Restoration interventions in the fire afflicted forests of Mountain Attaviros, a protected area on the island of Rhodes – Greece

G. Arapis[A], E. Evergetis[B], D. Mavrogiorgos[B], F. A, Pavlidis[A]

A. Laboratory of Ecology & Environmental Sciences of the Agricultural University of Athens, Iera Odos 75, Athens 11855

B. ELLINIKI ETAIRIA Society for the Environment & Cultural Heritage, Tripodon 28, Athens 10558

EXTENDED ABSTRACT

Fires in the Mediterranean region are nothing but a rear phenomenon. Nowadays with climate change impacts becoming increasingly prominent, forest fires in Greece occur more often and result mostly to national disasters. Because of this increased frequency, post-fire management and fires impact research are becoming rather popular within the scientific and environmental conservation community. Major effects detected are the decrease of the soil's hydraulic volume and organic matter, erosion and high seed mortality due to CO intoxication. Up to date post fire management includes mainly types of large-scale interventions, namely, log barriers, fencing, logging and plantations, which however only address the latter two of the aforementioned effects. The more severe effects which relate to soil's fertility, affect two of the major element cycles, namely carbon and water, and despite their significance, an appropriate intervention has not yet been identified. The significance of these effects grows exponentially when referred to a NATURA 2000 site, where special care is required towards the achievement of an environmentally sound management.

Such a case is the NATURA 2000 site of Mountain Attaviros on the island of Rhodes, in the Dodecanese region of Greece, which was devastated by the fire in the summer of 2008. The importance of the implementation area and the rationale behind the method of choice in the experimentation is based on the numerous species of flora and fauna, which inhabit this protected area. These include: endemic plants such as the *Paeonia clusii Stern ssp.Rhodia*, the endemic and endangered freshwater fish *Ladigesocypris ghigii* as well as the Dama dama deer, characteristic of the islands fauna and the typical Mediterranean habitats *Juniperus* matorral, Cypress forests (Acero-Cupression) with endemic pine forests.

On this specific background the LIFE08 NAT/GR/000533 project, entitled *"Fire RestorAtion Methodology for MEditerranean Forests – environmental safety & sustainability of 4 interventions in the Rhodes NATURA 2000 site FRAMME",* was developed, with the ambition of covering the knowledge gap in contemporary science regarding management and restoration of fire afflicted Mediterranean forests. This will be achieved through the combinatorial study of 4 different restoration interventions, 2 commonly used and 2 innovative incorporating the reuse of treated wastewater and sludge, standalone and in combinations with each other, in an area of 1 ha each, that will be realized in 4 geographically targeted repetitions, covering a total area of 64 ha. Subjects of the interventions evaluation are environmental soundness, restoration effectiveness and economic efficiency, concluding to a Restoration Guide for Mediterranean fire afflicted forests in the form of a policy decision tool readily applicable to the greater area of the Mediterranean basin, which will be presented here for the first time.

Key words:
Forest fires, Mediterranean, ecosystems, restoration, Natura 2000, FRAMME

INTRODUCTION

Forest fires on the Island of Rhodes, before the exponential development of tourism, were mainly humanly induced and caused by practices which are no longer carried out today; such as the periodical fires set off by stock farmers aiming to regenerate the vegetation used to feed their stock. The result of this practice was the creation of brushwood ecotypes.
Currently, the islands economy depends exclusively on tourism. As a result traditional occupations, which involved the utilization of forests, have been relinquished thus reducing the maintenance of any basic routes of approach to such areas making their access harder. In addition, the eradication of controlled periodical forest fires led to the accumulation of highly flammable organic matter on the forest floor resulting in forest fires, which grow much larger in area and more catastrophic.

The impacts of forests fires, which have been identified and assessed best, are addressed mostly to soil properties. Those can be further divided into many categories. A most critical impact regards the hydrology of the burned area and consequently the erosion phenomenon. In relation to the water retention capacity of soil, fire is proven to increase runoff by almost 77% (Gonzalez-Pelayo et al., 2006), thus leading to the post-fire hillslope erosion by direct rain-drop impact and overland flow (Smith & Dragovich, 2008, Gonzalez-Pelayo et al., 2010). Though runoff and erosion is proven to depend upon the post-fire type of vegetative cover (Glenn & Finley, 2010), it also presents an additive effect that leads to considerably greater runoff and sediment yield, over a period of seven years (Mayor et al., 2007). In total the above impacts involve hydraulic changes as well as geomorphological changes. These changes may be caused directly by weathering bedrock surfaces as well as changes in soil properties and structure, or indirectly due to the effect of the changes to the soil and vegetation on the hydrological and geomorphological processes. In addition, forest fires may alter the rates at which hydrological and geomorphological processes operate, during the period after the fire until the environmental conditions return to levels similar to those before it. Changes that can affect hydrological and geomorphological processes include alterations to aggregate stability, porosity, organic matter and water repellence characteristics. (Shakesby & Doerr, 2006). Variations in climate, vegetation, soil, topography and fire severity cause differences in Mediterranean post-wildfire erosion, first-year post-wildfire soil losses are similar to or even lower than those reported for fire-affected land elsewhere or other disturbed in the Mediterranean, while removal of organic matter and nutrients in the commonly thin, degraded soils is arguably just as if not more important than the total soil loss (Shakesby, 2011). This nutritional and trace elements runoff is also a suspected risk for disruption impacts on water supply from forest catchments (Smith et al., 2011).

