) and 4 (frank soil) compared to blocks 2 and 3 (sandy soil in the deeper levels). In blocks 1 and 4 there is a high humidity gradient between different strata of the soil and the treatments seem to be more effective.

When taking these factor into consideration we see a substantial increase of survival rate for some combination of treatments and species as shown in Figure 14.

Figure 14: Increase of the chance depending on Treatment (base case "No treatment") of surviving by Specie and block



However, we have no observed any improvement in biomass growth although it is likely that the small size of the trees are conditioning this result.

Chapter 7. Cost benefit-analysis

There are 2 aspects that deserve consideration when analysing the results achieved by the project. The first one is the savings that can be expected when using the treatments. The second one are the overall socio-economic benefits of the project. In this chapter we analyse both aspects of the project.

Savings expected by using the treatments without watering

In using the treatments proposed in the QUF project it is expected that economic savings will be achieved by increasing the survival rate of the seedlings to a point where replanting the trees will not be necessary and without incurring in high costs of watering. To assess and quantify this fact we perform a cost analysis based on the results of the project to compare the expected costs with and without the treatments. The analysis is made considering the specie, the soil characteristics and the treatment.

We compare the results without treatments to the results when using treatments. We base the analysis on the survival rates that we have observed during the project to compare the percentage of trees that have survived with and without the treatments.

For this analysis plots 2 and 3 have been combined due its similar behaviour.

We perform the analysis under the following considerations:

1. The cost of planting a tree without treatment is the base case. On top of that we add the cost of the treatments (retainer, mycorrhiza, and both). We consider that the cost of the retainers is the same for all the species. However, we allow a different cost of mycorrhization depending on the specie. The cost of the mixed treatment is the sum of both independent treatments.
2. On top of that we consider the cost of replanting the trees. To estimate this cost we define a minimum threshold. This threshold represents the percentage of trees that can die after a period of 2 years without replanting the trees (filing the gaps with new trees). For instance a threshold of 80% means that the death trees will be replaced if less than 80% of the initial trees survive after 2 years.
3. We only consider those treatments that provide statistically significant differences in the survival rate of the trees. In the following table the treatments that have a statistically significant improvement compared to the base case ("No treatment") are shown. The figure indicates the percentage of survival trees after the 2 years experiment.

Figure 15: Percentage of survival trees after the 2 years experiment

	Block 1			
Specie	**No treatment**	**Mic**	**Ret**	**Mix**
Al	93%	100%		
Ar	47%			
Jt	33%		67%	83%
Pp	57%			
Qi	38%	73%	73%	

	Block 2-3			
Specie	**No treatment**	**Mic**	**Ret**	**Mix**
Al	91%		100%	
Ar	53%			
Jt	45%			73%
Pp	77%			
Qi	60%		83%	

	Block 4			
Specie	**No treatment**	**Mic**	**Ret**	**Mix**
Al	100%			
Ar	67%			93%
Jt	73%	100%		100%
Pp	100%			
Qi	67%	93%		100%

	All blocks			
Specie	**No treatment**	**Mic**	**Ret**	**Mix**
Al	93%			
Ar	55%			
Jt	49%		63%	83%
Pp	78%			
Qi	57%		82%	

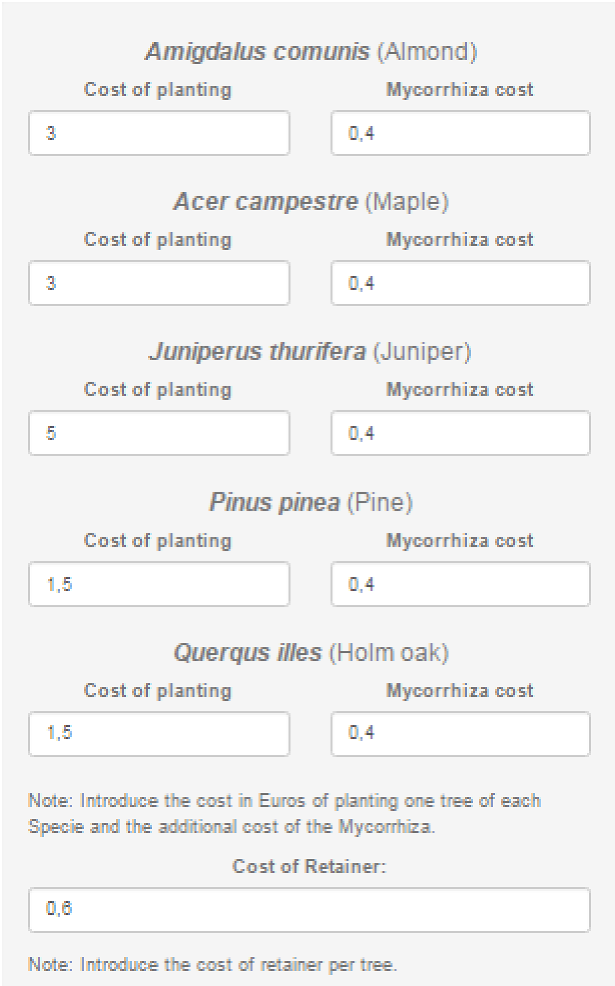
Results of the scenario

We assume that the costs can be very different depending on the location, bargaining power, market, etc. Therefore, as a delivery of the project, we have developed an online tool that allows the user to specify its own costs. The tool also allows the user to define the minimum threshold to fill the voids with new trees. The tool is available at the web-site of the project.

Based on our project's results and user-specific inputs, the tool estimates the most effective treatment for each type of soil and for a combination of all soils.

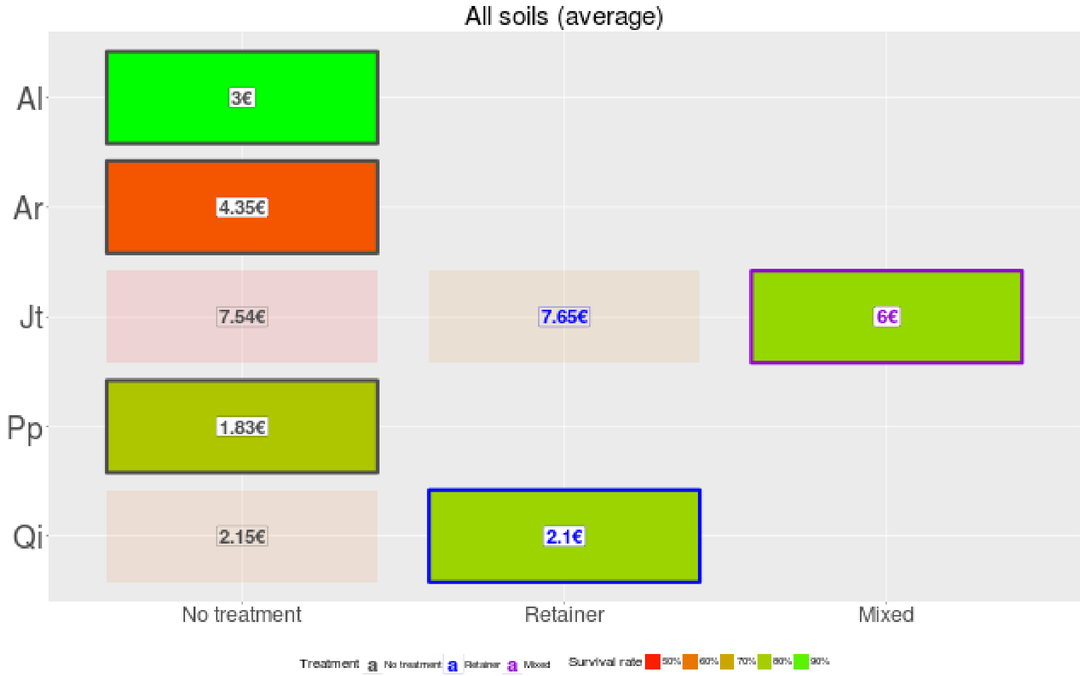
As an example we present the results of the analysis using the following figures:

Figure 16: Cost of plants and treatments (In Euros)



Based on the costs provided by the user and on the findings of the project the tools recommends the most efficient treatment for each specie. The recommendations for this specific scenario are as follows:

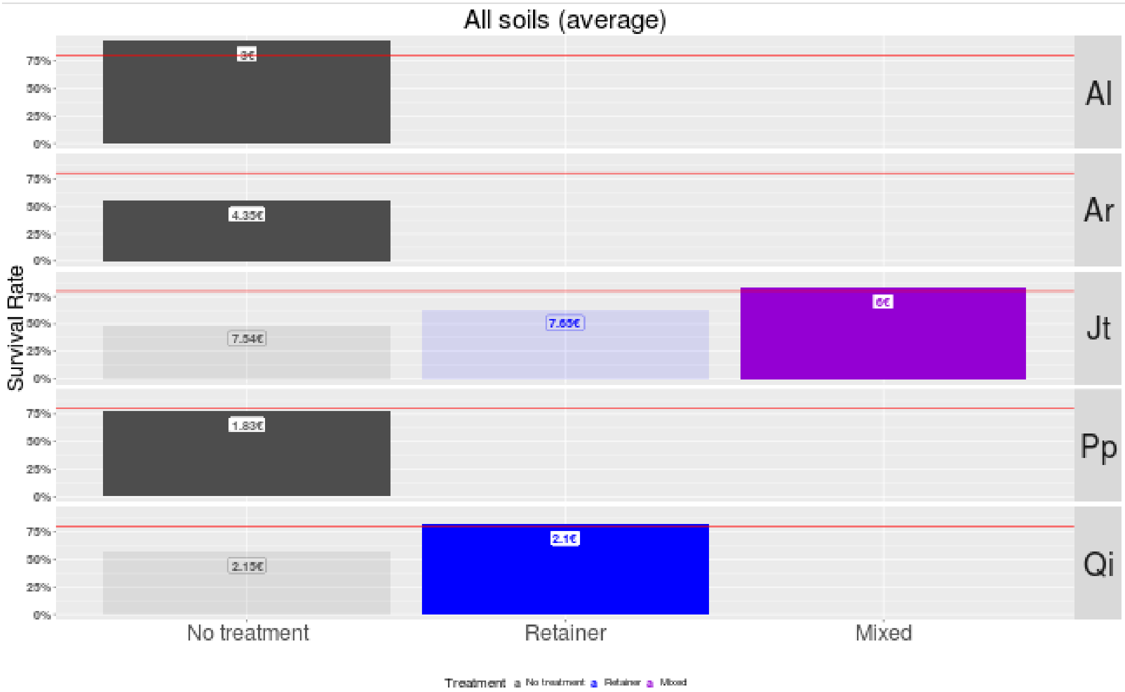
Figure 17: Cost and survival of plants (all soils)



In considering all soils, the treatments are only advised for the *Quercus ilex* (retainer) and *Juniperus thurifera* (mixed). The average cost of planting a Qi without treatment is 2.15€ and 7.54€ for the Jt. When using treatments, the cost of planting a Qi decreases to 2.1€. The saving is higher for the Jt when using mixed with an estimated cost of 6€.

The reason is shown in the following graph:

Figure 18: Survival rate and cost of plants (all soils)



The survival rate of the Jt without treatment is 49%, much lower than the 80% threshold (therefore the death trees must be replaced). It means that we need to plant 51% of the total number of Jt, raising the average cost 51% up to 7.54€. In using the mixed treatment, the survival rate increases up to 63%, also below the threshold and therefore we need to plan 37% of new trees. The price of the tree with the retainer treatment is 6€.

The survival rate of the Qi without treatment is 57%, much lower than the 80% threshold. It means that we need to plant 43% of the total number of Qi, raising the average cost 43% up to 2.15€. In using retainers, the survival rate increases up to 82%, above the threshold and therefore we do not need to plan new trees. Therefore, the average price of the tree with treatment is 2.1€.

For instance, if we consider a plantation of 30.000 Jt or 30.000 Qi, the total expected savings would be negligible for the Jt but 23% for the Qi.

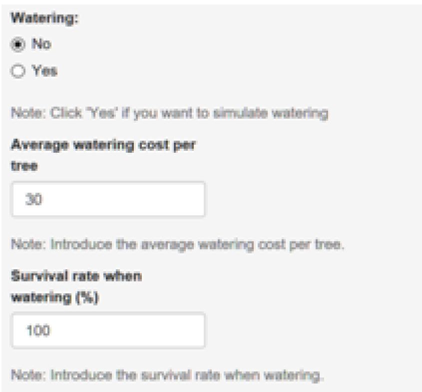
Users can ran their own scenarios using their market prices and their minimum threshold for replanting.

Savings expected by using the treatments without watering

Using the tool, users can also simulate the cost of a scenario with watering by providing the average cost of watering per tree during the 2 years period and the survival rate when watering the trees. The tool makes an analysis to estimate which treatments are worthy under those conditions.

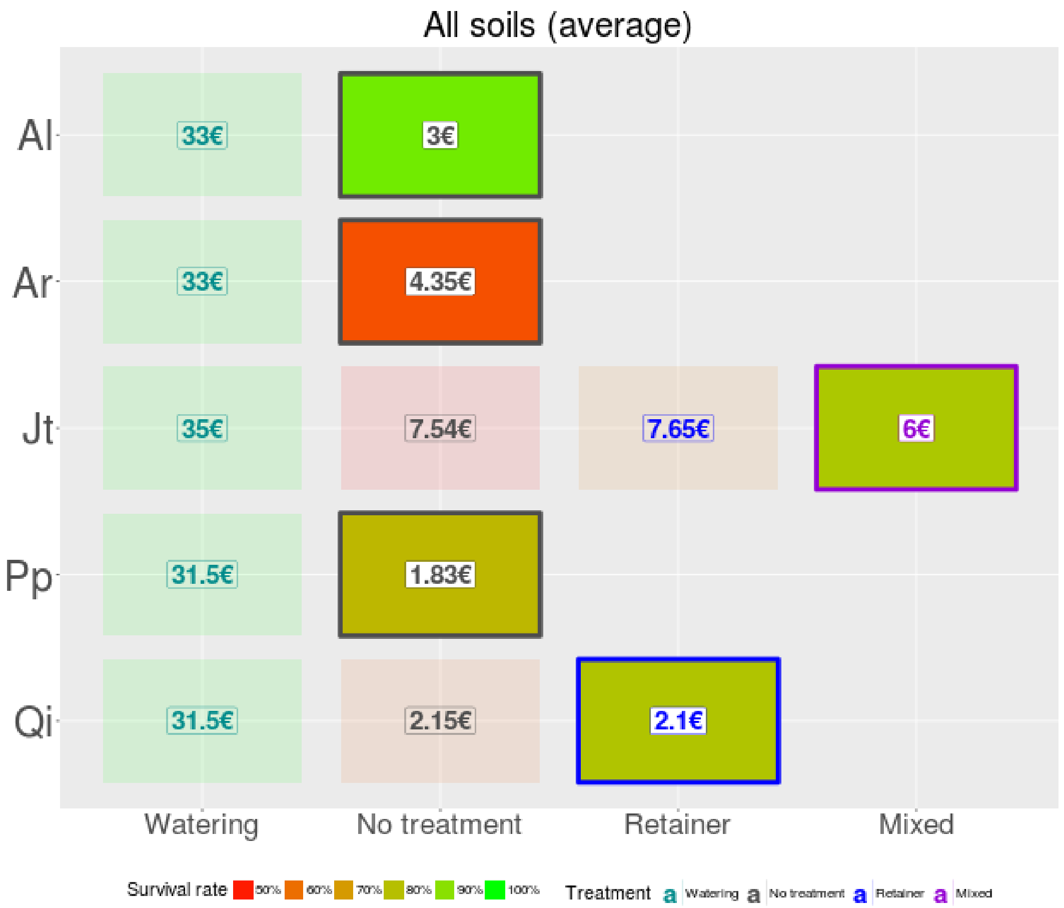
As an example, using the same cost and threshold value of the previous scenario and with the following values for the watering cost and survival rate when watering:

Figure 19: Watering cost and survival rate



We get the following results:

Figure 20: Cost and survival of plants (all soils) with water or without water



In this case the cost of not using treatments and watering the trees increases substantially to 35€ per tree making many of the alternatives with treatments worthy. Taking into account all soils, the results are the same as in the scenario without irrigation. The retainers are advised for the Qi and the mixed for the Jt. The scenario with irrigation infrastructure usually gives worse results than the scenario without irrigation due to the high costs of tree irrigation. The scenario is presented for descriptive purposes but it is advisable to use the tool mainly to compare non-treatments to treatments without irrigation.

Overall socio-economic benefits of the plantation

Extensive trees plantations in urban areas are expected to have relevant socio-economic benefits for the cities, such as capture of CO_2, decrease of pollutant gases and particles in the atmosphere, and groundwater protection. There are also other intangible benefits such as children living in areas with abundant green space being more active and less likely to be obese or showing higher levels of attention, an overall health improvement (less respiratory diseases or stress), and reducing travels to leisure areas.

To assess the socio-economic impact of the plantation we will follow the methodology suggested by Kroeger et al. (2014) that uses available air quality and meteorological data and a simplified forest structure to assess the effectivity of reforestation on several factors such as pollutant abatement and carbon sequestration.

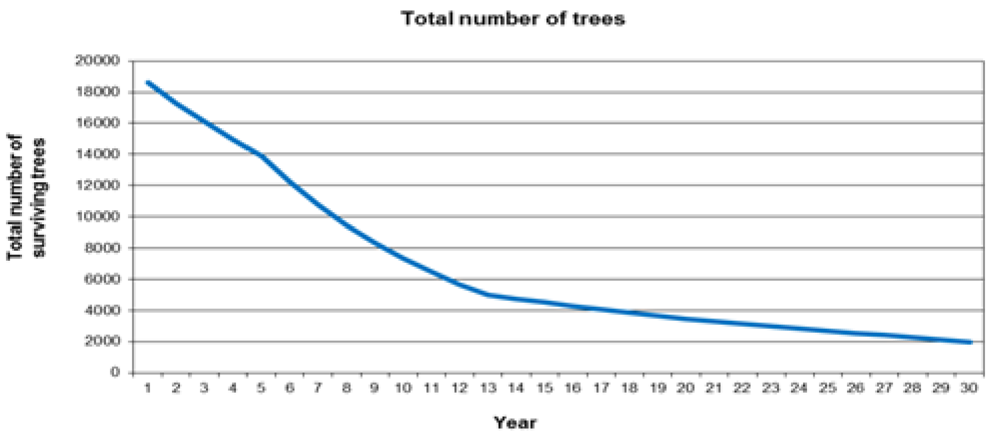
The planting of the QUF project is still in its preliminary phase and it has been challenging to estimate the impact on these factors due to the smaller size of the trees. Therefore, we intend to use the simulation developed by Kroeger et al., to evaluate the effect of our plantation over the next 30 years. Simulations are expected to be of great value in the decision making process by helping to predict the future impact depending on different decision alternatives. These models have nowadays a relevant role in guiding forest policies in many countries.

The results should be handled with caution because of being based on data and variables from other environments, but we believe that the method provides a valuable method to estimate the potential impact of our plantation in the medium and long term. We strongly recommend doing this type of analysis in public urban reforestation projects to support the decision-making process with evidence. Generally, these projects are not adequately evaluated using a cost-benefit approach as suggested in this book.

The results after the simulation are as follows:

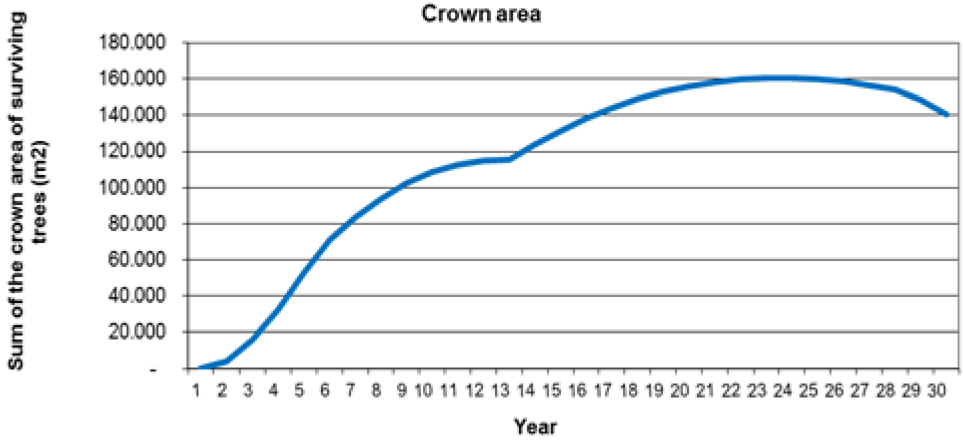
The total number of trees will decrease up to 2.000 in 30 years. It is likely that these survival trees will be big healthy trees.

Figure 21: Number of trees in the next 30 years



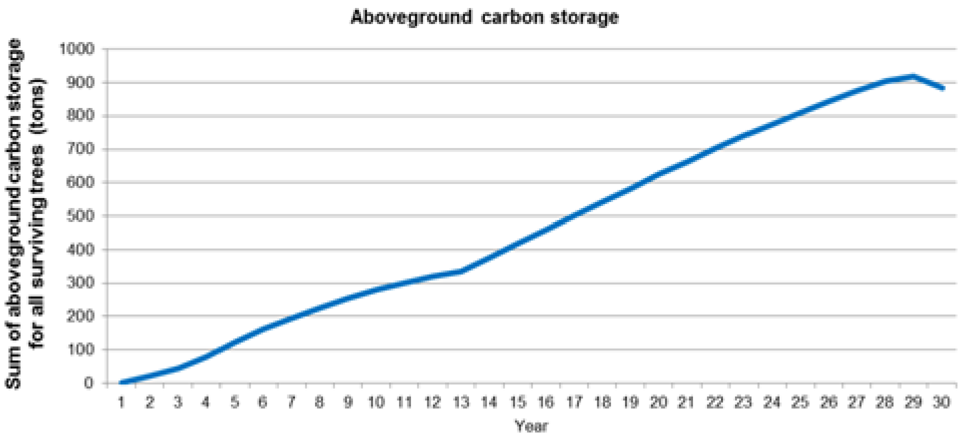
The crown area of the forest will cover the whole area of the plantation in 17 years.

Figure 22: Crown area in the next 30 years



In the following graphs is shown the aboveground carbon storage in the next 30 years.

Figure 23: Aboveground carbon storage in the next 30 years



The carbon storage will reach 917 Tm in the year 29.

In analysing the annual air pollution removal we get the following results for Ozone, Nitrogen Dioxide, and Sulfur dioxide.

Figure 24: Annual air pollution removal (Ozone) in the next 30 years

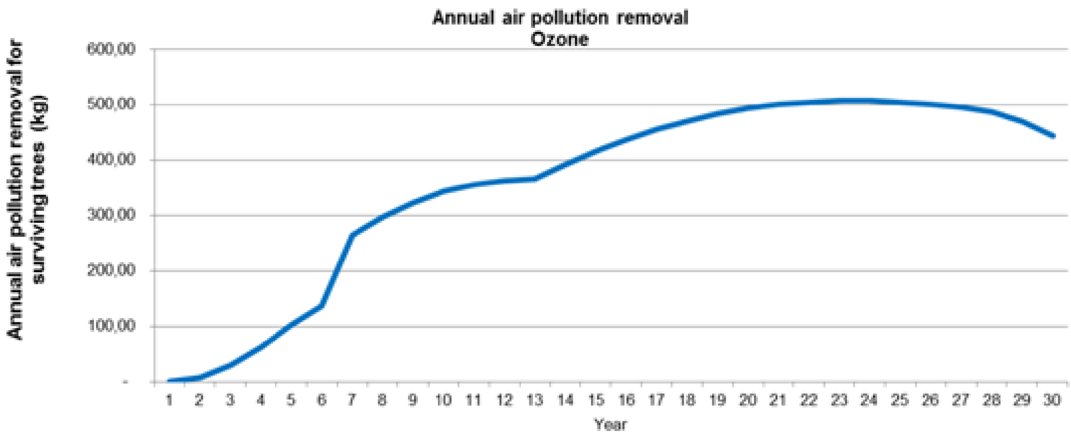


Figure 25: Annual air pollution removal (Nitrogen dioxide) in the next 30 years

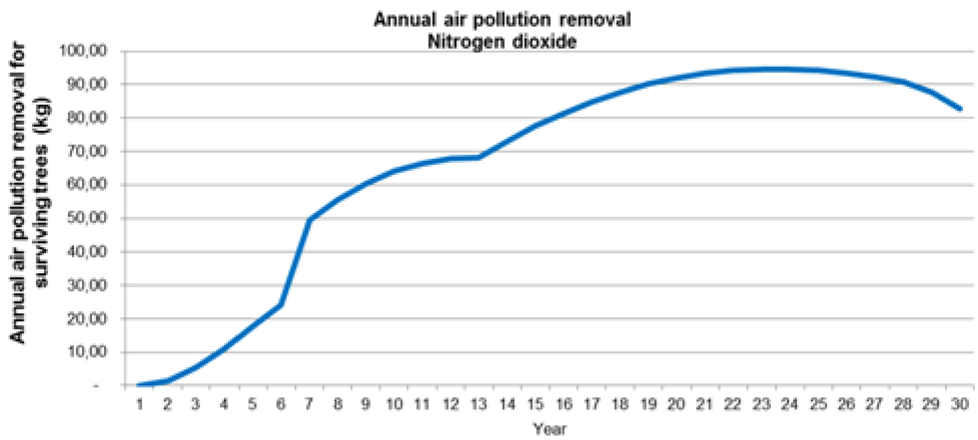
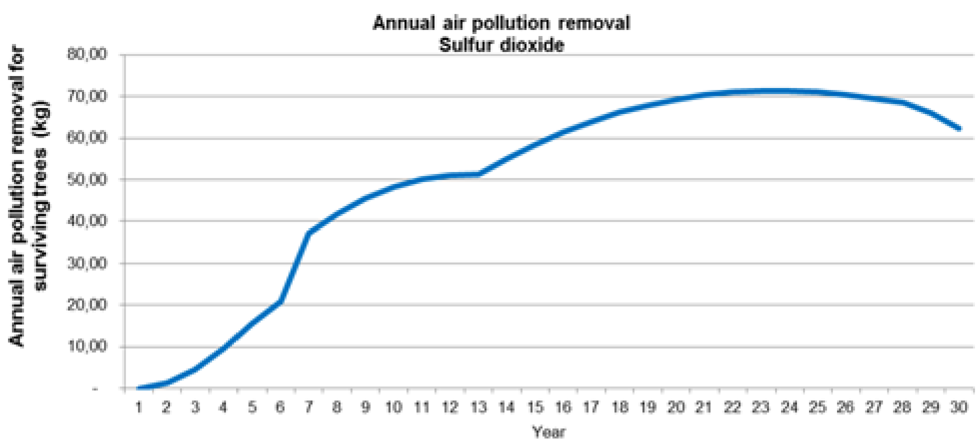


Figure 26: Annual air pollution removal (Sulfur dioxide) in the next 30 years



In our project we get a value of 5.247 grams of carbon for the 119 biomass samples (2 years and a half after planting the trees). This result is obtained by summing the carbon absorption, both in the stem and in the roots of the plants. That means an average 44 grams of carbon per tree. If we extrapolate our results to the 20.000 trees, we would get a total of 881.879 grams, close to a ton of carbon.

Chapter 8. Involving the community.

The importance of involving society in environmental projects

Nowadays social participation and engagement is necessary in all environmental projects. When the community is effectively engaged it can provide a more accurate vision of the local needs, allowing for a more pragmatic design of the project, as well as guaranteeing the long term sustainability of the plantation.

Involving the community in a wide sense facilitates the creation of the so- called collective intelligence that improves efficiency, enhances creativity and co-responsibility. It should be a citizens' right —and also a duty— to have the chance to participate efficiently (1) in the decision-making process and (2) in the implementation of the project and related activities. On the other hand, it also requires a minimal civil society and collective organization[8].

Complex actions to promote profound changes are required in our current society, particularly in the environmental area. It is necessary to encourage a stronger participation of citizens through social activities and environmental education to foster a real changes in attitudes.

However, social actors in urban areas usually perceive environmental issues and climate change outside their scope. Proposals and initiatives to improve urban environment and tackle climate change are addressed in meetings of experts at the international level, with still a minimal involvement of local communities, which are a critical agent.

It is essential to strength current initiatives while fostering new participatory spaces through formal and non-formal environmental education at the local level. Public policies that encourage training activities to increase community participation are required. These initiatives can stem from the projects themselves, seeking the participation of neighbours, teachers, youth, firms and other local stakeholders in activities related to the project to foster creativity and participation.

For that reason our project has focused on designing, organizing and implementing education and outreach activities targeting the local community, while keeping an eye on the international technical and academic sphere. Activities with the local community contribute to improving the knowledge of the constituents while raising awareness of civil society in the field of environment. We think that it is crucial for the success of the project to achieve an effective involvement of these groups in the projects and its outcomes.

At the international level we have worked in the creation of an international group of Mediterranean cities (GSEC[9]) aimed at exchanging experiences and knowledge. This chapter focuses however on the actions that we have carried out to engage with the local community that will directly benefit from the urban forest that we have created.

[8] BORJA, J. (1990): "Políticas y gobierno en las grandes ciudades" en BORJA, J., CASTELLS, M., DORADO, R. Y QUINTANA, I.: Las grandes ciudades en la década de los noventa. Madrid: Editorial Sistema, p. 667.
[9] More information on the Group and its activities at: http://www.gsec-group.eu/

Objectives

The objectives of the activities carried out with the local community have been:

- To develop ways of integrating civil society in building projects of urban green areas.
- To promote environmental projects in the educational community.
- To give the opportunity to associations and groups to learn and experience first-hand the implementation and development of a European project targeting a sustainable reforestation benefiting the community.
- To use new technologies as an appeal to involve the society in the project to increase their knowledge about environmental issues.
- To involve the Valladolid community in taking care of the plantation to increase the sustainability of the plantation in the long-term.

Scope and problems encountered

The involvement of the society in environmental issues is increasing. However, it is happening slowly, particularly in Spanish society. The participation is even more difficult when a plantation is in its inception phase, with small plants that need a longer period of growth. It takes time before society is fully aware of its responsibility and level of commitment. In addition, civil society is generally weak and disorganized in many cities like Valladolid. There are few organizations carrying out this type of activities which are facing difficulties involving a large number of people in these actions. However, the enrolment of the City Council in dissemination tasks has been crucial to facilitate potential contacts and has also contributed to a greater commitment of the groups and individuals involved.

Education and outreach activities have focused on the educational environment (primary and secondary schools, professional associations, universities, etc.) and social organizations involved on improving the city environment. These actions have also been focused on both local authorities (in Valladolid and its surroundings) and other groups outside Valladolid which are interested on the insights stemming from the project (cities with similar characteristics, university groups specialized in restoration or any other area of Urban Forest).

On the other hand, a strategy of external communication and dissemination, targeting to potential direct beneficiaries and indirect target groups (decision-makers, other European regions, the media and society) should also be considered.

The strategy has focused on direct beneficiaries and other general public by including the following lines of action and dissemination tools:

- Corporate Image or Creation of a Logo and a Corporate Image.
- Website of the Project.
- Participation in Social Networks.
    - Facebook and Twitter.
- Promotional Material:

  - Brochures with general information about the project and disseminating information on specific activities and publications.
  - Promotional material for seminars, conferences, meetings, workshops.
- Working with the Media:
  - Press releases.
  - Articles.
  - Introduction of news on the project website.
- Awareness and social action:
  - Educational activities in schools and training centres.
  - Contests.
  - Participation activities.
  - Meetings with GSEC members.
  - International Forum.
- Publications and Reference Material

The tools and key elements of dissemination and communication are the following:

The **website of the project** is a central element aimed not only to provide direct information, but also as a tool for dissemination and delivery of other material, such as reference material, publications, brochures, brand and corporate image, and on-line tools and datasets. Likewise, the website is used to invite to events, as well as to create specific access for the press and the media. Also, it fosters a communication network with the partners involved in the city group (GSEC).

Promotional Material is composed of dissemination leaflets and other material such as banners that have been used during events.

Working with the media is an important subject. Press releases and articles have been published, using headlines, subtitles, organizing information according to their importance, using visual tools (graphics, photographs, etc.) and providing data to attract attention, with clear and direct language. The meetings, working groups, workshops or seminars have been good opportunities to organize press conferences and public presentations of the project to the media. All these events and materials were posted in the project web site where contact details were provided as well. The Commission co-financing has always been clearly stated throughout all the activities of the LIFE + program.

The **organization of events** in Valladolid has been carried out in collaboration with the Valladolid City Council. The work has been developed in a coordinated manner between the QUICK URBAN FOREST project team —in charge of defining and implementing the activities— and the City Council —responsible of disseminating these initiatives on corporative social networks, schools, organizations and the media. Other local agents have collaborated in the organization and dissemination through different target groups when these events have being held outside the city.

The **International Forum,** held in June 2016 in Valladolid, has been the most relevant activity to disseminate the project results. All consortium partners, outside experts, firms, stakeholders involved in specific project activities, actual and potential beneficiaries and the media were invited to the event. The forum was a success.

Activities and actions

The activities planned for the project are summarized in the following table:

Specific objectives	Activities
1. To give the opportunity to associations and groups to learn and experience first-hand from the implementation and development of a European project of sustainable urban reforestation benefiting the community.	Talks in schools.
	Real plantations, with the same methods used in the project, with educational groups and companies.
	Conduct training sessions in different cities of Southern Europe aimed at technicians and groups involved.
	Creation of events and activities to involve the society in specific dates: Arbour Day, World Forestry Day, World Environment Day, etc.
2. To use new technologies and innovative approaches to involve the society in the project to increase their knowledge about environmental issues.	Search for synergies with other environmental projects.
	Conduct contests, such as graffiti contest about environmental topics.
	Use virtual reality techniques (QR code).
	Sending newsletters of the project to more than 30.000 contacts.
	Posting relevant information about the project (news, members, results, on-line tools, and datasets) in the project and group website.
3. To involve the Valladolid community in taking care of the plantation to guarantee the further sustainability of the plantation.	Carrying out social participation activities such as contests and/or creative and educational activities about the project topics.

The actions carried out are divided into two sections:

- General actions: these are the dissemination project basis and are considered fundamental. These activities have not been carried out on specific dates. On the contrary they have been on-going actions throughout the project.

- Concrete actions: those which have been carried out in a concrete date.

Besides the general actions, other related activities have been developed as described below:

- Design and creation of logo and corporate image.
- Development of the website www.quickurbanforest.eu. To describe the project, its goals and results, and to provide information about the events and news emerging from the project progress.
- Creation of the Facebook page of the project. https://www.facebook.com/pages/QUF-Project-LIFE/423149617822323?fref=ts
- Account creation in Twitter @QUrbanForest.
- Submission of quarterly newsletters to more than 30.000 contacts.
- Sharing knowledge with other similar working projects.

Chapter 9. Lessons from the experiment and recommendations

After being concluded, specific lessons from the present experiment, useful for future implementations were learnt and are described below:

Overall results

In brief these have been the most relevant findings of the project:

- As expected, the **weather conditions** in Valladolid during the 2 years experiment have being very **challenging** particularly regarding the rainfalls. There has been a high variation of monthly rainfalls compared to the historic data, with very dry summers and heavy isolated rainfalls.
- The **treatments seem to be related to an increase of the water absorption of the soil after a rainfall**, particularly when the soil is dry.
- The **average moisture of the soil increases when using the treatments** (around 10%) although the effect is **only significant for the treatment mycorrhiza**.
- The **soil temperature is slightly smother** (hotter in the no vegetative period and colder in the vegetative period) **when using Retainers**.
- Although on average **the treatments increase the survival rate of the seedlings around 28%**, we have found that **the effect depends heavily on the specie and the soil characteristics**. While the effect is quite substantial for trees that are partially adapted to tough weather conditions such as the Quercus or Junipers, it is insignificant when working with species very well adapted to the dry climate (such as the Almond or the Pine) or very demanding (Maple).
- The treatments based on Retainers seem to be more effective. Previous research has shown that the Mycorrhizas can improve the survival rates and therefore the conclusions of this project regarding the Mycorrhiza should be taken carefully.
- We have **not found a significant effect of the treatments on increasing the biomass** of the trees after 2 and a half years. However, we think that the effect could exist but it has been impossible to detect due to the high dispersion of the measures of biomass and the small size of the trees.

Project design and management

- A **detailed work plan** is required in order to preview and manage any unexpected events, mainly climatic episodes. Keep your work plan **flexible and review it periodically**. If unexpected events delay your plantation updated your whole work plan within your possibilities.

- Transparency is very important to engage with the society. **Be as transparent as possible both with your technical actions and your budget** to engage with authorities, enterprises through Social Corporate responsibility and citizens.
- The **time period between the formulation of a project of these characteristics and its execution is very long**. Stability of the work team during the project is very important for success. Additionally, if you count with external funding, particularly if it is a public grant, make sure that you consider the long lapses of time from the elaboration of the proposal and the beginning of the project.
- We strongly advice to work applying the methodology of the **standards that guide the certification of forests.** However, you should know that nowadays the national standards on which forest certification works, both PEFC and FSC, require that plantation soil to be classified as 'Forestry' in the urban planning legislation to obtain the certification. However, a repopulation such as this, in a degraded industrial peri-urban space will rarely be done under these conditions. The project has worked on the methodology to make it possible in the future to certify an urban forest.
- We have given general recommendations depending on the soil and species that need to be carefully adapted when trying to apply the results to a different environment. For future experiments it is advised to reduce the number of factors been analysed.

The plantation and the treatments

- The urban soil characteristics (with different soil texture and structure due to the variety of contributing sources) have strongly affected the survival and moisture results. **Analyse your soil carefully**, identify different soils and take it into consideration when designing your plantation and selecting the treatments.
- Besides the poor quality of the soil (with little organic matter and slight profile development and high alkalinity) the rainy pattern is the most conditioning factor in the moisture absorption and moisture absolute value. **Analyse the rainy patterns at the location of your plantation and take them into consideration when selecting the type of treatments.**
- **Avoid planting outside of the recommended season** (autumn) particularly in Mediterranean climate.
- It is important to **carefully select the species and to plan in advance the purchase** of plants to avoid plant scarcity in the nurseries. Some species are difficult to differentiate when the plant is in the vegetative period and has very little development, so the correct selection is basic.
- The **quality of the plant at origin** is a key factor for the success of a project like this. The selection of the tree nursery is very important, as well as the preparation for its planting, with previous hydration. In our project, the meteorological conditions of the weeks prior to planting were extreme, as described, and it was necessary to hydrate the soil with an implantation irrigation.

