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Effect of land preparation methods on restoration success of degraded oak forest ecosystems

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Abstract: Estimation of the success of ecosystem restoration through different methods is essential of planning restoration projects, especially nowadays when the world community has declared the target for an effective restoration of 25% of degraded ecosystems in the next years. In the present study, we introduce the results of the application of two land preparation methods – soil ripping and land terracing - on ecosystem restoration success twenty years after restoration actions. The study concerns two reforested areas with the species *Quercus pubescens*, a deciduous oak species. In both reforested areas an estimation of the ecological conditions was carried out as well as stand growth and volume data, based on the following field measurements: soil fertility data, vegetation analysis, tree morphological characteristics, and tree volumetric characteristics. The analysis of the results showed that the land preparation method "soil ripping", greatly improved all the studied ecosystem parameters as well as oak stand characteristics, comparing to the "terracing" method. More specifically, it improved the physical and chemical properties of the soils, the coverage and the composition of flora species, and enhanced the existence of more woody species. It privileged the growth of *Quercus pubescens* trees contributing to a higher stand volume.

Keywords: land preparation methods, soil ripping, land terracing, reforestation, pubescent oak, *Quercus pubescens*

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Introduction

It has been recognized during the last decades that reforestations can play an important role on climate change mitigation since they can sequester significant quantities of carbon (Dixon et al., 1994). Especially, new forest establishment as well as restoration of degraded ecosystems are considered of great importance in carbon dioxide removal from the atmosphere and function as carbon sink throughout the world, and thus can mediate the climate changes impacts (Lugo, 1997; Carnevale & Montagnini, 2002, Maestre et al., 2002; Tzamztis & Ganatsas, 2020). Also, in many cases, reforestation help in forest succession of degraded ecosystems towards to more productive forest ones (Honnay et al., 2002; Ganatsas et al., 2012). The above reasons lead the world community to declare the target for an effective restoration of 25% of degraded ecosystems in the next years. Estimation of the success of ecosystem restoration through different methods is essential of planning restoration and reforestation projects (Vallauri et al., 2005).

Reforestation projects are often carried out in areas formerly being forests that were destroyed in the past, usually due to long-term human interventions. However, a common reforestation practice in the past was planting pines. Last years, due to many problems presented by coniferous monocultures coming from wide reforestation projects throughout the world, there is an increasing policy to use broadleaved tree species for achieving better restoration results. It has been observed that many wide reforestation programs with conifers resulted in pine monocultures, which usually are characterized by low biodiversity, due to the single-layer stand and dominance of one pine species the restrict food chains and biological processes (Ganatsas et al., 2003; Cortina et al., 2006). Thus, the use of multispecies plantings or broadleaves species could result in a higher biodiversity ecosystems. However, data on the success of reforested areas by broadleaves species is generally very few (Ganatsas & Tsitsoni, 2003). Especially, for the oak species it is considered that their artificial establishing by planting or seeding is characterized by low growth, especially during the early life of the plants (Rey Benayas et al., 2005). Many studies report low survival rates, attributed to low adaptation ability of young plants to the changed environmental conditions (McGee & Loftis, 1992), and they face strong difficulties in their root expansion to soil (Ruehle & Kormanik, 1986). Thus, any new knowledge on the performance of oaks on reforestation projects are extremely useful, since it can help in the evaluation of their role in carbon sink potential (Wallertz et al., 2018). As concerns as, for the studied species *Quercus pubescens* Willd., this is a deciduous oak widely naturally distributed in the zone of broadleaved deciduous species, and occasionally, in the zone of evergreen broadleaves, where it forms pure or mixed stands with other broadleaved deciduous species, mainly oak species (e.g. *Quercus frainetto*). It is a drought tolerant species, that is distributed in dry, often degraded woodlands. It is a well resprouting species, even after forest fires.