Beside a considerable risk for human health those element leaks are also a serious threat for soil's fertility. Humic substances and water extractable organic matter represent an important part of soil organic matter, and forest fires inarguably cause both quantitative and qualitative changes on those deposits (Vergnoux et al., 2011a). The extent of those alterations depends on the frequency and intensity of the fire. Polycyclic aromatic hydrocarbons concentration in burned soils are more than 20 times higher than in the control soils and still remain important years after the last fire event (Vergnoux et al., 2011b). Fire may burn part or all of a standing plant in its pacing as well as the organic matter in the upper layers of soil. The nutrients found in the organic matter are either made more available or volatilised and lost. Ash on the other hand is an important nutrient source for ecosystem recovery, affecting pH, electrical conductivity and trace elements concentration improving soil fertility, especially in acidic soils (Pereira et al. 2011). If plants do not absorb ash soluble nutrients right away, then it is highly likely for them to be lost due to leaching in the groundwater or erosion. (Guerrero et al., 2000)

Plant regeneration after a forest fire involves either the growth of new plants from seed or by re-sprouting. A lot of attention has been given to the first; however the re-sprouting mechanism allows the survival of many perennial shrubs. Sprouting plants begin growing almost immediately after the fire, this way the population turnover of plants is reduced and the impacts of the fire are minimised. Seed germination depends mostly on the intensity of the fire since temperatures above 500 ^{o}C effectively kill most species (Emery et al., 2011), while low intension fires may cause CO intoxication and a decreased germination rate of the seeds (Gomez-Gonzalez et al., 2008). Mediterranean pine forests present uniqueness among burnt forests described by the phenomenon of autosuccession (direct regeneration), which has been found to be often combined with an increase of species richness during the first years after fire due to the high abundance of short-lived herbaceous plants facilitated by plentiful nutrients and light (Buhk et al., 2006). Though Mediterranean plant adaptation to fire is a prevailing theory current trends appear to be more sceptic, treating this approach as a pervading concept accepted by most environmental managers, that can lead to a deliberate increase of fire frequencies and a consequent ecosystem degradation and plant extinctions (Bradshaw et al., 2011).

Re-sprouting is the other main regeneration mechanism, which takes place in Mediterranean-type ecosystems; examples of shrubs which apply this mechanism include: *Arbutus unedo*, *Pistakia lentiscus* and *Olea europaea* (Figure 1). When the top part of a plant has been destroyed re-sprouting occurs from underground buds. The rate with which plats re-sprout, depends largely on the condition of the plant before the fire, i.e. its height, as well as on fire intensity and the environmental conditions after the fire. In order for these shoots to survive, sufficient reserves of carbon and nitrogen must be available. (Konstantinidis et al, 2005).

Figure 1: *Arbutus unedo* re-sprouting

Impacts on faunal biodiversity due to forest fires is less developed. Even though, for many conservation agencies protection of biodiversity stands as of their major goals, information on the effects of fire on fauna in these biomes is fragmentary. Only a few studies have examined the effects of fire on amphibians or reptiles, and work on invertebrates is likewise sparse. The majority of studies that have been published are observational reports, and few experimental studies have been undertaken using an experimental fire regime, or over appropriately long period intervals (Parr & Chown, 2003). The recovery of vertebrates seems to depend on topographic refugee, thus, connectivity-reducing management activities, may not affect the early stages of population recovery in remaining strands of burnt forest. Rather, ongoing recovery is likely to be limited by demographic rates and resource availability (Banks et al. 2011). Reptile recovery has been studied for *Testudo graeca*, an endangered terrestrial tortoise, which was found to cope with a regular fire frequency of 20 years, but the effects of more recurrent fires may severely threaten the species (Sanz-Aguillar et al. 2011). Although forest fire impacts on invertebrates is less studied and sporadic there are clear indications that forest fires seem to favor ground insects (Moretti et al., 2004), and cause significant extinction rates for butterflies (Hirowatari & Makihara, 2007).

As it becomes clear, forest fires are causing multi-layered impacts that cover every aspect of biodiversity. Nowadays a compromise for forest management is often suggested, which considers the risk of damage by fire to people and goods, while avoiding the risk of damage to biodiversity by imitating the effects of sporadic fires and providing a mosaic forest with open gaps of different successional stages. Conservation planning is the process of locating, configuring, implementing and maintaining areas that are managed to promote the persistence of biodiversity and other natural values.