- In our project the **introduction of mycorrhiza directly in field has been successful**. Although mycorrhization is usually done in nursery, we decided to carry out this alternative method due to the lack of mycorrhizal plants in the nursery. In the project we have found evidence that this methodology for mycorrhization has worked better than it was expected, and it seems to be especially effective in urban sterile soils where there is no previous *mycorrhizal propagule*. Select the method for mycorrhization that is most suitable for your project, and don't dismiss the option of introducing mycorrhiza directly in field.
- The **herbaceous competition removal is indispensable** for the success of the experiment, in particular around the planted species. The abundance of annual competitive herbaceous vegetation around planted trees is likely to produce greater water stress thus increasing mortality rates.

Ecosystem

- An **analysis of the impact of the existing fauna or possible plagues** around the plantation is necessary, even in urban plantations. For example, in our project the height and degree of development of 1 sap-plants were very attractive for rabbits. The trees were protected with tubex with breathing, while the aromatic plantation did not. This second was largely destroyed by these animals. A **properly protection against wild animals should be imperative**. It is suspected than wild animals (deer and rabbits mainly) attacked several of the trees before the plants were covered by a plastic mesh netting.
- A newly established forest park with small plants generates a poor landscape perception among the local population. Therefore it is necessary to carry out **awareness rising campaigns that help adjusting the expectations of citizens regarding what the urban forest will look like** and what it really is at the moment of the plantation (small trees inside protectors). This will help ensuring that the visitors and the community around the plantation will respect it from the beginning.

Data analysis

- When obtaining and analysing data from plantations **the high complexity of measuring nature has to be taken into account**. Variables affecting the development of species are multiple and varied and can't always be controlled when operating in the field, as opposed to a laboratory. Therefore big dispersion in the measurements should be expected challenging getting significant results. A great number of controlled and uncontrolled factors in the analysis are likely to coexist, making difficult to unravel the pure effects of the treatments. Keep this in mind when designing you project, as it might limit the true insights you might obtain from it.
- **Select the data collection technologies more appropriate for your objectives**. The data obtained in this project has been very relevant for scientific and experimental purposes, particularly humidity and temperature of the soil, but this might not be the case of your project. In a real urban forest project, collecting a high amount of data, such as the data

obtained in this project, might not always be necessary. In reforestation projects data on survival is probably the most interesting data for the general aim of the plantation. Collecting data every six months might be sufficient for a correct monitoring and evaluation of the action.

- Most of the sensors in the market are developed to be applied in agriculture[10] and the experience in forestry is still limited. Look for the most updated solution in the market and use **technologies that have been previously tested in similar environments to yours**. In our case, for example, we analysed and indirect measure of soil moisture, the SUF (frequency) provided by the probes. The calibration process was not totally successful and, eventually, we decided to work with the raw data.
- When trees are very small and similar species are used, such as *Quercus faginea* and *Quercus pirenaica,* there might be confusions when obtaining data from the field. Having a **smaller number of species and selecting species that can be easily identified** is advised to get more accurate measurements, particularly if the objective of the project has a scientific character.
- An important risk of the project was that the equipment for data collection could be stolen or victim of vandalism. As precautionary measures the existence of a sensor network was not disseminated publicly until the end of the project and the equipment and infrastructure was hidden and covered with wooden protectors. As a result the installation has successfully remained untouched during the whole project. **Consult the local authorities about the risks, analyse them carefully and design mitigation measures before installing your network**.

Public administration role

- The collaboration of the City Council has been very active and positive throughout the life of the project. In this project it has adopted the position of an in-kind collaborator, ceding the land for the plantation and supporting the project particularly in dissemination actions. The commitment of its technicians from different areas (Environment, Parks and gardens and civic participation) has been enthusiastic, considering the project as its own. Not only technically, but also political commitment has been very relevant. During the life of the project there has been a change into the municipal team, win an incoming Major and technicians from a different political party. The project has not been affected at any time by this change, assuming and enhancing the incoming political team the commitments acquired by the outgoing one. We consider that **the commitment of the Council, both at the political and the technical levels, has been key to the success of the project** and it is highly recommended to have the local authorities on board from the beginning of nay project of this kind.
- It is crucial that the plantation is continuously maintained and improved. There must be a

[10] We base this comment in our experience when examining the market at the moment of the implementation of the sensor network, 2013-2014. However, data collection technology evolves very quickly and it is possible that more advanced sensors specific for forestry have been developed since then.

clear responsible for the land to guarantee the plantation sustainability. In our case we have signed an agreement with the City Council that will integrate the plantation in its network of parks and gardens. In this agreement, a work plan including detailed actions is strongly advised.

- To **maximize the social value of the planting space**, it is particularly important to connect the area with other green spaces located in the city, or keeping in mind the potential recreational uses of the land by the citizens. This might include the creation of paths and bicycles routes and the incorporation of urban furniture.

Social participation

- **Social engagement is essential** to ensure the medium and long-term sustainability of the plantation. Therefore dissemination actions should be included in the project, targeting the most varied population possible.
- To obtain a successful social participation, the **Council should be involved in actions** with the different social groups in order to give credibility to the actions to be undertaken. Involving the local authorities in social engagement activities also helps guaranteeing the commitment of the public sector itself, since dissemination implies certain public commitment towards the electoral body.
- Public participation of adults, associations and corporations which implement Corporate Social Responsibility (CSR) initiatives was more difficult than expected in our project. This kind of action is particularly difficult in Spain where civil society organizations are scarce and weak. **We recommend to get civil society involve in the project from early stages**, taking into consideration their suggestions as much as possible.
- Mobilization of the school community is key for the long term sustainability of the project, since kids from the area of the plantation will be important users of the forest in the future. The great interest showed by the schools, institutes and vocational training centres during our project has made possible an active involvement of these collectives in educational and informative initiatives. We strongly recommend to **involve educational institutions in the project, since they are particularly receptive to this type of actions** and children and young people can be a catalyst for the commitment of the whole community.
- One of our objectives was creating an international group of cities (GSEC) to exchange experiences and share knowledge. The GSEC group's dynamic activity has been continuous throughout the project, both through massive contacts, personal and direct. However, the degree of response in foreign councils has been low, we believe that mainly because of the workload of its technicians, the perception of lack on immediate and the lack of financing for their work in the network. If you plan to create a similar network or you want to exchange your experience **seek for specific funding or design an elaborated system of benefits and rewards for participation**.
- As we have already indicated, it is essential to the smooth running of the project and all the activities set out in the work plan, the support of the local government and, it is possible, any other public agencies which are developing actions related to the goal of the

project. The **continued support and commitment of these entities** will help to:

- Set up an appropriate legal framework prior, during and after the project execution with the local city council.
- Implement new regulations, certification and/or standardisation measures.
- Guarantee the future of the urban forest in a medium and long-term fostering the idea that this plantation is part of each actor involved in the local community and through, not only by means of their common media platforms (social media, websites, press release, etc.) but also the organization of related official events where all the elements which take part of the local ecosystem will be called to participate in.
- Identify local organizations which are developing activities identified as project topics so potential synergies are fully exploited. These actions will also help to promote the social participation, especially with adult population. Moreover, it could foster further inter-sector collaborative actions.
- Connect with the educational and vocational training centres. According to our experience, these type of organisations are extremely active which should provide a participatory approach in the implementation of all scheduled social activities.
- Strengthen public awareness on the environmental impact of these actions and projects, emphasizing how important is the implementation of these activities in the community in general and in the local ecosystem in particular, highlighting the positive effects in health, well-being, safer cities, etc.

Annex 1. Detailed data analysis

This annex includes the empirical model and the detailed results of the analysis carried out from the beginning of the project until the end of the project in March of 2017.

Empirical Model

Statistical tools used in the analysis and acknowledgments

To perform the analysis the R (R Core Team 2015) and RStudio (Studio 2012) tools are used with the following packages:

- "ggplot2" (Wickham 2009)
- "grid"
- "gridExtra" (Auguie 2015)
- "KMsurv" (Klein, Moeschberger, and Yan 2012)
- "lme4" (Bates et al. 2015:4)
- "nlme" (Pinheiro et al. 2015)
- "plyr" (Wickham 2011)
- "png" (Urbanek 2013)
- "reshape" (Wickham and Hadley 2007)
- "scales" (Wickham 2016a)
- "stargazer" (Hlavac 2015)
- "survival" (Therneau 2015)
- “car” (Wang et al. 2014)
- “chron” (James and Hornik 2015)
- “sandwich” (Zeileis 2006)
- “shiny” (Winston, 2016)
- “tidyr” (Wickham 2016b)

We want to thank all of them for these incredible tools that makes quantitative analysis feasible.

We have used as threshold for statistical significance a p -value of 0.95 on a 2-tailed test.

Model for the analysis of moisture retention of rainfall depending on treatment

The analysis of moisture retention is performed by using 24 linear regression models for the following observed variables: Moisture at 20 cm, moisture at 40 cm and gradient of moisture. In the n model (n from 1 to 24) the dependent variable is the difference of those variables between the period of observation and the period n hours before the observation and the independent variable is the hourly rate of rainfall in the n period (considering only rainfalls higher than 1 mm. per hour) prior to the observation interacting with the treatment to assess the change in the variable (humidity or gradient of humidity) per unit of rainfall depending on the treatment (comparing each treatment with the “No treatment”).

We control for the rainfall between the observation and the n-1 period and for the rainfall 24 hours before the n period to control for other rainfalls before and after the assessed rainfall. An overall calculation will be made and separated by block and by different initial soil moistures. Moisture at 20 and 40 cm. n hours before the observation is also included in the model because it is expected that the effect depends on previous moisture and to avoid bias due to other unobserved effects before the observation period that will be mainly controlled by that variable.

The model is too simple and therefore the conclusions must be taken very carefully. For instance there is no interaction between soil moisture and the rainfall. We take care of this by analysing the effect for different initial soil moistures (the quartiles of humidity at 20 and 40 cm 24 hours before the observation). The interaction between rainfall and treatment is linear without considering quadratic terms. This is partially solved by considering only rainfalls higher than 1 mm. per hour. Still the model is too simple, challenging the results of the analysis. Our goal is to give an idea of what is going on, particularly when the soil is very dry.

The standard error is obtained by clustering per plant to correct for the violation of the independent and identically distributed error assumption.

The proposal model for the n period (1:24) is as follows:

$\text{Diff\_Hum\_20\_n} = \beta_{n0} + \beta_{n1}\,\text{treatment}_t + \beta_{n2}\,\text{Rainfall}_n + \beta_{n3}\,\text{treatment}_t * \text{Rainfall}_n\ +$

$B_{n4}\,\text{Hum\_20\_n} + \beta_{5ni}\,\text{Rainfall}_{ni} + \beta_{6nj}\,\text{Rainfall}_{nj} + €$

Where:

n will be assessed for 1 to 24 periods before the observation.

i will control for rainfalls between the observation and the n period before the observation.

j will control for rainfalls between the n+1 period and n+24 periods.

t indicates Treatment.

The parameter of interest is $\beta_{n3.}$

Fixed-Effect and Random-Effect models for moisture

In order to explain or predict a measurable phenomenon it is common to use statistical models. Mixed models are a generalization of the classical linear regression model, considering the possible existence of heterogeneous variability correlated or linked to the presence of random factors observations. They provide an optimal environment to answer questions of a complex experimental study design, as QUF project simultaneously modelling the expected value of the response and its variability in different scales following the hierarchy of data.

A clustered database can have a level or multiple hierarchical relationships, these being independent or crossed. An element always belongs to a group of higher rank. Examples of such “nested" databases are:

i. Individuals with spatial heterogeneity between them as trees located within sample blocks which in turn are located within a forest that belongs to a forest stratum.
ii. Geographically separate observations or experiments with repeated measurements.

For the treatment of these databases two types of models are used, the "fixed - effect" and the "random- effect". The first assumes that the independent variables are fixed, known at the population level, there are no more data than used and those data are considered to be correct.

$y_{ik} = u + e_i$
(1)

where y_{ik} is the individual variable of interest i within the group k, u is the fixed component for group k and e_i is the random residual for the individual i within the group k.

The "random- effect" model in turn assumes that the observations are random occurrences where variability exists because of working with samples within a population.

Mixed models is nothing but a combination of both approaches. Mixed models are composed of a fixed component or "fixed effect" which is set to binary variables (ie, 1 belongs to the group i, 0 no). The coefficients are estimated for each level of the interest groups.

In a Mixed model the variance of the residuals is divided between groups and within each group for a single level of hierarchy. There is a group fixed component and a random component, or "random", within each group for each individual.

Predictions are therefore within groups and between groups, although it is possible to make predictions for individual elements within groups. To observe differences in the population, a simple mixed model to explain the variance is the simplest case. Let's see it by simulating a single level of hierarchy (ie, scale treatment or specie in the project):

$y_{k_i} = u + b_k + e_{k_i}$ (2)

where µ is the average value of the fixed population and bk + Ɛki two random parameters. The residual error is divided into two independent parts: the random effect of the k group, and the random residual error for each element i within the group k.

For statistical computing these models we use R, an integrated environment for data manipulation, calculation and graphics.

We test the effect of the treatments on the following dependent variables:

- log_Hum20=log (Hum20).
- log_Hum40=log (Hum40).
- grad_Hum=abs (Hum40-Hum20).
- Tem20.
- Tem40.
- grad_Tem=abs (Tem40-Tem20).

We use 3 different models for each of these dependent variables to compare the results:

- An OLS model clustering by tree to avoid the violation of the independent and identically distributed principle due to all the observations coming from only 64 trees. The model is:

  variable = $\beta_0 + \beta_1$ treatment$_t$ + β_2 block + β_3 Specie + β_4 Specie

The parameter of interest is β_1 that estimates the percentage increase in the log variables due to the treatment and the increase in absolute value in the other dependent variables.

- A mixed model using the library lmer of R with the following model:

  “~Treatment+(1|IdTree)+(1+Treatment|Specie)+(1+Treatment|Block)+(1|Month)"

  The fixed effect is the treatment (our parameter of interest) and and we consider the following random effects:

  - Individual: to allow for different intercepts at the individual level
  - Specie: to allow for different intercepts and slopes depending on treatment for each specie
  - Block: to allow for different intercepts and slopes depending on treatment for each block
  - Month: to allow for different intercepts for each month

- A mixed model using the lme4 library of R with the following model:

  fixed="~Treatment+Block+Specie"

  random=c(~ 1 |IdTree,~ 1 |Month)

  The fixed effect is the treatment (our parameter of interest), Block and Specie and we consider the following random effects:

  - Individual: to allow for different intercepts at the individual level.
  - Month: to allow for different intercepts for each month.

Although the models are slightly different the results should be similar. We do not use interaction terms. Instead of that we run different models sub-setting for Block and for period (vegetative and no vegetative). Vegetative period are the months from March to October. We do not analyse the results by specie because the difference is very small.

Kaplan-Meier and Cox Survival models

Survival analyses are based on observing a number of individuals of different species and different treatments over time. The event considered is the status of the individual in each observation, which can have the values : dead or alive. In this type of analysis are 2 relevant factors, the non-normality of the answers (it can only take 2 values) and the fact that the observations may be censored, meaning that there are individuals that we observe, for which the event has not occurred at the time of observation, but it may occur in future observations.

Our variable of interest is the time T when an individual dies. The cumulative probability function of T is given by the formula:

$$F(t) = P(T \leq t), (t \geq 0)$$

Our interest is focused on the survival function that is the likelihood that the individual will survive until a time T, which is given by

$$S(t) = 1-F(t)= P(T>t).$$

To estimate the survival function we usually model the hazard function, which for each T is the instantaneous ratio of individuals who die at the time T and is given by the formula:

$$h(t) = \lim_{c \to 0} (P(t \leq T < t + c | T \geq t)/c)$$

It is straightforward to quantify h depending on the cumulative probability function, F as follows:

$$c*h(t) = Pr(t < T < t + c \mid T > t) = Pr(t < T < t + c)\, [Pr(T > t)]^{-1} = \frac{F(t+c)-F(t)}{1-F(t)}$$

In having the differentiable function f (t) = dF (t) / dt it follows:

$$h(t) = \lim_{c \to 0} \frac{F(t+c) - F(t)}{c} \cdot \frac{1}{1 - F(t)} = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)}$$

As we know that the derivative of S (t) = 1 - F (t) is f (t) we arrive to:

$$h(t) = -\frac{d \log S(t)}{dt}$$

Applying integrations we estimate the probability of survival that is given by the formula:

$$S(t) = exp\left[-\int_0^t h(s)ds\right]$$

However, as far as we do not know the shape of the hazard function and our main interest is the effect of the treatments in the survival chance we apply a non-parametric approach as suggested by Cox, D.R. (1972). This method allows to estimate the change in the survival rate depending on the factors of interest, namely the treatment and the specie. We also include in our model an analysis depending on the soil characteristics. Although we do not know the hazard function the underlying model estimates the change in this function depending on the interest factors:

$$h(t; e, r, x) = \lim_{c \to 0} \frac{P(t \leq T < t + c : T \geq t, e, r, x)}{c}$$

Where e is the specie, r the treatment and x other control variables.

Our model assumes a proportional hazard model, where the hazard function is expected to be based on a base function that is multiplied by a factor that depends on the interest variables:

$$h\ (t; e, r, x) = k(e, r, x).h_0(t)$$

In our study we quantify how risk varies depending on the species and treatment. We will also make a graphical analysis of the survival function based on the nonparametric model suggested by Kaplan & Meier (1958) that yields very intuitive results.

Additionally the assumptions will be verified, particularly, proportionality and linearity of the parameters. The former assumption will be check by using two tests. The cox.zph function provided by R will be used and also time-dependent variables constructed as interactions between our variables of interest and time will be included. In both cases no significant values should be estimated. The latter assumption will be checked by generating Martingale residues.

It is expected than the predicted values will match the observed values.

PCA. OLS and mixed-models for biomass

For the establishment of our response variable Biomass, we performed a Principal Component Analysis (PCA). It is a statistical technique of information synthesis. In using a database with many variables (Diameter, Height, absorption of Carbon in the Root and absorption of Carbon in the Stem), the goal has been to reduce them to a smaller number by losing the least amount of information possible.

The PCA constructs a linear transformation that chooses a new coordinate system for the original set of data, in which the largest variance of the dataset is captured on the first axis (First Main Component), the second largest variance is the second axis (Second Main Component). To obtain this linear transformation, the covariance matrix must first be constructed.

For a Principal Component Analysis, the correlation matrix must first be analysed.

Next, we indicate that the variables are expressed in logarithmic scale to favour their symmetry. From this, it follows that all variables have comparable scales. In this case, it will be more appropriate to perform a Principal Component Analysis based on the covariance matrix of the data.

The first component of the PCA explains approximately 90.3% of the original variance, while the second component accounts for 8.3%, so the sum of the first two dimensions accounts for almost 100%. However, we can conclude that we need the first component to explain 90% of the original variance of the data.

As a summary, the first component of the PCA explains 90% of the original variance, so we will stay with this component when it comes to summarizing the data, and, therefore, establishing our Biomass response variable in terms of this analysis performed.

We will use again the linear and mixed linear models, as was done in the analysis of moisture.

We test the effect of treatments on the following dependent variables:

- Biomass.
- Biomass *Amigdalus communis.*
- Biomass *Acer campestre.*
- Biomass *Juniperus thurifera*.
- Biomass *Pinus pinea*.
- Biomass *Quercus ilex*.

We use 2 different models for each of these dependent variables to compare the results: a general OLS model and another OLS model for each of the species. The model is:

- Biomass = β0 + β1*Treatment + β2*Block + β3*Specie
- Biomass Specie = β0 + β1*Treatment + β2*Block

A mixed model using the lme4 R library with the following model:

- Fixed = "Treatment + Specie"

- Random = c (~ 1 | Block)

The mixed model for each species is the following:

- Fixed = "~ Treatment"
- Random = c (~ 1 | Block)

The fixed effect is the Treatment (our parameter of interest) and Specie in the general model, considering the Block as a random effect.

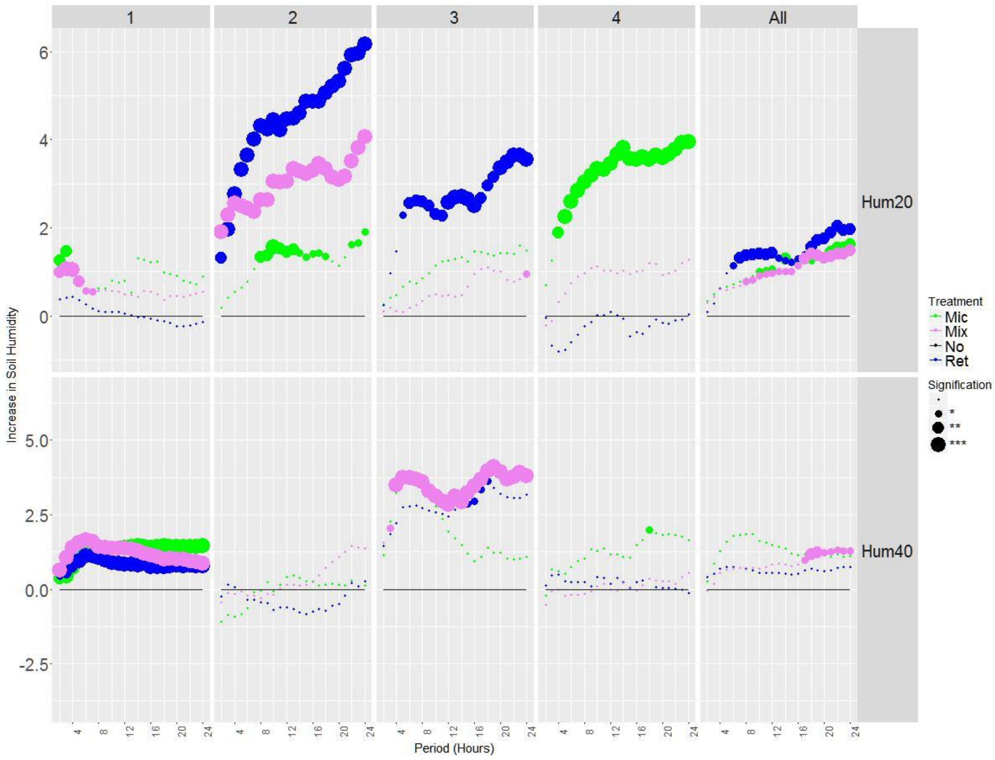
We will not use interactions between independent variables.

Results of the analysis of soil moisture absorption of rainfall

One of our hypothesis is that the capacity of moisture absorption of the soil is changed by the treatments. We are going to present the results considering all blocks and by block when the soil is dry (moisture at 20 or 40 cm is lower than the median of the sample). The results of the regression for the parameter of estimate (interaction treatment and rainfall) at the periods 6, 12, 18, and 24 hours before the observation are presented. However, due to the complexity of the model we think that a graphical representation is more adequate. Therefore we include the graphs of the difference in the dependent variables (moisture at 20 cm and 40 cm) depending on the treatments for a rainfall of 10 mm. in the n period after the rainfall, indicating the statistical significance of the estimate. We also include a graph with the total change of the Moisture at 20 and 40 cm to see the evolution in the next hours for a rainfall of 10 mm per hour depending on the treatments.

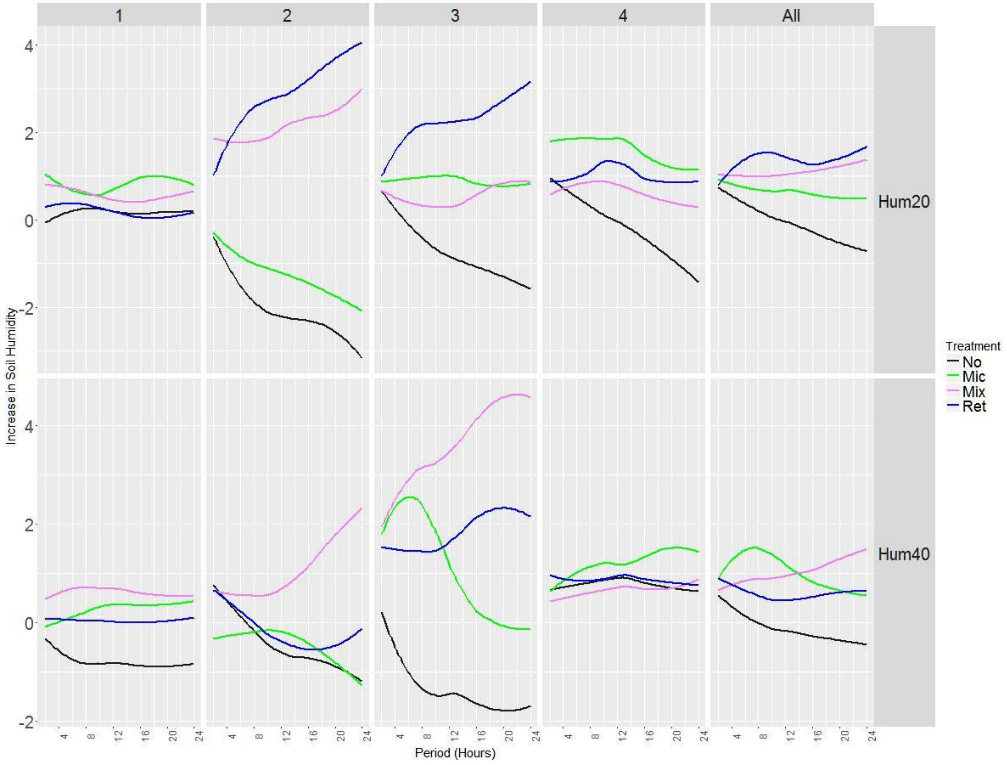
The soil moisture increases more when using the treatments particularly at 20 cm. in the following 24 hours after a 10 mm. rainfall as shown in Figure 27. When considering the four blocks together the effect is significant for all the treatments at 20 cm. The effect is not equal for the different blocks. Retainers seem to be more effective in Block 2 and 3 at 20 cm while mycorrhiza seems to be more effective at block 4. In block 1 the effect of the treatments is only significant at 40 cm.

Figure 27: Interaction term of rainfall and treatment for dry soil (base case No treatment) by block



The total change in the soil moisture can be seen in Figure 28.

Figure 28: Change in the variable after the rainfall depending on treatment for dry soil by block



The treatments seem to have a significant effect in increasing the soil moisture compared to not having treatment for lower soil initial humidity, particularly at 20 cm, although the effect depends on the soil characteristics of the block.

The results of the regressions for all blocks in periods 6, 12, 18, and 24 are shown in the following tables.

Tabla 12: Regression results Hum20 of rainfall absorption after 6, 12, 18, and 24 hours

Regression results for all observations

	Dependent variable:			
	OLS- Hum20 (difference)			
	6	12	18	24
	(1)	(2)	(3)	(4)
treatmentMic:Precipitation_H_6	0.07			
	(0.06)			
treatmentRet:Precipitation_H_6	0.11			
	(0.06)*			
treatmentMix:Precipitation_H_6	0.06			
	(0.04)			
treatmentMic:Precipitation_H_12		0.11		
		(0.06)*		
treatmentRet:Precipitation_H_12		0.14		
		(0.07)**		
treatmentMix:Precipitation_H_12		0.10		
		(0.05)*		
treatmentMic:Precipitation_H_18			0.13	
			(0.07)*	
treatmentRet:Precipitation_H_18			0.16	
			(0.08)**	
treatmentMix:Precipitation_H_18			0.14	
			(0.06)**	
treatmentMic:Precipitation_H_24				0.16
				(0.07)**
treatmentRet:Precipitation_H_24				0.20
				(0.09)**
treatmentMix:Precipitation_H_24				0.15
				(0.06)**
Observations	15,593	15,519	15,461	15,211
R^2	0.18	0.21	0.25	0.30
Adjusted R^2	0.18	0.21	0.25	0.30
Residual Std. Error	3.09 (df = 15555)	3.93 (df = 15475)	4.47 (df = 15411)	4.78 (df = 15155)
F Statistic	92.43*** (df = 37; 15555)	95.02*** (df = 43; 15475)	105.18*** (df = 49; 15411)	118.81*** (df = 55; 15155)

Note: *p<0.1; **p<0.05; ***p<0.01
Cluster s.e. by tree

Table 13: Regression results Hum40 of rainfall absorption after 6, 12, 18, and 24 hours

Regression results for all observations

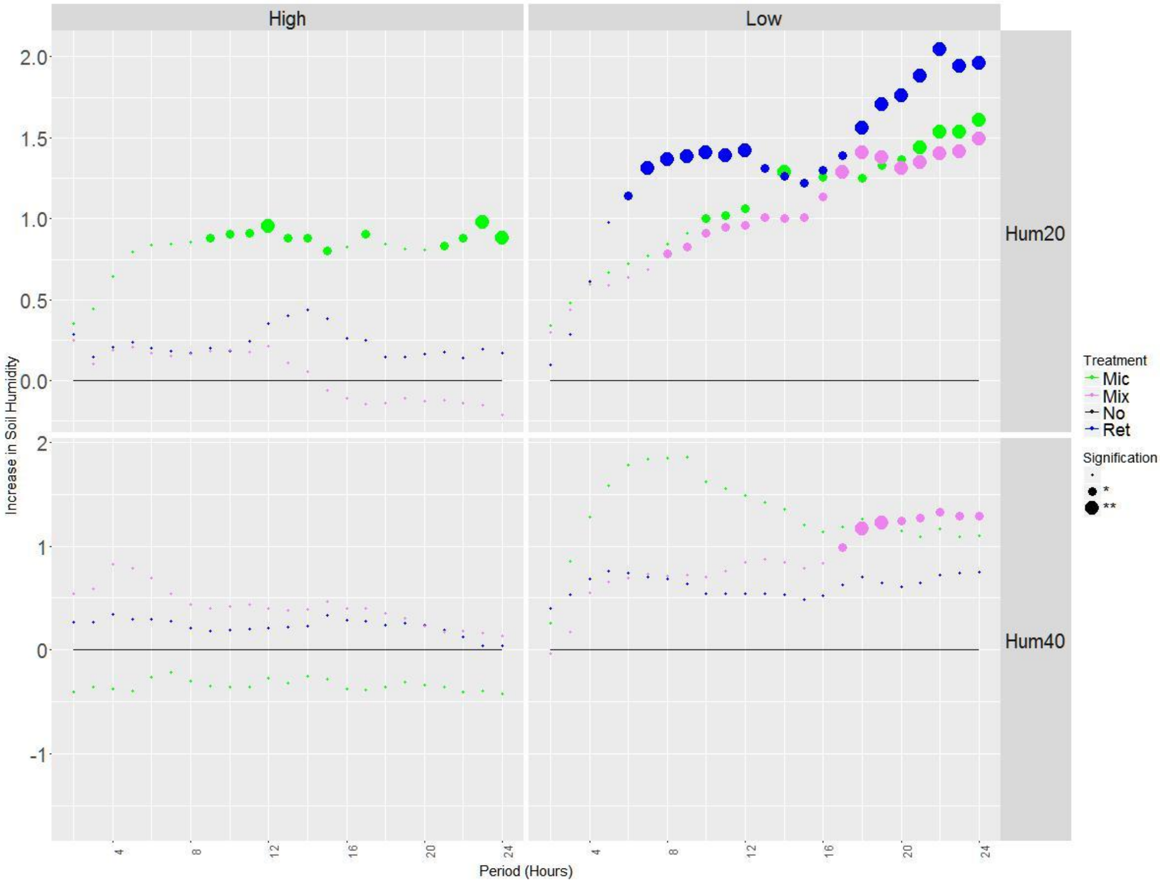
	Dependent variable:			
	OLS- Hum40 (difference)			
	6	12	18	24
	(1)	(2)	(3)	(4)
treatmentMic:Precipitation_H_6	0.18 (0.15)			
treatmentRet:Precipitation_H_6	0.07 (0.09)			
treatmentMix:Precipitation_H_6	0.07 (0.06)			
treatmentMic:Precipitation_H_12		0.15 (0.10)		
treatmentRet:Precipitation_H_12		0.05 (0.08)		
treatmentMix:Precipitation_H_12		0.08 (0.06)		
treatmentMic:Precipitation_H_18			0.13 (0.08)	
treatmentRet:Precipitation_H_18			0.07 (0.09)	
treatmentMix:Precipitation_H_18			0.12 $(0.06)^{**}$	
treatmentMic:Precipitation_H_24				0.11 (0.08)
treatmentRet:Precipitation_H_24				0.07 (0.10)
treatmentMix:Precipitation_H_24				0.13 $(0.07)^{*}$
Observations	15,732	15,712	15,693	15,568
R^2	0.17	0.20	0.20	0.22
Adjusted R^2	0.17	0.19	0.19	0.22
Residual Std. Error	3.46 (df = 15694)	4.22 (df = 15668)	4.68 (df = 15643)	4.75 (df = 15512)
F Statistic	85.11^{***} (df = 37; 15694)	88.58^{***} (df = 43; 15668)	78.00^{***} (df = 49; 15643)	80.14^{***} (df = 55; 15512)

Note: *p<0.1; **p<0.05; ***p<0.01
Cluster s.e. by tree

Therefore it is likely than the treatments will have an effect on increasing the soil absorption of humidity after a heavy isolated rain as those happening in the Mediterranean area, thus increasing the time the moisture will be available for the plant. However the results are not conclusive due to the complexity of the model and the high dispersion of the results.

The effect is much lower when the soil is wet as shown in Figure 29. As expected the increase in soil moisture depends on the initial moisture. The effect is not significant for higher initial moistures, as expected. When the soil is very dry the increase is much higher than when the soil is already wet. In fact, for higher levels of soil humidity, the rain does not increase the soil moisture.

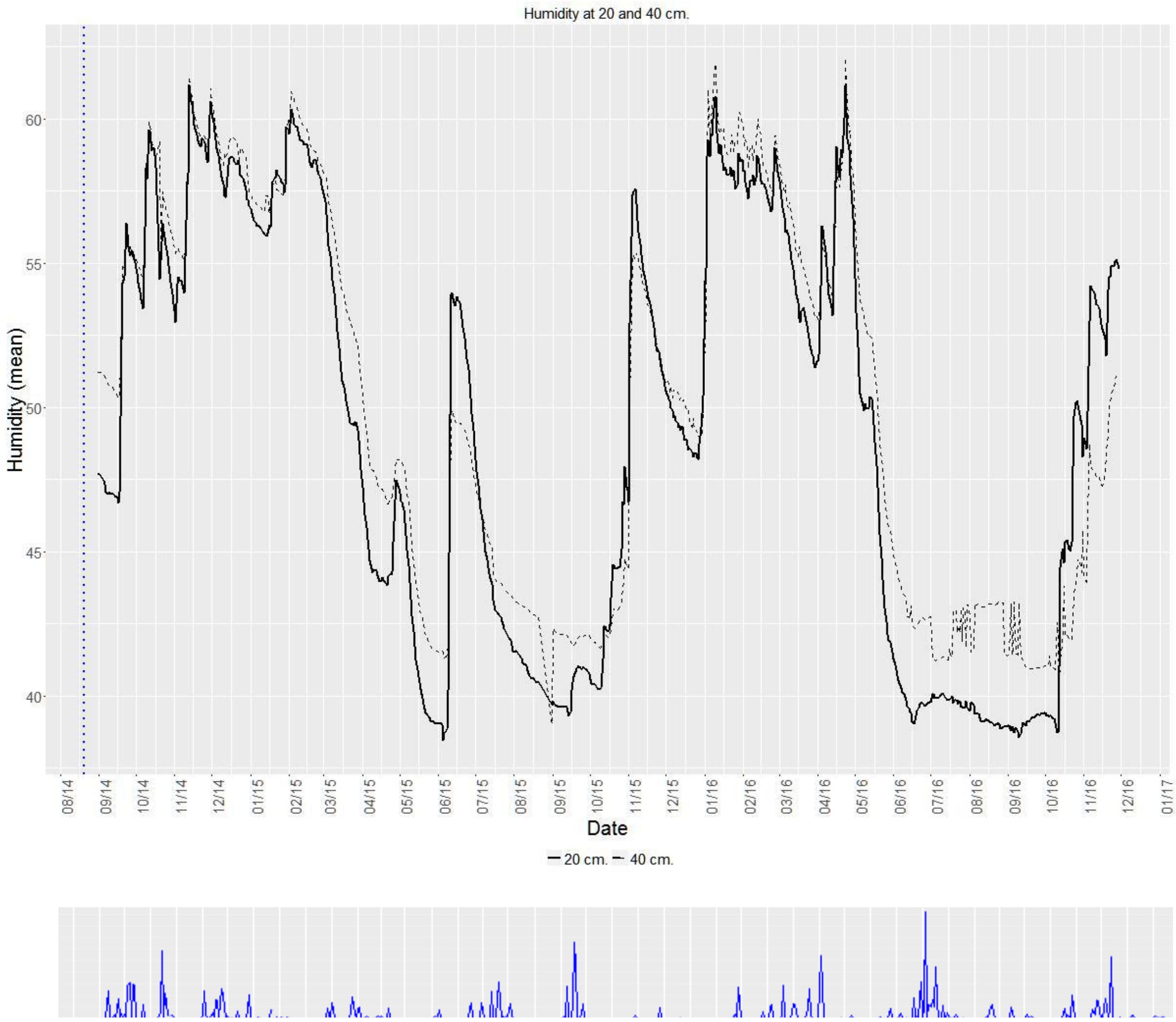
Figure 29: Interaction term of rainfall and treatment for dry and wet soil (base case No treatment) for all blocks



Analysis of soil humidity

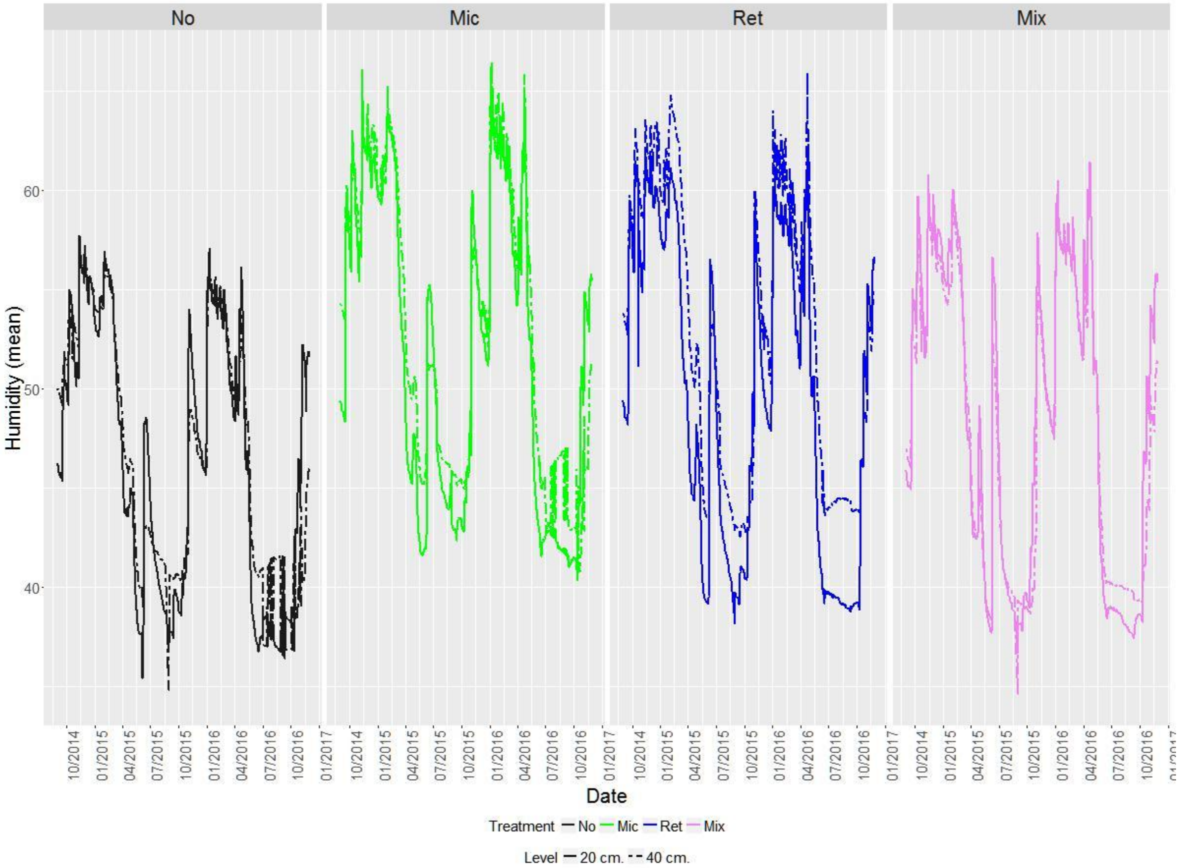
The evolution of soil humidity during the observation period, both at the 20 cm. and 40 cm. levels is strongly related to the rainfall as shown in Figure 30:

Figure 30: Evolution of soil humidity during the observation period



In analysing the humidity by treatment, all the treatments show higher humidity at 20 cm. and 40 cm. compared to not having treatment as can be seen in Figure 31. The effect seems to be higher for the mycorrhiza and the retainer.

