Rewilding Kalamos

Restoration plan for a protection forest on the island of Kalamos, Greece

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Cover photo: One of the few Valonia oaks (Quercus ithaburensis) in the restoration area with the village of Kalamos in the background. (Photo by C. van der Laan)

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Preface

This bachelor thesis is my final work at Van Hall Larenstein University of Applied Sciences as part of the major International Forest and Nature Management (IFNM). For this, I spent several weeks in Greece to which I happily look back to.

I would like to thank Ted for allowing me to do this project at Terra Sylvestris and all his support. I would also like to thank Georgia for the nice talks and always being willing to help with anything.

Also thanks to my fellow intern, Stanislas, for helping me out with the vegetation and soil survey which made that so much quicker and easier.

Finally, I want to thank Peter for his professional support and feedback.

I hope you will enjoy reading this thesis.

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Summary

This report contains a restoration plan for degraded lands near the village of Kalamos on Kalamos island. The island is one of the Ionian islands off the west coast of Greece. There used to be deciduous evergreen forests that have now been reduced to small groves or individual trees. To restore this lost habitat and to rewild Kalamos, a restoration plan was developed. Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Rewilding is one of the restoration approaches that promotes self-regulating ecosystems by bringing back species that drive dynamic processes in order for nature to manage itself. In this case, that species is the Valonia oak (*Quercus ithaburensis*). The Valonia oak has shifted from an economical to rather ecological importance as if forms some of the rare deciduous oak forests in the eastern Mediterranean zone. The aim was to develop a plan to restore a forest that could be self-supporting in the long-term while providing important ecosystem services to the adjacent community. Examples of these ecosystem services are local climate regulation during hot summer days, water-retention and prevention of flooding and soil erosion.

The plan was developed by means of literature studies, fieldwork and a desktop study. Results from these studies were used in designing a programme of requirements in which a set of criteria for the restoration plan was formulated. Based on these criteria, a plan was developed containing a nursery, establishment and monitoring element. The nursery will be used to produce the planting material of locally sourced acorns of Valonia oaks. Planting will be done in three rotations to eventually reforest an area of about 17 hectares by planting a total of 14,161 trees. Monitoring will give valuable feedback which will be used to test if the practices have the desired effect and whether additional measures will be necessary or not.

Chapter 1 is the introduction and will elaborate more on the concepts of ecosystem restoration, rewilding, the context of the problem and the problem statement. The overall objective is presented in chapter 2 together with the research question and sub-questions. Chapter 3 explains the methodology and shows how this plan has been developed. Results of the literature study, fieldwork and desktop study are presented in chapter 4. Chapter 5 contains the actual plan including actions, costs and planning. Finally, chapter 6 contains a critical reflection on this plan and recommendations on further research.

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List of abbreviations

a.s.l.	Above sea level
DBH	Diameter at breast height (1.3 metres)
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GPS	Global Positioning System
NGO	Non-governmental organisation
N/ha	Number per hectare
ppph	Per person per hour

List of tree and shrub species

Common name	***Scientific name***
Aleppo pine	*Pinus halepensis*
Carob tree	*Ceratonia siliqua*
Kermes oak	*Quercus coccifera*
Valonia oak	*Quercus ithaburensis*
Olive tree	*Olea europaea*
Mastic/lentisk	*Pistachia lentiscus*
Almond-leaved pear	*Pyrus spinosa*

1 Introduction

The growing trend of urbanisation and abandonment of agricultural land is a phenomenon that is taking place on a global scale. Farm abandonment in Europe (Pointereau et al., 2008) has let to initiatives as Rewilding Europe that aims to restore ecosystems in these 'empty' spaces. Also elsewhere in the world there is the trend of agricultural land abandonment by people that are moving to the urban areas. On the other hand, forests are still being converted to agricultural land and global forest cover is decreasing and degrading (FAO, 2018). However, land abandonment provides opportunities for forest cover to increase by restoring forests and, by doing so, relieving the pressure on remaining forests (Dumroese, Williams, Madsen, Palik, & Stanturf, 2014; Lamb, Stanturf, & Madsen, 2012). Even though not all forests are the same, forest definitions often fail to distinguish between natural and planted forests or plantations (Chazdon et al., 2016). So what exactly does forest restoration mean, and how can we measure it?

1.1 Forest restoration

There is not a single definition on forest restoration, in fact, there are many definitions in a broad context surrounding restoration practices (Higgs, 1997). They can have a different view on history and focus more on the technical, ecological or social part of restoration practices. In general, ecological restoration is regarded as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2004). But successful restoration of a disturbed ecosystem depends on our understanding of that ecosystem (Bradshaw, 1987). So in order to successfully restore an ecosystem we first need to understand that ecosystem, and all the factors that are affected by and have an effect on the ecosystem.

Silvicultural practices in the Mediterranean were mostly adapted from those applied in central and northern Europe and have mainly been applied to the more temperate region of the Mediterranean (Papageorgiou, 2003). So these systems are not suitable in large parts of the Mediterranean where rainfall is less equally distributed throughout the year. Mediterranean climates have a dry summer which implies the risk of increased mortality of planting material and desertification. However, much research has been done on reforestation and forest restoration in Australia which also has a Mediterranean climate in certain parts (Lamb, 2014; Manning et al., 2011). And there are methods that have proven to be effective even in areas with a Mediterranean climate (Schirone, Salis, & Vessella, 2011).

The effectiveness of restoration projects has often been measured by merely focussing on the recovery of vegetation (Young, 2000). These projects have been aimed at establishing a forest with limited species diversity, and without consideration of animals and 'minor' plant species (Dobson, Bradshaw, & Baker, 1997). Commonly, species were chosen that are important for functioning of the ecosystem, together with species that would be its main components. This leaves out the many animal and plant species that would complete the ecosystem and make up the final biodiversity. So this project is not just about establishing a plantation forest for the purpose of having a forest there. It is rather about the ecosystem services it will provide while being self-supporting in the long-term. This is why vegetation structure, species diversity and ecosystem processes (Ruiz-Jaén & Aide, 2005) were also considered in this restoration plan. Ecosystem services are usually classified into the four groups of provisioning, regulating, cultural and supporting services. Where provisioning services are products obtained from ecosystems; regulating services are benefits obtained from regulation of ecosystem processes; cultural services are recreational and spiritual; and supporting services are needed for the production of all other ecosystems (Millennium Ecosystem Assessment, 2003). However, ecosystem services can be hard to identify or even quantify, like the role of biodiversity or water regulation (Bauhus, Van der Meer, & Kanninen, 2010).

Restoration in this plan has been designed with the concept of rewilding in mind. Rewilding means bringing back species that drive dynamic processes and letting nature take its course from there. Rewilding promotes self-regulating ecosystem while re-engaging people with nature (Ermgassen et al., 2018). It is not about recreating an ideal ecosystem but rather about taking the first steps to give nature a head start in its development and succession. Rewilding approaches should consider stakeholder's needs and expectations since changes in society will affect the way we manage nature (Perino et al., 2019). The effect of this approach on the project is that there are no silvicultural practices like thinning or removal of existing trees in the area. It is in essence about bringing back lost species and letting nature take care of itself.

Forest modelling can be a useful tool in making predictions on succession and stand characteristics of a forest at some point in the future (Von Gadow & Hui, 1999). For this reason, formulas on tree characteristics and virtual simulation models were used to make these predictions for the restored forest.

1.2 Problem description

The island of Kalamos is one of the Ionian islands off the west coast of Greece. It has a community forest with mixed conifer species, and it once also had a forest composed of deciduous and evergreen broadleaves (mostly oaks, Figure 1). The latter forest surrounded the main village of Kalamos and probably served as a protection forest by preventing floods and regulating the local climate in summer. In past times it probably served as a hiding place or place to repel pirates like in other forests on neighbouring islands.

Figure 1: The remarkable acorn of the Valonia oak, one of the deciduous broadleaf trees.

However, the deciduous and evergreen forests have mainly disappeared on the island and today only a small degraded grove and some scattered trees remain near the village of Kalamos. There are indications that there still is a relatively intact old community forest with deciduous broadleaves on the other side of the island but Terra Sylvestris is currently investigating this. This forest is presumably located on a mountainside that is not easily accessible, or there was no reason to go there anymore. So, it was likely left and forgotten so not much is known about this forest yet. The deciduous broadleaf forests have mainly disappeared or are heavily degraded and the land in the restoration area currently has a very low land use value for agriculture or nature conservation. Degradation of the forest probably happened in the early 20th century as a consequence of the political unrest in the country, although this remains uncertain. The exact reason for degradation has proven to be difficult to retrieve due to, among other things, the lack of a land registration system in Greece.