However, further negative factors in using broadleaves species in reforestation projects are: the lack of long experience of using a such species, the low quality of the used planting material, the lack of setting appropriate (sound scientific) rules during the reforestation works, especially in plantings, the bad site conditions commonly appeared in target areas, and in some cases the problematic genetic reproductive material (Fuchs et al., 2000; Maestre et al., 2002).

One of the crucial factors determining reforestation success is the land preparation technique. Land or soil preparation is almost always necessary for improving the existed bad site conditions, especially in restoration projects that usually are carried out in degraded land. This degraded land is often characterized by compact surface soil layers, low water availability, low soil porosity, adverse physical and chemical soil conditions, and bad climatic characteristics (low precipitation, high air temperatures during the summer, prolonged drought periods, etc.). In such cases, appropriate land preparation methods are needed for an effective reforestation works. Many methods have been applied along the world. Land terracing is a wide used method in agriculture as well as in forestry from the ancient times. However, due to the great landscape damages, last years terracing is not suggesting. Thus, more friendly to the landscape methods are suggested, such as soil ripping, soil disk tenching, planting in holes, seeding in lines etc.

The application of the land preparation methods usually result in direct improvement of soil physical properties, such as soil porosity, bulk density, water infiltration, characteristics that favor plant root growth (Schmidt et al., 1996). They also, decrease the weed competition, especially for water, and improve water cycling (Lof et al., 2012). Two of the most common use methods are land terracing and soil ripping that have been applied in many reforestation projects along the world (Hatzistathis & Dafis, 1989, Grammatikopoulos,1999). Especially for the oaks, much research attests to the fact that oak plantations probably cannot be established consistently without intensive site preparation, herbaceous weed control, continued release from invading competitors (Malac et al., 1979; Kennedy & Harvey, 1981; Woodrum; 1982, Nix, 1989; Miller, 1993).

A lot of research deals with different land preparation methods in the world. Most of them come from northern Europe and North America (Makitalo, 1999; Archibold et al., 1999; McCarthy et al., 2017), where the climatic and edaphic conditions greatly differ from the conditions existing in Mediterranean areas (e.g. very low temperatures, wet soil conditions). Also, they often concern studies on conifer species (Varelides & Kritikos, 1995; Varelides et al., 2005; Mc Donald et al., 1980; Minore & Weatherly, 1990).

Thus, the aim of this study was the estimation,in a medium-term, the effect of the two most common land preparation methods used in reforestation projects, along the Mediterranean region: i) land terracing and ii) soil ripping, twenty years after reforestation actions. The study concerns two reforested areas with the species *Quercus pubescens*, a common deciduous oak species in low woodlands along the Mediterranean region, for which there is no report for its performance in reforestation projects. In both restored ecosystems, the ecosystem ecological conditions were estimated as well as the study of stand growth and volume data, based on the following field measurements: soil fertility sampling, vegetation analysis, tree morphological measurements, and tree volumetric characteristics. The hypothesis was if there were any significant effect of the applied land preparation methods on the ecosystem ecological parameters as well as the stand growth and yield. More specifically on i) stand composition and structure, ii) soil conditions in the surface layers, iii) plant community diversity and structure, and v) tree size, stand density and stand growth and volume (V/ha).

Material and Methods

Two degraded woodland areas – due to extreme pasture and fires, subjected to reforestation twenty years ago, were selected for studying the effect of different land preparation methods on reforestation success in medium-term perspectives. In both sites planting of one year old seedlings of the deciduous oak species *Quercus pubescens* Willd were planted 20 years ago (in 1997). The studied area belongs to the prefecture of Thessaloniki (Fig. 1) and lays in a distance of 60 km far away from the city of Thessaloniki, northern Greece. The area lays in the west part of the mountain Vertiskos, geographical coordination: Site A: 40°47'8.98"E, 23°7'44.75"N and Site B: 40°47'14.83"E, 23°7'41.65"N. The distance between them is approximately 5.5 km. The altitude ranges between 313 m and 329 m for the first studied area and between 520 m and 569 m a.s.l. for the second studied area. The slope aspect for both sites is east-northeast, with mild inclination (10–25%).