Figure 31: Humidity by treatment at 20 and 40 cm

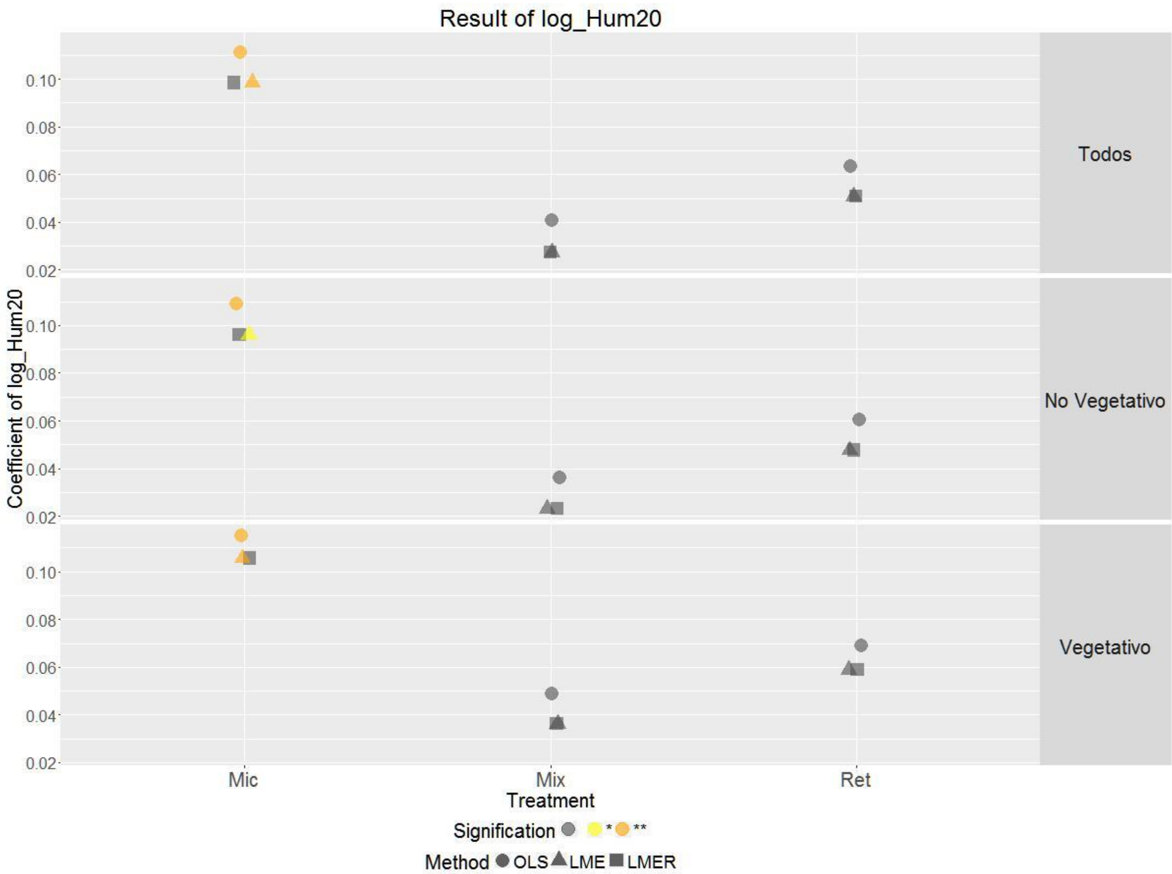


It is interesting also to analyse how the soil humidity varies by block as shown in Figure 32. Blocks 2 and 3 show a similar behaviour with both the humidity at 20 cm. and 40 cm. having similar levels. However, block 1 and block 4 show very different behaviours. In block 1 the humidity at 20 cm. level is much lower than at 40 cm. level and the changes are much smoother after a rainfall, particularly at the 40 cm. level, suggesting a soil with sand at the higher levels and clay at the lower levels. Conversely, humidity in the block 4 is higher at the 20 cm. level compared at the 40 cm. level and the changes at the 20 cm. level are very disruptive after the rainfall. It suggests than the 20 cm. level show higher level of clays.

Figure 32: Humidity by block at 20 and 40 cm

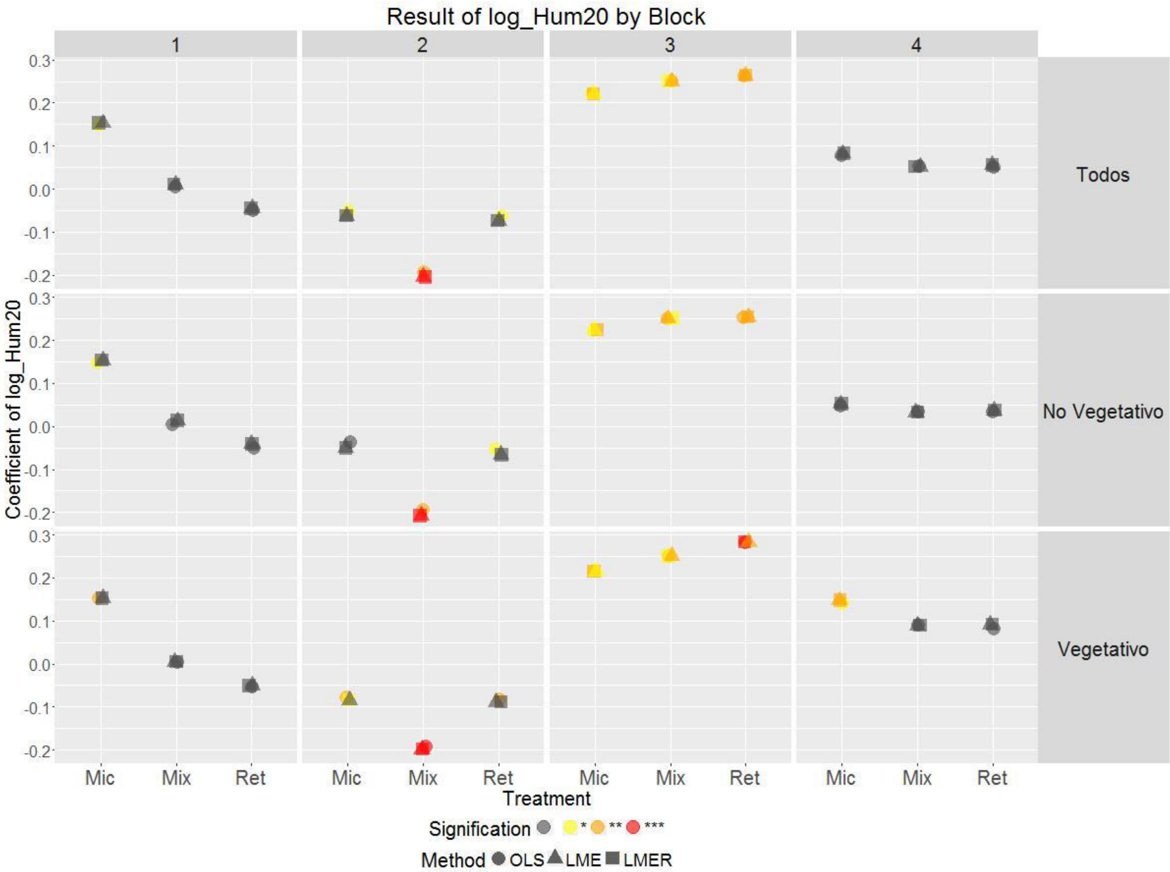
To test whether or not the effect of the treatment in the increase of soil humidity are significant we use the models described in the empirical analysis. The results of the parameter of interest (treatment) are represented in a graphical form in the following graphs:

Figure 33: Graphical representation of the effect of treatment in log (hum 20) all blocks



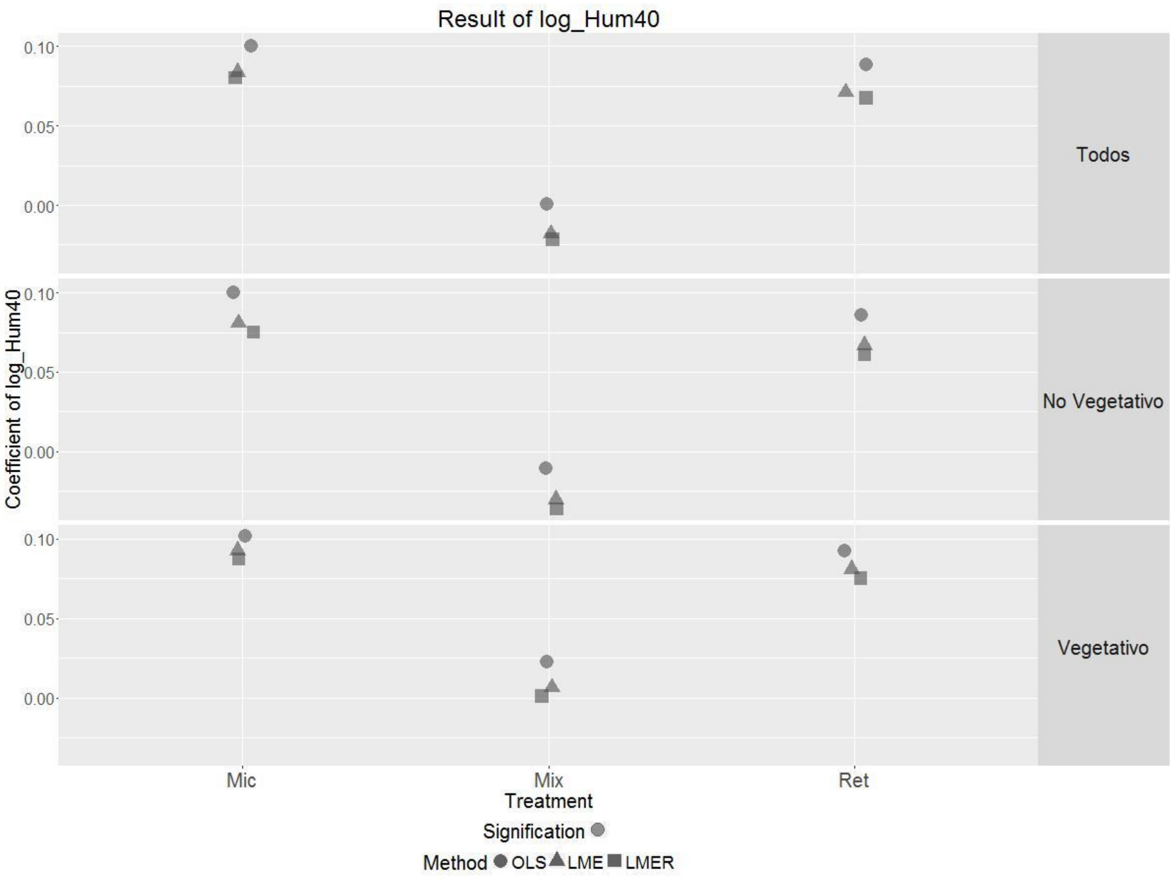
Although there is an increase of 11% (mycorrhiza), 6% (retainer), and 4% (mixed) on average humidity at 20 cm. compared to “No treatment” the results are only statistically significant for the mycorrhiza. The results are very similar in the vegetative and no vegetative periods. The effect is likely not to be practically significant because the increase in moisture is quite low.

Figure 34: Graphical representation of the effect of treatment in log (hum 20) by block



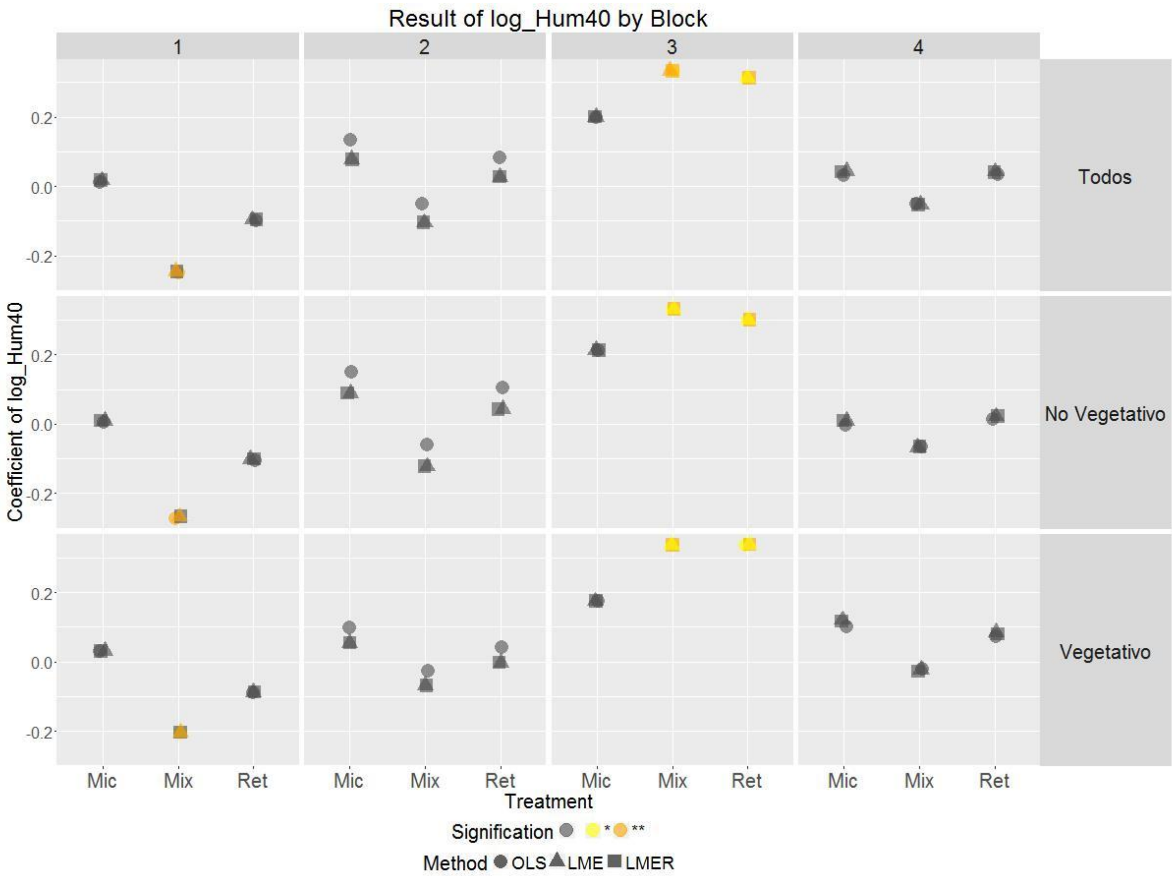
The effect of the treatments is very different depending on the block, although the reason can be the lower number of observations and the measurement errors.

Figure 35: Graphical representation of the effect of treatment in log (hum 40) all blocks



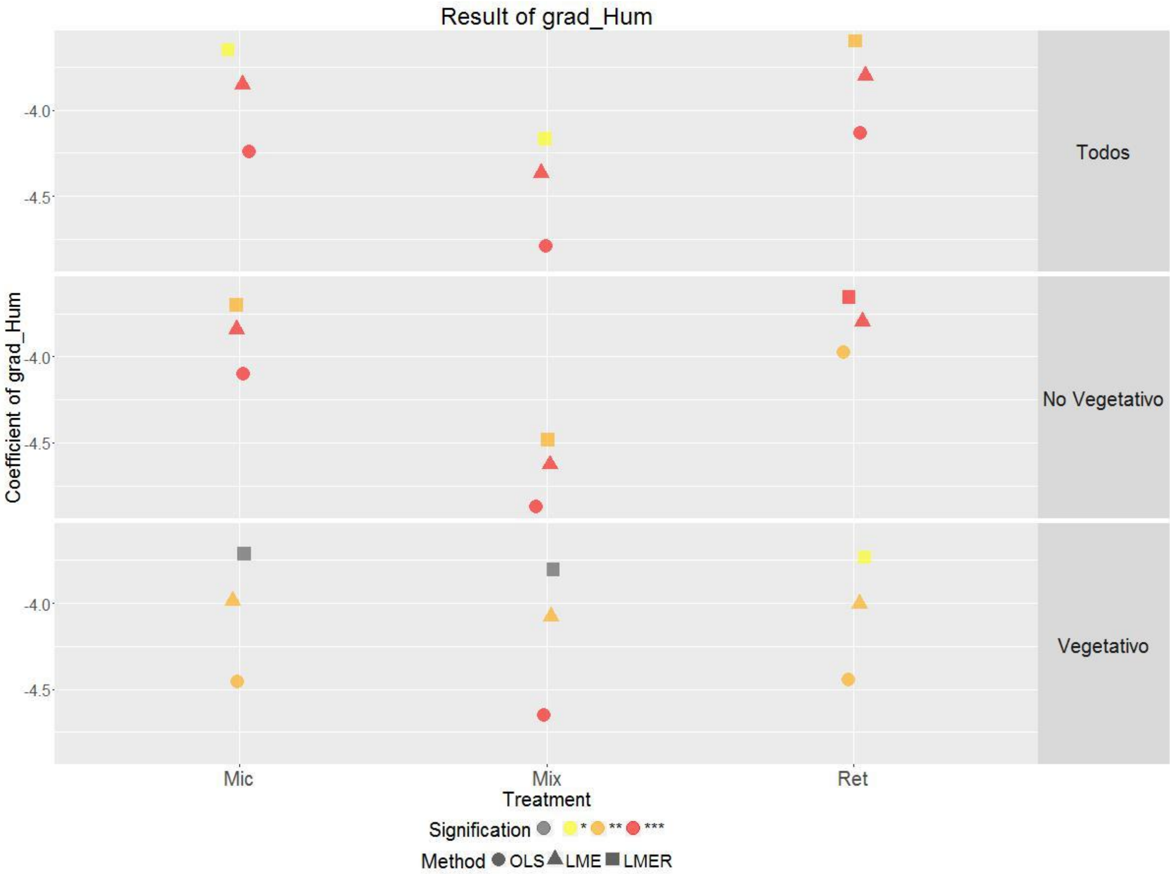
The effect of the treatments is not significant in the soil moisture at 40 cm.

Figure 36: Graphical representation of the effect of treatment in log (hum 40) by block



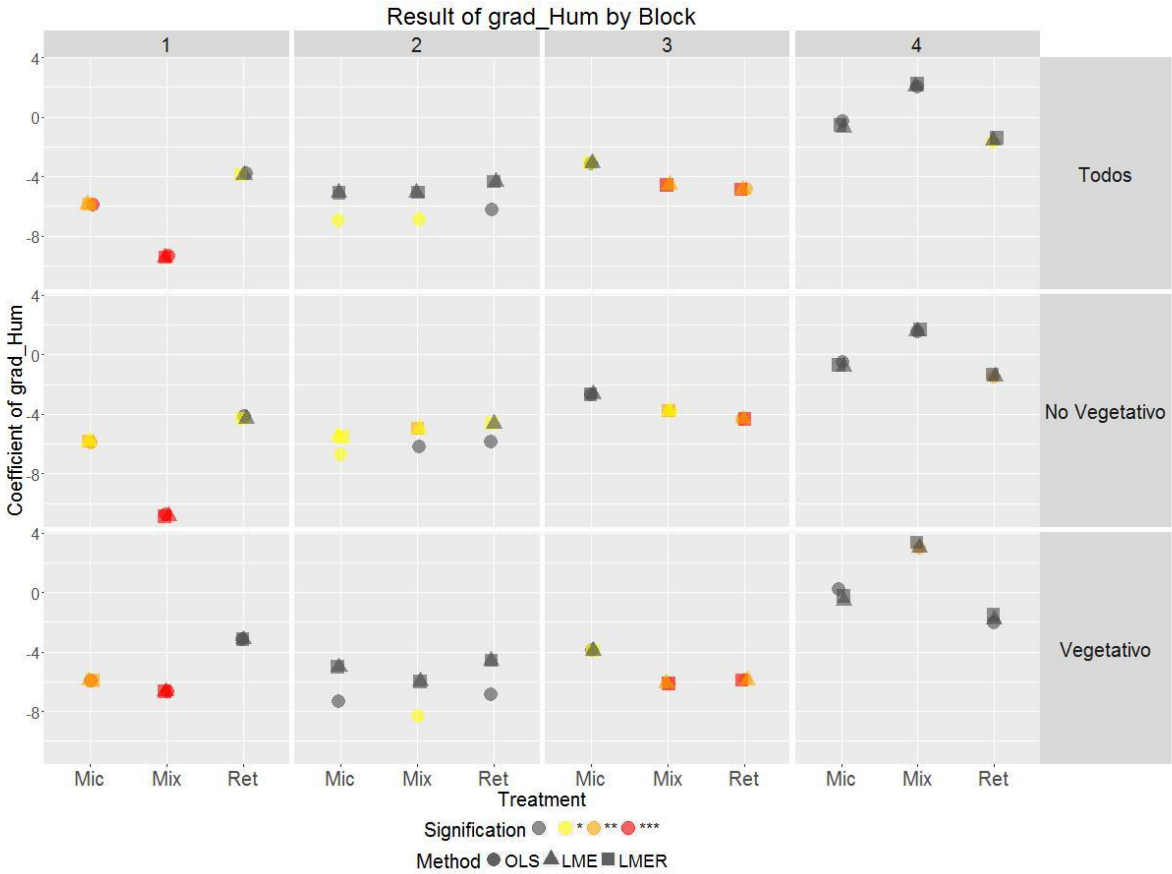
Again the effect of the treatments is very different depending on the block, although it is difficult to get any conclusion. Again we think that is due to the measurement errors in a small number of observations.

Figure 37: Graphical representation of the effect of treatment in abs (hum40-hum 20) all blocks



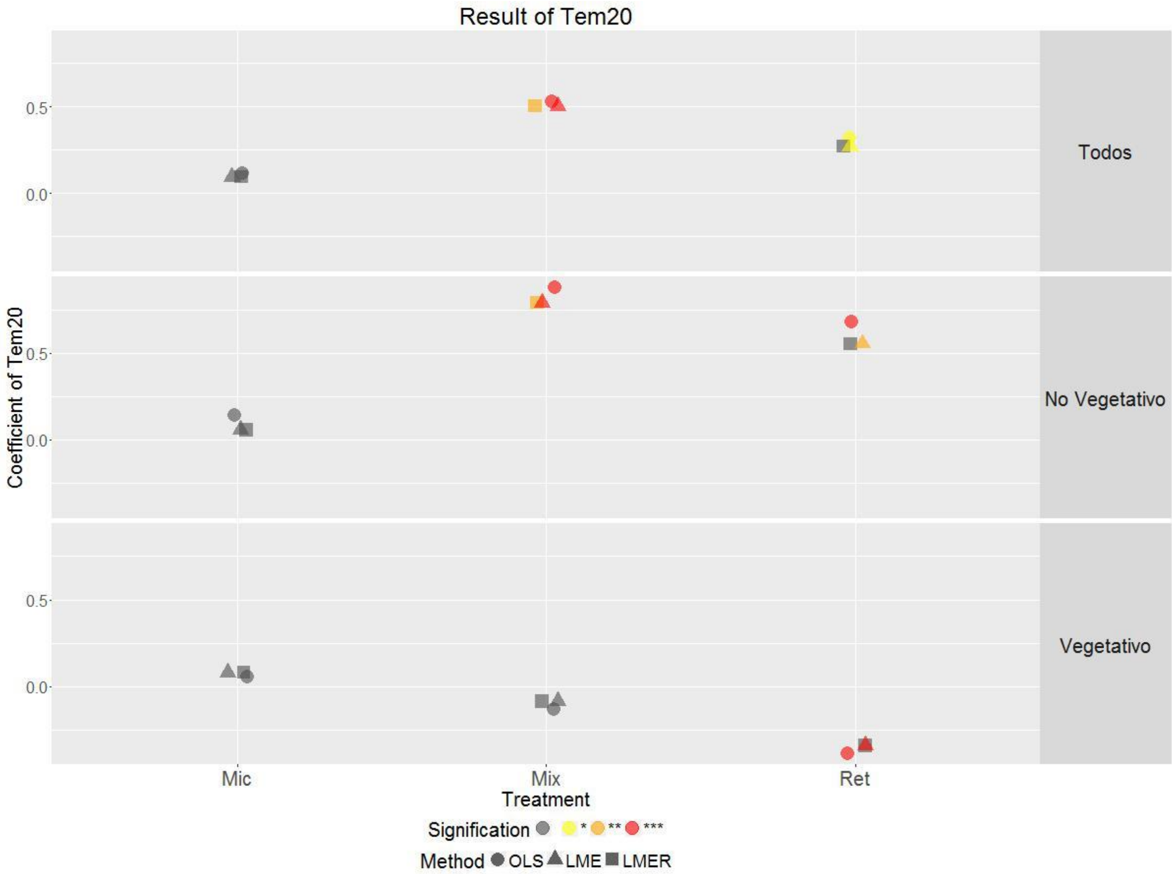
There is a reduction in the gradient of humidity between the 2 layers due to the treatments, around 4 points for the mycorrhiza and the retainer and 4.5 for the mixed. The effect is higher in the no vegetative period.

Figure 38: Graphical representation of the effect of treatment in abs (hum40-hum 20) by block



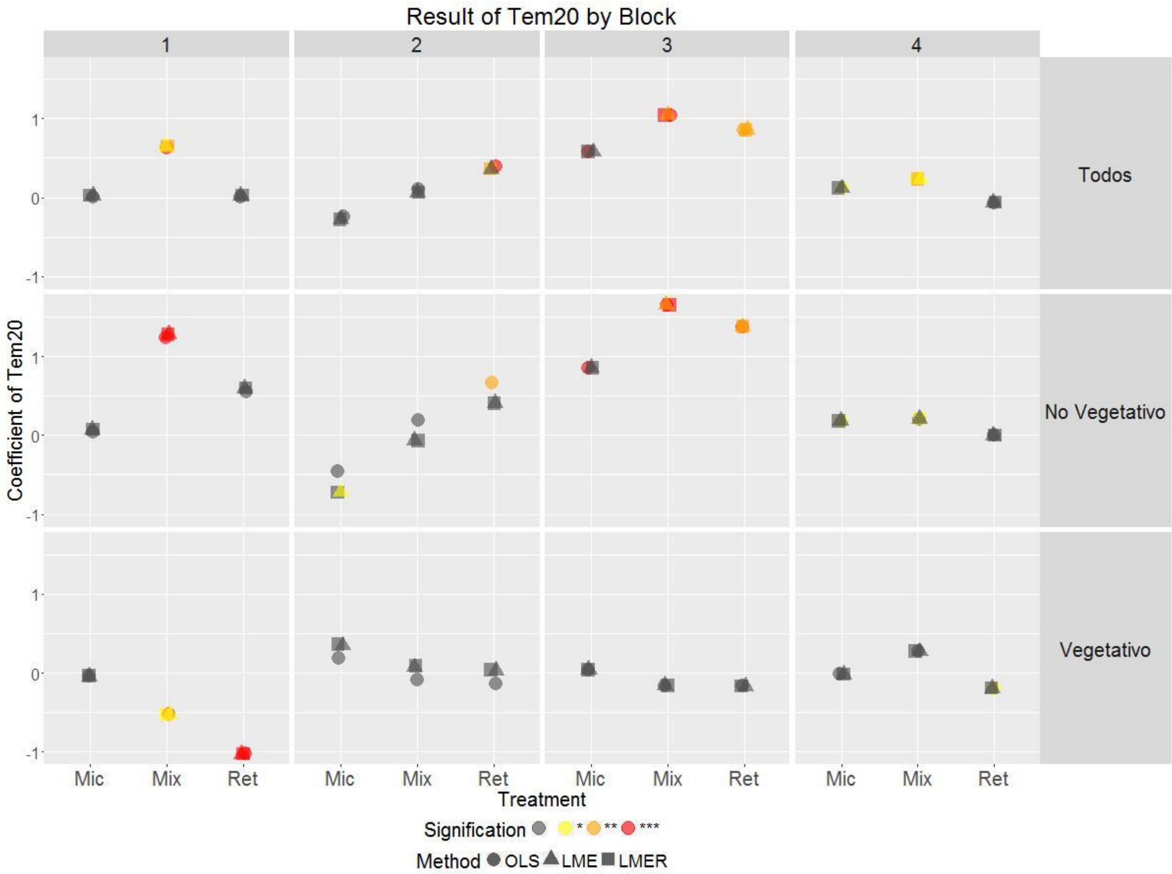
The effect is particularly significant for block 1 with values close to 8 points. It may be important because in block 1 there is a high gap between the moisture at different levels.

Figure 39: Graphical representation of the effect of treatment in soil Temperature at 20 cm. all blocks



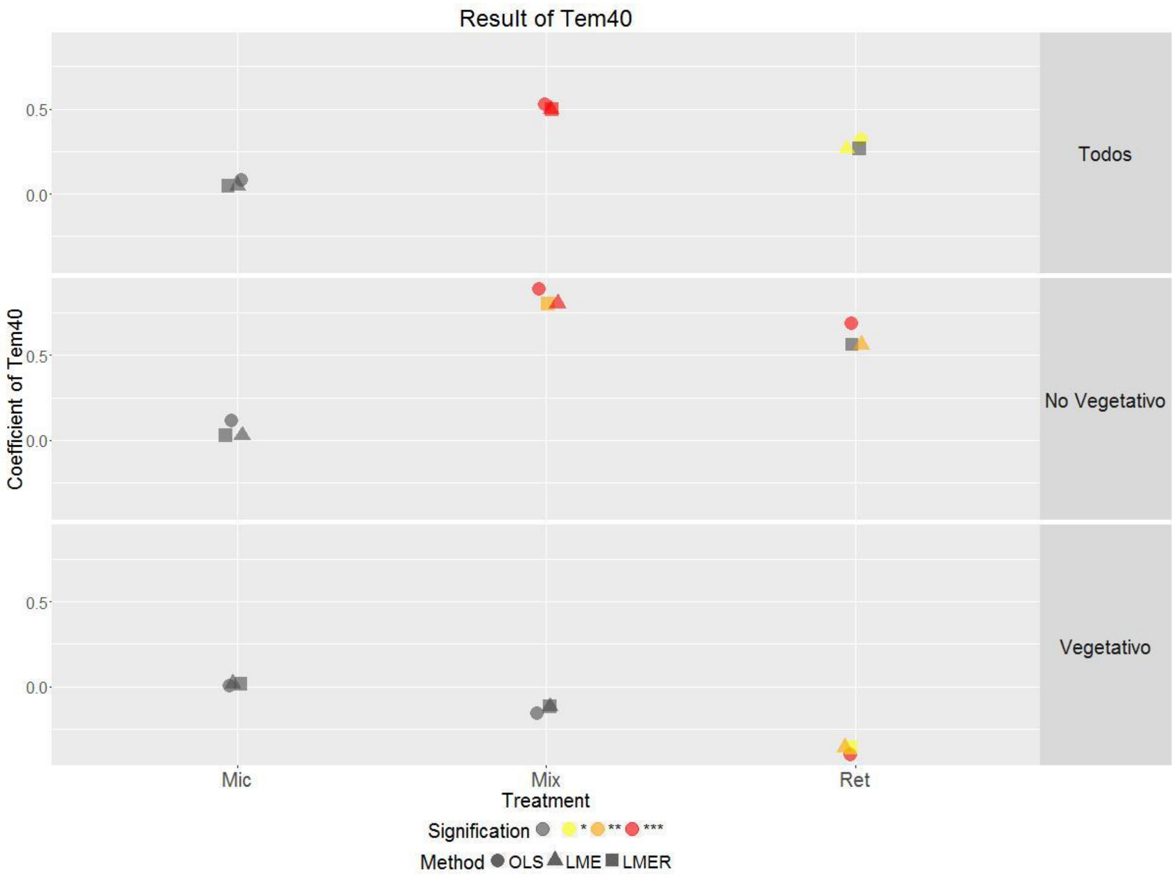
There is increase in the temperature of the soil at 20 cm. in the treatments using retainers, particularly in the no vegetative period. However the effect is very small, less than 1ºC of difference.

Figure 40: Graphical representation of the effect of treatment in soil Temperature at 20 cm. by block



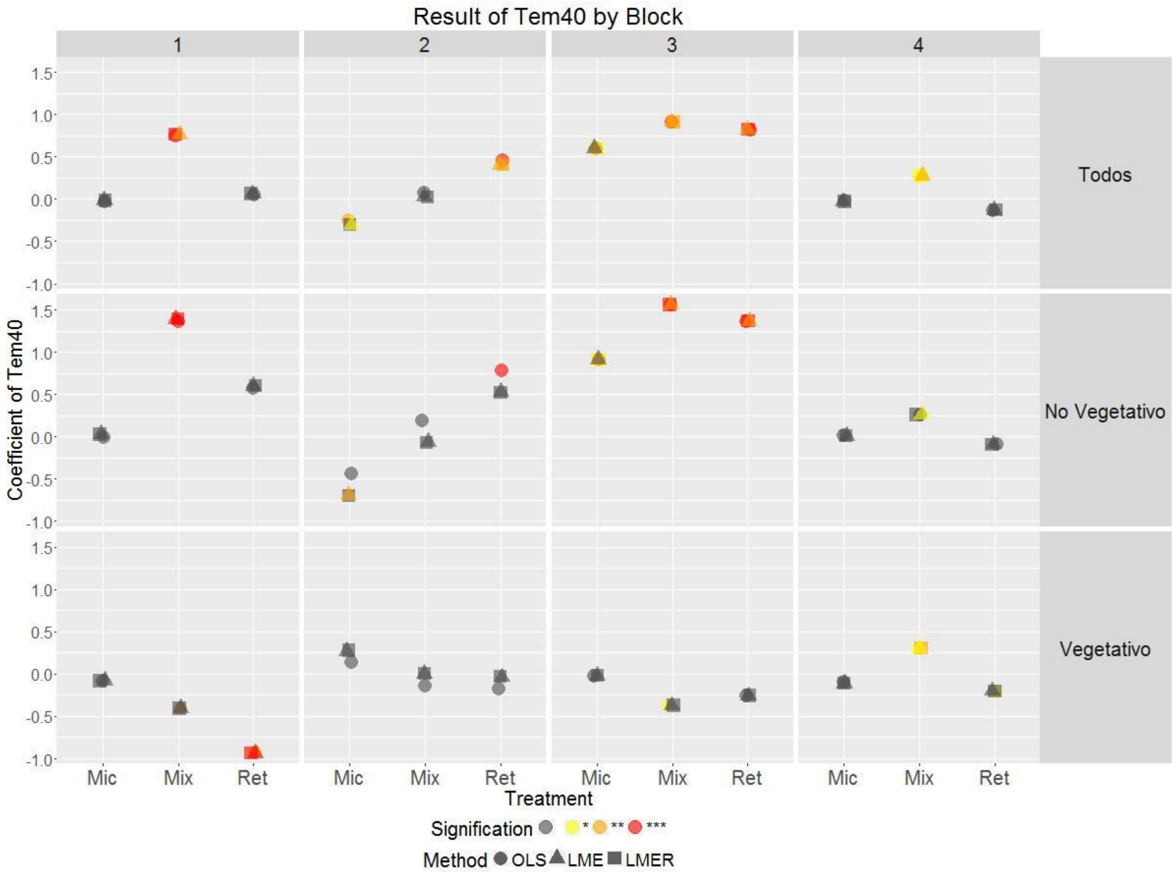
The effect is particularly significant for block 1 and 3 although the values are still very small.