The commissioning organisation in this project is Terra Sylvestris. This is a non-profit non-governmental organisation located on Kalamos and is dedicated to the protection of the environment and sustainable development (Terra Sylvestris, 2016). Their efforts are aimed at rewilding the landscape of Kalamos through research or management. They currently work on several projects from wildlife monitoring to conducting research to anthropogenic impacts on ecosystems. This restoration plan contributes to their efforts in protecting the environment and promoting sustainability. Forests provide numerous ecosystem goods and services that could make life on Kalamos more sustainable. A forest surrounding the village of Kalamos would for example have a cooling effect on the village, especially during hot summer days. It would also reduce the water runoff and erosion with heavy rainfall and, of course, increase the aesthetic value of the area. Terra Sylvestris is especially interested in restoring the former oak forest since it will be an important contribution to their work as an environmental

NGO. Besides the ecosystem goods and services provided to the community, the forest will also serve as a new habitat for wildlife.

1.3 Problem statement

In contrast to the broadleaf forest, the pine forest on the island is not degraded and is in fact regenerating and expanding. The problem however, is that it is regenerating with mostly pioneer tree species (pine species). This will eventually lead to a forest with a low biodiversity value, and without effective regeneration of the desired climax species like oak, ash, rowan and pistachio. A more (bio)diverse forest would provide many more and better ecosystem services to the community. Therefore, this project is aimed at bringing back the species that drive ecosystem processes to restore the forest in a way that it again can provide ecosystem services to the community.

2 Objective & research questions

2.1 Objective
The overall objective of this project is:

> *Produce a full forest restoration plan, taking into account ecological, social and financial factors, to restore forest in an area of about 25 hectares near the village of Kalamos.*

2.2 Research questions
A set of research questions has been designed to reach the overall objective. Answering these questions resulted in an overall restoration plan containing a nursery, establishment (planting) and monitoring element. These research questions are:

- How should a tree nursery, using local reproductive material from remnant trees or nearby populations, be developed?

- How will the restored forest develop, taking into account succession based on the selected planting method and reference vegetation?

- How should future monitoring of the forest, and the ecological and social changes it will bring about, be done?

2.3 Sub-questions
In order to be able to answer the main research questions and achieve the objective above (2.2), the following sub-questions were created:

Nursery
- How should a tree nursery with locally adapted genetic material be designed?

Establishment
- Why was the area degraded and how could repetition be prevented?
- What is the most suitable planting method based on soil and vegetation characteristics in the area?
- What will the restored forest look like?
- How will succession and development shape the restored forest?

Monitoring
- How should monitoring of the new forest habitat be done?

3 Methodology

This project consisted of four phases: the preliminary phase, fieldwork, desktop study and reporting, and was aimed at answering the sub-questions. In the preliminary phase a literature survey was conducted to gain background knowledge on Mediterranean/Greek forests, restoration projects and techniques, community forests, etc. In the fieldwork phase, fieldwork was conducted to gain area specific data relevant for the project and to use this in the desktop study. Finally, all the collected data from the literature studies and fieldwork was combined to design the actual restoration plan. Figure 2 gives an overview of the different steps that were taken in the research and design process.

Preliminary phase:
1. Literature survey

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Fieldwork:
2. Locating seed trees
3. Soil profile description
4. Vegetation survey

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Desktop study:
5. Determine most suitable planting methods
6. Predict the succession and development of the restored forest
7. Produce virtual images of the restored forest

↓

Reporting:
8. Creating maps
9. Develop plan for tree nursery
10. Describe replanting method

Figure 2: Schematic diagram of the methodology.

3.1 Study site

The island of Kalamos is situated in the inner Ionian Archipelago, Greece (Figure 3). The island has a surface area of about 25 km^2 (2,500 ha) with a dimension of roughly 11 km by 4 km at its longest and widest points. It has a small population of a few hundred people divided over the two villages, Kalamos and Episkopi (Figure 3). The main village is Kalamos and there is one asphalted road between the villages. Most people on the island are fishermen and/or sailors and fish or work on cargo vessels to make a living. There are also some people that have goats, sheep and/or horses. Goats and sheep are often herded and even though there are not that many, they still affect the vegetation composition on the island and are thus considered in designing the restoration plan. Besides fishing and herding, hardly any farming is done on the island. People grow fruit and vegetables in their gardens but this is done on a small scale so reforestation practises will not conflict with farming.

Annex C shows a more detailed map of the restoration area and the planting (reforestation) area.

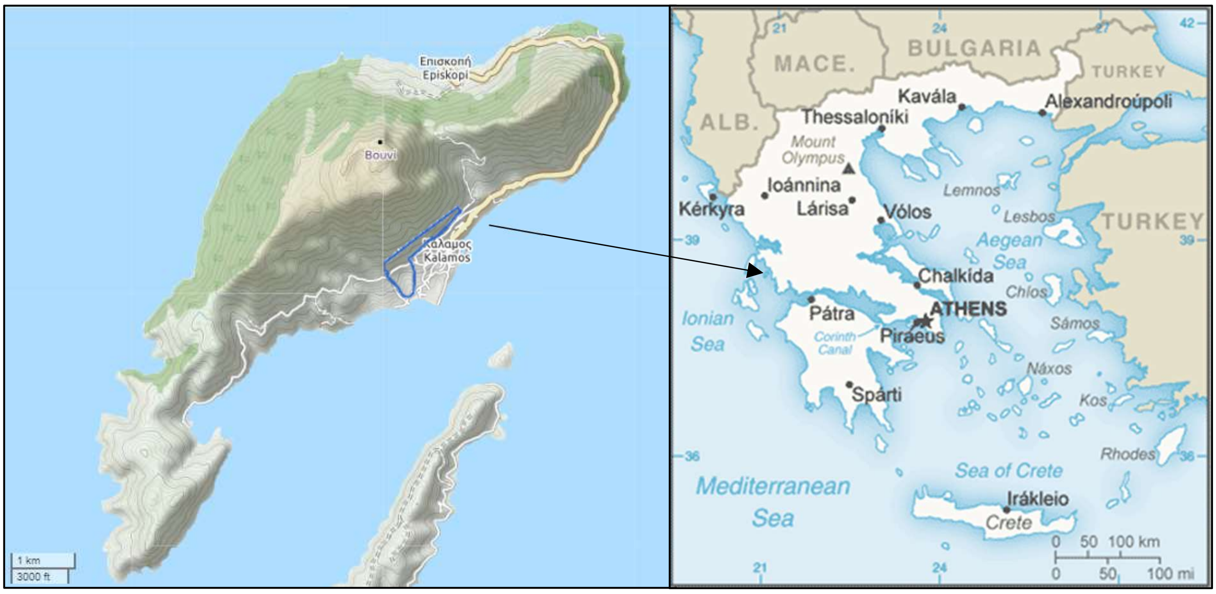

Figure 3: Map of the island of Kalamos (left) with the focus area in this project marked in blue. And a map of Greece (right) with the arrow indicating the location of Kalamos island. Adapted from OpenStreetMap (2019) and CIA (2016).

3.2 Literature survey

3.2.1 Cause of degradation

A literature study was conducted to give an indication of possible causes of degradation. This was supplemented by a vegetation and tree inventory.

3.2.2 Planting method

Suitable planting methods were also investigated in the literature study. This included, for example, finding literature on the planting density and the most effective way of growing and planting seedlings, e.g. bare root, container, etc.

3.2.3 Predictions on restored forest

Another literature study was conducted to gain knowledge on stand characteristics of oak forests in Greece. This allowed projections to be made on how the forest in the project area could develop. Articles found in literature provided valuable information on stand characteristics and species composition. This was used for giving suggestion for planting densities when replanting the forest.

3.3 Fieldwork

A vegetation survey was conducted to gain information on the current stage of degradation and soil and vegetation characteristics of the area.

3.3.1 Seed trees

When planting trees in an effort to reforest the area, local planting material should be used as long-distant transfer and the use of material of unknown origin poses threats to the adaptive potential of planted trees (Finkeldey & Ziehe, 2004). Using local seeds reduces the transfer time from the tree to the nursery which benefits the viability of the seeds due to reduced seed dehydration (Castro-Colina et al., 2012; Luna & Wilkinson, 2009). For this reason, it is necessary to know the number of seed trees in the area and their location. To get this information, seed trees were located by walking through the area and looking out for old oak trees since these will be used as seed trees. The seeds from these trees will ultimately be used in the nursery to produce the local planting material. Seed trees are defined as trees with a DBH of at least 10 cm, that are in good health so that they can produce seeds for planting material. So of these trees, the species, DBH, living state (dead/alive) and location (coordinates) were recorded.