From geological point of view, the area belongs to Servomacedonian zone, and to the Vertiskos unit which consisted of crystalline and igneous rocks (Mountrakis, 2010). The vegetation of the area belongs to the *Quercetalia pubescentis* and the subzone *Ostryo-carpinion*. According to the Koeppen classification system, the climate of the area belongs to the Csa type, while according the Emberger method, the rainfall quotient Q2 is determined to be 78.5, and the bioclimatic storey belongs to subhumid type with sharp winter. According to the UNESCO-FAO terminology, the duration of the dry period is zero (Fig. 2). Based on the data of the nearest meteorological station in Xiloupolis (geographical coordination E 23°10.7137', and N 40°54.78217', owned by ELGO - Dimitra Organization), lying in a distance of approximately 10–15 km from the research sites, and at a similar altitude of 520 m a.s.l., for the period 1997–2017, the mean annual air temperature was 11.9 °C, and the annual precipitation 705.9 mm (Table 1). During the growing period (March to September) the mean amount of precipitation was 414.3 mm, while the number of rain days 141. It is worth point out that the year of plantings (1997) was the less rainy year, with only 518 mm precipitation and 67 rainy days. The coldest month during the studied period was January, with a mean temperature 2.0 °C, and the warmest July and August (22.4 °C and 22.2 °C, respectively). The absolute minimum temperature recorded was −17.9 °C (January 2017), and the absolute maximum +47.1 °C (August 2014). The mean maximum temperature of the warmest month was 29.9 °C (July and August), and the mean minimum temperature of the coldest month was −1.4 °C (December). The mean annual air relative humidity was 76%, ranging from 67–72% in the summer months, and 79–82% during the winter. The mean wind speed was low 1.6 m s^{-1} (5.76 km h^{-1}), and the mean wind direction NW, relatively constant during the year.

Fig. 1. Map showing the studied area, approximately 60 km from Thessaloniki, northern Greece

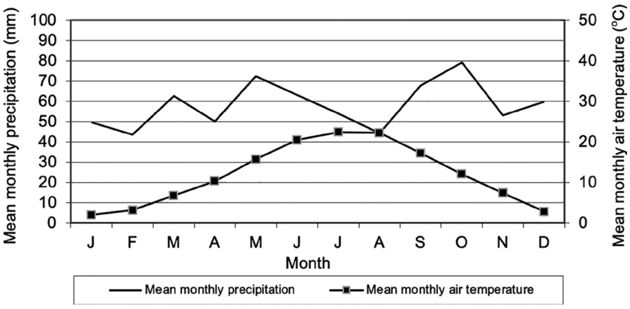

Fig. 2. Climate-temperature diagram of the meteorological station in Xiloupolis, northern Greece, for the years 1997–2017

Table 1. Mean monthly precipitation and mean monthly air temperature of meteorological station in Xiloupolis, for the years 1997–2017

	J	F	M	A	M	J	J	A	S	O	N	D
Mean monthly precipitation (mm)	49.6	43.6	62.6	50.1	72.5	63.2	54.0	44.2	67.7	79.1	53.1	59.9
Mean monthly air temperature (°C)	2.0	3.2	6.8	10.3	15.7	20.5	22.4	22.2	17.2	12.0	7.4	2.8

The study concerns the oak species *Quercus pubescens* Willd, the downy oak or pubescent oak. It is a species of white oak (genus *Quercus* sect. *Quercus*) native to southern Europe and southwest Asia, from northern Spain east to the Crimea and the Caucasus. It is also found in France and parts of central Europe. It is a medium-sized deciduous tree growing up to 20 m. Forest-grown trees grow tall, while open-growing trees develop a very broad and irregular crown. They are long-lived, to several hundred years, and eventually grow into very stout trees with trunks up to 2 m in diameter. Open-grown trees frequently develop several trunks. It is a light demanding species, warm resistant, and of low nutrient demands (Dafis, 1986). It usually occurs from 200 to 800 m a.s.l. Typically grows in dry, lime-rich soils. It is a submediterranean species, growing from the coastline to deep in the continent. Its optimum is in the submediterranean region, characterized by hot dry summers and cool winters with little rain fall. In western and central Europe, downy oak is confined to areas with submediteranean microclimate (gorges, sandplains, steppe slopes) or to coastlines of former lakes. It is a drought tolerant species as well as cold-tolerant species (Pasta et al., 2016).