Figure 41: Graphical representation of the effect of treatment in soil Temperature at 40 cm. all blocks



There is also an increase in the temperature of the soil at 40 cm. in the treatments using mixed, particularly in the no vegetative period. However the effect is very small, less than 1ºC of difference.

Figure 42: Graphical representation of the effect of treatment in soil Temperature at 40 cm. by block



The effect is particularly significant for block 1 and 3 although the values are still very small.

Figure 43: Graphical representation of the effect of treatment in abs (Tem 40 - Tem 20) all blocks

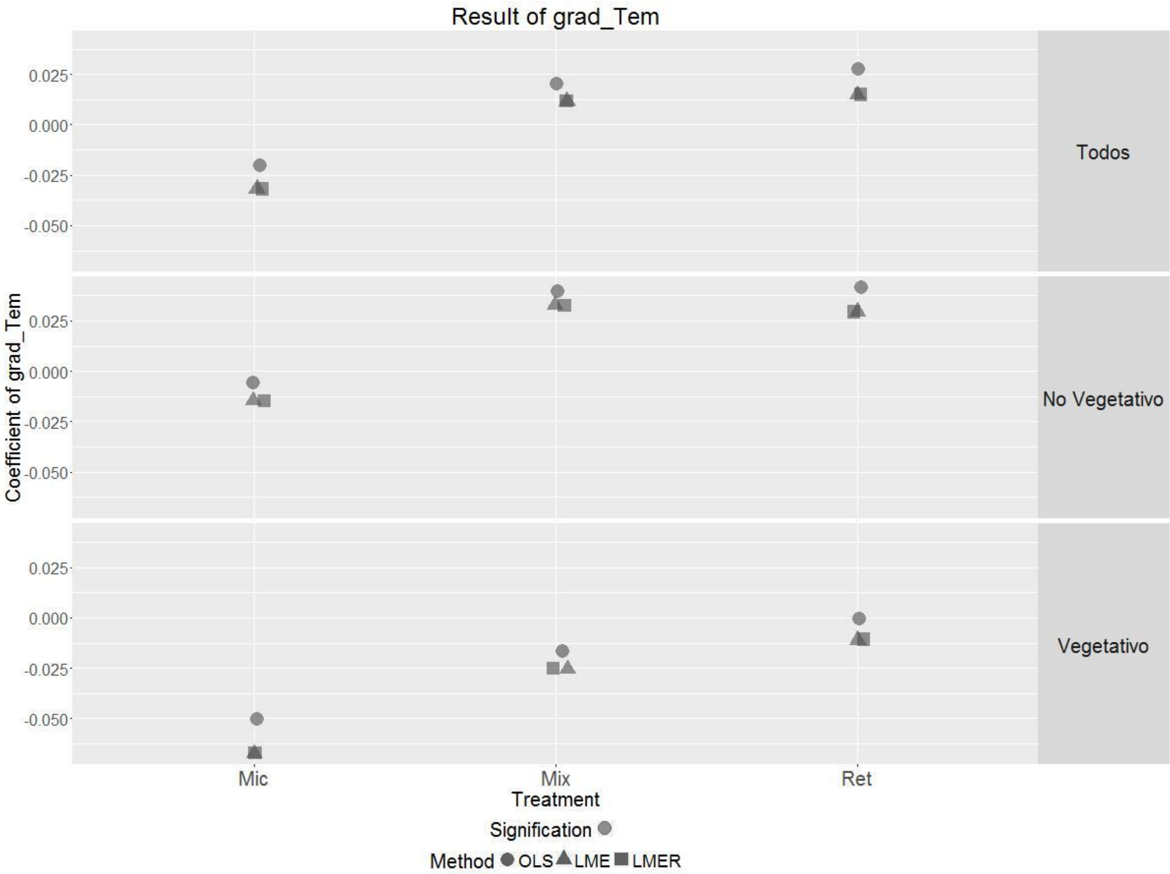
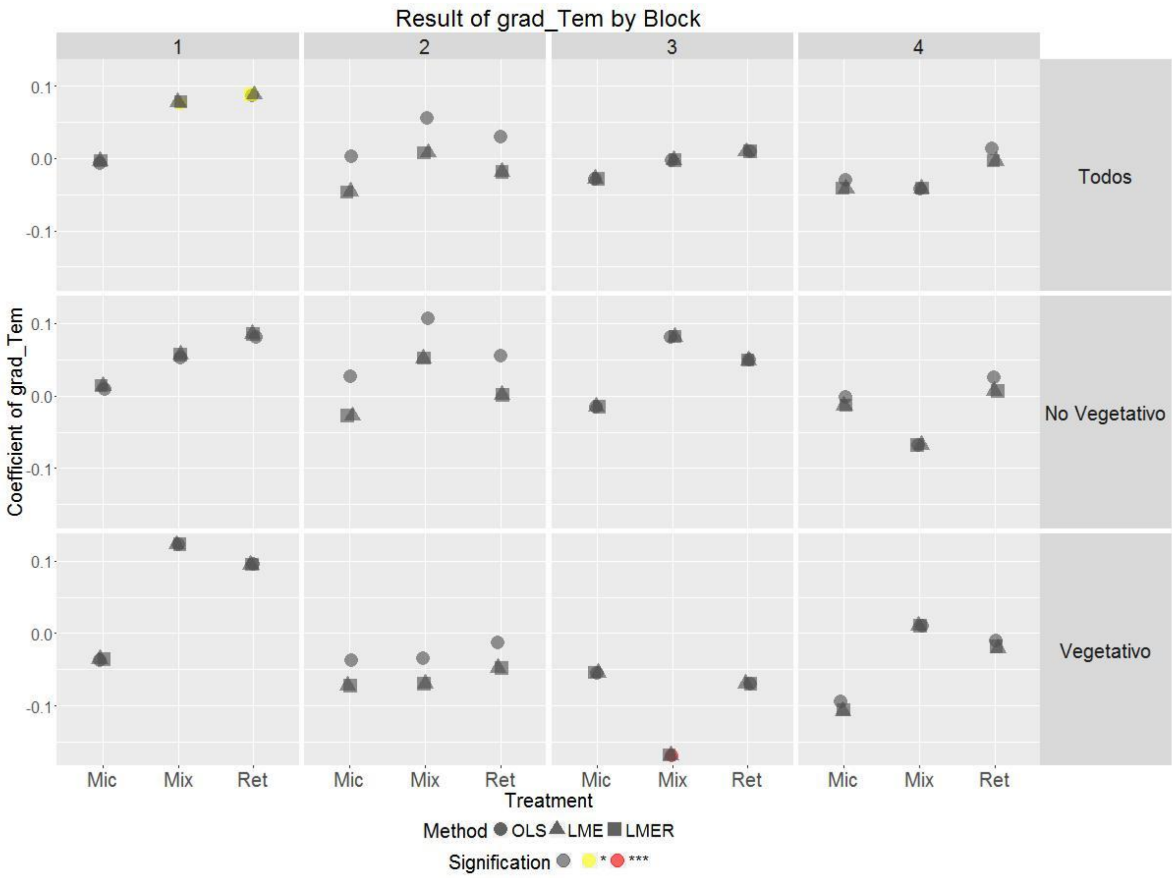


Figure 44: Graphical representation of the effect of treatment in abs (Tem 40 - Tem 20) by block



There is no any significance evidence in the change of gradient of temperatures between the layers neither when considering all blocks nor when analysing each block.

The results of the regressions for all the blocks (all the months and vegetative and no vegetative months) are shown in the following tables.

Table 14: Results of the regression analysis for all the blocks

Regression results for all observations

	Dependent variable:														
	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.113	0.099	0.099	0.100	0.080	0.084	-4.240	-3.651	-3.850	0.116	0.094	0.095	0.080	0.048	0.048
	(0.051)**	(0.060)*	(0.048)**	(0.075)	(0.071)	(0.063)	(1.535)***	(2.072)*	(1.398)***	(0.099)	(0.196)	(0.160)	(0.093)	(0.184)	(0.152)
Retainer	0.063	0.051	0.051	0.088	0.068	0.071	-4.133	-3.601	-3.800	0.319	0.270	0.271	0.318	0.265	0.266
	(0.053)	(0.071)	(0.048)	(0.073)	(0.105)	(0.063)	(1.585)***	(1.648)**	(1.398)***	(0.169)*	(0.250)	(0.160)*	(0.163)*	(0.260)	(0.152)*
Mixed	0.041	0.027	0.027	0.001	-0.022	-0.018	-4.791	-4.167	-4.366	0.528	0.504	0.504	0.525	0.497	0.498
	(0.053)	(0.083)	(0.048)	(0.077)	(0.116)	(0.063)	(1.580)***	(2.180)*	(1.398)***	(0.149)***	(0.198)**	(0.160)***	(0.136)***	(0.185)***	(0.152)***
Block 2	0.173		0.187	-0.095		-0.083	-6.693		-7.211	-1.191		-1.162	-1.128		-1.096
	(0.046)***		(0.048)***	(0.052)*		(0.062)	(1.468)***		(1.374)***	(0.150)***		(0.160)***	(0.147)***		(0.152)***
Block 3	0.168		0.168	-0.096		-0.099	-8.233		-8.317	-1.261		-1.257	-1.133		-1.130
	(0.054)***		(0.048)***	(0.072)		(0.062)	(1.209)***		(1.374)***	(0.186)***		(0.159)***	(0.176)***		(0.151)***
Block 4	0.097		0.096	-0.283		-0.283	-5.929		-6.209	-0.348		-0.366	-0.342		-0.368
	(0.042)**		(0.048)**	(0.049)***		(0.063)***	(1.406)***		(1.398)***	(0.134)***		(0.160)**	(0.139)**		(0.152)**
Observations	35,366	35,366	35,366	34,773	34,773	34,773	34,773	34,773	34,773	35,363	35,363	35,363	35,363	35,363	35,363
R^2	0.423			0.374			0.369			0.930			0.934		
Adjusted R^2	0.422			0.374			0.369			0.930			0.934		
Log Likelihood		24,924.380	24,901.420		25,084.100	25,062.280		-92,410.630	-92,385.440		-72,113.650	-72,077.400		-68,212.450	-68,178.900
Akaike Inf. Crit.		-49,794.760	-49,760.840		-50,114.200	-50,082.560		184,875.300	184,812.900		144,281.300	144,196.800		136,478.900	136,399.800
Bayesian Inf. Crit.		-49,565.970	-49,582.910		-49,885.870	-49,904.980		185,103.600	184,990.500		144,510.100	144,374.700		136,707.700	136,577.700
Residual Std. Error	0.175 (df = 35347)			0.203 (df = 34754)			4.984 (df = 34754)			1.898 (df = 35344)			1.705 (df = 35344)		
F Statistic	1,437.247*** (df = 18; 35347)			1,154.597*** (df = 18; 34754)			1,131.303*** (df = 18; 34754)			25,951.180*** (df = 18; 35344)			27,610.210*** (df = 18; 35344)		
Note:													*p<0.1; **p<0.05; ***p<0.01		

Table 15: Results of the regression analysis for all the blocks (vegetative period)

Regression results for observations in vegetative period

	Dependent variable:														
	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.118	0.108	0.108	0.102	0.087	0.093	-4.454	-3.715	-3.985	0.056	0.080	0.081	0.004	0.015	0.016
	(0.052)**	(0.065)*	(0.048)**	(0.074)	(0.075)	(0.064)	(1.737)**	(2.564)	(1.585)**	(0.100)	(0.120)	(0.126)	(0.113)	(0.156)	(0.138)
Retainer	0.069	0.059	0.059	0.092	0.075	0.081	-4.447	-3.735	-4.005	-0.389	-0.342	-0.342	-0.402	-0.360	-0.360
	(0.054)	(0.077)	(0.048)	(0.074)	(0.121)	(0.064)	(1.776)**	(2.243)*	(1.585)**	(0.137)***	(0.224)	(0.126)***	(0.152)***	(0.203)*	(0.138)**
Mixed	0.049	0.036	0.036	0.022	0.001	0.007	-4.652	-3.806	-4.076	-0.130	-0.087	-0.086	-0.157	-0.119	-0.119
	(0.054)	(0.083)	(0.048)	(0.076)	(0.123)	(0.064)	(1.699)***	(2.617)	(1.585)**	(0.110)	(0.198)	(0.125)	(0.111)	(0.169)	(0.137)
Block 2	0.185		0.198	-0.030		-0.018	-4.516		-5.070	-2.128		-2.179	-2.070		-2.115
	(0.044)***		(0.048)***	(0.050)		(0.062)	(1.532)***		(1.558)***	(0.128)***		(0.125)***	(0.139)***		(0.137)***
Block 3	0.183		0.183	-0.030		-0.031	-6.170		-6.186	-2.232		-2.236	-2.210		-2.214
	(0.052)***		(0.048)***	(0.071)		(0.062)	(1.172)***		(1.557)***	(0.126)***		(0.125)***	(0.143)***		(0.137)***
Block 4	0.125		0.129	-0.224		-0.213	-2.475		-2.787	-2.208		-2.229	-2.280		-2.309
	(0.042)***		(0.048)***	(0.049)***		(0.064)***	(1.469)*		(1.585)*	(0.132)***		(0.126)***	(0.137)***		(0.138)***
Observations	11,886	11,886	11,886	11,687	11,687	11,687	11,687	11,687	11,687	11,884	11,884	11,884	11,884	11,884	11,884
R^2	0.301			0.240			0.296			0.688			0.760		
Adjusted R^2	0.300			0.239			0.295			0.688			0.760		
Log Likelihood		15,162.880	15,139.570		11,347.230	11,326.870		-28,236.500	-28,222.670		-20,880.220	-20,879.040		-19,326.880	-19,322.340
Akaike Inf. Crit.		-30,271.760	-30,253.150		-22,640.470	-22,627.740		56,526.990	56,471.350		41,814.440	41,784.080		38,707.770	38,670.690
Bayesian Inf. Crit.		-30,072.410	-30,157.180		-22,441.580	-22,531.990		56,725.880	56,567.100		42,013.780	41,880.050		38,907.110	38,766.650
Residual Std. Error	0.145 (df = 11875)			0.191 (df = 11676)			4.816 (df = 11676)			1.425 (df = 11873)			1.268 (df = 11873)		
F Statistic	510.416*** (df = 10; 11875)			367.891*** (df = 10; 11676)			490.826*** (df = 10; 11676)			2,615.293*** (df = 10; 11873)			3,759.702*** (df = 10; 11873)		
Note:													*p<0.1; **p<0.05; ***p<0.01		

Table 16: Results of the regression analysis for all the blocks (no vegetative period)

Regression results for observations out of vegetative period

	Dependent variable:														
	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.110	0.096	0.096	0.100	0.075	0.081	-4.102	-3.701	-3.843	0.140	0.057	0.058	0.113	0.027	0.027
	(0.052)**	(0.056)*	(0.049)*	(0.076)	(0.080)	(0.064)	(1.492)***	(1.820)**	(1.391)***	(0.169)	(0.345)	(0.241)	(0.162)	(0.315)	(0.228)
Retainer	0.060	0.048	0.048	0.086	0.061	0.067	-3.973	-3.655	-3.797	0.679	0.553	0.554	0.686	0.562	0.563
	(0.054)	(0.066)	(0.049)	(0.073)	(0.109)	(0.064)	(1.544)**	(1.400)***	(1.391)***	(0.236)***	(0.391)	(0.241)**	(0.227)***	(0.395)	(0.228)**
Mixed	0.036	0.023	0.023	-0.011	-0.036	-0.030	-4.874	-4.485	-4.627	0.877	0.790	0.791	0.887	0.803	0.804
	(0.054)	(0.081)	(0.049)	(0.078)	(0.126)	(0.064)	(1.602)***	(2.231)**	(1.391)***	(0.238)***	(0.356)**	(0.241)***	(0.224)***	(0.351)**	(0.228)***
Block 2	0.167		0.182	-0.129		-0.117	-7.835		-8.277	-0.698		-0.585	-0.632		-0.524
	(0.047)***		(0.049)***	(0.054)**		(0.063)*	(1.530)***		(1.367)***	(0.203)***		(0.241)**	(0.195)***		(0.228)**
Block 3	0.160		0.160	-0.130		-0.134	-9.312		-9.454	-0.746		-0.729	-0.564		-0.549
	(0.056)***		(0.049)***	(0.073)*		(0.063)**	(1.313)***		(1.367)***	(0.267)***		(0.241)***	(0.251)**		(0.228)**
Block 4	0.083		0.081	-0.314		-0.317	-7.668		-7.952	0.591		0.579	0.637		0.615
	(0.044)*		(0.049)	(0.050)***		(0.064)***	(1.464)***		(1.391)***	(0.185)***		(0.241)**	(0.184)***		(0.228)***
Observations	23,480	23,480	23,480	23,086	23,086	23,086	23,086	23,086	23,086	23,479	23,479	23,479	23,479	23,479	23,479
R^2	0.282			0.327			0.424			0.894			0.905		
Adjusted R^2	0.281			0.327			0.424			0.893			0.905		
Log Likelihood		13,438.310	13,416.190		15,564.000	15,542.480		-60,909.050	-60,888.910		-48,534.280	-48,511.700		-45,489.540	-45,468.870
Akaike Inf. Crit.		-26,822.620	-26,798.390		-31,074.000	-31,050.960		121,872.100	121,811.800		97,122.560	97,057.400		91,033.080	90,971.730
Bayesian Inf. Crit.		-26,604.900	-26,661.310		-30,856.740	-30,914.170		122,089.400	121,948.600		97,340.280	97,194.480		91,250.800	91,108.810
Residual Std. Error	0.188 (df = 23465)			0.208 (df = 23071)			4.950 (df = 23071)			2.000 (df = 23464)			1.771 (df = 23464)		
F Statistic	657.668*** (df = 14; 23465)			801.920*** (df = 14; 23071)			1,213.235*** (df = 14; 23071)			14,061.710*** (df = 14; 23464)			15,930.290*** (df = 14; 23464)		
Note:													*p<0.1; **p<0.05; ***p<0.01		

The results of the regressions for the different blocks (all the months and vegetative and no vegetative months) are shown in the following tables.

Table 17: Results of the regression analysis for block 1

Regression results for all observations Block 1

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.149	0.153	0.153	0.013	0.017	0.017	-5.919	-5.876	-5.876	0.011	0.026	0.026	-0.033	-0.017	-0.017
	(0.078)*	(0.101)	(0.110)	(0.072)	(0.078)	(0.111)	(2.271)***	(2.683)**	(2.763)*	(0.199)	(0.309)	(0.361)	(0.171)	(0.294)	(0.369)
Retainer	-0.051	-0.045	-0.045	-0.100	-0.096	-0.096	-3.794	-3.888	-3.889	0.009	0.028	0.028	0.048	0.063	0.063
	(0.117)	(0.108)	(0.110)	(0.085)	(0.083)	(0.111)	(2.519)	(2.317)*	(2.763)	(0.412)	(0.444)	(0.361)	(0.432)	(0.405)	(0.369)
Mixed	0.004	0.010	0.010	-0.249	-0.246	-0.246	-9.336	-9.432	-9.433	0.629	0.647	0.647	0.752	0.766	0.766
	(0.091)	(0.104)	(0.110)	(0.118)**	(0.157)	(0.111)**	(2.422)***	(2.539)***	(2.763)***	(0.243)***	(0.300)**	(0.361)	(0.176)***	(0.297)***	(0.369)*
Block 2	-0.046		-0.049	-0.053		-0.059	-3.467		-3.568	0.205		0.195	0.185		0.174
	(0.068)		(0.078)	(0.069)		(0.079)	(1.699)**		(1.954)*	(0.226)		(0.255)	(0.231)		(0.261)
Block 3	0.023		0.023	0.009		0.009	-0.757		-0.757	0.435		0.435	0.157		0.157
	(0.005)***		(0.005)***	(0.003)***		(0.004)**	(0.296)**		(0.183)***	(0.038)***		(0.086)***	(0.039)***		(0.075)**
Block 4	-0.063		-0.063	-0.023		-0.023	1.401		1.401	1.743		1.743	1.197		1.197
	(0.006)***		(0.005)***	(0.007)***		(0.004)***	(0.455)***		(0.178)***	(0.114)***		(0.083)***	(0.104)***		(0.073)***
Observations	9,101	9,101	9,101	9,101	9,101	9,101	9,101	9,101	9,101	9,098	9,098	9,098	9,098	9,098	9,098
R^2	0.441			0.429			0.424			0.934			0.937		
Adjusted R^2	0.440			0.428			0.423			0.934			0.937		
Log Likelihood		8,941.841	8,927.746		9,845.840	9,825.415		-24,142.760	-24,115.560		-17,267.300	-17,229.550		-16,096.180	-16,059.340
Akaike Inf. Crit.		-17,849.680	-17,819.490		-19,657.680	-19,614.830		48,319.510	48,267.120		34,568.610	34,495.110		32,226.360	32,154.690
Bayesian Inf. Crit.		-17,728.710	-17,691.430		-19,536.710	-19,486.770		48,440.490	48,395.180		34,689.570	34,623.160		32,347.330	32,282.740
Residual Std. Error	0.159 (df = 9085)			0.155 (df = 9085)			4.717 (df = 9085)			1.656 (df = 9082)			1.472 (df = 9082)		
F Statistic	476.953*** (df = 15; 9085)			455.554*** (df = 15; 9085)			446.097*** (df = 15; 9085)			8,550.372*** (df = 15; 9082)			9,062.045*** (df = 15; 9082)		
Note:															*p<0.1; **p<0.05; ***p<0.01

Table 18: Results of the regression analysis for block 1 (vegetative period)

Regression results for observations in vegetative period Block 1

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.151	0.152	0.152	0.029	0.030	0.030	-5.966	-5.945	-5.945	-0.037	-0.039	-0.039	-0.079	-0.080	-0.080
	(0.071)**	(0.095)	(0.100)	(0.065)	(0.072)	(0.099)	(1.784)***	(2.621)**	(2.450)**	(0.112)	(0.239)	(0.294)	(0.131)	(0.306)	(0.345)
Retainer	-0.053	-0.051	-0.051	-0.090	-0.088	-0.088	-3.151	-3.182	-3.181	-1.026	-1.027	-1.027	-0.934	-0.936	-0.936
	(0.102)	(0.101)	(0.100)	(0.075)	(0.078)	(0.099)	(2.596)	(2.255)	(2.450)	(0.321)***	(0.265)***	(0.294)***	(0.387)**	(0.286)***	(0.345)**
Mixed	0.003	0.005	0.005	-0.206	-0.204	-0.204	-6.644	-6.675	-6.674	-0.527	-0.529	-0.529	-0.404	-0.406	-0.406
	(0.087)	(0.101)	(0.100)	(0.109)*	(0.142)	(0.099)*	(1.516)***	(1.964)***	(2.450)**	(0.166)***	(0.272)*	(0.294)*	(0.174)**	(0.344)	(0.345)
Block 2	-0.047		-0.048	-0.051		-0.053	-3.746		-3.760	0.219		0.218	0.213		0.211
	(0.061)		(0.071)	(0.061)		(0.070)	(1.500)**		(1.732)*	(0.181)		(0.208)	(0.212)		(0.244)
Block 3	0.023		0.023	0.009		0.009	-0.757		-0.757	0.435		0.435	0.157		0.157
	(0.005)***		(0.003)***	(0.003)***		(0.004)**	(0.296)**		(0.158)***	(0.038)***		(0.069)***	(0.039)***		(0.059)***
Block 4	-0.079		-0.082	-0.095		-0.095	-0.656		-0.594	4.453		4.452	4.674		4.676
	(0.008)***		(0.003)***	(0.015)***		(0.003)***	(0.752)		(0.143)***	(0.044)***		(0.062)***	(0.041)***		(0.054)***
Observations	3,127	3,127	3,127	3,127	3,127	3,127	3,127	3,127	3,127	3,125	3,125	3,125	3,125	3,125	3,125
R^2	0.331			0.374			0.386			0.670			0.746		
Adjusted R^2	0.329			0.372			0.385			0.669			0.745		
Log Likelihood		4,401.906	4,389.385		3,756.821	3,742.556		-7,868.515	-7,857.288		-5,246.697	-5,241.023		-4,794.788	-4,788.516
Akaike Inf. Crit.		-8,769.812	-8,758.770		-7,479.642	-7,465.113		15,771.030	15,734.580		10,527.390	10,502.050		9,623.576	9,597.033
Bayesian Inf. Crit.		-8,666.999	-8,698.318		-7,376.829	-7,404.660		15,873.840	15,795.030		10,630.200	10,562.490		9,726.378	9,657.479
Residual Std. Error	0.131 (df = 3119)			0.137 (df = 3119)			4.127 (df = 3119)			1.327 (df = 3117)			1.179 (df = 3117)		
F Statistic	220.100*** (df = 7; 3119)			265.659*** (df = 7; 3119)			280.038*** (df = 7; 3119)			904.019*** (df = 7; 3117)			1,306.097*** (df = 7; 3117)		
Note:															*p<0.1; **p<0.05; ***p<0.01

Table 19: Results of the regression analysis for block 1 (no vegetative period)

Regression results for observations out of vegetative period Block 1

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.148	0.153	0.153	0.004	0.009	0.009	-5.897	-5.839	-5.839	0.037	0.071	0.071	-0.008	0.026	0.026
	(0.082)*	(0.104)	(0.117)	(0.076)	(0.082)	(0.118)	(2.615)**	(2.792)**	(3.108)*	(0.324)	(0.410)	(0.451)	(0.279)	(0.348)	(0.432)
Retainer	-0.050	-0.041	-0.041	-0.106	-0.101	-0.101	-4.156	-4.293	-4.294	0.556	0.596	0.596	0.568	0.602	0.602
	(0.125)	(0.112)	(0.117)	(0.090)	(0.087)	(0.118)	(2.624)	(2.431)*	(3.108)	(0.515)	(0.585)	(0.451)	(0.504)	(0.516)	(0.432)
Mixed	0.004	0.013	0.013	-0.272	-0.268	-0.268	-10.733	-10.871	-10.872	1.237	1.276	1.277	1.359	1.392	1.392
	(0.095)	(0.107)	(0.117)	(0.122)**	(0.165)	(0.118)**	(2.952)***	(3.185)***	(3.108)***	(0.383)***	(0.419)***	(0.451)**	(0.305)***	(0.384)***	(0.432)***
Block 2	-0.046		-0.050	-0.054		-0.062	-3.323		-3.500	0.196		0.180	0.169		0.151
	(0.073)		(0.082)	(0.073)		(0.084)	(1.910)*		(2.198)	(0.283)		(0.319)	(0.272)		(0.305)
Block 3	-0.062		-0.062	-0.041		-0.041	0.419		0.419	3.075		3.075	2.713		2.713
	(0.011)***		(0.005)***	(0.006)***		(0.004)***	(0.473)		(0.171)**	(0.096)***		(0.087)***	(0.092)***		(0.076)***
Block 4	-0.173		-0.173	-0.122		-0.122	0.936		0.936	6.479		6.479	5.719		5.719
	(0.011)***		(0.005)***	(0.010)***		(0.004)***	(0.759)		(0.169)***	(0.267)***		(0.086)***	(0.244)***		(0.075)***
Observations	5,974	5,974	5,974	5,974	5,974	5,974	5,974	5,974	5,974	5,973	5,973	5,973	5,973	5,973	5,973
R^2	0.306			0.404			0.438			0.909			0.919		
Adjusted R^2	0.305			0.402			0.437			0.909			0.919		
Log Likelihood		5,188.470	5,174.858		6,325.049	6,307.871		-15,570.730	-15,553.400		-11,547.570	-11,523.370		-10,743.270	-10,719.640
Akaike Inf. Crit.		-10,342.940	-10,321.720		-12,616.100	-12,587.740		31,175.450	31,134.800		23,129.140	23,074.740		21,520.540	21,467.270
Bayesian Inf. Crit.		-10,229.120	-10,228.010		-12,502.280	-12,494.040		31,289.270	31,228.510		23,242.960	23,168.440		21,634.350	21,560.970
Residual Std. Error	0.171 (df = 5962)			0.163 (df = 5962)			4.897 (df = 5962)			1.739 (df = 5961)			1.534 (df = 5961)		
F Statistic	238.989*** (df = 11; 5962)			366.661*** (df = 11; 5962)			422.132*** (df = 11; 5962)			5,398.352*** (df = 11; 5961)			6,119.609*** (df = 11; 5961)		
Note:															*p<0.1; **p<0.05; ***p<0.01

Table 20: Results of the regression analysis for block 2

Regression results for all observations Block 2

	Dependent variable:														
		log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40	
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	-0.052	-0.062	-0.062	0.132	0.077	0.077	-6.960	-5.107	-5.106	-0.242	-0.279	-0.278	-0.250	-0.303	-0.300
	(0.031)*	(0.052)	(0.061)	(0.118)	(0.082)	(0.107)	(4.168)*	(4.212)	(3.151)	(0.189)	(0.271)	(0.227)	(0.122)**	(0.208)	(0.173)
Retainer	-0.064	-0.074	-0.074	0.082	0.027	0.027	-6.225	-4.370	-4.369	0.400	0.362	0.363	0.456	0.403	0.406
	(0.033)*	(0.055)	(0.061)	(0.140)	(0.177)	(0.107)	(4.418)	(3.395)	(3.151)	(0.141)***	(0.164)**	(0.227)	(0.149)***	(0.164)**	(0.173)**
Mixed	-0.195	-0.205	-0.205	-0.050	-0.105	-0.105	-6.933	-5.078	-5.077	0.104	0.065	0.067	0.077	0.024	0.026
	(0.077)**	(0.052)***	(0.061)***	(0.122)	(0.079)	(0.107)	(4.116)*	(3.107)	(3.151)	(0.219)	(0.178)	(0.227)	(0.161)	(0.128)	(0.173)
Block 2	-0.019		-0.024	-0.057		-0.085	1.762		2.697	-0.124		-0.142	-0.106		-0.131
	(0.041)		(0.043)	(0.057)		(0.076)	(1.516)		(2.228)	(0.152)		(0.160)	(0.111)		(0.121)
Block 3	0.007		0.007	0.011		0.011	-0.150		-0.159	0.665		0.665	0.332		0.332
	(0.002)***		(0.007)	(0.003)***		(0.007)	(0.167)		(0.193)	(0.066)***		(0.094)***	(0.059)***		(0.082)***
Block 4	-0.135		-0.135	-0.104		-0.104	0.039		0.039	2.559		2.559	1.936		1.936
	(0.009)***		(0.006)***	(0.009)***		(0.007)***	(0.642)		(0.187)	(0.181)***		(0.091)***	(0.164)***		(0.079)***
Observations	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692	8,692
R^2	0.489			0.402			0.266			0.943			0.949		
Adjusted R^2	0.488			0.401			0.265			0.942			0.949		
Log Likelihood		6,191.816	6,174.915		5,553.642	5,536.884		-23,226.760	-23,203.550		-16,971.750	-16,935.530		-15,774.750	-15,740.360
Akaike Inf. Crit.		-12,349.630	-12,313.830		-11,073.280	-11,037.770		46,487.510	46,443.090		33,977.500	33,907.050		31,583.490	31,516.720
Bayesian Inf. Crit.		-12,229.440	-12,186.600		-10,953.090	-10,910.540		46,607.710	46,570.320		34,097.690	34,034.280		31,703.690	31,643.950
Residual Std. Error (df = 8676)	0.139			0.177			5.023			1.711			1.486		
F Statistic (df = 15; 8676)	552.519***			388.380***			209.984***			9,483.311***			10,800.730***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 21: Results of the regression analysis for block 2 (vegetative period)

Regression results for observations in vegetative period Block 2

	Dependent variable:														
		log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40	
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	-0.079	-0.084	-0.084	0.097	0.054	0.054	-7.319	-5.019	-5.022	0.187	0.363	0.348	0.134	0.280	0.273
	(0.034)**	(0.050)*	(0.062)	(0.110)	(0.074)	(0.111)	(4.677)	(5.773)	(3.849)	(0.255)	(0.397)	(0.252)	(0.296)	(0.460)	(0.275)
Retainer	-0.084	-0.089	-0.089	0.041	-0.002	-0.002	-6.886	-4.586	-4.589	-0.135	0.041	0.027	-0.177	-0.031	-0.038
	(0.039)**	(0.059)	(0.062)	(0.139)	(0.194)	(0.111)	(4.970)	(5.607)	(3.849)	(0.229)	(0.366)	(0.252)	(0.216)	(0.265)	(0.275)
Mixed	-0.194	-0.199	-0.199	-0.026	-0.069	-0.069	-8.298	-5.998	-6.001	-0.086	0.089	0.075	-0.139	0.007	0.0003
	(0.073)***	(0.051)***	(0.062)***	(0.111)	(0.078)	(0.111)	(4.551)*	(4.661)	(3.849)	(0.250)	(0.453)	(0.252)	(0.204)	(0.338)	(0.275)
Block 2	-0.024		-0.027	-0.055		-0.077	2.230		3.378	0.083		0.163	0.043		0.113
	(0.040)		(0.044)	(0.064)		(0.079)	(1.917)		(2.721)	(0.136)		(0.177)	(0.159)		(0.194)
Block 3	0.007		0.007	0.011		0.011	-0.150		-0.163	0.665		0.664	0.332		0.331
	(0.002)***		(0.004)	(0.003)***		(0.006)*	(0.167)		(0.140)	(0.066)***		(0.076)***	(0.059)***		(0.067)***
Block 4	-0.049		-0.048	-0.116		-0.113	1.318		1.133	4.810		4.797	5.183		5.172
	(0.013)***		(0.004)***	(0.027)***		(0.006)***	(0.646)**		(0.126)***	(0.105)***		(0.069)***	(0.113)***		(0.060)***
Observations	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962
R^2	0.329			0.179			0.319			0.668			0.759		
Adjusted R^2	0.328			0.177			0.317			0.667			0.759		
Log Likelihood		3,245.513	3,230.062		2,223.040	2,207.669		-7,008.155	-6,997.778		-5,173.667	-5,173.411		-4,776.990	-4,773.532
Akaike Inf. Crit.		-6,457.026	-6,440.123		-4,412.080	-4,395.337		14,050.310	14,015.560		10,381.330	10,366.820		9,587.981	9,567.064
Bayesian Inf. Crit.		-6,355.134	-6,380.214		-4,310.188	-4,335.428		14,152.200	14,075.470		10,483.230	10,426.730		9,689.872	9,626.973
Residual Std. Error (df = 2954)	0.109			0.172			5.001			1.399			1.236		
F Statistic (df = 7; 2954)	207.174***			91.878***			197.599***			850.039***			1,329.982***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 22: Results of the regression analysis for block 2 (no vegetative period)

Regression results for observations out of vegetative period Block 2

	Dependent variable:														
		log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40	
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	-0.037	-0.051	-0.051	0.151	0.089	0.089	-6.748	-5.519	-5.517	-0.460	-0.727	-0.719	-0.441	-0.701	-0.691
	(0.031)	(0.053)	(0.062)	(0.124)	(0.088)	(0.108)	(4.043)*	(3.252)*	(2.916)*	(0.384)	(0.659)	(0.401)	(0.305)	(0.591)	(0.337)*
Retainer	-0.053	-0.066	-0.066	0.104	0.042	0.042	-5.861	-4.630	-4.627	0.668	0.400	0.408	0.780	0.520	0.529
	(0.030)*	(0.053)	(0.062)	(0.142)	(0.169)	(0.108)	(4.311)	(2.527)*	(2.916)	(0.299)**	(0.396)	(0.401)	(0.279)***	(0.396)	(0.337)
Mixed	-0.194	-0.208	-0.208	-0.061	-0.123	-0.123	-6.213	-4.981	-4.978	0.197	-0.071	-0.062	0.189	-0.072	-0.062
	(0.079)**	(0.053)***	(0.062)***	(0.128)	(0.082)	(0.108)	(4.072)	(2.490)**	(2.916)	(0.338)	(0.314)	(0.401)	(0.270)	(0.262)	(0.337)
Block 2	-0.016		-0.023	-0.057		-0.088	1.541		2.169	-0.230		-0.359	-0.180		-0.305
	(0.042)		(0.043)	(0.054)		(0.076)	(1.448)		(2.061)	(0.249)		(0.283)	(0.204)		(0.237)
Block 3	-0.017		-0.017	-0.054		-0.054	-0.815		-0.815	3.556		3.556	3.252		3.252
	(0.010)*		(0.007)**	(0.009)***		(0.007)***	(0.597)		(0.197)***	(0.070)***		(0.096)***	(0.073)***		(0.083)***
Block 4	-0.152		-0.152	-0.189		-0.189	-1.694		-1.694	7.837		7.837	7.053		7.053
	(0.008)***		(0.007)***	(0.010)***		(0.007)***	(0.547)***		(0.195)***	(0.194)***		(0.095)***	(0.192)***		(0.082)***
Observations	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730	5,730
R^2	0.305			0.319			0.234			0.912			0.927		
Adjusted R^2	0.304			0.318			0.233			0.912			0.927		
Log Likelihood		3,404.178	3,386.177		3,513.737	3,497.086		-15,564.760	-15,547.820		-11,448.110	-11,425.380		-10,582.520	-10,562.170
Akaike Inf. Crit.		-6,774.355	-6,744.355		-6,993.473	-6,966.171		31,163.520	31,123.640		22,930.220	22,878.750		21,199.030	21,152.340
Bayesian Inf. Crit.		-6,661.246	-6,651.236		-6,880.364	-6,873.052		31,276.620	31,216.760		23,043.330	22,971.870		21,312.140	21,245.460
Residual Std. Error (df = 5718)	0.152			0.177			5.012			1.822			1.563		
F Statistic (df = 11; 5718)	228.024***			243.876***			158.978***			5,414.743***			6,583.429***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 23: Results of the regression analysis for block 3