The information on these seed trees gives an indication of the extension of the forest before it became degraded. This information was also used to assess whether the population of seed trees has a sufficient genetic diversity to support a healthy forest. For example, a small isolated population is not suitable as a seed source since the genetic base is likely to be very small.

Tree core samples were meant to be used in this project to give information on tree ages and growth rates. This could tell us for example how old the olive trees are and thus when they were planted. This is an indication of when the forest was removed to make way for olive groves. However, due to a broken increment borer this part could not be implemented in the project.

3.3.2 Soil

Investigation of the main soil characteristics in the area helped to select the most suitable tree species and predict future species composition. The method used in this project was adopted from the guidelines on soil description developed by the FAO (2016).

The soil samples provided information on soil fragment sizes, organic matter content, soil horizons, pH value, rock fragments, biological activity, effective soil depth and groundwater level. When tree seeds were present in the soil, the species/genus and abundance was noted since this is an important factor for the natural regeneration in the area. Also the location (coordinates), altitude and slope gradient class of each soil sample was recorded. (See Annex A for the field form.) Soil samples were taken using a shovel and a putty knife so when soils were too rocky to dig out a soil profile, only the topsoil was used in the description. The soil pH was measured by using test strips. Slope gradient class was taken from Google Earth. Nine soil samples were taken inside the vegetation inventory plots as will be described later. Additionally, six samples were taken along a road since this already provided clearly visible soil profiles which turned out to be very valuable since digging in the area was difficult due to a very rocky soil (Figure 4).

Figure 4: Two of the soil profiles along the road.

3.3.3 Vegetation
The soil and vegetation inventory was done by laying out research plots in the restoration area. Nine plots were spread out over the area in a way that gave a clear indication of the vegetation and soil in the area (i.e. avoiding roads, buildings, etc.). The plots were placed on a transect line of 1,350 m in total with a plot at every 150 m starting from the church as a reference point. Plot sites were selected prior to fieldwork and located in the field using a GPS.

3.3.4 Inventory plots
Several plot sizes were used in which different types of vegetation were taken into account (Figure 5). Plots of 10 m by 10 m were used for trees with a DBH of 10 cm or more (>=10), 5 m by 5 m plots for trees with a DBH between 2 cm and 10 cm (>=2 and <10), and 2 m by 2m plots for seedlings with a DBH of less than 2 cm (<2). For every recorded tree, the species, DBH and whether the tree was alive or not was noted (see Annex B for the field form). Also the slope aspect, dominant tree species and estimated dominant tree height (H_{dom}) were recorded in each plot. In the centre of each plot (10 m x 10 m), a soil sample was taken as described in subparagraph 3.3.2.

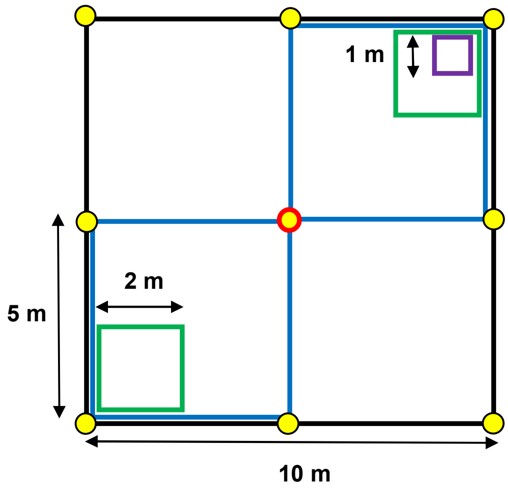

Figure 5: Vegetation inventory plot with the main plot in black, the sub-plots in blue, sub-sub plots in green and the sub-sub-sub plots in purple. The nine yellow dots indicate the locations of the ground cover measure points, and the red dot in the centre represents the location of the soil sample.

DBH
Tree diameter at breast height (DBH) was measured at a height of 1.30 m. When the tree was on a slope, the DBH was measured from the uphill side of the tree. If a tree was split into multiple stems above 1.30 m, a single DBH was measured below the split. If the split occurred below 1.30 m all stems were measured individually. To calculate a single DBH for a multi-stem tree, the following formula was used:

$$DBHmultistem = \sqrt{DBH1^2 + DBH2^2 + DBH3^2 \ldots}$$

Herbaceous vegetation
The Canopeo app (2015) was used to measure the ground cover percentage. Nine ground cover measurements were taken in each plot to give the average ground cover percentage per plot.

Sub-sub-sub-plots (1 m x1 m) were used to determine the present herbaceous species and their abundance. In each 1 m^2 quadrat, all present herb species and their abundance were recorded. Abundance was determined by using cover classes, for example 0-5 %, 5-10 %, etc. If a species could not be identified in the field, pictures were taken so that species could be identified later. When species could not be identified, they were called species A, species B, etc.

3.4 Data analysis

Data from the soil and vegetation analysis was put in an Excel database. This was then used to calculate the results on seed trees, soil and vegetation as presented in paragraph 4.2. Calculations were done on minimum, maximum and mean DBH values, number of trees per hectare (N/ha) and percentage of ground cover in each plot.

3.5 Forest modelling

Tree growth models were used in extrapolations as part of a desktop study to make projections of growth rates for the newly planted trees. Models on forests in Greece were used for higher accuracy of the results. The formulas were taken from Apatsidis (1999, 2000).

The formula used to calculate the dominant stand height (H_0) is:

$$H_0 = EXP(3.109977-19.2158/A)$$

Where 'H_0' is the dominant stand height in metres and 'A' is the age at breast height in years.

To calculate the absolute site index, the following formula was used:

$$\Delta\Pi T_\alpha = H_0/1.2380145 * (EXP(-19.2158/A))$$

Where '$\Delta\Pi T_\alpha$' is the site index at an age 'α', i.e. α=90 years. 'H_0' is again the dominant stand height in metres and 'A' is the age at breast height in years.

Crown diameter was calculated using the following formula:

$$D = d(EXP(-1.703951 + 4.191526/d))$$

Where 'D' is the crown diameter in metres and 'd' is the barked diameter of that tree at breast height in centimetres. Growth rate was taken from a cross section of a tree in the restoration area by counting the growth rings and measuring their width. Oaks had a 'd' of 4.8 cm at the age of 10 years.

Results from the growth rate models were used in forest simulation software to produce virtual images of the forest. These virtual images can be used in communication with local people to give them a better view on the results of this project. A Spatially Explicit Individual-based Forest Simulator (SExI-FS) was used to produce these images (ICRAF, IRD, 2008).

4 Results

This chapter presents the results of the literature and fieldwork studies (4.1-4.2) as well as the virtual images of the restored forest (4.3). These results were then used in designing a programme of requirements for the restoration plan (4.5).

4.1 Literature survey

4.1.1 Cause of degradation
Some efforts had already been made in answering this question by the commissioning organisation, Terra Sylvestris. However, this question has proven to be a difficult one to answer. It is still important to know because it could allow measures to be taken in the future to prevent repetition.

It is said that at some point during the 19th century the island hosted more than 20,000 people, who were refugees created during the Greek war of independence (1821-1829) ("History," 2016). This would have seriously constrained the natural resources on the island. Much forest was probably destroyed during this time and later following the Balkan wars, World War I and II, Greek Civil War (1946-1949) and a military regime.

Acorns and foliage of the Valonia oak have been used as fodder and in tanneries (Longinou, Efthimiou, & Detsis, 2017; Papanastasis, 2002). After the development and introduction of alternatives (for example by using chemicals for tanning), oaks lost their value. Nowadays the species has a rather ecological than economical importance as it forms some of the few deciduous oak forests in the eastern Mediterranean zone (Pantera, Papadopoulos, Fotiadis, & Papanastasis, 2008). Wood has a good quality and makes excellent charcoal and firewood (Schultz et al., 1987) so this could be the reason why most oaks were cut down and replaced by olive trees. After deforestation, the land could also be used as pasture land for goats and sheep.

Part of the reason may therefore have been goat herding. From field observation, it can be concluded that goats are common in the area and are often left free to roam. Goats are known for having a severe effect on vegetation composition and density (Coblentz, 1978). Studies on feral goats have shown that they cause habitat destruction through overbrowsing, weed dispersal and soil erosion (Masters, Markopoulos, Florance, & Southgate, 2018; Parkes, 1990).

4.1.2 Planting method
The information found in literature was used in paragraph 5.2 when designing the reforestation method. This information was related to the planning, competitive vegetation, planting density, mortality and prevention of degradation.

4.1.3 Predictions on restored forest
A study of Valonia oak (*Q. ithaburensis*) stands in Greece (Longinou et al., 2017) showed that pure stands had a density of 227 trees/ha, with a mean DBH of 27 cm and a mean height of 6 m. DBH values ranged from 4.6 cm to 39.8 cm, and the maximum tree height was 14.5 m.