The used planting material in both sites were produced in containers (paper pots) in the state Forest Nursery of Lagada, Thessaloniki, which is in a distance of approximately 30 km from the studied sites. After plantings, no treatment (fertilization or irrigation program) was applied in both areas.

In the first studied area, the land terracing method was applied by mechanical flattening, the slopes for stripes of three meters width. In the second methods soil surface layers were ripened by mechanical machine. A number of plots, 15 for each treatment, were sampled in 2018. The sampling plots were of a size of 200 m^2 (10.0 m × 20.0 m). All the oak individuals, with a height over one meter were recorded. The following measurements were included: tree height in accuracy of 0.1 m and diameter at breast height. Based on the initial planting spacing the survival rate was estimated. Furthermore, all plant species were recorded, as well as their presence and coverage per layer (tree, shrub and herb layer) following the Domin scale (Ganatsas et al., 2012). Also, for each plot, we estimated the basal area, as well as the total stem volume. For the last estimation, we used the standard form (equation) set by Hellenic Forest Service of Ministry of Agriculture for the species stands in northern Greece.

In each plot, and at the center of the plot, two soil samples were taken from different depths (0–10 cm, and 11+ cm up to bedrock) after litter removal. Soil depth in all cases was less than 30 cm. A sample of approximately one kg was extracted, put in a plastic bag, and transported to the laboratory for analysis. Standard soil analysis was performed for each soil sampling, including mechanical particle size analysis, pH, soil organic carbon, nitrogen (N), phosphorus (P) and potassium (K) by applying the following methods (Jones 2001, Papaioannou et al. 2016). Soil particle size analysis was carried out according to the method of Bouyoucos, pH was determined using a glass electrode on a soil–distilled water paste (1:1), soil organic carbon was determined with the potassium dichromate ($K_2Cr_2O_7$) method, N using the Kjeldahl method, P with a solution of NaHCO3, according to the method of Olsen, and K by atomic absorption spectroscopy, after extraction of 10 g soil with CH_3COONH_4 1M, pH 7.

Data statistical analysis performed using the SPSS software. Distribution was tested for normality by Kolmogorov–Smirnov criterion and the homogeneity of variances was tested by Levene's test. Wherever treatment effects were significant the t-Test was initially carried out to compare the means, and consequently an analysis of variance (ANOVA) was used to assess the difference between the measured variables. When ANOVA indicated a significant F-value, Duncan's test at $p<0.05$ was performed to compare the means (Snedecor & Cochran, 1989).

Results

Effect of land preparation method on soil conditions

The two methods applied for land preparation resulted in some differentiation of soil physical and chemical properties twenty years after their application, in the surface soil layers (Table 2). Sites subjected to ripping presented higher values of soil organic

Table 2. Soil characteristics of the surface layers in the two land preparation treatments. Values are means and standard error (in parenthesis). Means followed by different letters, within a column, are significantly different ($p < 0.05$)

Preparation methods/Soil depth (cm)	Soil texture	pH	Organic matter (%)	N (%)	P (ppm)	K (ppm)
Terracing depth 0–10	Medium-Sandy-loam	6.42(0.138)	2.39(0.094)b	0.088(0.138)b	3.63(0.464)b	89(8.041)b
Terracing depth 10+	Medium-Sandy-loam	6.23(0.219)	1.62(0.211)c	0.057(0.088)c	2.47(0.365)c	61(4.271)c
Ripping depth 0–10	Light-Loamy Sand to Medium-Sandy-loam	6.59(0.138)	3.84(0.603)a	0.140(0.022)a	4.45(1.000)a	139(22.314)a
Ripping depth 10+	Light-Loamy Sand to Medium-Sandy-loam	6.40(0.157)	2.24(0.242)b	0.085(0.013)b	2.89(0.477)b	82(15.154)bc

matter, as well as for the main soil nutrients (nitrogen, phosphorus and potassium), especially in the upper soil layer (0–10 cm depth). These differences were statistically significant in the case of organic matter, nitrogen and potassium. On the contrary, pH values were similar in both sites, without any differentiation between the two sampled soil layers (Table 2).