Regression results for all observations Block 3

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.221	0.221	0.221	0.200	0.200	0.200	-3.099	-3.099	-3.099	0.580	0.580	0.580	0.598	0.598	0.598
	(0.125)*	(0.088)**	(0.115)*	(0.202)	(0.177)	(0.169)	(2.382)	(1.772)*	(2.126)	(0.131)***	(0.361)	(0.434)	(0.131)***	(0.315)*	(0.372)
Retainer	0.264	0.264	0.264	0.312	0.312	0.312	-4.872	-4.872	-4.872	0.857	0.857	0.857	0.821	0.822	0.822
	(0.103)**	(0.114)**	(0.115)**	(0.177)*	(0.145)**	(0.169)*	(2.313)**	(1.772)***	(2.126)**	(0.341)**	(0.375)**	(0.434)*	(0.285)***	(0.304)***	(0.372)**
Mixed	0.251	0.251	0.251	0.332	0.332	0.332	-4.573	-4.572	-4.572	1.042	1.042	1.042	0.909	0.909	0.909
	(0.115)**	(0.140)*	(0.115)*	(0.180)*	(0.136)**	(0.169)*	(2.369)*	(1.772)***	(2.126)*	(0.381)***	(0.392)***	(0.434)**	(0.339)***	(0.385)**	(0.372)**
Block 2	0.017		0.017	-0.036		-0.036	0.279		0.279	-0.148		-0.148	-0.184		-0.184
	(0.070)		(0.082)	(0.103)		(0.120)	(1.289)		(1.503)	(0.263)		(0.307)	(0.225)		(0.263)
Block 3	0.0004		0.0004	0.0005		0.0005	-0.097		-0.097	0.710		0.710	0.453		0.453
	(0.002)		(0.006)	(0.003)		(0.007)	(0.099)		(0.151)	(0.055)***		(0.101)***	(0.054)***		(0.091)***
Block 4	-0.112		-0.112	-0.107		-0.107	-0.777		-0.777	2.614		2.614	2.119		2.119
	(0.016)***		(0.006)***	(0.017)***		(0.006)***	(0.502)		(0.147)***	(0.197)***		(0.098)***	(0.180)***		(0.088)***
Observations	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482	9,482
R^2	0.452			0.361			0.238			0.926			0.932		
Adjusted R^2	0.451			0.360			0.237			0.926			0.932		
Log Likelihood		6,949.062	6,934.635		6,231.609	6,219.103		-23,350.270	-23,329.580		-19,532.880	-19,492.780		-18,505.190	-18,466.970
Akaike Inf. Crit.		-13,864.120	-13,833.270		-12,429.220	-12,402.210		46,734.550	46,695.170		39,099.750	39,021.560		37,044.390	36,969.930
Bayesian Inf. Crit.		-13,742.450	-13,704.470		-12,307.550	-12,273.410		46,856.220	46,823.960		39,221.420	39,150.360		37,166.060	37,098.730
Residual Std. Error (df = 9466)	0.178			0.235			3.763			1.948			1.743		
F Statistic (df = 15; 9466)	520.491***			357.243***			196.989***			7,952.619***			8,603.104***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 24: Results of the regression analysis for block 3 (vegetative period)

Regression results for observations in vegetative period Block 3

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.215	0.215	0.215	0.174	0.174	0.174	-3.926	-3.926	-3.926	0.039	0.039	0.039	-0.018	-0.018	-0.018
	(0.123)*	(0.088)**	(0.115)*	(0.206)	(0.177)	(0.172)	(2.859)	(2.291)*	(2.518)	(0.192)	(0.246)	(0.188)	(0.215)	(0.210)	(0.248)
Retainer	0.283	0.283	0.283	0.337	0.337	0.337	-5.898	-5.898	-5.898	-0.165	-0.165	-0.165	-0.258	-0.258	-0.258
	(0.104)***	(0.109)***	(0.115)**	(0.186)*	(0.149)**	(0.172)*	(2.622)**	(2.043)***	(2.518)**	(0.205)	(0.220)	(0.188)	(0.257)	(0.270)	(0.248)
Mixed	0.251	0.251	0.251	0.336	0.336	0.336	-6.131	-6.131	-6.131	-0.158	-0.158	-0.158	-0.375	-0.375	-0.375
	(0.117)**	(0.130)*	(0.115)*	(0.188)*	(0.139)**	(0.172)*	(2.667)**	(2.049)***	(2.518)**	(0.201)	(0.235)	(0.188)	(0.216)*	(0.237)	(0.248)
Block 2	0.005		0.005	-0.061		-0.061	0.109		0.109	0.025		0.025	-0.083		-0.083
	(0.070)		(0.081)	(0.104)		(0.122)	(1.526)		(1.781)	(0.114)		(0.133)	(0.150)		(0.175)
Block 3	0.0004		0.0004	0.0005		0.0005	-0.097		-0.097	0.710		0.710	0.453		0.453
	(0.002)		(0.003)	(0.003)		(0.005)	(0.099)		(0.160)	(0.055)***		(0.076)***	(0.054)***		(0.067)***
Block 4	-0.035		-0.035	-0.091		-0.091	1.066		1.066	4.460		4.460	4.726		4.726
	(0.005)***		(0.003)***	(0.019)***		(0.005)***	(0.819)		(0.143)***	(0.050)***		(0.068)***	(0.061)***		(0.060)***
Observations	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184	3,184
R^2	0.371			0.303			0.271			0.623			0.706		
Adjusted R^2	0.369			0.301			0.269			0.622			0.705		
Log Likelihood		4,185.731	4,171.692		2,688.021	2,677.676		-8,049.959	-8,038.844		-5,644.056	-5,641.402		-5,263.332	-5,258.249
Akaike Inf. Crit.		-8,337.461	-8,323.385		-5,342.043	-5,335.352		16,133.920	16,097.690		11,322.110	11,302.810		10,560.660	10,536.500
Bayesian Inf. Crit.		-8,234.341	-8,262.751		-5,238.922	-5,274.718		16,237.040	16,158.320		11,425.230	11,363.440		10,663.780	10,597.130
Residual Std. Error (df = 3176)	0.149			0.226			4.199			1.428			1.282		
F Statistic (df = 7; 3176)	267.106***			197.136***			168.274***			748.761***			1,089.397***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 25: Results of the regression analysis for block 3 (no vegetative period)

Regression results for observations out of vegetative period Block 3

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*	*OLS*	*linear mixed-effects*	*linear mixed effects*
	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)	(lm-cluster se)	(lmer)	(lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.224	0.224	0.224	0.213	0.213	0.213	-2.682	-2.682	-2.682	0.854	0.854	0.854	0.910	0.910	0.910
	(0.127)*	(0.087)**	(0.117)*	(0.201)	(0.178)	(0.169)	(2.188)	(1.684)	(2.016)	(0.229)***	(0.563)	(0.676)	(0.245)***	(0.514)*	(0.611)
Retainer	0.254	0.254	0.254	0.300	0.300	0.300	-4.354	-4.354	-4.354	1.373	1.374	1.374	1.367	1.367	1.367
	(0.102)**	(0.117)**	(0.117)*	(0.173)*	(0.143)**	(0.169)	(2.189)**	(1.684)***	(2.016)*	(0.515)***	(0.569)**	(0.676)*	(0.468)***	(0.502)***	(0.611)**
Mixed	0.250	0.251	0.251	0.331	0.331	0.331	-3.785	-3.784	-3.784	1.648	1.650	1.650	1.558	1.559	1.559
	(0.115)**	(0.145)*	(0.117)*	(0.177)*	(0.134)**	(0.169)*	(2.269)*	(1.684)**	(2.016)*	(0.629)***	(0.639)***	(0.676)**	(0.587)***	(0.603)***	(0.611)**
Block 2	0.023		0.023	-0.024		-0.024	0.364		0.365	-0.235		-0.235	-0.235		-0.235
	(0.071)		(0.082)	(0.103)		(0.120)	(1.222)		(1.425)	(0.410)		(0.478)	(0.370)		(0.432)
Block 3	-0.049		-0.049	-0.068		-0.068	0.299		0.299	3.550		3.550	3.278		3.278
	(0.007)***		(0.007)***	(0.011)***		(0.007)***	(0.416)		(0.135)**	(0.126)***		(0.104)***	(0.126)***		(0.092)***
Block 4	-0.192		-0.192	-0.189		-0.189	-0.376		-0.376	7.935		7.935	7.191		7.191
	(0.006)***		(0.007)***	(0.011)***		(0.007)***	(0.397)		(0.134)***	(0.367)***		(0.103)***	(0.355)***		(0.091)***
Observations	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298	6,298
R^2	0.318			0.277			0.215			0.882			0.894		
Adjusted R^2	0.317			0.276			0.214			0.882			0.894		
Log Likelihood		3,716.951	3,701.643		3,781.406	3,767.925		-14,930.520	-14,915.760		-13,282.330	-13,255.440		-12,513.930	-12,488.060
Akaike Inf. Crit.		-7,399.903	-7,375.286		-7,528.812	-7,507.849		29,895.030	29,859.510		26,598.670	26,538.880		25,061.860	25,004.130
Bayesian Inf. Crit.		-7,285.187	-7,280.841		-7,414.096	-7,413.404		30,009.750	29,953.960		26,713.390	26,633.330		25,176.580	25,098.570
Residual Std. Error (df = 6286)	0.191			0.238			3.488			2.125			1.886		
F Statistic (df = 11; 6286)	266.611***			218.811***			156.951***			4,280.699***			4,830.047***		

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 26: Results of the regression analysis for block 4

Regression results for all observations Block 4

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.078	0.082	0.082	0.031	0.042	0.044	-0.275	-0.545	-0.722	0.119	0.118	0.117	-0.023	-0.031	-0.031
	(0.057)	(0.057)	(0.062)	(0.085)	(0.060)	(0.071)	(1.788)	(1.856)	(2.236)	(0.063)*	(0.111)	(0.130)	(0.094)	(0.114)	(0.131)
Retainer	0.049	0.055	0.055	0.034	0.040	0.042	-1.653	-1.402	-1.579	-0.064	-0.062	-0.062	-0.129	-0.129	-0.128
	(0.057)	(0.052)	(0.062)	(0.074)	(0.059)	(0.071)	(0.867)*	(1.822)	(2.236)	(0.097)	(0.111)	(0.130)	(0.100)	(0.097)	(0.131)
Mixed	0.052	0.052	0.052	-0.052	-0.054	-0.052	2.009	2.219	2.042	0.229	0.229	0.229	0.274	0.274	0.274
	(0.067)	(0.058)	(0.062)	(0.079)	(0.059)	(0.071)	(1.252)	(2.095)	(2.236)	(0.118)*	(0.108)**	(0.128)*	(0.142)*	(0.158)*	(0.129)*
Block 2	-0.032		-0.034	0.016		0.014	-3.178		-2.981	0.0005		-0.006	0.108		0.103
	(0.042)		(0.044)	(0.037)		(0.048)	(1.237)**		(1.519)*	(0.081)		(0.092)	(0.088)		(0.093)
Block 3	-0.001		0.001	-0.0002		0.004	-0.039		-0.109	1.066		1.065	0.802		0.800
	(0.003)		(0.008)	(0.003)		(0.007)	(0.162)		(0.192)	(0.030)***		(0.105)***	(0.033)***		(0.090)***
Block 4	-0.109		-0.107	-0.079		-0.074	-2.394		-2.493	3.667		3.667	3.044		3.043
	(0.019)***		(0.008)***	(0.016)***		(0.007)***	(0.686)***		(0.186)***	(0.066)***		(0.102)***	(0.057)***		(0.087)***
Observations	8,091	8,091	8,091	7,498	7,498	7,498	7,498	7,498	7,498	8,091	8,091	8,091	8,091	8,091	8,091
R^2	0.528			0.469			0.400			0.949			0.957		
Adjusted R^2	0.527			0.468			0.399			0.949			0.957		
Log Likelihood		4,755.747	4,742.800		5,610.628	5,595.134		-19,127.080	-19,092.740		-16,102.860	-16,066.600		-14,794.460	-14,760.080
Akaike Inf. Crit.		-9,477.494	-9,449.599		-11,187.260	-11,154.270		38,288.160	38,221.480		32,239.710	32,169.200		29,622.920	29,556.170
Bayesian Inf. Crit.		-9,358.520	-9,323.662		-11,069.580	-11,029.700		38,405.840	38,346.040		32,358.690	32,295.140		29,741.890	29,682.110
Residual Std. Error	0.153 (df = 8075)			0.138 (df = 7482)			3.811 (df = 7482)			1.761 (df = 8075)			1.501 (df = 8075)		
F Statistic	601.007*** (df = 15; 8075)			440.581*** (df = 15; 7482)			333.193*** (df = 15; 7482)			9,985.380*** (df = 15; 8075)			12,000.890*** (df = 15; 8075)		

Note: *p<0.1; **p<0.05; ***p<0.01

Table 27: Results of the regression analysis for block 4 (vegetative period)

Regression results for observations in vegetative period Block 4

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.141	0.147	0.147	0.100	0.116	0.121	0.239	-0.240	-0.572	-0.008	-0.019	-0.019	-0.092	-0.109	-0.111
	(0.075)*	(0.062)**	(0.073)*	(0.101)	(0.073)	(0.086)	(2.835)	(2.585)	(3.175)	(0.089)	(0.154)	(0.179)	(0.116)	(0.147)	(0.170)
Retainer	0.080	0.091	0.091	0.072	0.080	0.084	-2.015	-1.510	-1.842	-0.194	-0.194	-0.191	-0.204	-0.202	-0.200
	(0.073)	(0.062)	(0.073)	(0.083)	(0.070)	(0.086)	(1.314)	(2.557)	(3.176)	(0.115)*	(0.195)	(0.179)	(0.107)*	(0.146)	(0.170)
Mixed	0.089	0.089	0.089	-0.022	-0.028	-0.023	2.959	3.332	3.000	0.273	0.273	0.273	0.304	0.304	0.304
	(0.078)	(0.062)	(0.073)	(0.091)	(0.072)	(0.086)	(1.352)**	(3.031)	(3.175)	(0.183)	(0.174)	(0.174)	(0.171)*	(0.149)**	(0.166)*
Block 2	0.004		-0.005	0.047		0.038	-3.903		-3.655	-0.050		-0.072	0.062		0.040
	(0.051)		(0.052)	(0.047)		(0.058)	(1.616)**		(2.157)	(0.118)		(0.127)	(0.112)		(0.120)
Block 3	0.001		0.004	0.002		0.009	-0.065		-0.189	1.056		1.055	0.796		0.794
	(0.002)		(0.003)	(0.003)		(0.003)***	(0.149)		(0.094)**	(0.031)***		(0.089)***	(0.033)***		(0.078)***
Block 4	-0.011		-0.014	0.0003		-0.006	-0.607		-0.429	4.707		4.709	4.983		4.987
	(0.002)***		(0.003)***	(0.004)		(0.002)***	(0.175)***		(0.081)***	(0.030)***		(0.077)***	(0.032)***		(0.067)***
Observations	2,613	2,613	2,613	2,414	2,414	2,414	2,414	2,414	2,414	2,613	2,613	2,613	2,613	2,613	2,613
R^2	0.250			0.258			0.388			0.625			0.715		
Adjusted R^2	0.248			0.256			0.386			0.624			0.714		
Log Likelihood		3,790.839	3,775.729		4,120.028	4,104.979		-4,470.419	-4,457.884		-4,769.974	-4,766.356		-4,417.955	-4,414.070
Akaike Inf. Crit.		-7,547.677	-7,531.458		-8,206.057	-8,189.959		8,974.838	8,935.767		9,573.948	9,552.712		8,869.911	8,848.140
Bayesian Inf. Crit.		-7,447.917	-7,472.806		-8,107.643	-8,132.102		9,073.252	8,993.625		9,673.708	9,611.364		8,969.671	8,906.792
Residual Std. Error	0.107 (df = 2605)			0.106 (df = 2406)			3.389 (df = 2406)			1.501 (df = 2605)			1.313 (df = 2605)		
F Statistic	124.306*** (df = 7; 2605)			119.397*** (df = 7; 2406)			218.129*** (df = 7; 2406)			619.790*** (df = 7; 2605)			933.406*** (df = 7; 2605)		

Note: *p<0.1; **p<0.05; ***p<0.01

Table 28: Results of the regression analysis for block 4 (no vegetative period)

Regression results for observations out of vegetative period Block 4

Dependent variable:

	log(Hum20)			log(Hum40)			abs(Hum20-Hum40)			Tem20			Tem40		
	OLS (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)	*OLS* (lm-cluster se)	*linear mixed-effects* (lmer)	*linear mixed effects* (lme)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Mycorrhiza	0.048	0.052	0.052	-0.003	0.010	0.008	-0.512	-0.690	-0.815	0.179	0.181	0.181	0.009	0.006	0.007
	(0.048)	(0.060)	(0.062)	(0.079)	(0.059)	(0.068)	(1.339)	(1.663)	(1.975)	(0.103)*	(0.125)	(0.146)	(0.117)	(0.174)	(0.147)
Retainer	0.034	0.038	0.038	0.015	0.023	0.022	-1.517	-1.345	-1.471	-0.002	-0.001	-0.0005	-0.093	-0.095	-0.093
	(0.051)	(0.051)	(0.062)	(0.072)	(0.056)	(0.068)	(0.710)**	(1.664)	(1.975)	(0.126)	(0.126)	(0.146)	(0.124)	(0.135)	(0.147)
Mixed	0.033	0.033	0.033	-0.067	-0.066	-0.067	1.524	1.678	1.553	0.207	0.207	0.207	0.259	0.259	0.259
	(0.067)	(0.063)	(0.062)	(0.076)	(0.057)	(0.068)	(1.337)	(1.787)	(1.974)	(0.128)	(0.121)*	(0.143)	(0.159)	(0.239)	(0.144)
Block 2	-0.049		-0.048	0.001		0.002	-2.844		-2.674	0.025		0.023	0.130		0.130
	(0.042)		(0.044)	(0.035)		(0.046)	(1.155)**		(1.342)*	(0.090)		(0.103)	(0.097)		(0.104)
Block 3	0.021		0.021	0.013		0.013	1.020		1.039	3.934		3.933	3.679		3.679
	(0.014)		(0.009)**	(0.014)		(0.008)	(0.257)***		(0.212)***	(0.102)***		(0.112)***	(0.088)***		(0.095)***
Block 4	-0.232		-0.230	-0.202		-0.194	-2.405		-2.599	9.867		9.871	9.079		9.080
	(0.032)***		(0.009)***	(0.029)***		(0.008)***	(0.565)***		(0.221)***	(0.099)***		(0.116)***	(0.082)***		(0.098)***
Observations	5,478	5,478	5,478	5,084	5,084	5,084	5,084	5,084	5,084	5,478	5,478	5,478	5,478	5,478	5,478
R^2	0.399			0.323			0.343			0.910			0.927		
Adjusted R^2	0.398			0.321			0.342			0.910			0.926		
Log Likelihood		2,495.292	2,482.637		3,132.771	3,117.847		-13,467.320	-13,443.180		-11,234.560	-11,213.510		-10,302.960	-10,284.610
Akaike Inf. Crit.		-4,956.585	-4,937.275		-6,231.543	-6,207.695		26,968.630	26,914.350		22,503.120	22,455.010		20,639.910	20,597.220
Bayesian Inf. Crit.		-4,844.240	-4,844.786		-6,120.467	-6,116.254		27,079.710	27,005.790		22,615.460	22,547.500		20,752.260	20,689.710
Residual Std. Error	0.170 (df = 5466)			0.149 (df = 5072)			3.963 (df = 5072)			1.872 (df = 5466)			1.582 (df = 5466)		
F Statistic	330.230*** (df = 11; 5466)			219.729*** (df = 11; 5072)			241.042*** (df = 11; 5072)			5,052.627*** (df = 11; 5466)			6,274.539*** (df = 11; 5466)		

Note: *p<0.1; **p<0.05; ***p<0.01

We perform a more detailed analysis by running a daily OLS regression. The estimate of the coefficient for the increase of humidity at 20 cm. and 40 cm. and the confidence intervals are graphically displayed. Only the treatment mycorrhiza is significant during most days of the observation period.

Figure 45: Average soil humidity percentage increase at 20 cm. in the observation period (base case "No treatment")

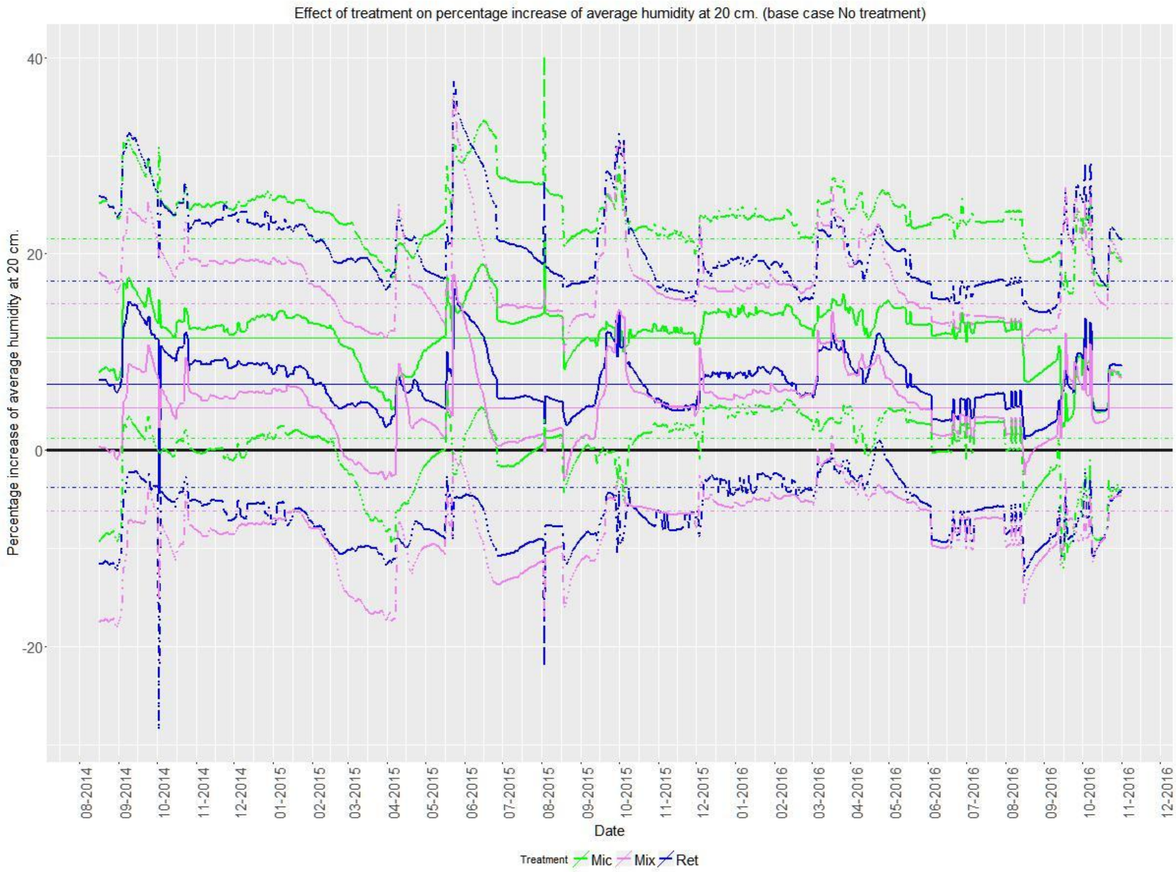
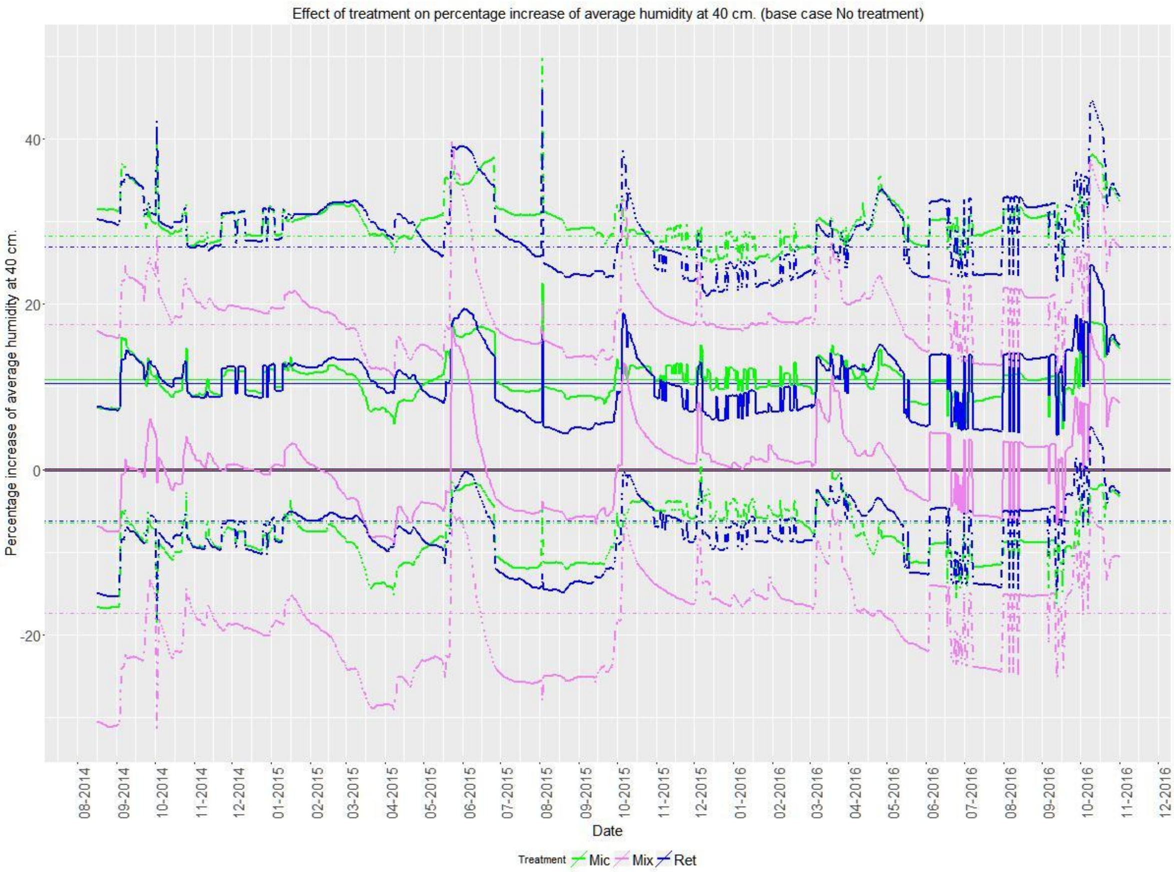


Figure 46: Average soil humidity percentage increase at 40 cm. in the observation period (base case "No treatment")



The treatments seems to be related to a slight increase in humidity at 20 and 40 cm, although we are getting statistically significant results only for mycorrhizas at 20 cm. A possible reason is that there are strong variations due to measurement errors or other unobserved factors, such as individual features of the plants or specific characteristics of the soil surrounding the tree, and we do not have enough observations (only 16 trees by treatment) to achieve significant results.

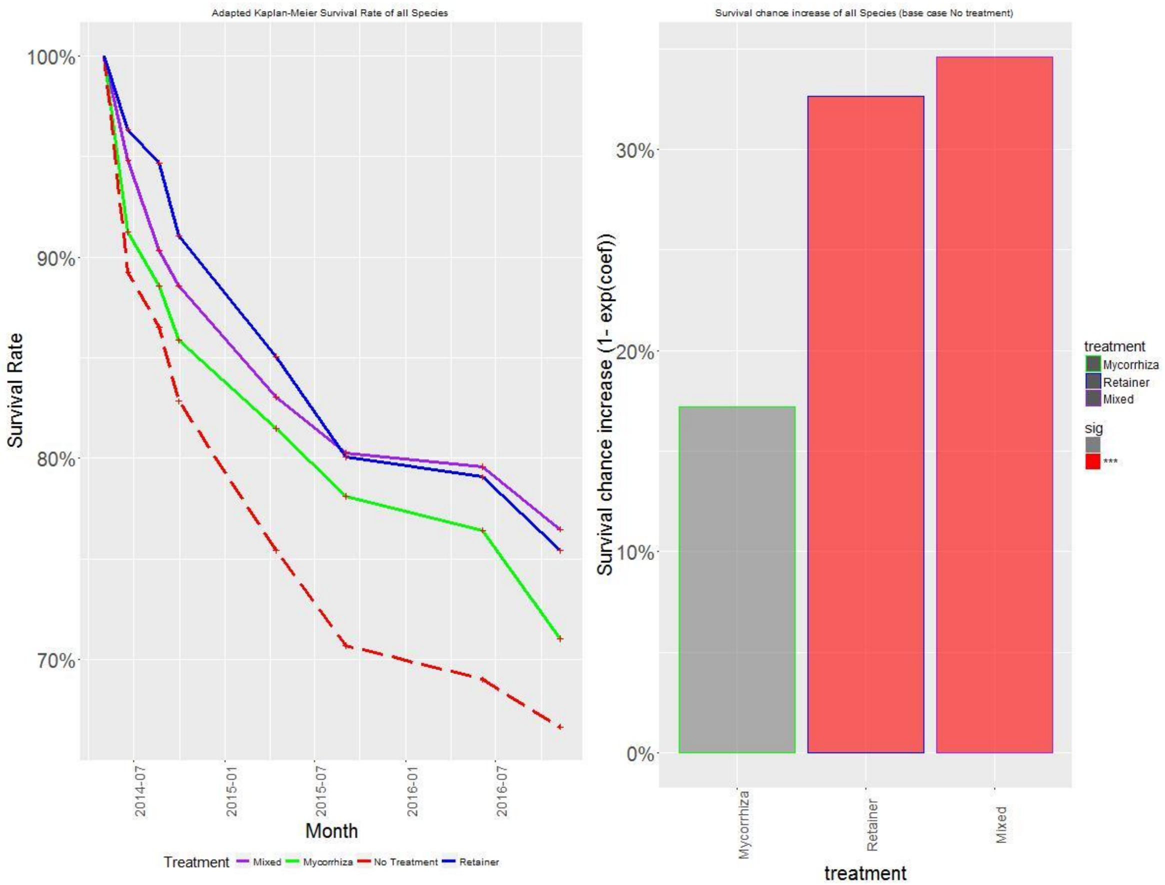
The treatments, particularly using retainers, are also related to an increase in the soil temperature during the no vegetative period, although the value is very small and it is likely that is not practically significant (around 1ºC).

Results of the survival analysis

In the previous sections we have analysed the effect of the treatments in the humidity of soil. It is expected than higher levels of humidity yield better survival rates of the trees. Survival rate is the main outcome of the project. We are interested in knowing whether the treatments are related to higher survival rates of the trees and to analyse how these survival rates change by specie and soil characteristics.

In considering all the species and how the survival rate for all the species change by treatment the results are shown in Figure 47. The survival rate of the trees having "No treatment" is less than 70%, and the different treatments increase the survival rate to 72% (mycorrhiza) and around 76% (retainer and mixed). The increase of the survival rate is statistically significant at the 0.01 level for retainer and mixed.

Figure 47: Survival rate by treatment (all the species)

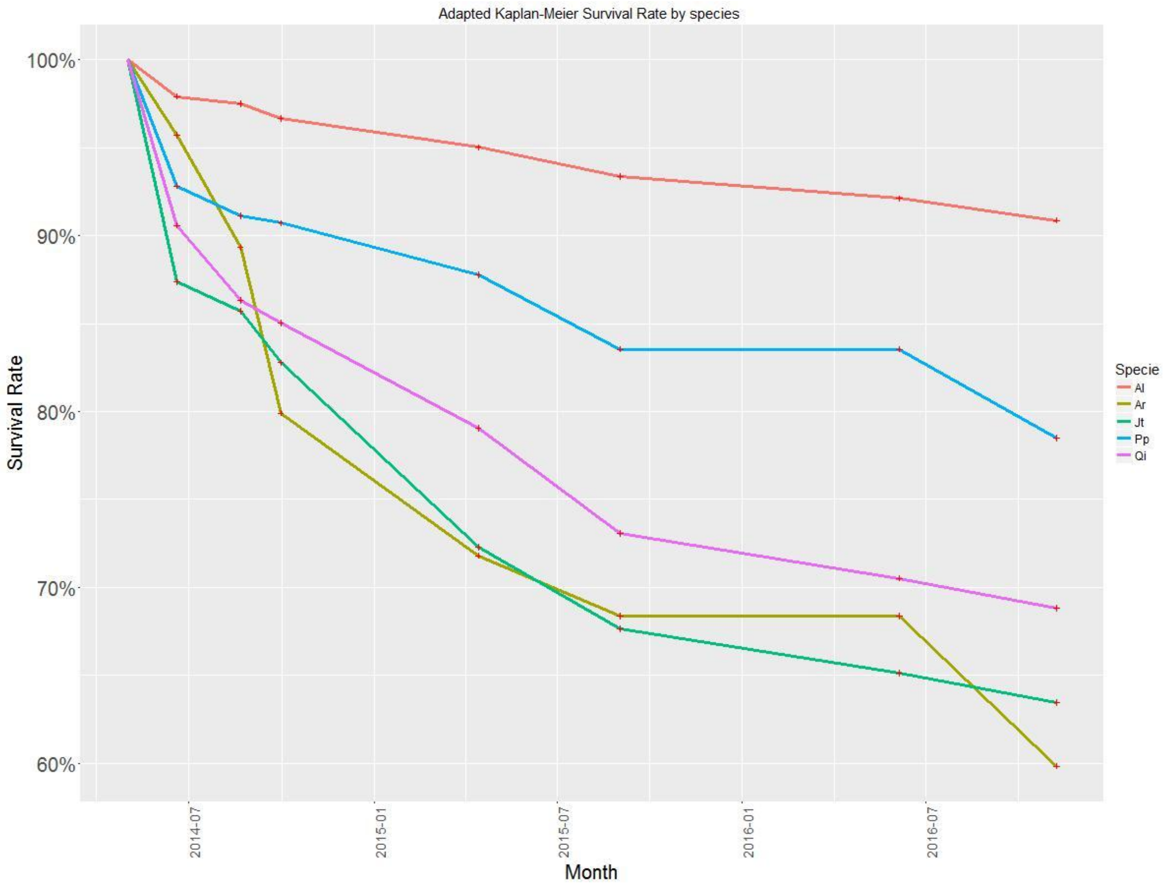


Analysis of the survival results depending on the specie

The next step is to understand how the survival rate changes by specie. We have selected 5 species in the project. There are 78 trees that show a different specie depending on the year of observation (2014, 2015 and 2016), mainly in the Quercus faginea and pirenaica (under certain circumstances it is difficult to differentiate both species). We have decided not to include in the analysis those species due to the high uncertainty of the true specie.

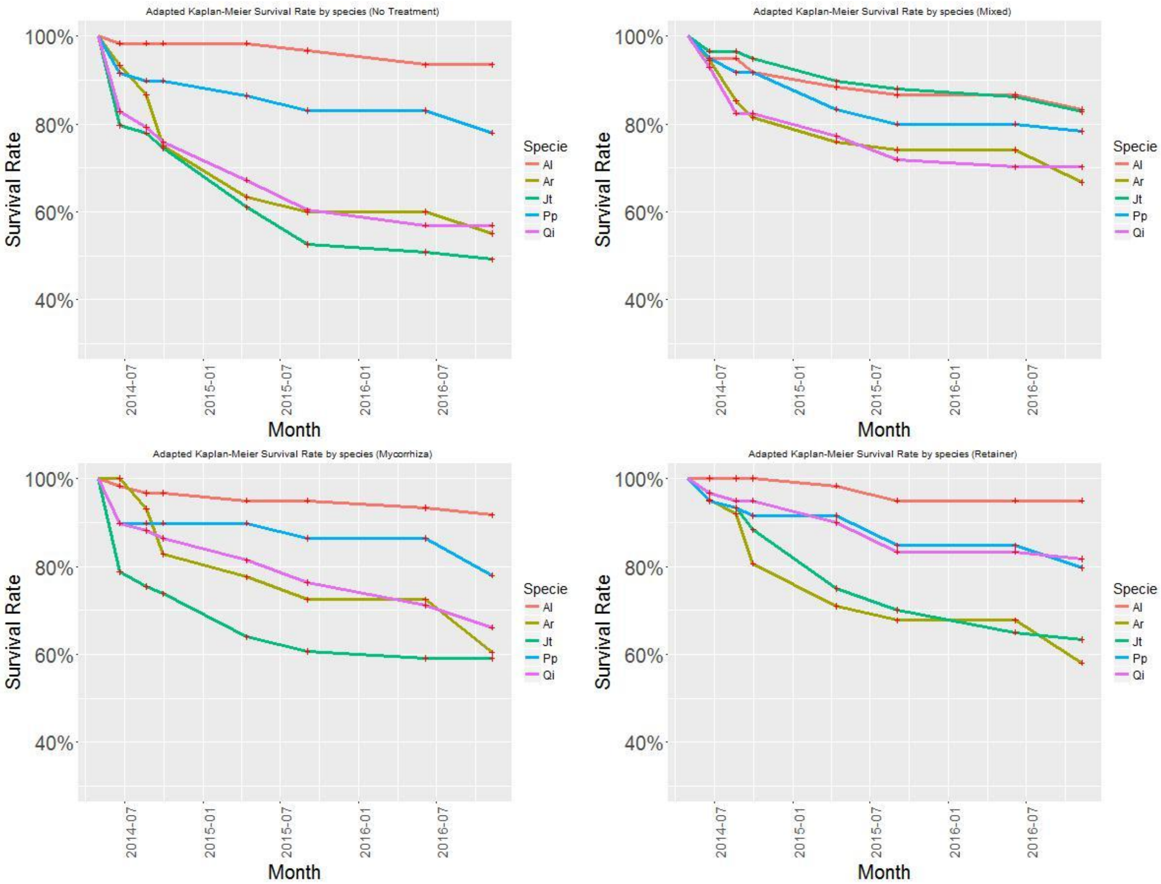
As shown in Figure 48 the survival rate of the different species is very different. For instance, the *Amigdalus communis*, a specie well adapted to the characteristics of the climate in Valladolid shows a very high survival rates, close to 90% while the *Acer campestre*, a much more demanding specie shows a survival rate of 60%. It is worth mentioning the low survival rates of the *Juniperus thurifera* and the *Quercus ilex* although it is supposed that those species are well adapted to dry conditions.