The same study also showed the stand characteristics of Valonia oak (*Q. ithaburensis*) along with kermes oak (*Q. coccifera*) and Aleppo pine (*P. halepensis*). In these stands the N/ha of Valonia oak, Kermes oak and Aleppo pine was 450, 27 and 10 respectively. Also scattered individuals (3 N/ha) of Almond-leaved pear (*Pyrus spinosa*) were found in these stands. Valonia oaks in these forests had a mean DBH of 12.5 cm (4.0 cm - 49.0 cm) and a mean height of 3.5 m.

Succession
The results from the study described here, were taken from a supposedly degraded forest due to human actions such as agriculture, animal husbandry, urbanization and wildfires (Longinou et al., 2017). This means that characteristics of Valonia oak in the restored forest might differ from this. However, results from the vegetation survey (4.2.3) and additional field observations indicate that the invasion of Aleppo pine (*P. halepensis*) and regeneration of kermes oak (*Q. coccifera*) are also happening on Kalamos. This suggests that the stand characteristics of the restored forest would ultimately be more similar to the mixed forest stand as described above. Also the old olive trees that are currently present in the area will remain, so the forest will be a mixed forest of predominantly Valonia oak with remaining olive trees and spontaneous regeneration of Aleppo pine and kermes oak.

4.2 Fieldwork

4.2.1 Seed trees and cause of degradation
A total of 21 seed trees of Valonia oak (*Q. ithaburensis*) has been found in the area. Seed trees have a mean DBH of 22.7 cm with a minimum DBH of 10.1 cm and a maximum DBH of 52.1 cm. Annex C shows a map of the restoration area with the location of the seed trees.

4.2.2 Soil
Soils in the area are neutral to basic with pH-values ranging from 7.1 to 8.1. Elevation of the profiles ranged between 84 m and 149 m a.s.l. Slope classes were either 8 (15-30 %) or 9 (30-60 %). The effective soil depth or rooted depth was always more than the depth of the soil profile. All soil profiles had calcareous clay with an organic matter content of between 0-0.5 % and 1-1.5 % in the topsoil. Soil horizons had rock size classes between N (none) and B (boulders) which means rocks had a size of up to 200 mm to 600 mm (Annex A). Rock abundance classes were between N (none) and A (abundant), or between 0 % and 40 % - 80 %.

Seeds of Valonia oak (*Q. ithaburensis*), kermes oak (*Q. coccifera*), Aleppo pine (*P. halepensis*), and olive tree (*O. europaea*) were found in the litter layer and topsoil. However, the presence of seeds was restricted to certain areas since there is no equal distribution of seed trees throughout the area. Only olive trees can be considered to be present throughout the restoration area.

4.2.3 Vegetation
Results from the vegetation inventory show that slope class is mostly 9. Only plot 2 had a slope class of 8. Slopes on plot sites faced directions between east (E) and south southwest (SSW). Elevation of the plots range between 116 and 149 metres above sea level. Ground cover was on average 26.1 %, ranging from 17.9 % up to 33.6 %. The dominant tree species in the area is the olive tree, with 6 out of 9 plots having olive trees as the most dominant species. However, tree densities are extremely low, with a maximum of three trees per plot, so no species is in fact ‘dominant’. Dominant in this case means the most abundant, or only, species present. See Annex D for the plot data.

Analysis of the results from the vegetation inventory shows that olive trees were the most dominant tree species in the majority of the plots (Table 1). Valonia oak and Aleppo pine were the dominant species in only one plot each. In the plot where Aleppo pine was the most dominant species, there were no trees with a DBH of at least 10 cm (DBH=>10) and ground cover was only 23.9 %. Therefore, it could be stated that no species was, in fact, dominant at all. The Valonia oak plot had the highest average ground cover of 30.3 % and an average dominant tree height class 5 (7-8 m), which is also the highest. Plots with olive trees as the most dominant species had an average ground cover of 27.3 % with an average dominant tree height class 3 (5-6 m). These results show that Valonia oaks are overall the highest trees with the densest ground cover and that olive trees are the most abundant species. Aleppo pines have not fully established yet but are regenerating in the area.

Table 1: Results from the plot data, sorted per dominant tree species.

Dominant tree species	Number of plots	Average ground cover (%)	Average dominant tree height class	N/ha (DBH = >10)	N/ha (DBH =>2 and <10)
Olive tree	6	27.2	3	88.9	177.8
Aleppo pine	1	23.9	1	0	22.2
Valonia oak	1	30.3	5	22.2	22.2

Tree density of trees with a DBH of at least 10 cm (>=10) was 111.1 trees/ha (Table 2). Olive trees (*O. europaea*) accounted for 88.9 trees/ha while the other 22.2 trees/ha were Valonia oaks. Olive trees had a mean DBH of 42.9 cm with a minimum and maximum DBH of 10.7 cm and 106.0 cm respectively. Valonia oaks had DBH values between 15.1 cm and 24.6 cm with a mean DBH of 19.9 cm.

Table 2: Stand characteristics per species, of trees with a DBH of at least 10 cm (DBH >=10).

Species	Scientific name	N/ha	Mean DBH (cm)
Olive tree	*Olea europaea*	88.9	42.9
Valonia oak	*Quercus ithaburensis*	22.2	19.9
Total		**111.1**	

Trees between 2 cm and 10 cm (>=2 and <10) had a density of 244.4 trees/ha (Table 3). Olive trees had a density of 177.8 trees/ha. Valonia oak, Aleppo pine and carob tree (*Ceratonia siliqua*) had a density of 22.2 trees/ha each. Olive trees had DBH values ranging from 3.2 cm up to 8.7 cm with a mean DBH of 6.3 cm. Valonia oak, carob tree and Aleppo pine had a DBH of 2.9 cm, 4.6 cm and 6.2 cm respectively, with only one individual per species found in the plots.

Table 3: Stand characteristics per species, of trees with a DBH between 2 cm and 10 cm (DBH >=2 and <10).

Species	Scientific name	N/ha	Mean DBH (cm)
Olive tree	*Olea europaea*	177.8	6.3
Valonia oak	*Quercus ithaburensis*	22.2	2.9
Aleppo pine	*Pinus halepensis*	22.2	4.6
Carob tree	*Ceratonia siliqua*	22.2	6.2
Total		**244.4**	

In addition to this, kermes oak was not present in the inventory plots. However, this species has been seen in the area and seeds have been found in the soil samples. It grows in dense patches and can be relatively abundant in certain places.

Herbaceous vegetation
In the 1 m by 1 m plots a total of 17 herb species was found in nine plots. The most abundant species was sage (*Salvia sp.*), followed by 'species A' (*Fabaceae*). Sage was present in six out of nine plots with a cover percentage of up to between 45 % and 50 %. 'Species A' mostly had a cover percentage of less than 5% and between 10 % to 15 % at most (Figure 6).

Figure 6: An example of 'Species A' (Fabaceae) in one of the inventory plots.

4.3 Forest modelling

The formulas described in paragraph 3.5 were used to calculate stand characteristics for short and long term (10 to 100 years) (Table 4).

Table 4: Calculated characteristics of Valonia oak at different ages (A).

A (age in years)	d (cm)	H_0 (m)	D (m)	$\Delta\Pi T_\alpha$
10	4,8	3,28	2,09	0,388023
20	9,6	8,58	2,70	2,650871
50	24,0	15,27	5,20	8,396678
100	48,0	18,50	9,53	12,33144

After ten years (A=10), the dominant tree height (H_0) will be 3.28 m and trees will have a crown diameter (D) of 2.09 m. Absolute site index at age 10 ($\Delta\Pi T_{10}$) is 0.388.

The Spatially Explicit Individual-based Forest Simulator (SExI-FS) was used in stand visualisation for different ages after planting of Valonia oaks in an area of 0.25 ha (50 m by 50 m) (Figure 7). In addition to these maps, virtual images of the forest were created (Annex E). This could provide local people with an image of how the landscape is going to change in the short to medium term. Results from the calculations above were implemented in the visualisation model. Olive trees and random seeds were also implemented in the visualisation to give a more realistic model of the area since these trees will have an effect on the planted trees. Also the topography of the area was taken into account since the area is located on a mountainside. Succession was has already been predicted in subparagraph 4.1.3 as part of the literature study.

Stand densities of Valonia oak in the maps below (Figure 7) are 833 N/ha at age 0 (at the time of planting), 692 N/ha at age 10, 392 N/ha at age 30 and 160 at age 60.