Effect of land preparation method on vegetation composition and community structure

Generally, the vegetation composition was similar in the two treatments, twenty years after plantings. The total number of plant species recorded were 32 and 31, for terracing and ripping sites, respectively, with an average number of 18.1 and 17.8 species per plot, respectively. However, data analysis showed some differentiations in vegetation composition between the two sites (Table 3). Even though the dominant woody species were the same in the two treatments (*Quercus pubescens, Quercus coccifera, Cistus creticus, Crataegus monogyna, Pyrus spinosa*), there were observed some additional woody species that were found only in the ripping treatment; those are the species *Rubus idaeus, Pyrus pyraster, Robinia pseudoacacia, Lonicera xylosteum*. We have to point out that all the species recorded are indigenous, and only one exotic (*Robinia pseudoacacia)*.

The community structure is similar for both restored ecosystems. They are characterized by a tree layer, dominated by the planted oak individuals, with a medium coverage (56% and 64%, for terracing and ripping methods, respectively) (Table 4), a relative abundant shrub layer (26% and 32%, respectively), and an abundant understory, with a high coverage (62% and 88%, respectively). The plant species coverage of ground flora layer is significantly higher in the ripping method.

Effect on planting success and forest stand structure

In the sites subjected to terracing, the oak seedlings' survival was found 84% 20 years after planting, resulting in a stand density of 3880 trees per hectare (Table 5). The tree cover is 56%, the canopy of shrub layer 26%, and the cover at ground flora 62%. The mean tree height was 2.91 m, and the mean diameter at breast height 4.94 cm, with maximum values 5.50 m and 11.0 cm respectively (Table 4, Fig. 3).

In the sites subjected to ripping the oak survival was found lower 72%, resulting in a stand density of 2540 trees per hectare (Table 5). The tree cover is

Table 3. List of flora species and mean coverage of each species, according to Domin scale in the two treatments

	Terracing	Ripping
Woody species	Coverage (Domin scale)	
Quercus pubescens	8	8
Quercus coccifera	6	6
Cistus creticus	6	6
Crataegus monogyna	4	3
Pyrus spinosa	4	3
Rubus idaeus	–	4
Pyrus spinosa	–	3
Pyrus pyraster	–	2
Robinia pseudoacacia	–	1
Lonicera xylosteum	–	1
Species of ground flora		
Moss	6	6
Lichen	4	7
Trifolium angustifolium	3	3
Colchicum automnale	2	2
Petrorhagia dubia	2	2
Teucrium capitatum	2	1
Linum hirsutum	1	1
Eryngium campestre	1	1
Campanula trachelium	1	1
Phleum phleoides	1	1
Galium verum	1	1
Festuca sp.	4	–
Trifolium arvense	3	–
Hypericum perforatum	3	–
Onopordum acanthium	2	–
Linum trigynum	2	–
Cynosurus echinatus	2	–
Aira elegantissima	2	–
Avena barbata	2	–
Silene viridiflora	1	–
Acinos sp.	1	–
Thymus sp.	1	–
Thymus sibthorpii	1	–
Knautia arvensis	1	–
Vicia sp.	1	–
Oenanthe pimpinelloides	1	–
Melica ciliata	1	–
Allium guttatum	1	–
Lolium perenne	1	–
Chrysopogon gryllus	–	2
Chinopodium vulgare	–	1
Vicia cracca	–	1
Geranium rotundifolium	–	1
Geranium sanguineum	–	1
Hypericum olympicum	–	1
Filipendula hexapetala	–	1
Tolbis barbata	–	1
Medicago sp.	–	1
Centaurea sp.	–	1
Teucrium chamaedrys	–	1
Anthemis sp.	–	1