Figure 48: Survival rate by specie (all treatments)



More interesting is to analyse the effect of the treatments on the survival rate of the species as shown in Figure 49. The survival rate seems to increase in many of the species when using the treatments, particularly for the mixed and retainer treatments.

Figure 49: Survival rate by specie depending on treatment

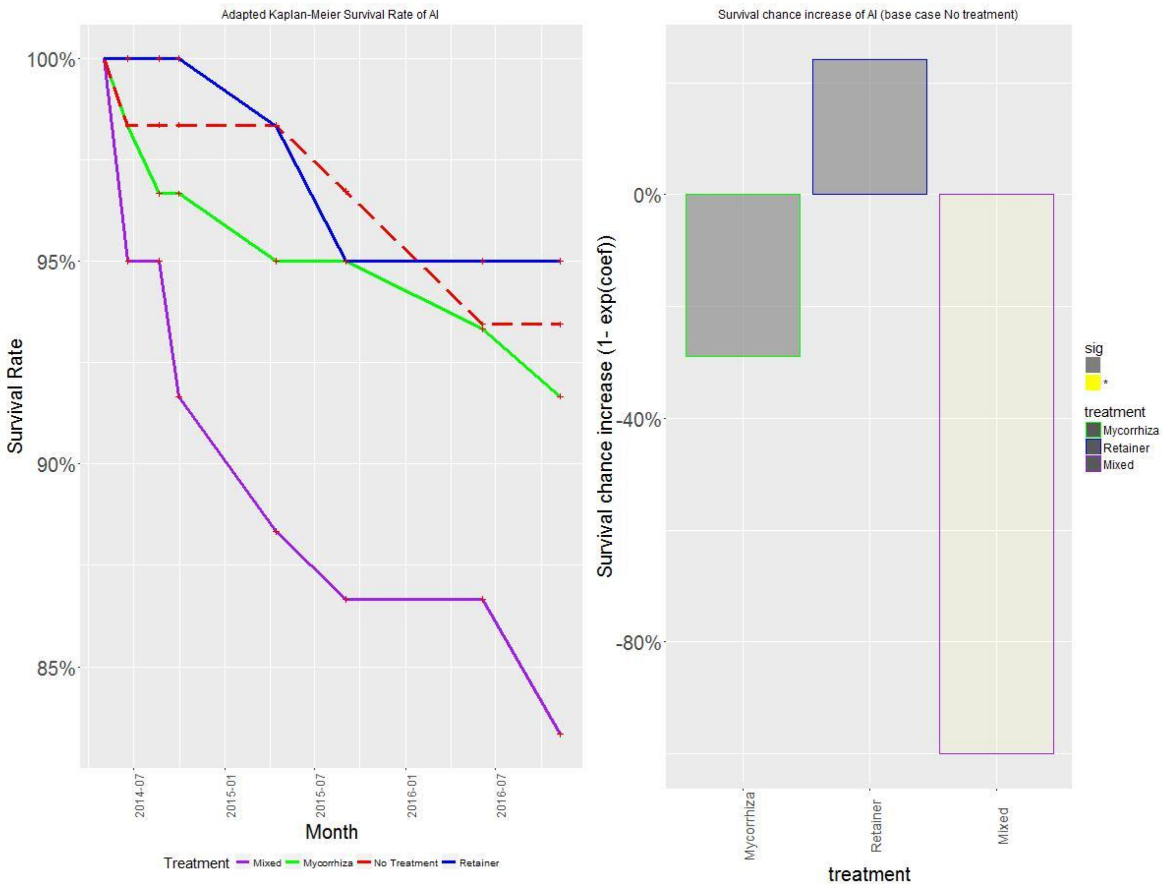


We are going to analyse the effect of the treatments specie by specie and whether or not the survival increase is statistically significant.

Amigdalus communis (Almond)

The survival rate of the *Almonds* and their change of the survival chance depending on the treatments are shown in Figure 50. The *Almond* is the only specie in the study that substantially decreases the survival rate when using some of the treatments although the results are usually not statistically significant. The main conclusion is that treatments do not have any effect in a specie very well adapted to the dry climate conditions of our study.

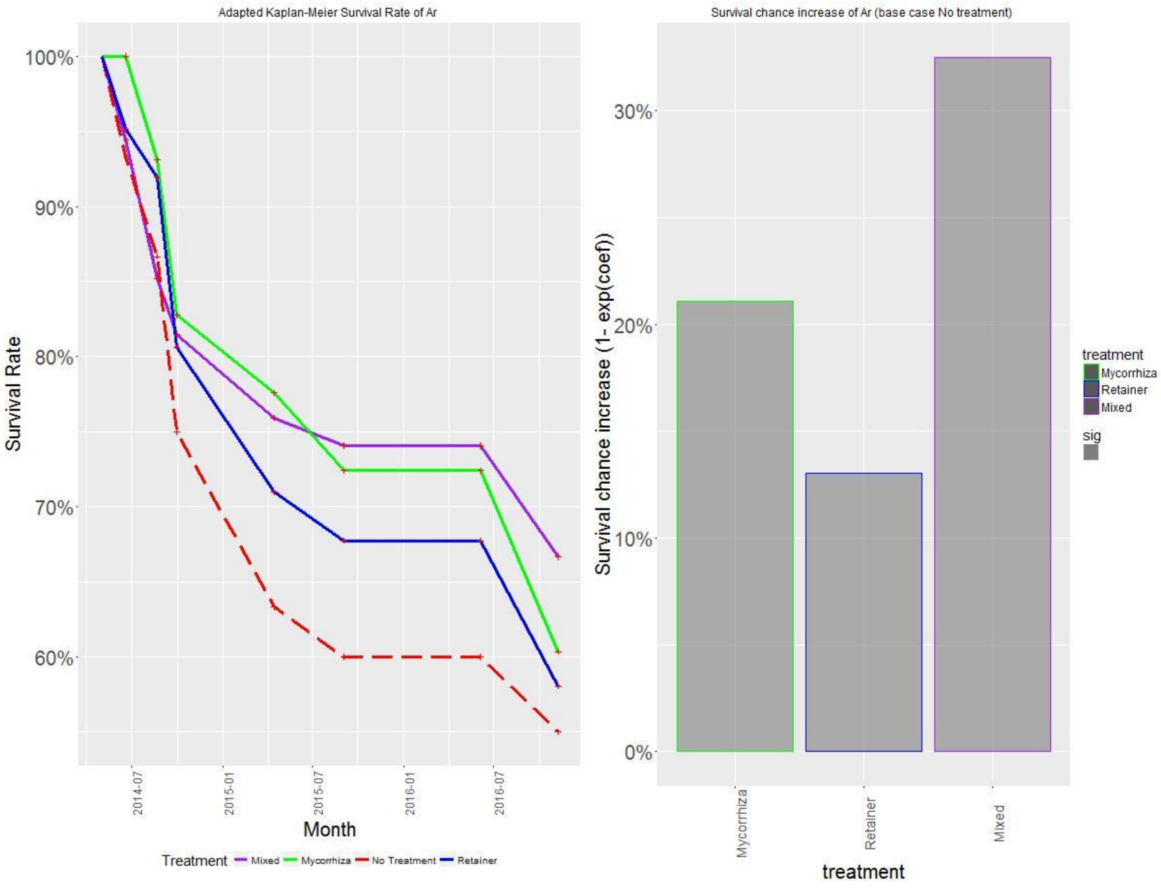
Figure 50: Survival rate of Almond depending on treatment



Acer campestre (Maple)

The survival rate of the *Maples* and their increase of the survival chance depending on the treatments are shown in Figure 51. The *Maple* slightly increases the survival rate when using the treatments although the results are not statistically significant.

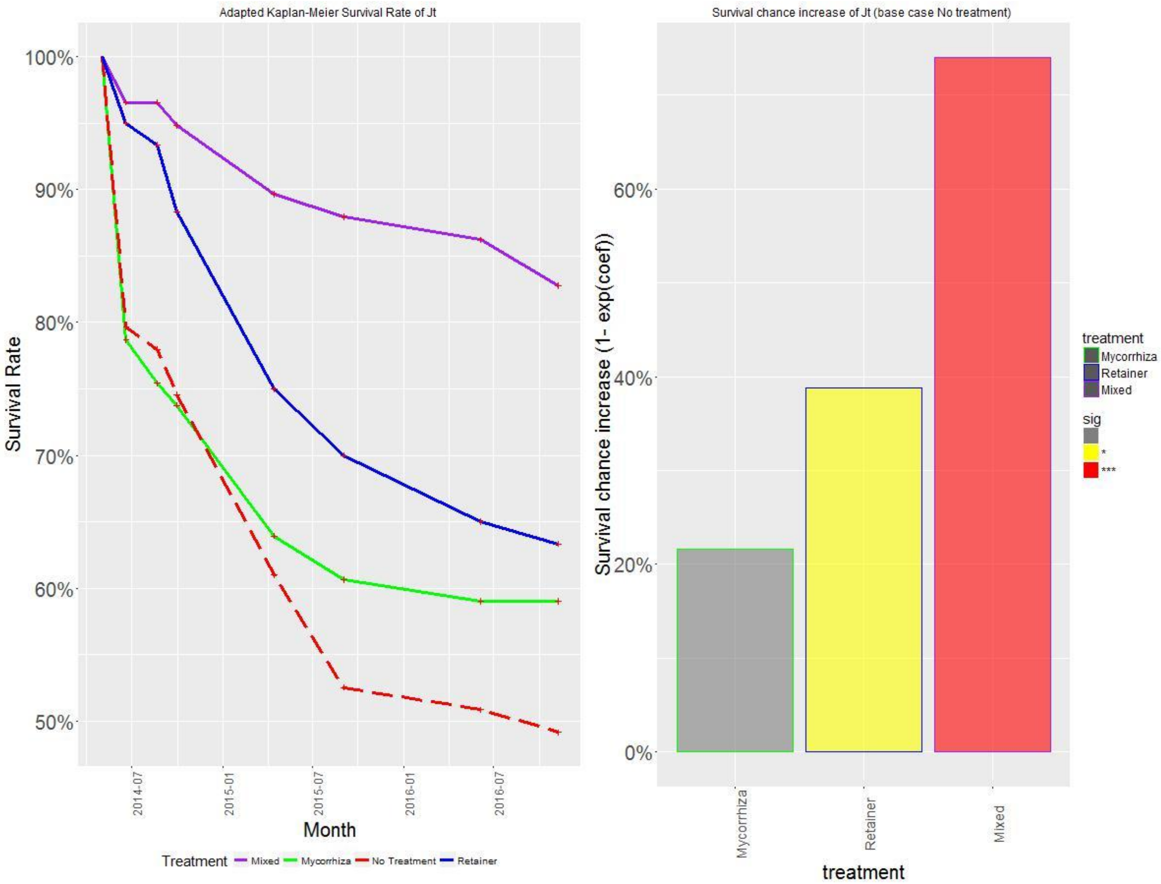
Figure 51: Survival rate of Maple depending on treatment



Juniperus thurifera (Juniper)

The survival rate of the *Junipers* and their increase of the survival chance depending on the treatments are shown in Figure 52. The *Junipers* substantially increase the survival rate when using retainers combined with mycorrhizas and the results are statistically significant at the 0.05 level. However, the results are not significant when using only mycorrhizas.

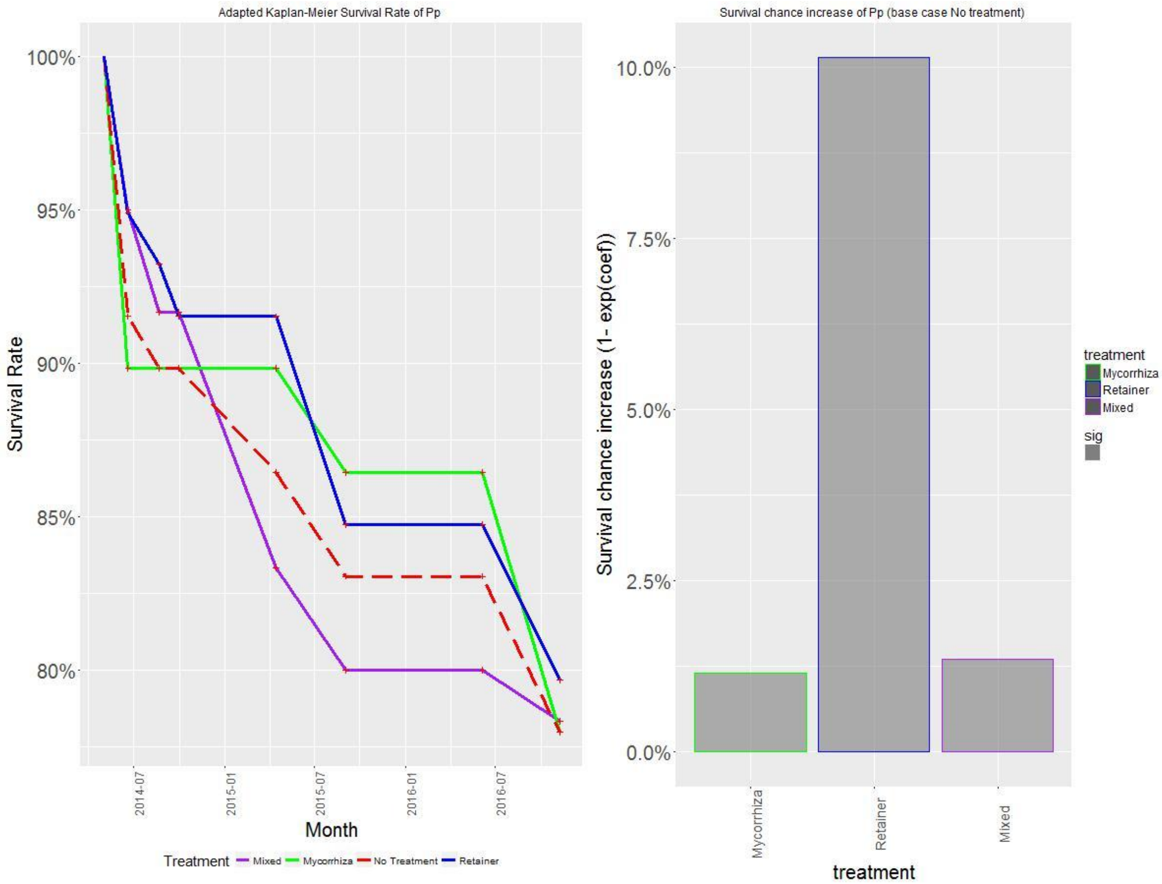
Figure 52: Survival rate of Juniper depending on treatment



Pinus pinea (Pine)

The survival rate of the *Pine* and their increase of the survival chance depending on the treatments are shown in Figure 53. The *Pines* do not significantly change the survival rate when using the treatments.

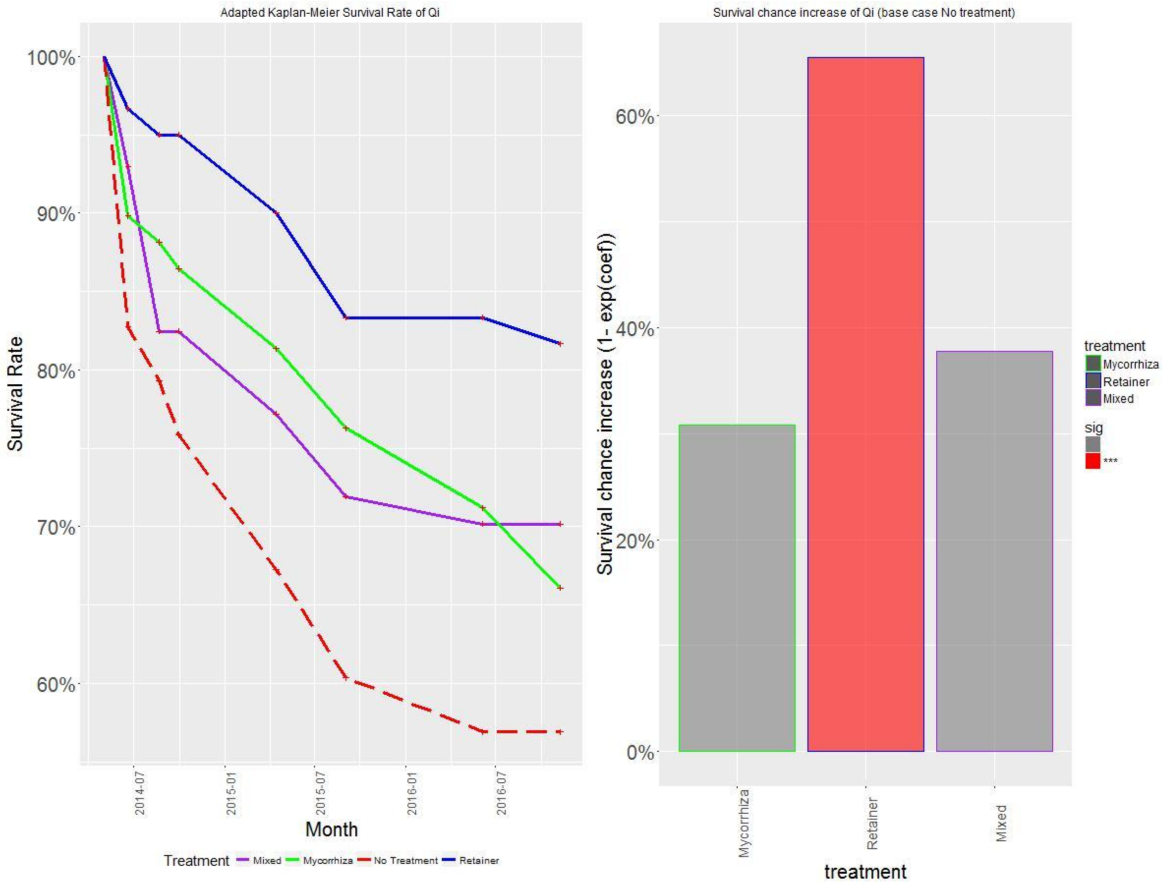
Figure 53: Survival rate of Pine depending on treatment



Quercus ilex (Holm Oak)

The survival rate of the *Holm Oaks* and their increase of the survival chance depending on the treatments are shown in Figure 54. The *Holm Oaks* substantially increase the survival rate when using retainers and the results are statistically significant at the 0.05 level, but only when not combined with mycorrhizas. The results are not statistically significant at the 0.05 level when using mycorrhizas.

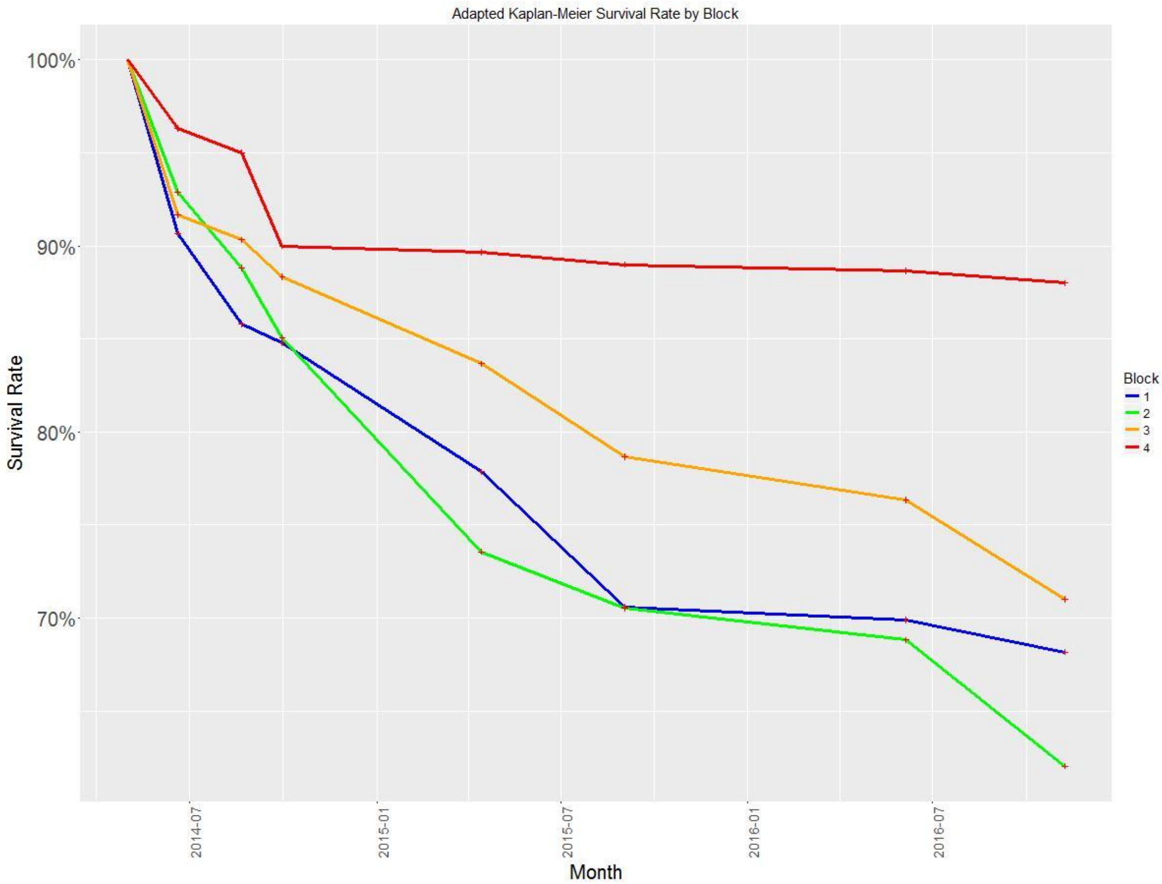
Figure 54: Survival rate of Holm Oak depending on treatment



Analysis of the survival results depending on the block

In analysing the survival rate for all species in the different blocks we see that block 4 has a higher survival rate than blocks 1, 2, and 3 as seen in Figure 55.

Figure 55: Survival rate by block (all species and treatments)



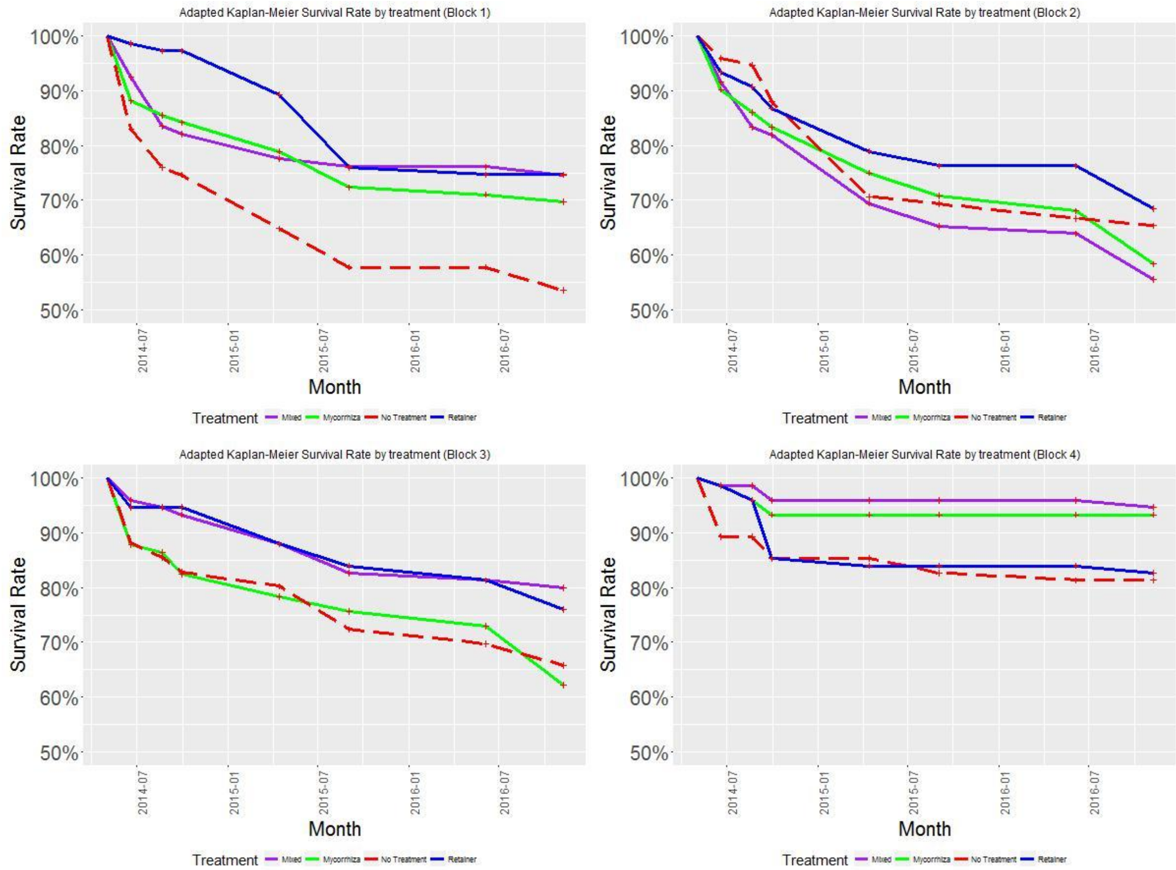
More interesting are the results of comparing the survival rate by treatments in the different blocks as seen in Figure 56.

In block 1 the survival rate when not using treatments is very low, about 50% and the survival rate substantially increases when using the treatments. The difference is higher than 15 percent points for all the treatments. Block 1 is challenging for the survival of the plants and treatments seem to be very effective.

Block 2 and 3 show a similar behaviour. Both have a slightly higher survival rate than block 1 and the treatments do not seem to be so effective.

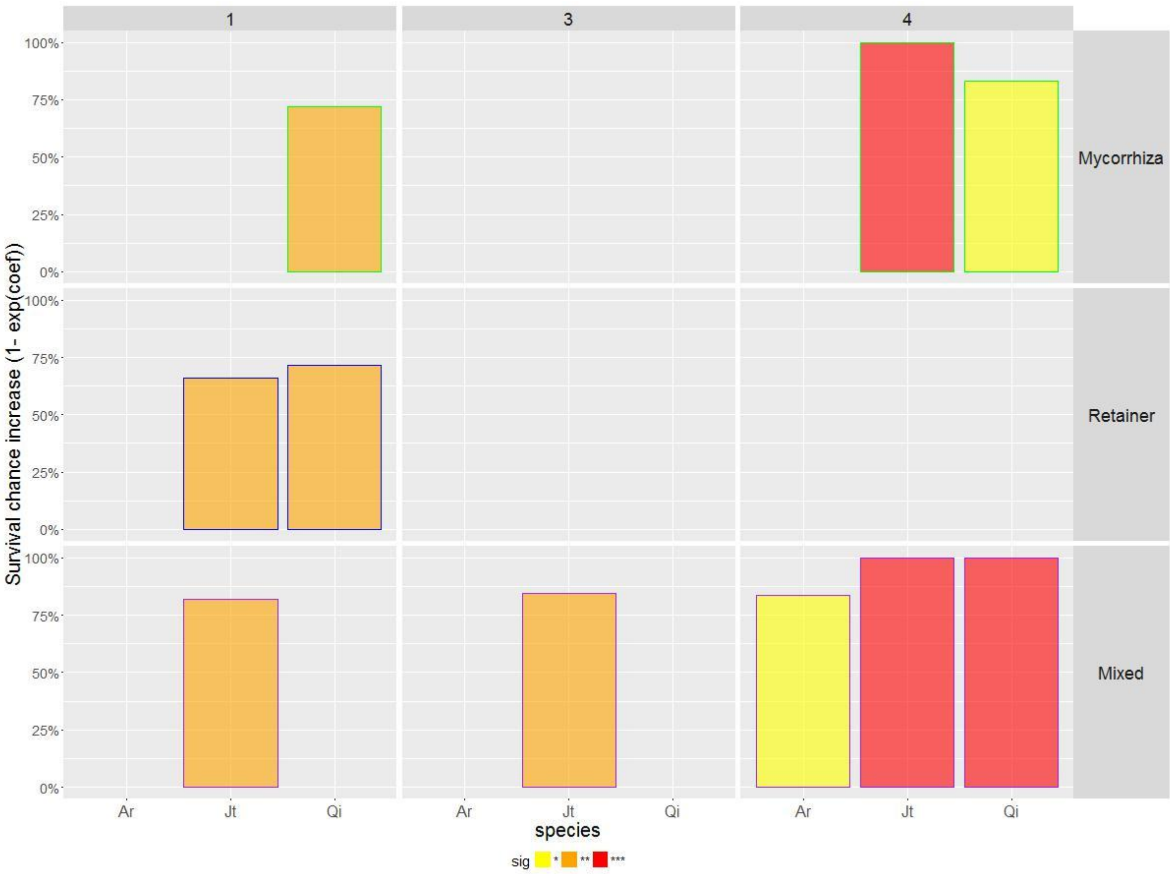
The survival rate in block 4 is very high for all the treatments and when using no treatment, although there is a substantial increase in the survival rate for the mixed treatment compared to no treatment.

Figure 56: Survival rate for different treatments by block (all species)



To check these results we have analysed the increase in the chance of survival for the different species depending on the blocks and whether or not they are statistically significant. The results are shown in Figure 57. We only show the significant results.

Figure 57: Survival chance increase by Block, Treatment and Specie (base case "No treatment")



It is hard to make any valid conclusion considering the combination of species, treatments and blocks. It is likely that when reducing the number of trees, other unobserved effects might hinder the true effect of the treatments, making difficult to assess the results.

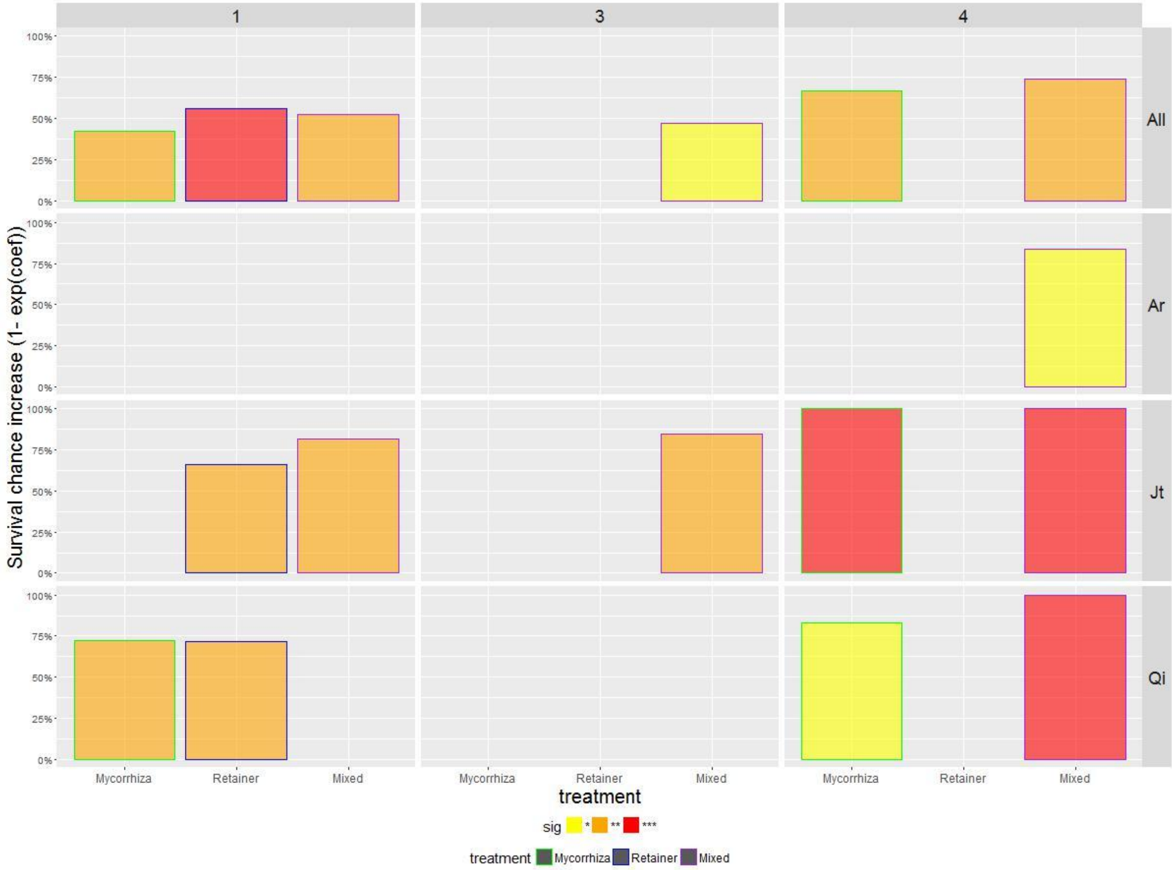
However we observe that in block 1 the treatments are more likely to have a significant effect, followed by block 4. Both blocks show a higher gradient between humidity at the lower and higher levels and it is likely than the treatments help the plants to survive in those circumstances.

Blocks 2 and 3 show higher levels of moisture absorption after the rainfall when using the treatments and therefore we could expect than the treatments might have higher effect in those blocks. However our findings show that the variation of the soil at different depths in blocks 1 and 4 (higher humidity gradient) is likely to be more relevant for the treatments having effect.

Analysis of the survival results by Species depending on the block

We can also study the effects of the treatments on the increase of surviving chance by specie depending on the block. The results are shown in Figure 58.

Figure 58: Increase of the chance depending on Treatment (base case "No treatment") of surviving by Specie and plot



When considering all the species the treatments are only effective in blocks 1 and 4 confirming the findings afore mentioned. Regarding the different species:

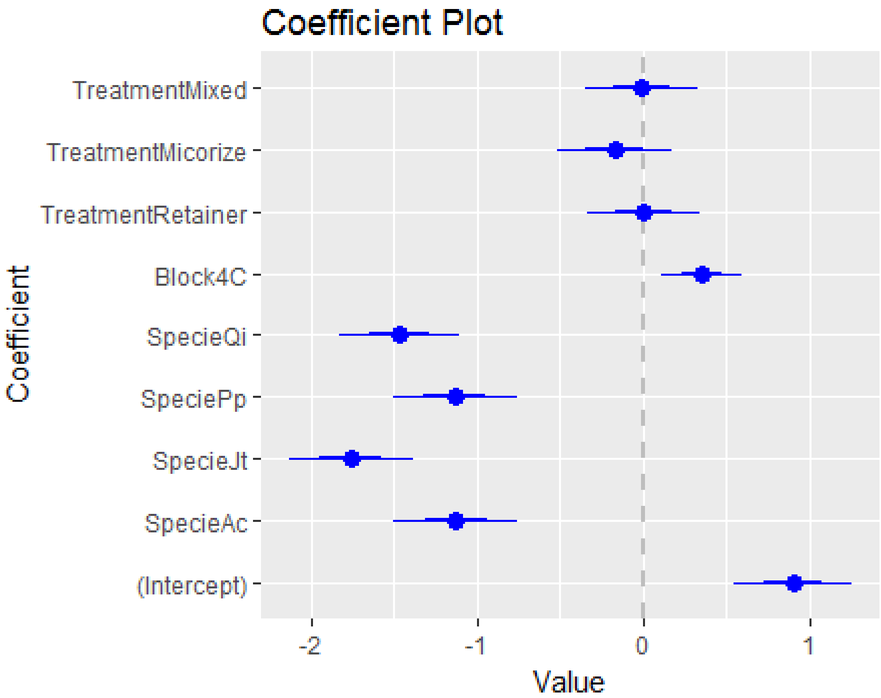
- There is not any significant effect for the *Acer campestre* in any of the plots.
- There are significant effects for the *Juniperus thurifera* in blocks 1 (retainer) and 4 (mycorrhiza and mixed)
- There are significant effects only on block 2 and Treatment mycorrhiza for the *Pinus pinea*.
- There are significant effects for the *Quercus ilex* in block 1 (treatments mycorrhiza and retainer) and 4 (mixed).

Results of the biomass analysis

One of the hypotheses raised in relation to the production of root biomass indicates better results in trees with presence of treatments compared to the absence of these. Through the model, we will observe what factors influence the production of biomass and we will try to corroborate this affirmation.