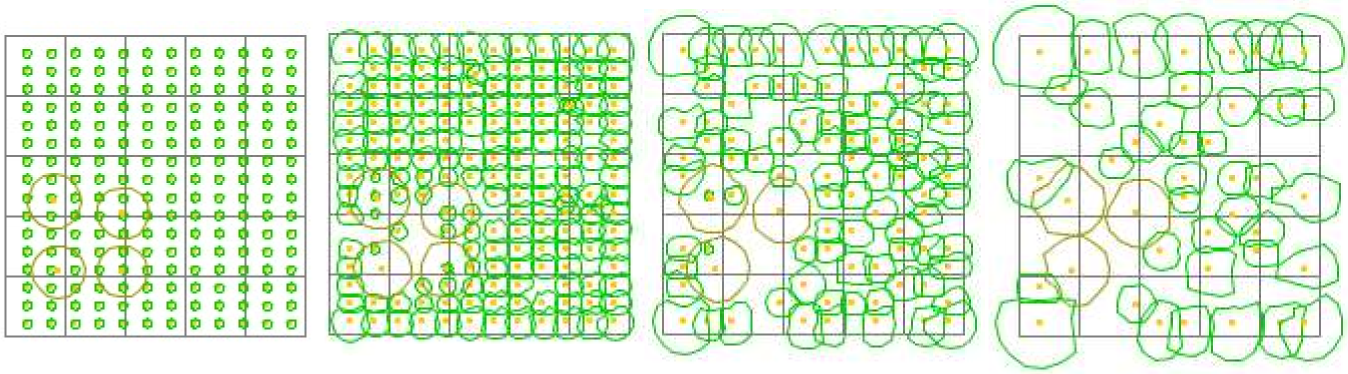

Figure 7: Schematic maps made with the simulator. From left to right, the forest after 0, 10, 30 and 60 years. The light brown circles represent the olive trees (O. europaea) and the green ones Valonia oaks (Q ithaburensis). The size of each square map is 0.25 ha (50 m by 50 m).

4.4 Programme of requirements

A programme of requirements has been formulated based on these results. This consists of a set of criteria that this restoration project should comply with. They are grouped by three major actions of reforestation, i.e. nursery, establishment and monitoring. These requirements are as follows and further explained in Table 5:

Nursery

- Seeds are collected from a locally adapted source.

Establishment

- Planting method is based on environmental restrictions (e.g. rainfall, soil, noxious weeds).
- Measures have been taken to prevent repetition of degradation.

Monitoring

- Valonia oak is the dominant tree species.
- Monitoring is focussed on tree growth, forest development, and biodiversity.

Table 5: Programme of requirements.

Requirement	Indicator/explanation
Seeds are collected from a locally adapted source.	Seeds are collected from mainland Greece due to the lack of a sufficient number of seed trees on the island itself. The source will be within 20 km from Kalamos.
Planting method is based on environmental restrictions (e.g. rainfall, soil, noxious weeds).	It has been assured that the restoration species is adapted to the soil in the area.
	Rainfall has been taken into account when deciding on the time of planting.
	The ecology between planted trees and other vegetation has been considered.
Measures have been taken to prevent repetition of degradation.	Actions to prevent grazing/browsing or clearing of young trees by goats, shepherds and/or farmers have been taken.
Valonia oak is the dominant tree species.	The species with the highest number of trees per hectare (N/ha) after 10 years will be Valonia oak.
Monitoring is focussed on tree growth, forest development, biodiversity and the public opinion.	Results of monitoring will give insight in tree growth rates (DBH, height), regeneration, species composition, bird and mammal species and local people's view on the forest.

A vison was created based on the programme of requirements. The plan as described in chapter 5 has been designed with the following vision in mind:

> A *restoration plan with implementation of local planting material of Valonia oak (Quercus ithaburensis) and a suitable planting method; where measures against degradation, and recommendations on a monitoring plan have been made.*

5 Restoration plan

This chapter contains the actual restoration plan based on the results given in chapter 4. It is divided into several paragraphs about the nursery, establishment and monitoring (5.1-5.3). An overview of time and costs has been given in paragraph 5.4.

The table below (Table 6) gives an overview of all activities that will have to take place in order to reforest the area. It starts with the collection of seeds at the right time of year when acorns are ready. Sowing will be done as soon as possible after collection. Seedlings will then grow in the nursery for about two years until they are planted in late summer/autumn when rainfall starts to increase. Before planting, weeding will be done to remove competitive vegetation which will benefit the planted trees. One year after planning, any dead trees will be replaced by trees that have been kept in the nursery. After establishment of the new forest, monitoring will be conducted to gain information on the development and succession of the new forest. Monitoring will be done on flora, fauna and public opinion. A further explanation of the activities and planning will be given in the following paragraphs.

Table 6: Calendar of all activities per month described in this restoration plan, from the collection of seeds to monitoring.

Activity/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seed collection												
Sowing												
Growing seedlings												
Applying compost												
Weeding												
Planting												
Replacing dead trees												
Monitoring (vegetation)												
Monitoring (other)												

5.1 Tree nursery

Literature on tree nurseries and the data about seed trees was used in designing the nursery. Seed trees on the island itself may not provide enough planting material to reforest the area and genetic diversity is probably very low. So, the use of mainland trees is also implemented in the plan.

5.1.1 Seed collection and sowing

Seeds will be collected from different locations on mainland Greece since the number of seed trees on Kalamos is too low to provide enough seeds. Taking seeds from different locations will also lead to a greater genetic diversity of the species in the restored forest through the gene flow between populations (Ratnam et al., 2014). Seeds will be collected in autumn since this is the time of year when acorns are ready. Acorn collection will be done by taking a car to a Valonia oak forest, or at least an area with a sufficient number of trees. Here, bags will be filled with acorns and these bags will be taken back to Kalamos.

When collecting acorns in the field, collection of obviously damaged acorns should be avoided. After collection, the seeds will be tested visually and any soft or damaged acorns will be discarded. Subsequently the seeds will be tested using the water bath method where the acorns will be put in a bucket filled with water and after a couple of minutes any floating acorns will be removed and discarded (Luna & Wilkinson, 2009, p.122; Pantera & Papanastasis, 2012). All the seeds that will have passed these tests will then be filed slightly to enhance germination. This has been tested by Terra Sylvestris and has proven to be effective.

Seeds should be planted as soon as possible since the viability will decrease over time. However, if too many seeds have been collected or there is not enough space in the nursery they can be stored. The way in which they are stored is an important factor for the decrease in viability. In an experiment with acorns kept at a near freezing temperature (1.6 ˚C) for six months, the acorns had a viability of 77 % compared to a viability of 89 % before storage (Devine, Harrington, & Kraft, 2010). Acorns stored at a near freezing temperature remained more viable than acorns stored at 4 ˚C. So, if any acorns are going to be stored they should be tested for viability as described above, then washed and stored in a near freezing temperature soon after collection.

5.1.2 Growing in nursery

The nursery has a total surface area of about 121 m^2. When using part of that area for things like walking paths, it leaves about 70 m^2 for seedbeds (see Annex F for a schematic map of the nursery). All seeds will be planted in containers since this has proven to be more effective than bare root seedlings (Tsitsoni, Tsakaldimi, & Gousiopoulou, 2015).
The year after planting, new seedlings will be produced to replace any dead trees

833 trees will be needed per ha, and 17 ha will be planted. This means a total of 14,160 trees is needed. If we take a 10 % mortality into account, a total of 15,577 trees is needed (833 trees/ha x 17 ha x 1.1). Seedlings can be placed in the nursery at 100 seedlings per m^2, so the nursery has a maximum capacity of 7,000 seedlings (70 m^2 x 100). Therefore three rotations will be needed to produce enough trees.

5.1.3 Applying compost

A soil mixture will be made from potting soil and soil (clay). The mixture will have a one to one ratio (1:1) of potting soil and soil. The containers have a volume of 1.5 litres, so this amount of soil mix is needed per container. Compost will be added to fertilise the soil mixture after a couple of months since potting soil will run out of nutrients eventually. The exact time of adding compost depends on the type of potting soil but after 6 months should be fine. This will be done two to three times during one rotation since trees remain in the nursery for two years.

5.2 Establishment

The tree species that will be used for restoration of the area is Valonia oak (*Quercus ithaburensis*) since the forest would have originally consisted of this species, and oak forests have mainly disappeared from the island having been replaced by pine forests or olive groves. The presence of remnant and regenerated Valonia oaks indicates that this is a suitable tree species to grow on the type of soil in the area.