Table 4. Plant ground coverage (%) per layer (trees, shrubs, and ground flora) in the two methods. Values are means and standard error (in parenthesis). Means followed by different letters, within a column, are significantly different ($p < 0.05$)

Preparation methods	Mean ground coverage of oaks (%)	Mean ground coverage of shrub layer (%)	Mean ground coverage of ground flora layer (%)
Terracing	56(2.449)b	26(4.000)b	62(7.348)b
Ripping	64(9.274)a	32(7.348)a	88(7.348)a

Fig. 3. Photos of the studied oak stands growing on: a – soil ripping and b – terracing method for land preparation

64%, the cover of shrub layer 32%, and at ground flora 88%. The mean tree height was found significantly higher (3.65 m) compared to the value recorded in the terracing treatment. Similarly, the mean diameter at breast height was found significantly higher (5.70 cm) compared to the trees in the terracing treatment, with maximum values 7.00 m and 11.0 cm respectively (Table 5).

Effect on forest stand productivity

The mean woody volume per tree was found 0.00288 m^3 in the sites subjected to the terracing treatment, while the average woody volume per hectare was found 9.4 m^3 ha^{-1}, and average basal area per hectare 7.13 m^2 ha^{-1} (Table 6). In the sites subjected to ripping treatment, the mean woody volume per tree was found significantly higher 0.00464 m^3(compared that in terracing), and the average woody volume per hectare was found also significant greater 11.1 m^3 ha^{-1}. On the contrary, the average basal area per hectare was found with no great differences (Table 6).

Discussion

Data analysis of the present study indicates that reforestation projects using oak tree species such as the species *Q. pubescens* can succeed ecosystem restoration by creating a new artificial forest that present characteristics similar to natural forests. The newly created forest stands twenty years after their establishment are characterized by a relative high plant diversity, improved soil conditions of the surface soil horizons, and a relative good tree growth. Even

Table 5. Characteristics of the two stands, according to preparation methods, 20 years after planting. Values are means and standard error (in parenthesis). Means followed by different letters, within a column, are significantly different ($p < 0.05$)

Preparation method	Planting spacing (m)	Mean stem density (N/ha)	Mean survival rate (%)	Mean tree diameter at breast height (cm)	Maximum diameter at breast height (cm)	Mean tree height (m)	Maximum height (m)
Terracing	1.5 × 1.5	3880(168.523)a	84(2.846)	4.90(0.101)b	11.00	2.91(0.048)b	5.50
Ripping	1.5 × 2.0	2540(232.056)b	72(4.619)	5.70(0.134)a	11.00	3.65(0.073)a	7.00

Table 6. Stand volume in the two treatments. Values are means and standard error (in parenthesis). Means followed by different letters, within a column, are significantly different ($p < 0.05$)

Preparation methods	Mean woody volume per tree (m^3)	Mean woody volume per hectare (m^3 ha^{-1})	Basal area per hectare (m^2 ha^{-1})
Terracing	0.00288 (3.597)b	9.4 (1.364)b	7.13 (0.735)
Ripping	0.00464 (8.201)a	11.1 (2.008)a	6.76 (1.116)

though the used species, pubescent oak, presents a low-growth rate during the first years after planting, which is something common for most oak species around the world (Ganatsas & Tsitsoni, 2003), the established stands present quite good tree growth and high survival rates. Taking into consideration that the restored area was highly degraded, due to long-time overgrazing and high human presence in the past, the results should be considered over optimistic, since the ecosystem restoration was achieved in that period of twenty years, in the view of all ecosystem parameters (e.g. soil conditions, plant community diversity, forest stand canopy cover, structure and stand productivity) (Honnay et al., 2002; Ganatsas et al., 2012).