First, we present a linear model for the biomass response variable, with the presence of the independent variables treatment, block and specie. The graph of the regression coefficients obtained is as follows:

Figure 59: Graphic of coefficients regression of biomass analysis



In the case of the mixed linear model (block as random effect) for the Biomass variable, the coefficients are practically similar. Thus, we will present a table with the regressions obtained, to further analyse the results:

Table 29: Results of the regression analysis for biomass

	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	0.004	0.006
	(0.169)	(0.169)
TreatmentMicorize	-0.170	-0.163
	(0.173)	(0.173)
TreatmentMixed	-0.007	-0.002
	(0.170)	(0.169)
Block4C	0.358***	
	(0.120)	
SpecieAc	-1.127***	-1.129***
	(0.187)	(0.187)
SpecieJt	-1.759***	-1.763***
	(0.187)	(0.187)
SpeciePp	-1.132***	-1.133***
	(0.187)	(0.187)
SpecieQi	-1.467***	-1.470***
	(0.183)	(0.183)
Constant	0.907***	1.085***
	(0.177)	(0.238)
Observations	119	119
R^2	0.517	
Adjusted R^2	0.482	
Log Likelihood		-122.455
Akaike Inf. Crit.		264.910
Bayesian Inf. Crit.		292.006
Residual Std. Error	0.646 (df = 110)	
F Statistic	14.705*** (df = 8; 110)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

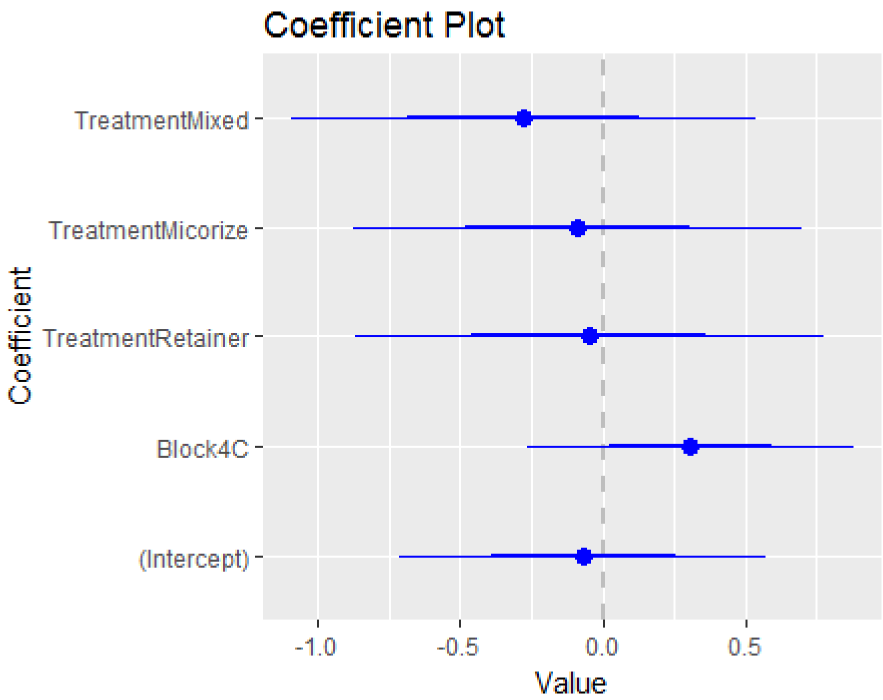
Both block 4 and the species *Amigdalus communis*, *Juniperus thurifera*, *Pinus pinea* and *Quercus ilex* are significant. However, the effect of the treatments, that it is the variable we are interested on is not significant and close to 0. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.517, the meaning of which is that the explanatory variables introduced in the model explain the 51.7% of the total variability of the Biomass response variable.

Analysis of the biomass results depending on the specie

Amigdalus comunis (Almond)

First, we present a linear model for the response variable Biomass *Amigdalus communis*, with the presence of the independent treatment and block variables. The graph of the regression coefficients obtained is as follows:

Figure 60: Graphic of coefficients regression of Amigdalus communis analysis



In the case of the mixed linear model (block as random effect) for the variable *Amigdalus communis*, the coefficients are practically similar. Thus, we will present a table with the regressions obtained to further analyse the results:

Table 30: Results of the regression analysis for almond biomass

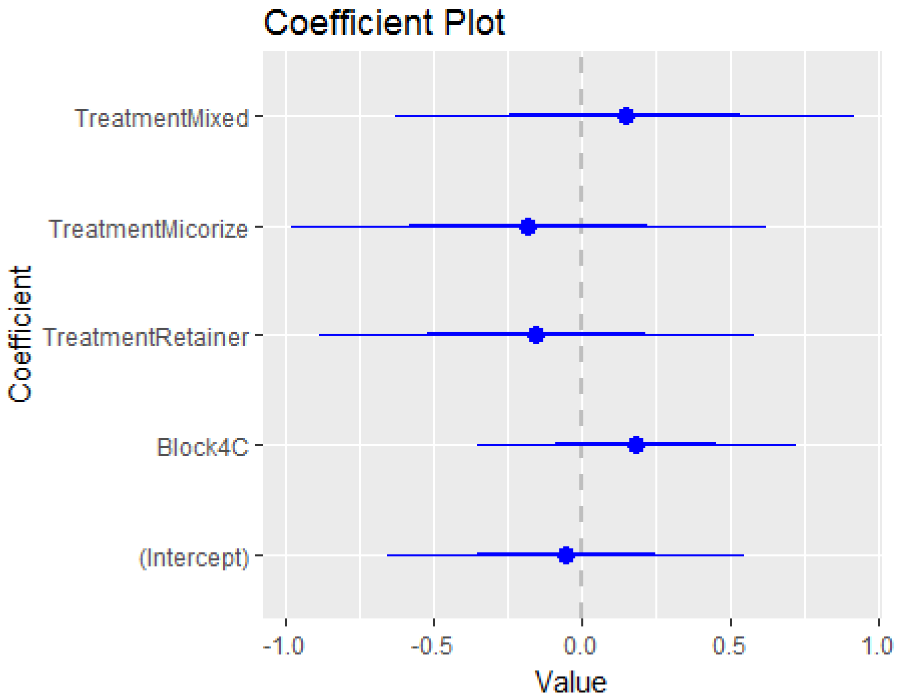
	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	-0.048	-0.003
	(0.410)	(0.408)
TreatmentMicorize	-0.091	-0.072
	(0.393)	(0.393)
TreatmentMixed	-0.280	-0.280
	(0.408)	(0.408)
Block4C	0.308	
	(0.287)	
Constant	-0.069	0.086
	(0.322)	(0.294)
Observations	25	25
R^2	0.082	
Adjusted R^2	-0.101	
Log Likelihood		-26.216
Akaike Inf. Crit.		64.431
Bayesian Inf. Crit.		70.699
Residual Std. Error	0.706 (df = 20)	
F Statistic	0.449 (df = 4; 20)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

No coefficient is significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.082, meaning that the explanatory variables introduced in the model explain 8.2% of the total variability of the Biomass *Amigdalus communis* response variable.

Acer campestre (Maple)

First, we present a linear model for the response variable Biomass *Acer campestre*, with the presence of the independent treatment and block variables. The graph of the regression coefficients obtained is as follows:

Figure 61: Graphic of coefficients regression of Acer campestre analysis



In the case of the mixed linear model (block as random effect) for the variable *Acer campestre*, the coefficients are practically similar. Thus, we will present a table with the regressions obtained to further analyse the results:

Table 31: Results of the regression analysis for maple biomass

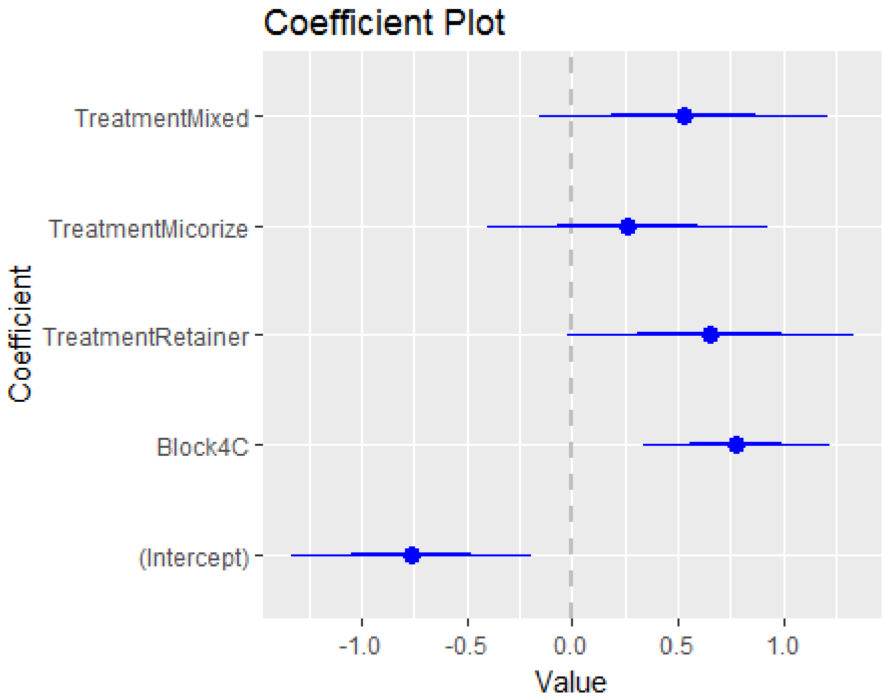
	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	-0.152	-0.147
	(0.368)	(0.363)
TreatmentMicorize	-0.180	-0.143
	(0.401)	(0.392)
TreatmentMixed	0.148	0.197
	(0.387)	(0.375)
Block4C	0.186	
	(0.269)	
Constant	-0.050	0.024
	(0.301)	(0.277)
Observations	23	23
R^2	0.085	
Adjusted R^2	-0.118	
Log Likelihood		-21.357
Akaike Inf. Crit.		54.714
Bayesian Inf. Crit.		60.380
Residual Std. Error	0.629 (df = 18)	
F Statistic	0.417 (df = 4; 18)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

No coefficient is significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.085, the meaning of which is that the explanatory variables introduced in the model explain the 8.5% of the total variability of the Biomass *Acer campestre* response variable.

Juniperus thurifera (Juniper)

First, we present a linear model for the response variable Biomass *Juniperus thurifera*, with the presence of the independent treatment and block variables. The graph of the regression coefficients obtained is as follows:

Figure 62: Graphic of coefficients regression of Juniperus thurifera analysis



In the case of the mixed linear model (block as random effect) for the variable *Juniperus thurifera*, the coefficients are practically similar. Thus, we will present a table with the regressions obtained to further analyse the results:

Table 32: Results of the regression analysis for Juniperus thurifera biomass

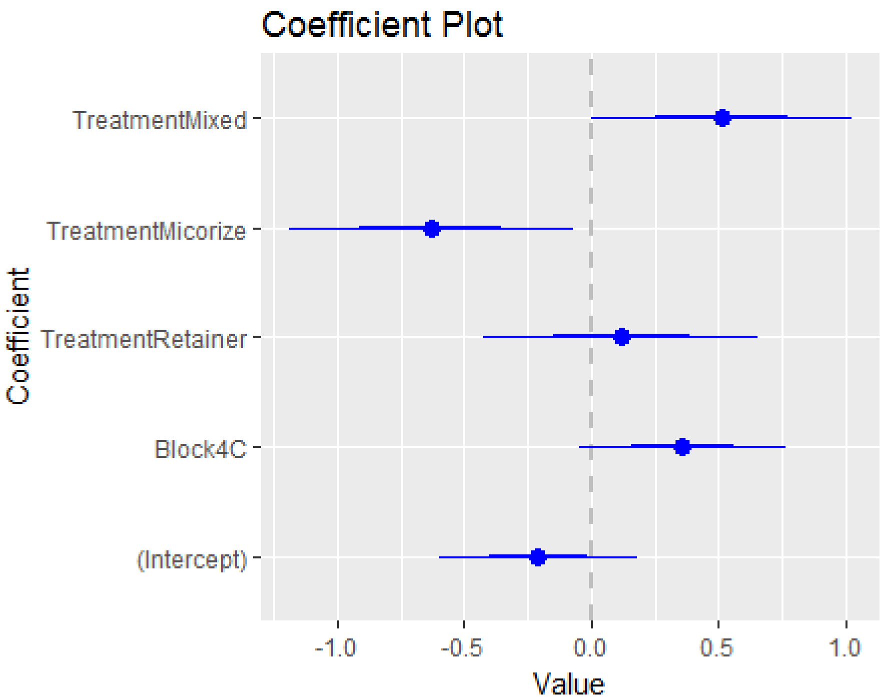
	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	0.656*	0.656*
	(0.341)	(0.341)
TreatmentMicorize	0.263	0.259
	(0.331)	(0.331)
TreatmentMixed	0.529	0.529
	(0.341)	(0.341)
Block4C	0.779***	
	(0.221)	
Constant	-0.762**	-0.372
	(0.286)	(0.457)
Observations	23	23
R^2	0.491	
Adjusted R^2	0.378	
Log Likelihood		-19.548
Akaike Inf. Crit.		51.097
Bayesian Inf. Crit.		56.763
Residual Std. Error	0.528 (df = 18)	
F Statistic	4.338** (df = 4; 18)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Retainer treatment is significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.491, the meaning of which is that the explanatory variables introduced in the model explain the 49.1% of the total variability of the Biomass *Juniperus thurifera* response variable.

Pinus pinea (Pine)

First, we present a linear model for the response variable Biomass *Pinus pinea*, with the presence of the independent treatment and block variables. The graph of the regression coefficients obtained is as follows:

Figure 63: Graphic of coefficients regression of Pinus pinea analysis



In the case of the mixed linear model (block as random effect) for the variable *Pinus pinea*, the coefficients are practically similar. Thus, we will present a table with the regressions obtained to further analyse the results:

Table 33: Results of the regression analysis for Pinus pinea biomass

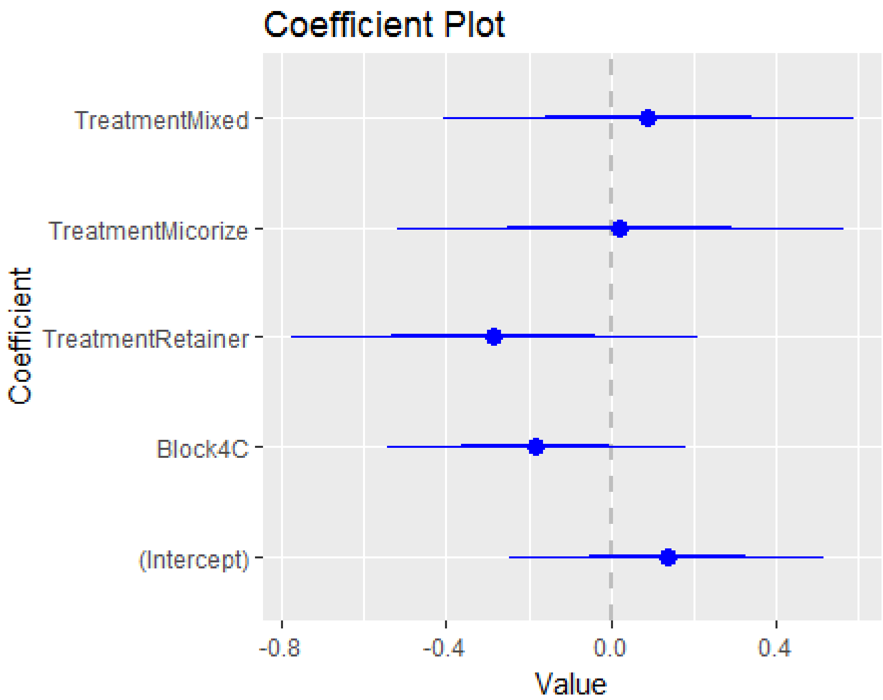
	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	0.119	0.116
	(0.270)	(0.270)
TreatmentMicorize	-0.630**	-0.588**
	(0.280)	(0.277)
TreatmentMixed	0.513*	0.521*
	(0.257)	(0.256)
Block4C	0.358*	
	(0.202)	
Constant	-0.210	-0.039
	(0.194)	(0.229)
Observations	23	23
R^2	0.487	
Adjusted R^2	0.374	
Log Likelihood		-16.274
Akaike Inf. Crit.		44.547
Bayesian Inf. Crit.		50.214
Residual Std. Error	0.460 (df = 18)	
F Statistic	4.280** (df = 4; 18)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Treatment with mycorrhiza and mixed treatment are significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.487, meaning that the explanatory variables introduced in the model explain the 48.7% of the total variability of the Biomass *Pinus pinea* response variable.

Quercus ilex (Holm Oak)

First, we present a linear model for the response variable Biomass *Quercus ilex*, with the presence of the independent treatment and block variables. The graph of the regression coefficients obtained is as follows:

Figure 64: Graphic of coefficients regression of Quercus ilex analysis



In the case of the mixed linear model (block as random effect) for the variable *Quercus ilex*, the coefficients are practically similar. Thus, we will present a table with the regressions obtained to further analyse the results:

Table 34: Results of the regression analysis for Quercus ilex biomass

	Dependent variable:	
	Biomass	
	OLS	*linear mixed effects*
	(1)	(2)
TreatmentRetainer	-0.285	-0.302
	(0.247)	(0.246)
TreatmentMicorize	0.023	-0.025
	(0.272)	(0.268)
TreatmentMixed	0.092	0.049
	(0.250)	(0.246)
Block4C	-0.182	
	(0.181)	
Constant	0.137	0.076
	(0.191)	(0.181)
Observations	25	25
R^2	0.153	
Adjusted R^2	-0.016	
Log Likelihood		-16.339
Akaike Inf. Crit.		44.679
Bayesian Inf. Crit.		50.946
Residual Std. Error	0.443 (df = 20)	
F Statistic	0.906 (df = 4; 20)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

No coefficient is significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.153, the meaning of which is that the explanatory variables introduced in the model explain 15.3% of the total variability of the Biomass *Quercus ilex* response variable.

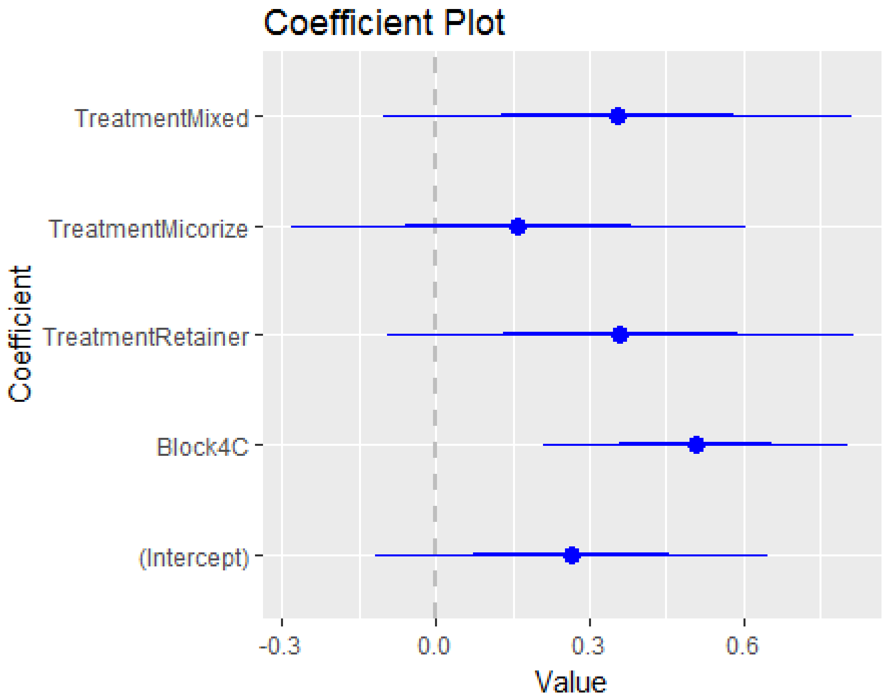
Analysis of the biomass of the species where the effect of the treatments is significant

In those species in which the treatments are significant, we will perform a new analysis through OLS. In these cases, we discard the application of a principal component analysis to establish the biomass response variable. In this case, the biomass response variable is defined as the sum of the carbon absorption in the stem and root of the trees. It is expressed logarithmically.

Juniperus thurifera (Juniper)

We will present a linear model with the presence of block and treatment independent variables. The graph of the estimated regression coefficients is as follows:

Figure 65: Graphic of coefficients regression of Juniperus thurifera new analysis



Thus, we will present a table with the regressions obtained, and analyse the results:

Table 35: Results of the regression new analysis for Juniperus thurifera biomass

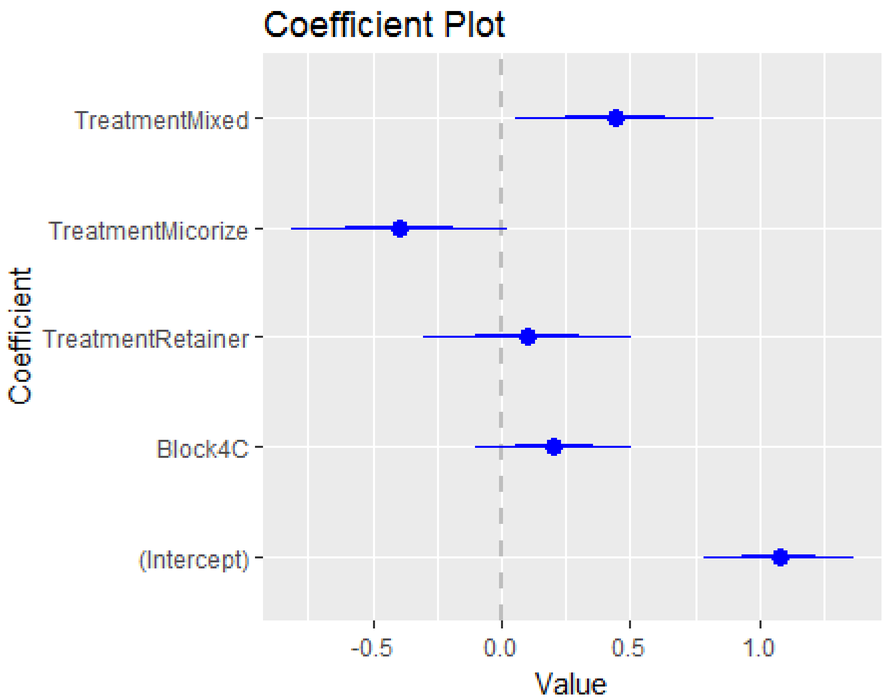
	Dependent variable:
	Biomass
TreatmentRetainer	0.360
	(0.228)
TreatmentMicorize	0.161
	(0.222)
TreatmentMixed	0.355
	(0.228)
Block4C	0.507^{***}
	(0.148)
Constant	0.265
	(0.192)
Observations	23
R^2	0.465
Adjusted R^2	0.346
Residual Std. Error	0.353 (df = 18)
F Statistic	3.913^{**} (df = 4; 18)
Note:	*p<0.1; **p<0.05; ***p<0.01

In the case of the species *Juniperus thurifera*, treatment with retainer is no longer significant. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.465, the meaning of which is that the explanatory variables introduced in the model explain 46.5% of the total variability of the Biomass *Juniperus thurifera* response variable.

Pinus pinea (Pine)

We will present a linear model with the presence of block and treatment independent variables. The graph of the estimated regression coefficients is as follows:

Figure 66: Graphic of coefficients regression of Pinus pinea new analysis



Thus, we will present a table with the regressions obtained, and analyse the results:

Table 36: Results of the regression new analysis for Pinus pinea biomass

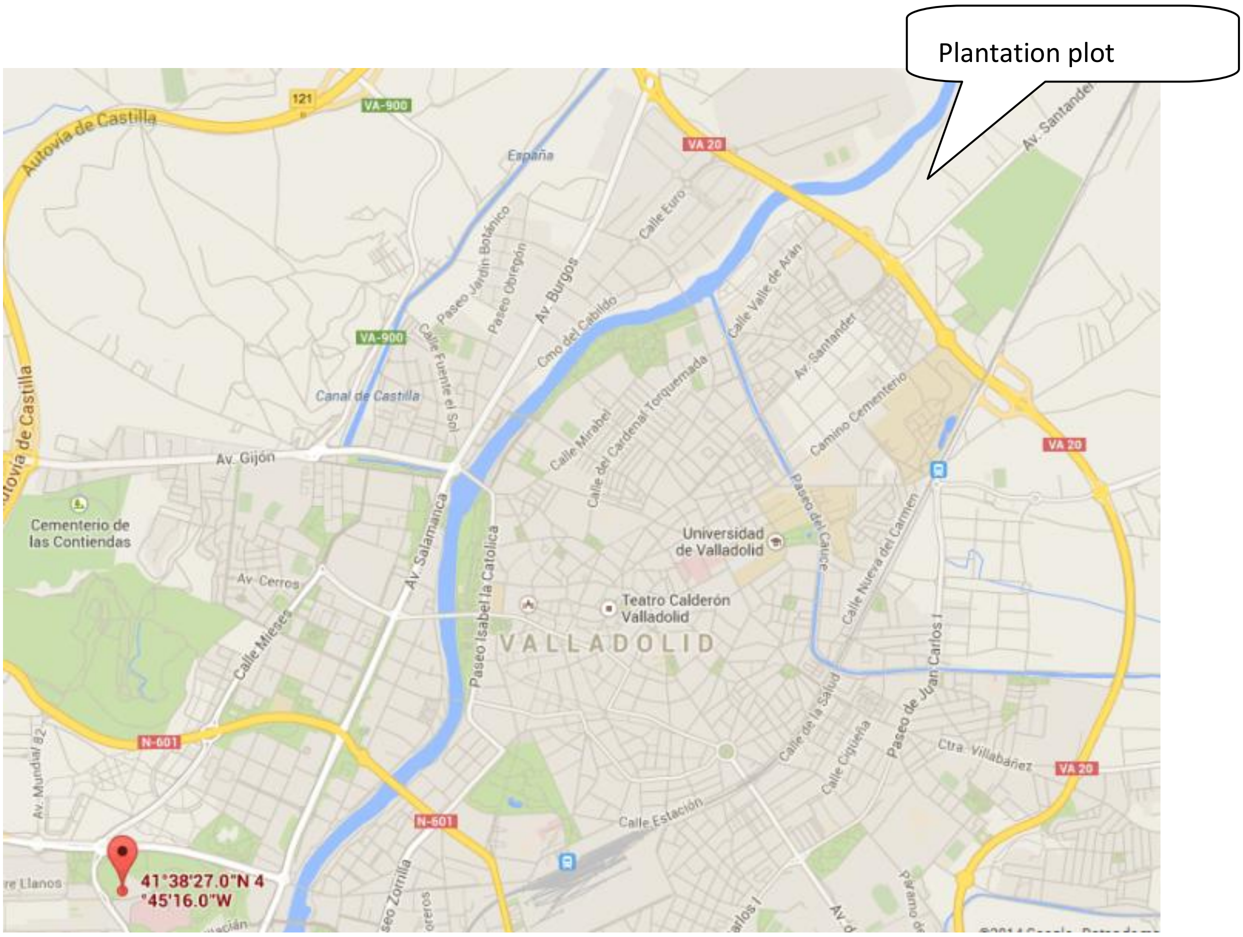
	Dependent variable:
	Biomass
TreatmentRetainer	0.098
	(0.202)
TreatmentMicorize	-0.397*
	(0.210)
TreatmentMixed	0.442**
	(0.192)
Block4C	0.203
	(0.151)
Constant	1.075***
	(0.146)
Observations	23
R^2	0.472
Adjusted R^2	0.355
Residual Std. Error	0.345 (df = 18)
F Statistic	4.023** (df = 4; 18)
Note:	*p<0.1; **p<0.05; ***p<0.01

In the case of *Pinus pinea*, both mixed and mycorrhiza treatments are significant. For each unit of mycorrhiza treatment, there is an average decrease in the biomass logarithm score of 0.397. Finally, for each mixed treatment unit, there is an average increase in the biomass logarithm score of 0.442. The adjusted linear model presents a coefficient of multiple determination that yields a value of 0.472, the meaning of which is that the explanatory variables introduced in the model explain 47.2% of the total variability of the Biomass *Pinus pinea* response variable.

Annex 2. Climate information

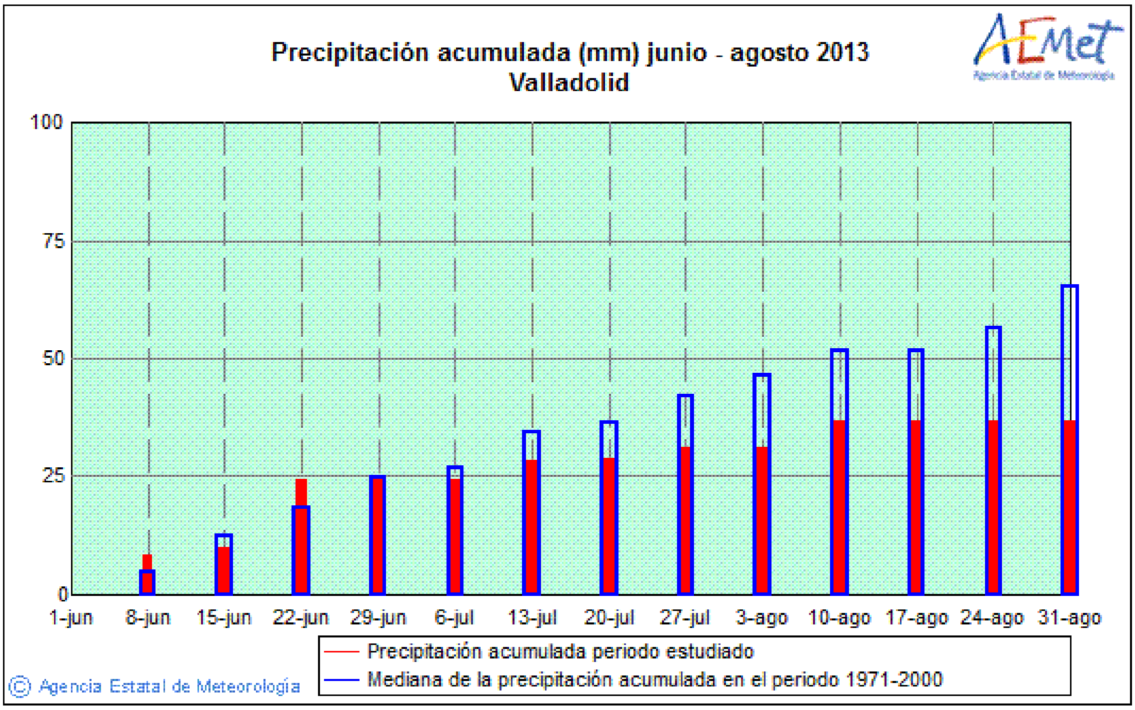
The information is based on the Valladolid climate station of the State Meteorological Agency (AEMET):

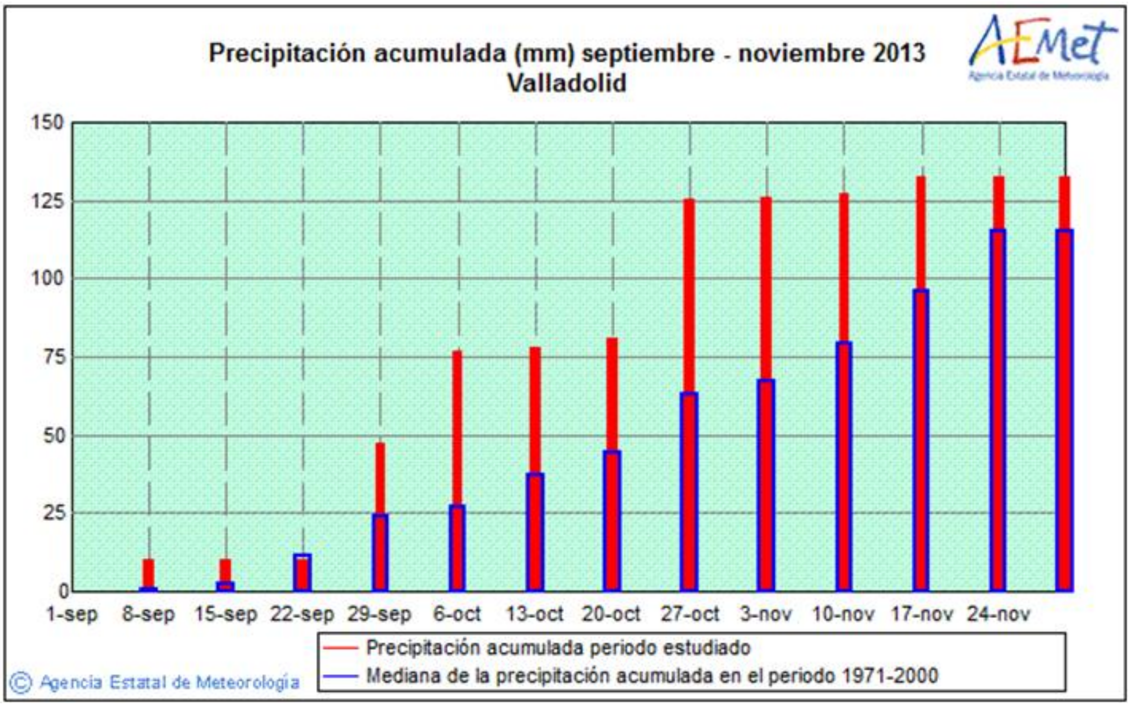
http://www.aemet.es/es/serviciosclimaticos/vigilancia_clima/analisis_estacional?w=3&l=2539&datos=prec

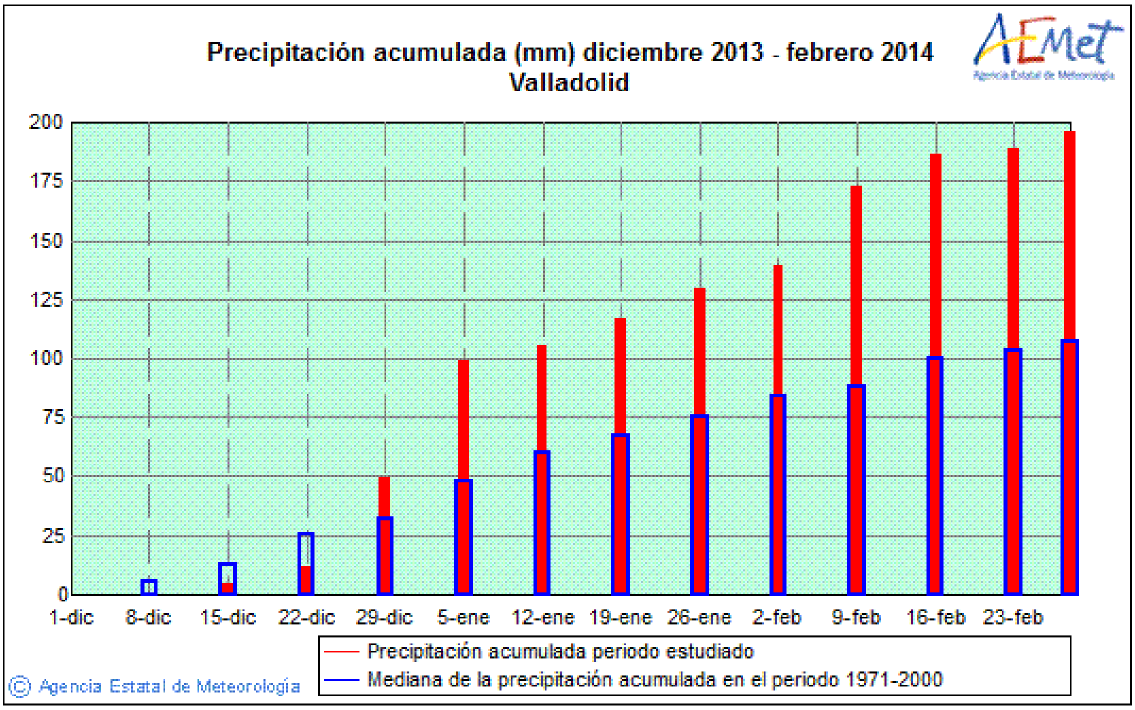


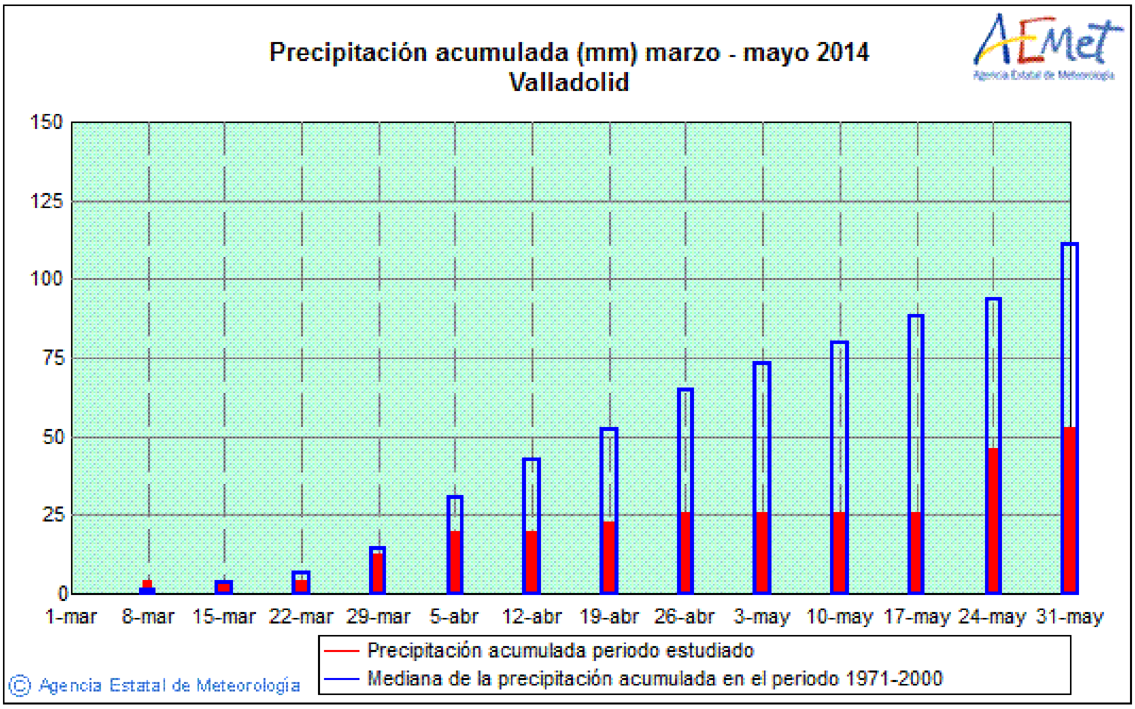
Valladolid climate Ind. 2422

- Altitude (m): 735
- Latitude: 41 ° 38 '27' 'N -
- Longitude: 4 ° 45 '16' 'W


Precipitación acumulada (mm) junio - agosto 2013
Valladolid
AEMet
100
75
50
25
0
1-jun 8-jun 15-jun 22-jun 29-jun 6-jul 13-jul 20-jul 27-jul 3-ago 10-ago 17-ago 24-ago 31-ago
Precipitación acumulada periodo estudiado
Mediana de la precipitación acumulada en el periodo 1971-2000
© Agencia Estatal de Meteorología