5.2.1 Planning

Kalamos has a Mediterranean climate with warm, wet winters and hot, dry summers. The coldest month is January with an average lowest and highest temperature of 2 ˚C and 10 ˚C (Weather Atlas, 2019). The warmest months are July and August with both having an average lowest and highest temperature of 16 ˚C and 29 ˚C. The wettest month is December with an average rainfall of 178 mm compared to only 17 mm in July, which is the driest month. Annual rainfall is 1,035 mm.

Trees will be planted in autumn/early winter since rainfall in summer is very low in Kalamos. So by planting trees in autumn/winter the young trees will receive enough water to help them survive during the first months after planting. Cardboard could be applied around seedlings to increase water availability by reducing soil water evaporation and holding moisture in the soil for longer (Silva, Resende, Santos, & Chaer, 2018). In addition to the soil moisture advantages it also reduces competition by suppressing weeds. The use of cardboard is cost-efficient and environmentally friendly since cardboard is cheap and biodegradable. There are even examples where used pizza boxes have been used for crowning seedlings (Ferreira, 2017). Cardboard could be collected from local shops such as supermarkets and restaurants that probably have used cardboard from packaging.

Trees will stay in the nursery for two years and the year after planting will be used to replace any dead trees. Which means a full rotation will take 3 years in total, from the starting point of seed collection and sowing in year zero, to replacing dead trees three years after that (Table 7). Collection of seeds for the second rotation can be done in the same year as replacing dead trees of the previous rotation because there will be new space in the nursery.

Table 7: Calendar overview of the years in which some of the nursery and establishment activities will take place. This overview contains three full rotations. (Table 6 shows in which months these activities take place)

Activity/year	0	1	2	3	5	6	7	8	9	10
Seed collection and sowing										
Growing in nursery										
Planting										
Replacing dead trees										

5.2.2 Weeding

The herbaceous plant composition can positively and negatively affect the growth of Valonia oak. Grasses have proven to negatively affect growth, whereas clovers favoured the growth of Valonia oak (Pantera & Papanastasis, 2012). This may be attributed to the higher availability of nitrogen in the soil due to the nitrogen fixing abilities of clovers.
Also, seedling height compared to that of the competitive vegetation is an important factor for regeneration success. Weeding is necessary when seedling height is less than that of competitive vegetation (Pantera & Papanastasis, 2012). When removal of competitive vegetation is impossible or too costly, taller oak seedlings should be used.

In the restoration area on Kalamos, the ground cover percentage of especially grasses is considered too low to severely affect tree growth. However, lentisk or mastic (*Pistacia lentiscus*), is a very abundant shrub in the area and can grow up to 4 m tall. This means that this plant should be partially removed when planting the oak seedlings. This can be achieved by scalping or cutting using a hoe or pruning shears for example.

5.2.3 Planting

Trees will be planted at about 833 trees per hectare, in rows separated by 4 m with a distance of 3 m between individual plants within a row (FAO, 1989). Planting rows will follow the contour lines as much as possible.

Mortality rates are expected to be 10-11 % after one year and 15-16 % after two years based on mortality rates of three oak species (Q*. ilex, Q. pubescens and Q. suber*) (Schirone et al., 2011). Most seedlings die in their first dry season, or summer, (Tsitsoni et al., 2015) so one year after planting in the field any dead trees will be replaced by new seedlings.

Planting seedlings will be supplemented by sporadically spreading seeds. This will decrease the visual impact of the planting pattern and create a more irregular and less plantation like forest. It can also fill up the gaps that occur when planted seedlings die.

5.2.4 Prevention of degradation

To prevent clearing of the planted trees, communication with local people is key. The needs of local people should be addressed so they have an interest in the forest and are motivated to keep it (Galabuzi et al., 2014). Before starting the planting, a community meeting should be organised where the restoration plan will be explained and the short- and long-term benefits of the project can be discussed. During the meeting local people should also be given the chance to raise any questions they might have. This will take away any doubts about the project and increase project support within the community.

It might take some effort to convince certain people to keep their herding flocks out and to see all the benefits of an oak forest over some scattered olive groves or even a pine forest. Benefits to local people can come from a new source of firewood and opportunities for bee keeping (this is already being done on the island). Also, other ecosystems services (climate regulation, erosion prevention, water-retention) as already mentioned in the introduction will be of interest to local people. The potential to receive carbon credits for the carbon that will be sequestrated by the restored forest might be appealing to the community.

Even though there is no real interest in the area to use the land for farming for example, there will most likely be conflicting interests somewhere. Shepherds should not keep their flocks close to the newly planted trees to prevent browsing. Fencing the area could also be a solution but this can be very expensive (especially for a large areas) and it is not always as effective since fences can be damaged or removed. Moreover, wildlife will be restricted by fences too. Subsidisation in which a shepherd gets paid for not grazing in certain areas could be an effective alternative. This could be done until the planted trees are tall enough and tree crowns are out of reach of goats. There are examples of Mytikas (just on the mainland from Kalamos) where people get paid 40 to 50 euros to let their herd graze in an area of about 1.5 hectares for a year. This could be used for the purpose of reforestation by paying people to keep their herd out of a certain area.

5.3 Monitoring

Monitoring is important because information gained by monitoring will give feedback on the restoration practices. This could lead to a change in plans or additional practices such as enrichment planting of Kermes oak if natural regeneration is failing. Also planting of other native trees like laurel (*Laurus sp.*) could be an option since this will add another provisioning ecosystem service to the forest that can be used by local people.

The methodologies as described in this paragraph are mainly based on the current research projects conducted by Terra Sylvestris.

5.3.1 Flora & fauna

Vegetation

Permanent plots will be used to monitor changes in vegetation structure and species composition. The use of permanent plots and enumeration of trees will allow Terra Sylvestris to monitor tree growth more accurately.

Birds & mammals

Bird monitoring should be done as currently conducted by Terra Sylvestris so the methodology is the same and results can be compared with other data. So, several ‘point counts’ should be located in the restoration area and bird species and abundances will be recorded. This will give information on the changes in species composition as the forest develops over time. In addition to the bird survey, camera traps will be used to track changes in mammal abundance. Similar to bird monitoring, it will give an insight into the presence of certain mammal species. Also the presence or absence of undesired mammals like goats and feral cats can be determined.

5.3.2 Public opinion

Interviews will be conducted to assess local people's opinion on the forest and how this might change over time. This will give a valuable insight into what is on people's minds and any issues that they have. When people have any issues, it should be known by Terra Sylvestris as soon as possible so measures can be taken to ensure that the problem does not escalate. On the other hand, it is also good to receive positive feedback on the project and to be sure that everybody is happy or satisfied with how things are changing.

5.4 Time and costs

In this paragraph the time and costs of materials and activities for the nursery, establishment and monitoring will be provided and explained. The total cost of this project is € 1,002.04.

5.4.1 Nursery

Material

The table below (Table 8) gives an overview of the material costs for establishing the nursery. Materials that are needed are containers to grow seedlings; a soil substrate to fill up the containers; compost to supplement the potting soil; and, of course, the seeds or acorns.

Table 8: Overview of materials and their corresponding quantities and costs of everything that is needed for establishing the nursery.

Item	**Quantity**	**Unit**	**Costs per item (€)**	**Total costs (€)**
Containers	16,284	Piece	0.01	162.84
Potting soil	8,142	Litre	0.10	814.20
Compost	1,628	Litre	0.00	0.00
Seeds (acorns)	18,693	Piece	0.00	0.00
Total				**977.04**

14,161 trees will be planted and an additional 10 % (1,416 seeds) should be collected for discarding of the non-viable ones, and another 10 % for direct seeding (Table 9). In addition to this, more trees will be needed to replace any dead trees one year after planting in the field. 15 % (2,124 trees) extra will be produced to assure there will be enough trees since mortality is expected to be 10 % to 11 %. This brings the total number of acorns to 19,116, and total number of containers to 16,284. Since there will be three rotations there will be 6,372 acorns needed for the planting of 4,720 trees per rotation, and 708 for replacing afterwards.

Table 9: Number of seeds that is needed in total and per rotation.

	Number of seeds	**Number of seeds (per rotation)**
Trees to be planted	14,161	4,720
Non-viable seeds	1,416	472
Seeds for direct seeding	1,416	472
Replacement of dead trees	2,124	708
Total	**19,116**	**6,372**

Manhours

Acorns can be collected at an estimated 360 per person per hour (ppph). Getting 6,372 seeds for one rotation will then take about 18 hours (Table 10). So this could be done with three people in a day depending on travel time. After collection the seeds will have to be tested which can be done at 700 seeds ppph. So, testing 6,372 seeds will take about 9 hours in total.

Filling containers and adding compost can be done at 300 containers ppph. When there are 5,428 containers in the nursery, this will take about 18 hours. Sowing seeds, including filing, can be done at about 60 seeds per hour. This means that sowing will take 91 hours in total per rotation.