Similar results were reported from other researchers for planting different oak species. For example, a number of successful oak plantations established by direct-seeding and plant seedlings have been reported for USA conditions (Miller, 1993), while for Europe the relevant data are limited. Kennedy et al. (1987), reported for four oak species established by seedlings that, after 10 growing seasons, the planted trees reached at height of 3.9 m. Krinard and Johnson (1988) also, reported that, twenty-seven years after plantings on an old-field soil in Louisiana, the new stands had a number of 1060 trees per ha with average tree dbh of 16.5 cm. For direct seeding of acorns, Johnson and Krinard (1987) reported that oak plantation after 15 years of establishment by direct-seeding, the trees were 6 m tall, and the stands had about 750 trees per ha in the dominant/codominant position a free-to-grow condition.

The application of both land preparation methods seems to positively contributed to the restoration success, since it has been reported that most soil and land preparation methods usually result in direct improvement of soil physical properties, such as soil porosity, bulk density, water penetration, characteristics that favor plant root growth (Schmidt et al., 1996). This in turn, favors the planted tree growth and increase forest stand productivity.

Even though no special measurements made on the soil physical properties during this study, except for size distribution of particles (texture), it is estimated that the improvement of soil chemical conditions affect some of physical soil properties such as soil porosity, soil bulk density, and water field capacity (Arvidsson, 1998). It may also reduce soil compaction of the surface horizon (Jordan et al., 2000).

As far the examined differences between the two applied land preparation methods for reforestation and ecosystem restoration, it is concluded that among the two methods applied, the ripping method was superior to the terracing method for most ecosystem parameters. It improved almost all ecosystem parameters (concerning soil, vegetation, community structure) as well as forest stand productivity and wood volume. Analytically,

- It improved all soil physical and chemical properties of the surface soil layers, such as soil structure, organic matter, total nitrogen, potassium, and calcium, thus providing better conditions for nutrient uptake by trees.
- It accelerated the growth of the planting trees of the oak species (*Quercus pubescens*), by improving tree diameter and height growth. This resulted in higher tree and stand volume, and thus enhanced stand productivity, in terms of wood production.
- It increases the soil cover for all vegetation stories (tree, shrub and grass layer).
- It improved the ecosystem structure, by increasing the presence of almost two-fold woody species in the tree and shrub layer.
- A secondary result is that *Quercus pubescens* is found to growth better in wider planting spacing (1.5 m × 2.0 m), in the higher altitudes (in the studied area), over 500 m a.s.l.

The above findings suggest that even though it is known that oak artificial establishment is characterized by a low tree increment during the first years (at least the early ten), a productive forest can be created if appropriate land preparation precedes in the planting area. The ripping method seems to be an effective technique for a successful and high survival rate of the planted oak seedlings, which improves soil physical and chemical properties, and creates favorable conditions for oak trees growth. This method is suggested by Grammatikopoulos (2009) for the Greek conditions. Taking into consideration that the reforested area was a high degraded area, with compact soils of low depth, the creation of a high forest contributes to the ecological restoration of such a degraded land, providing important ecosystem functions such as wood production, prevention of soil erosion (by the high soil canopy cover), improvement of water cycle (Ruehlmann & Korschens, 2009) (due to the better soil aeration by the presence and function of the tree roots, which generally are of greater dimensions compared to grass roots). Additionally, increasing soil carbon sequestration due to forest establishment mitigates global climate change and enhances food security (Lal, 2004).

It is true that, the use of oak species in reforestation presents difficulties in growth (Pope, 1993). However, a detailed species selection, the use of high quality seedlings, an appropriate land preparation method, and a post-planting care of the young plants are decisive factors that can improve reforestation success (Pope, 1993; Ganatsas et al., 2003). Also, several studies reported that oak plantations probably cannot be established consistently without intensive site preparation, herbaceous weed control, continued release from invading competitors (Malac et al., 1979; Kennedy & Harvey, 1981; Woodrum, 1982; Nix, 1989; Miller, 1993).

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