Precipitación acumulada (mm) septiembre - noviembre 2013
Valladolid
AEMet
150
125
100
75
50
25
0
1-sep 8-sep 15-sep 22-sep 29-sep 6-oct 13-oct 20-oct 27-oct 3-nov 10-nov 17-nov 24-nov
Precipitación acumulada periodo estudiado
Mediana de la precipitación acumulada en el periodo 1971-2000
© Agencia Estatal de Meteorología


Precipitación acumulada (mm) diciembre 2013 - febrero 2014
Valladolid
AEMet
200
175
150
125
100
75
50
25
0
1-dic
8-dic
15-dic
22-dic
29-dic
5-ene
12-ene
19-ene
26-ene
2-feb
9-feb
16-feb
23-feb
Precipitación acumulada periodo estudiado
Mediana de la precipitación acumulada en el periodo 1971-2000
© Agencia Estatal de Meteorología


Precipitación acumulada (mm) marzo - mayo 2014
Valladolid
AEMet
150
125
100
75
50
25
0
1-mar
8-mar
15-mar
22-mar
29-mar
5-abr
12-abr
19-abr
26-abr
3-may
10-may
17-may
24-may
31-may
Precipitación acumulada periodo estudiado
Mediana de la precipitación acumulada en el periodo 1971-2000
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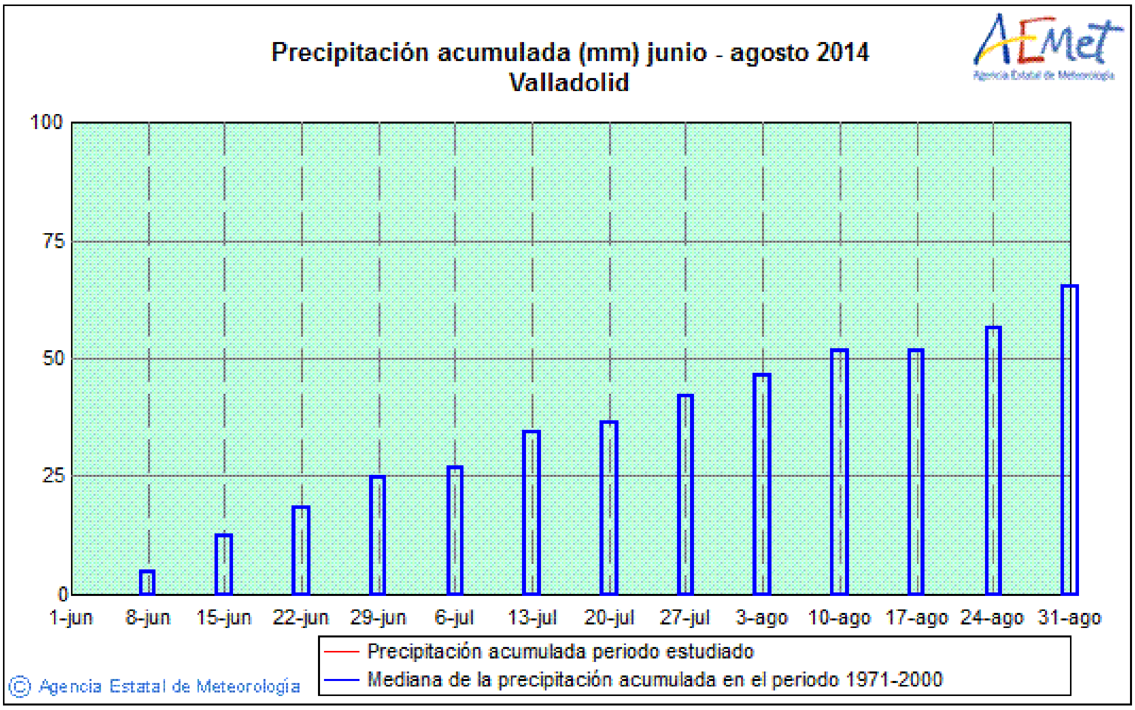
Precipitación acumulada (mm) junio - agosto 2014
Valladolid
100
75
50
25
0
1-jun
8-jun
15-jun
22-jun
29-jun
6-jul
13-jul
20-jul
27-jul
3-ago
10-ago
17-ago
24-ago
31-ago
Precipitación acumulada periodo estudiado
Mediana de la precipitación acumulada en el periodo 1971-2000
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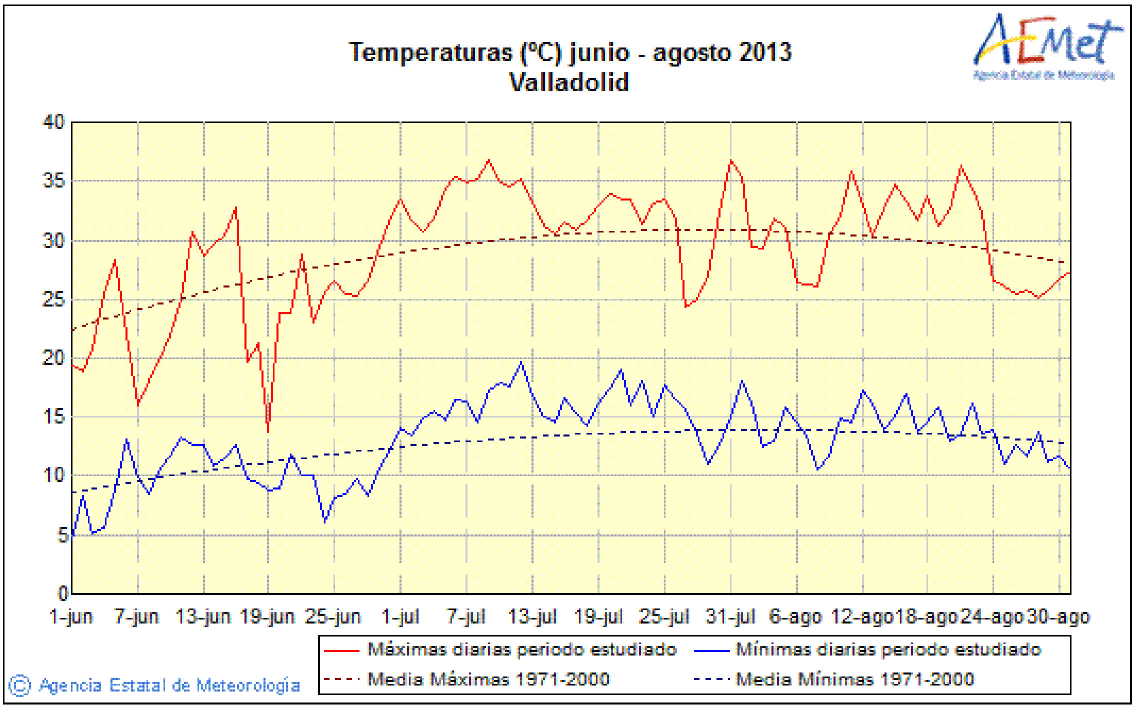
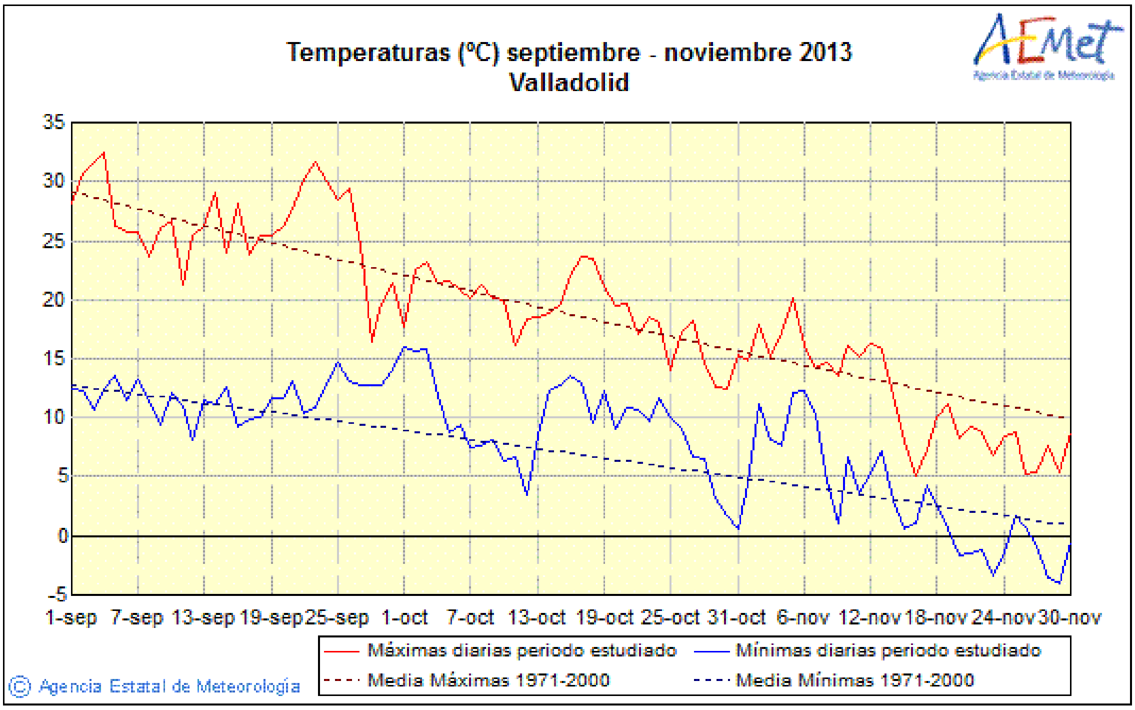
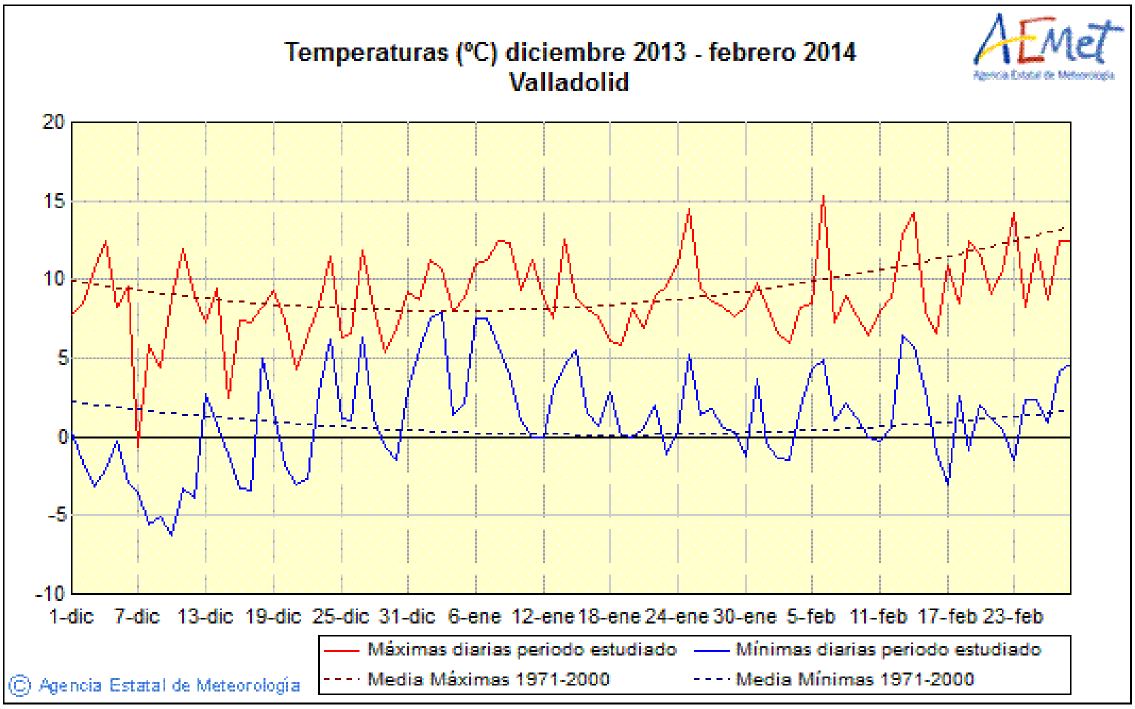
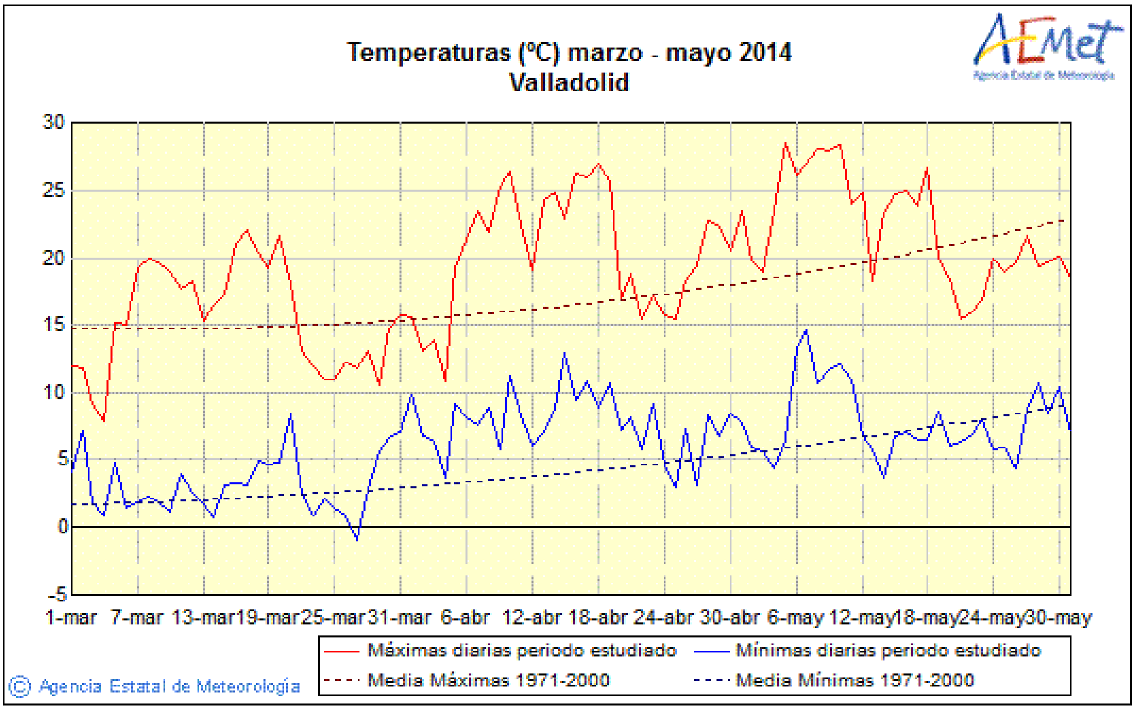
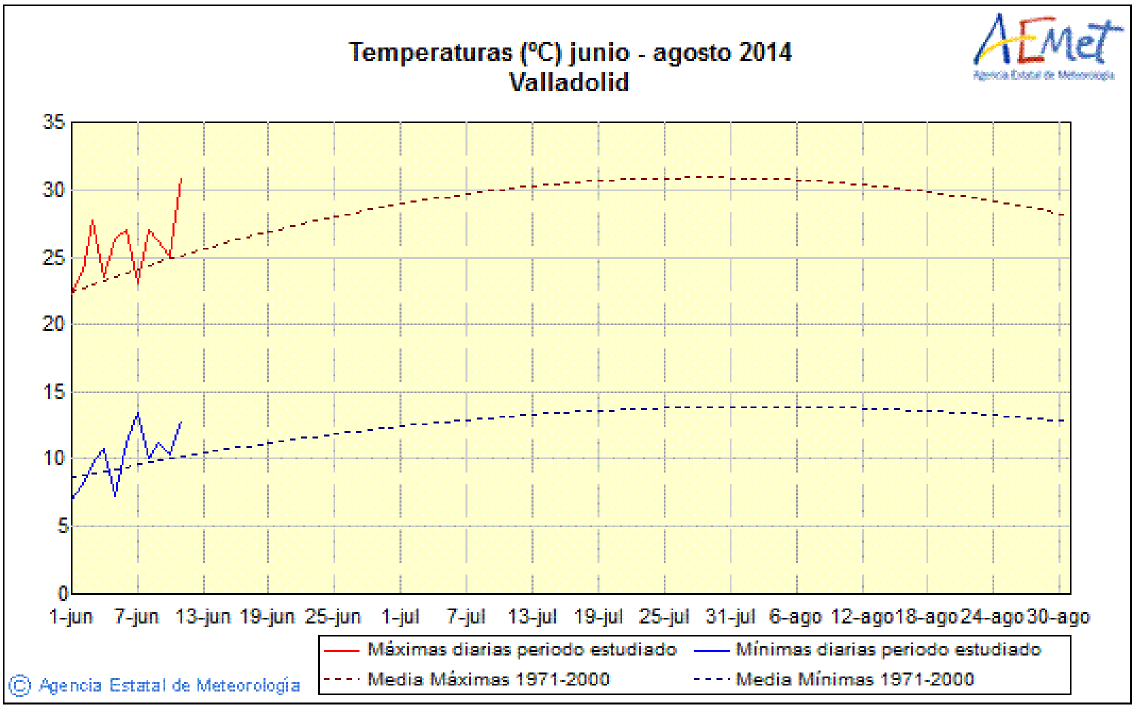

Temperaturas (ºC) junio - agosto 2013
Valladolid
40
35
30
25
20
15
10
5
0
1-jun
7-jun
13-jun
19-jun
25-jun
1-jul
7-jul
13-jul
19-jul
25-jul
31-jul
6-ago
12-ago
18-ago
24-ago
30-ago
Máximas diarias periodo estudiado
Mínimas diarias periodo estudiado
Media Máximas 1971-2000
Media Mínimas 1971-2000
© Agencia Estatal de Meteorología


Temperaturas (ºC) septiembre - noviembre 2013
Valladolid
35
30
25
20
15
10
5
0
-5
1-sep 7-sep 13-sep 19-sep 25-sep 1-oct 7-oct 13-oct 19-oct 25-oct 31-oct 6-nov 12-nov 18-nov 24-nov 30-nov
Máximas diarias periodo estudiado
Mínimas diarias periodo estudiado
Media Máximas 1971-2000
Media Mínimas 1971-2000
© Agencia Estatal de Meteorología


Temperaturas (ºC) diciembre 2013 - febrero 2014
Valladolid
20
15
10
5
0
-5
-10
1-dic 7-dic 13-dic 19-dic 25-dic 31-dic 6-ene 12-ene 18-ene 24-ene 30-ene 5-feb 11-feb 17-feb 23-feb
Máximas diarias periodo estudiado
Mínimas diarias periodo estudiado
Media Máximas 1971-2000
Media Mínimas 1971-2000
© Agencia Estatal de Meteorología



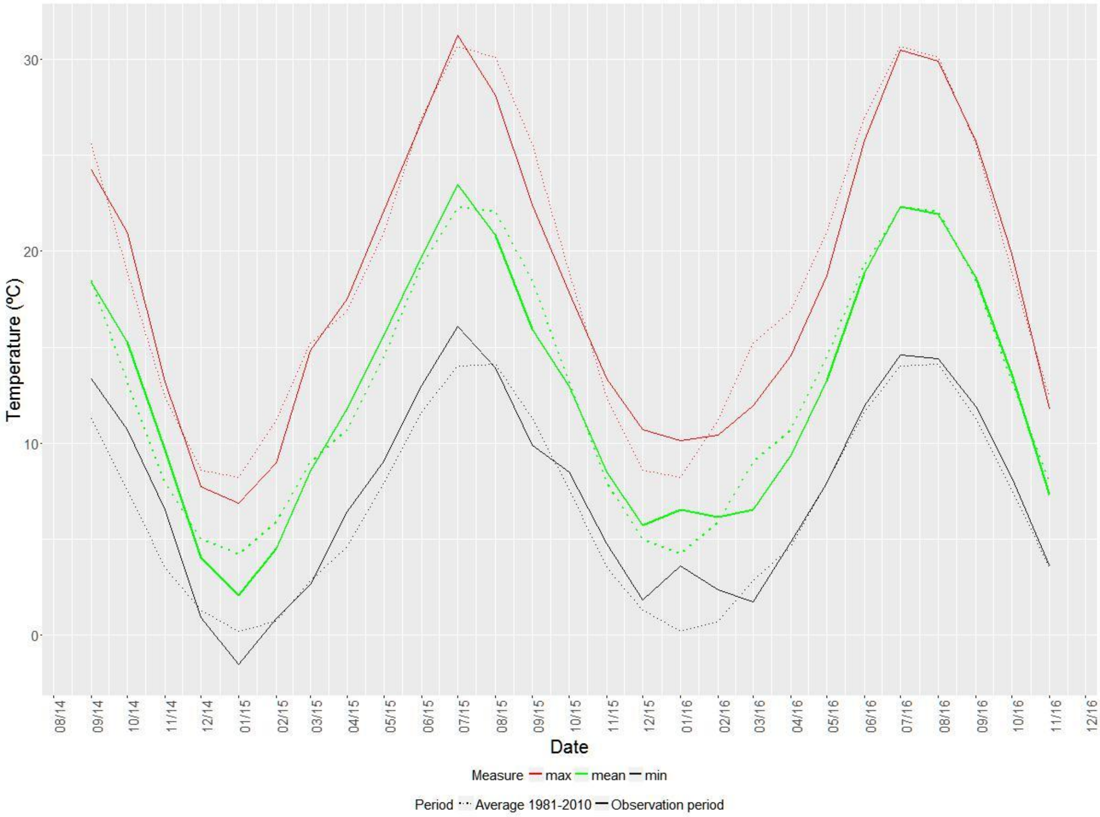


Weather information

To properly assess the results of the analysis it is important to study the weather information during the period of analysis.

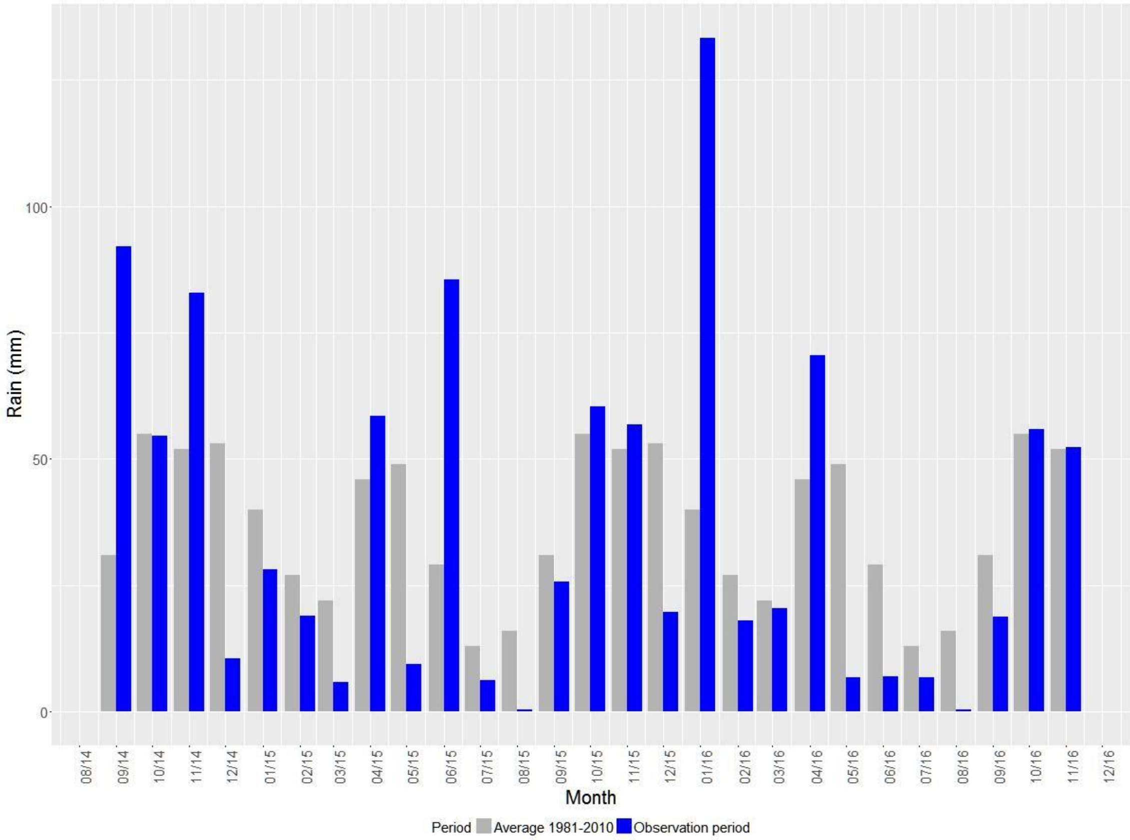
In comparing the monthly temperatures during the observation period to the historical average monthly temperatures in Valladolid since 1981 to 2010 we do not observe major differences as shown in Figure 67.

Figure 67: Monthly temperatures during the observation period compared to the historical ones



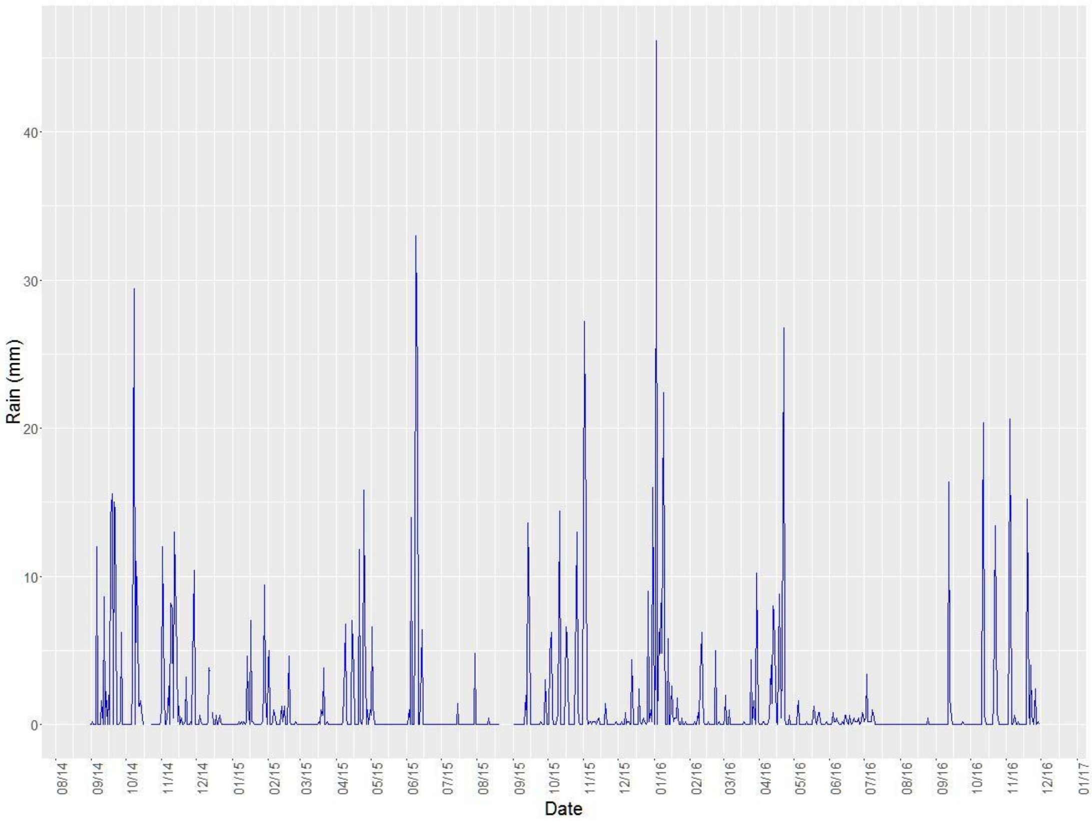
On the contrary, the rainfall during the observation period shows a very different pattern to the historical rainfall in Valladolid. Considering the monthly average rainfall we observe than the smooth historical pattern does not hold in the observation period as shown in Figure 68. There are months with much heavier rains than expected (September/14, November/14, June/15, Jan/16, and Apr/16) and months with much weaker rains than on average (December/14, March/15, May/15, Aug/15, Dec/15, and late Spring-Summer/16). It makes more important for the plants to be able to absorb the rainfall properly to keep the moisture soil for longer periods of drought.

Figure 68: Monthly rainfall during the observation period compared to the historical ones



Moreover, when analysing the instant rainfall we observe that there are many days with heavy rains as shown in Figure 69. Again, it makes very important for the plants that the soil to be able to absorb those torrential rainfalls that are followed by longer periods of drought.

Figure 69: Install rainfall during the observation period



Annex 3. References

2016a Scales: Scale Functions for Visualization. http://CRAN.R-project.org/package=scales.

2016b Tidyr: Easily Tidy Data with `spread()` and `gather()` Functions. https://CRAN.R-project.org/package=tidyr.

Arnott, J. T.; Grossnickle, S. C.; Puttonen, P.; Mitchel, A. K. y Folk, R. S. 1993. Influence of nursery culture on growth, cold hardiness, and drought resistance of ye- llow cypress. Canadian Journal of Forest Research 23: 2537-2547

Auguie, Baptiste 2015 gridExtra: Miscellaneous Functions for “Grid” Graphics. http://CRAN.R-project.org/package=gridExtra.

Bates, Douglas, Martin Mächler, Ben Bolker, and Steve Walker 2015 Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software 67(1): 1–48.

Bowen GD. 1991. Soil temperature, root growth and plant function. In: Waisel A, Eshel A, Kafkafi U, eds. Plant Roots: The Hidden Half. New York: Marcel Dekker, Inc., 309-330.

Burdett, A. N. 1990. Physiological processes in plantation establishment and the development of specifications for forest planting stock. Canadian Journal of Forest Research 20: 415-427.

Castro, J., Zamora, R.,Hodar, J.A., Gómez, J.M. 2005. Alleviation of summer drought boosts establishment success of Pinus sylvestris in a Mediterranean mountain: an experimental approach. Plant Ecology 181,191-202

Clarkson, D.T., Hopper M.J., Jones L.H.P. 1986. The Effect of Root Temperature on the Uptake of Nitrogen and the Relative Size of the Root-System in Lolium-Perenne .1. Solutions Containing Both Nh+4 and No-3. Plant Cell and Environment 9: 535-545.

Cox, D. R., & Oakes, D. (1984). Analysis of survival data (Vol. 21). CRC Press.

Cox, D.R. (1972). Regression Models and Life-Tables . Journal of the Royal Statistical Society. Series B (Methodological), Vol. 34(No. 2.), pp. 187-220.

Cox, D.R. 1972 Regression Models and Life-Tables . Journal of the Royal Statistical Society. Series B (Methodological) Vol. 34(No. 2.): 187–220.

De-Lucia E.H., Heckathorn, S.A., Day, T.A. 1992. Effects of Soil-Temperature on Growth, Biomass Allocation and Resource Acquisition of Andropogon-Gerardii Vitman. New Phytologist 120: 543-549

Franco, J. A.; Bañón, S.; Fernández, J. A., Leskovar, D. I. 2001. Effect of nursery regimes and establishment irrigation on root development of Lotus creticus seedlings follo- wing transplanting. Journal of Horticultural Science & Biotechnology 76: 174-179.

Füllner, K. The influence of spatially heterogeneous soil temperatures on plant structure and function. 2007. Mathematisch-Naturwissenschaftlichen Fakultät der Heinrich-Heine-Universität Düsseldorf

Hlavac, Marek 2015 Stargazer: Well-Formatted Regression and Summary Statistics Tables. Cambridge, USA: Harvard University. http://CRAN.R-project.org/package=stargazer.

James, David, and Kurt Hornik 2015 Chron: Chronological Objects Which Can Handle Dates and Times. http://CRAN.R-project.org/package=chron.

Jarrett, A. R., Hoover, J.R. 1985. Evaluating the effect of increasing concentrations of CO_2 on infiltration rate. Trans. ASAE. 28: 179–182

Jiménez, C. C., M. Tejedo, G. Morillas, and V. Neris. 2006. Infiltration rate in andosols: Effect of change in vegetation cover. Journal of Soil and Water Conservation. 61.3: 153–158.

Jiménez, M.N., Ripoll, M.A., Navarro, F.B., Bocio, I., De Simón, E., 2004. Modificación del micro clima edáfico producido por riegos en forestaciones de zonas semiáridas. InvestigaciónAgraria: Sistemas y Recursos Forestales Fuera de Serie, 142-152.

Johnson, C. W., and N. D. Gordon. 1988. Runoff and erosion from rainfall simulator plots on sagebrush rangeland. Trans. ASAE.31: 421–427

Kaplan, E. L., & Meier, P. (1958). Nonparametric estimation from incomplete observations. Journal of the American statistical association, 53(282), 457-481.

Klein, Original by, Moeschberger, and modifications by Jun Yan 2012 KMsurv: Data Sets from Klein and Moeschberger (1997), Survival Analysis. http://CRAN.R-project.org/package=KMsurv.

López, B., Sabaté, S., Gracia, C. 1998. Fine roots dynamics in a Mediterranean forest: effects of drought and stem density. Tree Physiology 18: 301-306.

Luis, V.C., Peters, J., González-Rodríguez, A.M., Jiménez, M.S., Morales, D. 2004. Testing nursery plant quality of canary island pine seedlings grown under different cultivation methods. Phyton 44: 231-244.

Lyr, H. 1996. Effect of the root temperature on growth parameters of various European tree species. Annales des Sciences Forestieres 53: 317-323.

Maestre, F. T., Cortina, J. 2004. Are Pinus halepensis plantations useful as a restoration tool in semiarid Mediterranean areas? *Forest Ecology and Management*, *198*(1-3), 303–317. doi:10.1016/j.foreco.2004.05.040

McKay, H. M. (1997). A review of effect of stresses between lifting and planting on nursery stock quality and performance. New Forests 13: 369-399.

McMichael BL, Quisenberry JE. 1993. The Impact of the Soil Environment on the Growth of Root Systems. Environmental and experimental botany 33: 53-61

Monserud, R. A., & Sterba, H. (1999). Modeling individual tree mortality for Austrian forest species. Forest Ecology and Management, 113(2), 109-123.

Navarro, R.M, Del Campo, A., Cortina, J. 2006. Calidad de planta forestal para la restauración en ambientes mediterráneos. Capítulo 2: Factores que afectan al éxito de una repoblación y su relación con la calidad de la planta pp 31-47. Serie Naturaleza y Parques Nacionales.

Pinheiro, Jose, Douglas Bates, Saikat DebRoy, Deepayan Sarkar, and R Core Team 2015 Nlme: Linear and Nonlinear Mixed Effects Models. http://CRAN.R-project.org/package=nlme.

R Core Team 2015 R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/.

Rey, P.J., Siles, G., Alcántara, J.M. 2009. Community-level restoration profiles in Mediterranean vegetation: nurse-based versus traditional reforestation. Journal of Applied Ecology 46,937-945.

Scagel, R.; Bowden, R.; Madill, M. y Kooistra, C. 1993. Provincial seedling stock type selection and ordering guidelines. British Columbia. Min. of Forests. SD404.P76. 76 pp.

Scheffer, F., Schachtschabel, P., Blume, H.P., Brümmer, G., Hartge, K.H., Schwertmann, U. 2002. Lehrbuch der Bodenkunde. Heidelberg: Spektrum Akademischer Verlag GmbH.

Serrada, R., Navarro, R.M., Pemán, J. 2005. La calidad de las repoblaciones forestales: una aproximación desde la silvicultura y la ecofisiología. Investigación Agraria: Sistemas y Recursos Forestales 14,462e481.

Siles, G., Rey, P. J., Alcántara, J. M., Bastida, J. M., & Herreros, J. L. (2010). Effects of soil enrichment, watering and seedling age on establishment of Mediterranean woody species. *Acta Oecologica*, *36*(4), 357–364. doi:10.1016/j.actao.2010.03.002

Smith R. E., Parlange, J.F. 1978. A parameter–efficient hydrologic infiltration model. Water Resources Res. 14: 533–538

South, D. B. 2000. Planting morphologically improved pine seedlings to increase survival and growth. Forestry and Wildlife Research Series N.º 1. Alabama Agricultural Experiment Station. Auburn University, Alabama. 12 pp.

Stone, J.A., Taylor, H. M. 1983. Temperature and the Development of the Taproot and Lateral Roots of 4 Indeterminate Soybean Cultivars. Agronomy Journal 75: 613-618.

Studio, R. 2012 RStudio: Integrated Development Environment for R. RStudio Inc, Boston, Massachusetts.

Team, R. D. C. (2008). R: A language and environment for statistical computing. . Vienna, Austria: R Foundation for Statistical Computing,.

Therneau, Terry 2015 A Package for Survival Analysis in S. R Package Version 2.37-7. 2014. URL Http://CRAN. R-Project. Org/Package= Survival.

Urbanek, Simon 2013 Png: Read and Write PNG Images. http://CRAN.R-project.org/package=png.

Wang, Jiahui, Ruben Zamar, Alfio Marazzi, et al. 2014 Robust: Robust Library. https://CRAN.R-project.org/package=robust.

Wickham, and Hadley 2007 Reshaping Data with the Reshape Package. Journal of Statistical Software 21(12). http://www.jstatsoft.org/v21/i12/paper.

Wickham, H. (2009). ggplot2: elegant graphics for data analysis.: Springer New York.

Wickham, H. 2009 ggplot2: Elegant Graphics for Data Analysis. Springer New York.

Wickham, Hadley 2011. The Split-Apply-Combine Strategy for Data Analysis. Journal of Statistical Software 40(1): 1–29.

Winston Chang, Joe Cheng, JJ Allaire, Yihui Xie and Jonathan McPherson (2016). shiny: Web Application Framework for R. R package version 0.14.2. https://CRAN.R-project.org/package=shiny

Zeileis, Achim 2006 Object-Oriented Computation of Sandwich Estimators.