Table 10: Overview of labour time and costs for establishing the nursery.

Activity	**Total hours required**	**Costs per hour (€)**	**Total costs (€)**
Collecting seeds	18	0.00	0.00
Travelling to and from forest for seed collection	1 – 3 (depending on distance)	25 (borrow/rent car per day)	25.00
Testing seeds	9	0.00	0.00
Filling containers	18	0.00	0.00
Sowing seeds	91	0.00	0.00
Adding compost	13	0.00	0.00
Total			**25.00**

5.4.2 Establishment

Manhours

Before planting, the planting site should be prepared and competitive vegetation should be removed. Mastic in particular, is a species that should be removed as this is probably the only one, or at least most dominant species that will compete with the planted trees. This will not be necessary throughout the whole planting area because there are also places with little or almost no vegetation. Clearing of planting sites where this is considered necessary will take about 96 hours per hectare (12 days). When assuming that clearing is needed for half of the planting area it will be 288 hours per rotation (96 hours x 3 ha).

Planting takes about 40 hours per ha (5 working days). When planting 6 hectares per rotation the total time is 240 hours or 30 working days (Table 11). So planting trees with 3 people will take about 10 days or 2 weeks when working 5 days a week.

Planting will be done by volunteers of Terra Sylvestris and preferably also locals to increase community involvement in the project (Pohnan, Ompusunggu, & Webb, 2015). This will all be done on a voluntary basis which means there are no labour costs.

Table 11: Overview of the labour time and costs for replanting the area.

Activity	**Total hours required**	**Costs per hour (€)**	**Total costs (€)**
Site preparation (weeding)	288	0.00	0.00
Planting	240	0.00	0.00
Replanting dead trees	4	0.00	0.00
Total			**0.00**

5.4.3 Monitoring

Monitoring can be done year-round but identification of plant species will be easier in spring since this is the time when most plants bear flowers. Also monitoring of migratory birds, can only be done at the right time of the year which will mostly be late spring, summer or early autumn. All monitoring activities will be done by interns and volunteers working with Terra Sylvestris.

6 Reflection and recommendations

This restoration plan has, on the whole, succeeded in answering the research questions and sub-questions in chapter 2 (2.2-2.3). The plan shows how the nursery should be developed, predictions have been made on how the forest will develop over time and a monitoring plan has been developed. However, the plan fails in answering the exact cause of degradation and the time at which this happened. Nevertheless, possible causes and points in time have been put forward.

By answering the research questions, the overall objective has been achieved even though this plan focusses more on the ecological rather than financial or social aspects. These aspects are still represented in for example the costs of the project, measures against degradation and monitoring of the social situation.

This plan will contribute to solving the problem as described in the introduction (1.2-1.3). The plan is aimed at bringing back the deciduous evergreen forests that were there many years ago and to restore the ecosystem. It will contribute to sustainable land use, making life in the community more sustainable and Kalamos an even more aesthetic island.

A short reflection on the given results on tree densities in subparagraph 4.2.3 should be given. These results should be taken cautiously since tree species were not equally distributed throughout the area. For example, the Valonia oaks were concentrated in one place while being absent in the rest of the area (Annex C). Results from the seed trees show that there are 21 Valonia oaks in the area (with a DBH of at least 10 cm), while the vegetation inventory results would indicate there is a total of 555 trees in an area of 25 ha (22.2 N/ha x 25 ha). This could be due to not enough plots or too small plot sizes.

I would like to give some recommendations to Terra Sylvestris for improving this restoration plan and doing additional work. I would encourage them to continue investigating into the history, what happened to the forest and when exactly it became degraded. I would also advise them to try and obtain a new increment borer to collect some core samples as these might provide valuable information on tree growth rates and tree ages.

Another valuable addition to this plan would be to conduct an Environmental Impact Assessment (EIA). This would be a study in itself and for that reason was not implemented in the plan given the limited amount of time. An EIA could assess whether some practices should be reconsidered or additional practices are needed. It would also show the exact benefits, or ecosystem goods and services provided by the restored forest, for example the cooling effect of the forest, erosion prevention and water-retention. The EIA could quantify these ecosystem services and show what the temperature difference will be, or how much erosion will be prevented, etc.

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Annexes

Annex A: Soil survey - field form

Soil profile description
field form

Profile no.	Name of investigator(s)	Date	Elevation a.s.l. (m)	Location
				Lon.: Lat.:

Slope gradient class	
Effective soil depth (cm)	
Maximum groundwater level (cm)	
Seed bank (species, abundance)	

Soil horizons

No.	Horizon	Depth (cm)	Organic matter (%)	pH	Texture of the fine fractions	Rock fragments size class	Rock fragments abundance class	Biological activity class	Remarks
1									
2									
3									
4									
5									
6									
7									

Slope gradient class:
(Table 7, FAO)

Class	Description	%
1	Flat	0 – 0.2
2	Level	0.2 – 0.5
3	Nearly level	0.5 – 1.0
4	Very gently sloping	1.0 – 2.0
5	Gently sloping	2 – 5
6	Sloping	5 – 10
7	Strongly sloping	10 – 15
8	Moderately steep	15 – 30
9	Steep	30 – 60
10	Very steep	>60

Rock fragments size classes:
(indicating the greatest dimension) (Table 27, FAO)
Also combinations, for example: FM, MC, CS, etc.

Class	Description	mm
N	None	0
F	Fine gravel	2-6
M	Medium gravel	6-20
C	Coarse gravel	20-60
S	Stones	60-200
B	Boulders	200-600
L	Large boulders	600<

Abundance of rock fragments classes:
(Table 26, FAO)

Class	Description	%
N	None	0
V	Very few	0-2
F	Few	2-5
C	Common	5-15
M	Many	15-40
A	Abundant	40-80
D	Dominant	80<
S	Stone line	

Horizon symbols:
H (organic horizon, wet)
O (organic horizon, dry)
A (organic matter)
E (eluviation)
B (illuviation)
C (parent material)
R (parent rock)

Abundance of roots (>2mm) classes:
(Table 80, FAO)

Class	Description	Abundance
N	None	0
V	Very few	1-2
F	Few	2-5
C	Common	5-20
M	Many	20<

Annex B: Vegetation survey - field form

Vegetation Survey - field form

10x10 m plots

Plot no.:	Name(s):	Date:	Plot location (plot centre):
			Lon.:
			Lat.:

Altitude (m):	
Slope gradient class:	
Slope aspect (north, east, south, west, etc.):	
Corresponding soil profile number:	

Dominant tree species:									
Dominant tree height (H_{dom}) (m):									
Ground cover:									

Main plots, 10x10m (DBH >=10 cm)

Tree no.	Species	DBH (cm)	Multi-stem DBH (optional)	Living state (class 0-1)	Remarks
1					
2					
3					
4					
5					
6					
7					

Sub-plots, 5x5m (DBH >=2 and <10 cm)

Tree no.	Species	DBH (cm)	Multi-stem DBH (optional)	Living state (class 0-1)	Remarks
1					
2					
3					
4					
5					
6					
7					

Sub-sub-plots, 2x2m (DBH <2 cm)

Tree no.	Species	Diameter (cm)	Living state (class 0-1)	Remarks
1				
2				
3				
4				
5				
6				
7				

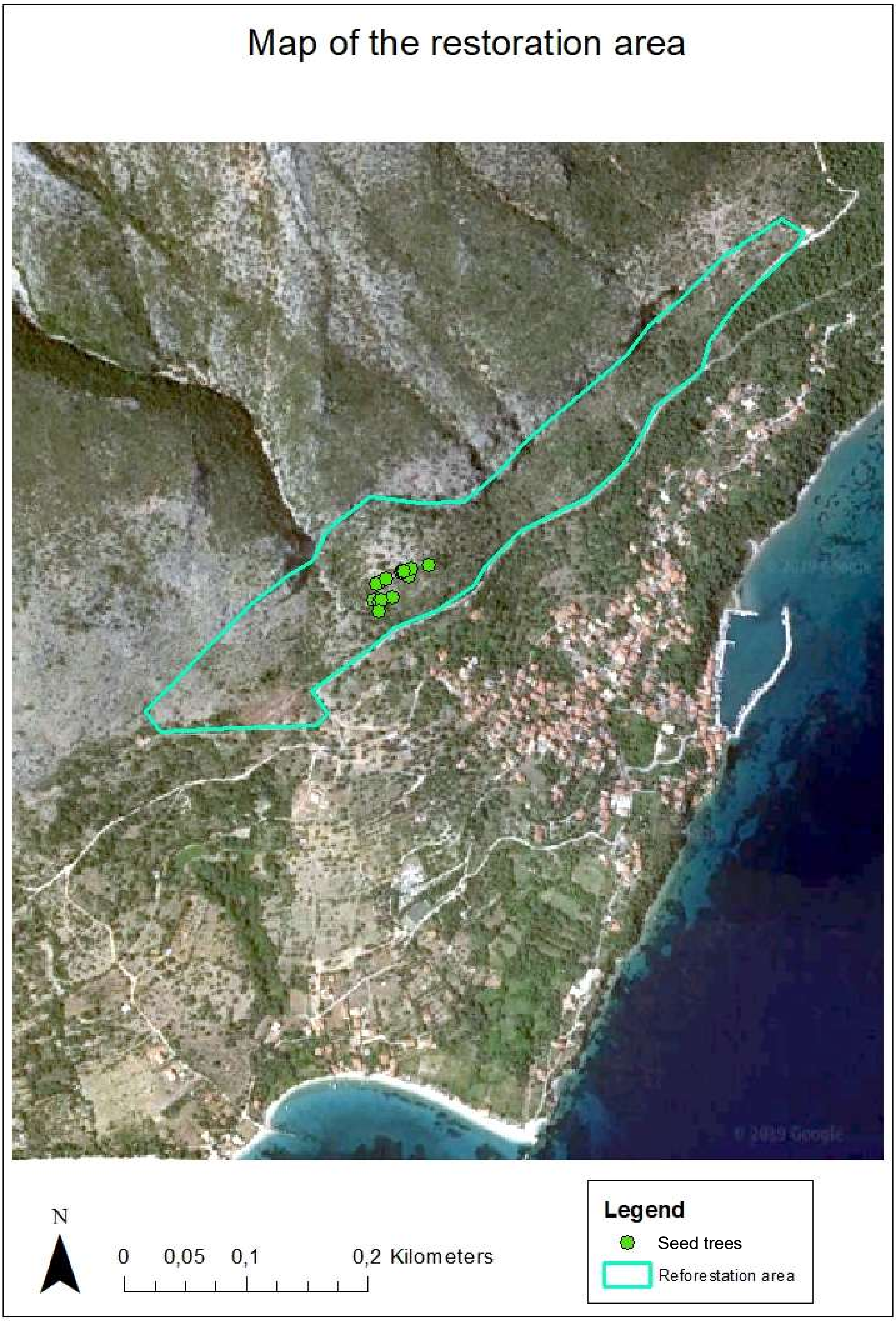
Sub-sub-sub-plots, 1x1m (Herbs/small shrubs)

No.	Species	Abundance (frequency)
1		
2		
3		
4		
5		
6		

Dominant tree height classes:

Class	H_{dom} (m)
1	<4
2	4-5
3	5-6
4	6-7
5	7-8
6	8-9
7	9-10
8	11-12
9	12-13
10	14-15

Annex C: Map of the restoration area



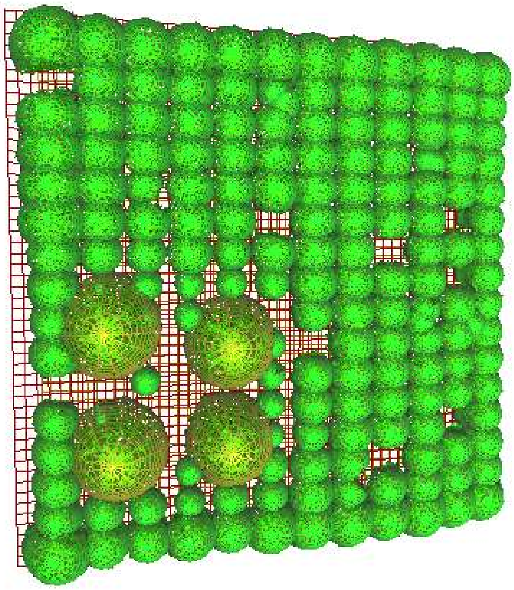
Annex D: Plot data

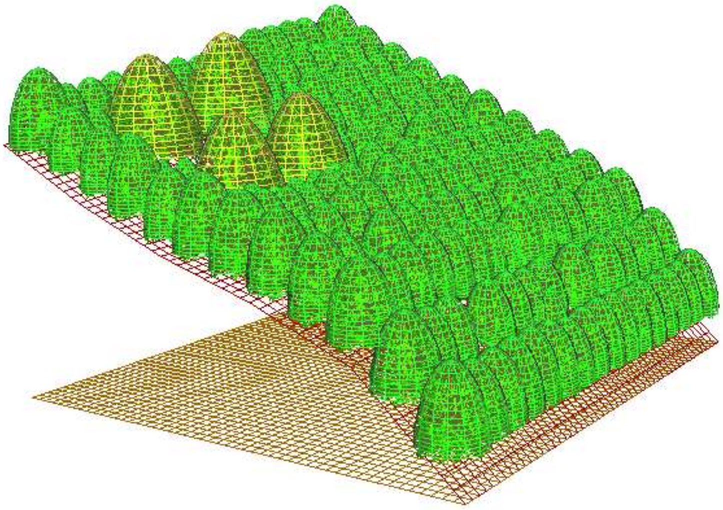
Results of the vegetation inventory per plot. Bold numbers give the average per category.

Plot no.	Slope class	Slope aspect	Elevation (m)	Ground cover (%)	Dominant tree species	Number of trees (DBH=>10)	Dominant tree height class
1	9	SE	116	23.9	Aleppo pine	0	1
2	8	SSE	123	30.4	Olive	1	4
3	9	SE	136	22.5	Olive	1	2
4	9	SE	135	33.6	Olive	1	2
5	9	E	133	32.7	Olive	1	2
6	9	SSE	149	30.3	Valonia oak	3	5
7	9	SSW	130	18.3	Olive	1	2
8	9	SE	138	17.9	/	0	0
9	9	SSE	130	25.6	Olive	2	5
	9		**132**	**26.1**		**1**	**3** (5 - 6 m)

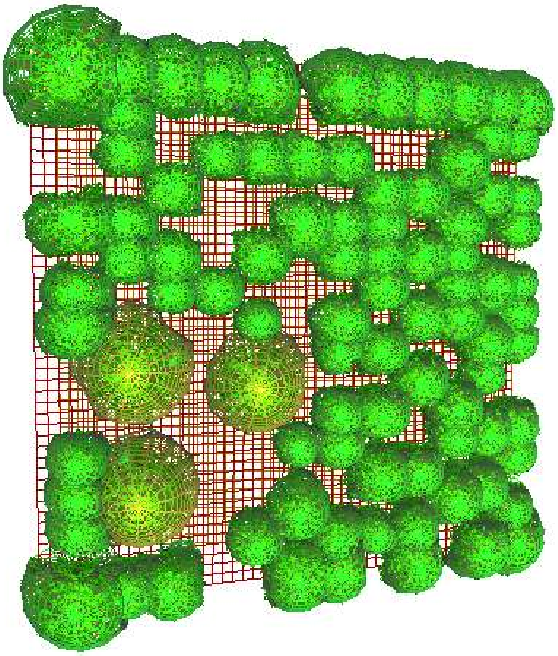
Annex E: Forest simulation models

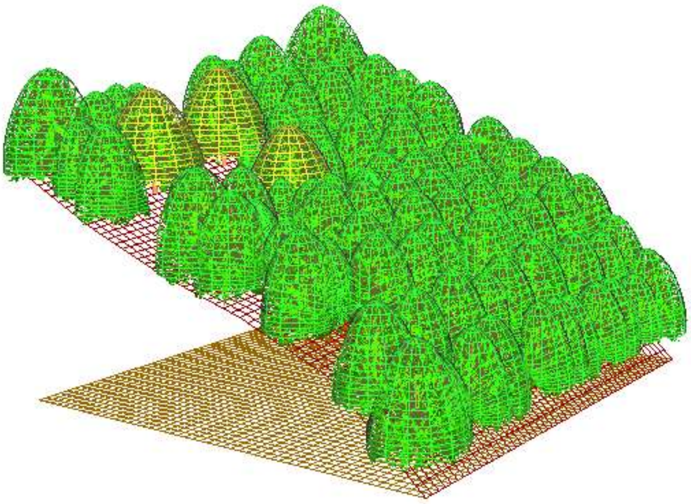
Simulation models of the forest after 10 years with four of the remaining olive trees. Top view (left) and side view (right).





Simulation models of the forest after 30 years with four of the remaining olive trees. Top view (left) and side view (right).





Annex F: Schematic map of the nursery

This is a schematic map of the area that has been assigned by Terra Sylvestris to be the nursery area. The green strips represent the seedbeds and the total surface area is 121 m^2.