Conservation planning is inherently spatial. The science behind it has solved important spatial problems and increasingly influenced practice. To be effective, however, conservation planning must deal better with two types of change. First, biodiversity is not static in time or space but generated and maintained by natural processes. Second, humans are altering the planet in diverse ways at ever-faster rates.

The manipulation of forests in the Mediterranean goes back to the ancient times and it is due to this as well as the abrasive and unpredictable climate and difficult socio-economical conditions that make it crucial for a scientifically sound conservation strategy and a sustainable management plan to be implemented. The risks that may be met if land is managed without a clear perception of structure and functionality are well known by ecologists. Therefore, the large gaps in the understanding of the function of Mediterranean ecosystems prevent us from applying a conservation strategy, which would be safe for the environment. (Scarascia-Mugnozza et al., 2000, Driscoll et al., 2010).

Based on these considerations and along with the devastation and impacts caused by the fires of 2008 in the forested areas of the Natura 2000 site in Rhodes it is evident that new European research policy, should be targeted to studies and experiments for scientifically sound conservation strategies and a locally-tailored sustainable management of the regional forest and landscape resources. For this purpose, rather than simply recommending adaptive management, we propose a research agenda to maximize the rate of learning in this difficult field. This includes measuring responses at a species level, building capacity to implement natural experiments, and judicious application of experimental approaches. Developing ecologically sustainable post-fire management practices requires sustained research efforts and a sophisticated research agenda based on carefully targeting appropriate methods to address the critical management questions discussed herein

1. METHODOLOGY

Mediterranean forests are both aesthetically attractive and fragile making it vital that they are managed with care. A characteristic of the Mediterranean region is the vast variation in the environmental conditions from country to country. In some cases forest growth is limited due to these conditions but in others, sometimes more often than expected, it allows the growth of lush mesic forests comparable to those of central Europe. Mediterranean forests are also known for their large diversity in plant and animal species caused by the survival of various broadleaf and conifer species during the glacial periods. (Scarascia-Mugnozza et al., 2000)

The GR4210005 site covers a total area of 27.696,22 ha and is situated at the south-west part of Rhodos island and includes the mountainous region of Attavyros (1217 m) and Akramytis, the area of Sianitis river, streams of Gadouras and Kontaris and the coastal area from Papagiorgis bay, to cape Armenistis and southwards to Apolakkias bay. The marine part covers 7% of the site. It is a region without many tourists, in contrast to other regions of the island. The more characteristic terrestrial habitats are the two types of coniferous wood along with matorrals *Juniperus* spp. (92/43/EEC code 5210). The first consists of *Pinus brutia* (9540) which creates mixed forests with *Cupressus sempervirens* v. Horizontalis (9290), which are predominantly found in the FRAMME project implementation area. These mixed forests are found in very few areas in Greece (Dodecanese and Crete) and the Rhodes case is one of their best and most representative expressions. The site also includes a broad area with maquis and phrygana. There are areas with garrigues of *Quercus coccifera*; the garrigues are grazed and low (YPEHODE, 1995).

The wild forest fire that took place in Rhodes during the summer of 2008 destroyed more than 10.000 ha of forestland affecting major producing facilities and downgrading the island's vital resources. Part of the fire reached the NATURA 2000 area of interest GR4210005 burning 11,1% (3.063 ha) of its area (WWF, 2008). This area was decided to become the field of the projects implementation, but since insufficient data were available for both the biodiversity and the abiotic elements of the environment a series of literature studies and surveys was performed for the area of interest. The biodiversity study (Chorianopoulos, 2010) outlined the presence of 66 fauna taxa and 503 herbal taxa the most important of which are presented in tables 1 and 2 respectively. The Geological survey on the other hand revealed the vulnerability of the site to erosion. More specifically the soils of the area may suffer from incised erosion, along the major streams, slope instability, with landslides and soil creep and erosion of the upper organic soil, and ultimately desertification. The steep slopes in the area accompanied by excessive rainfall, also play an important role to the extent of erosion. All the above-mentioned factors suggest that the area needs immediate antierosion measures, in order to avoid desertification from taking place (Kontari, 2010). The drainage network of the area of interest is made up of 4 main and several secondary streams, which drain the area and create a basin. The various levels of permeability of the geological formations are influenced directly by the compactness of the rocks and the coherence of the sediments. From a hydro geological point of view the area is characterized by the presence of low and non-permanent outflow springs whose water quality is expected to be acceptable given there are no potential pollution sources up stream. However, the karstic aquifer of the area of interest appears to have a remarkable recharge and discharge rate (Dikarou, 2010). From the analysis of the climatic and bioclimatic data of the island of Rhodes, it was concluded that high priority for anti-erosive works must be given to the sloping regions with westerly- north-westerly orientation as well as to the burnt areas from the fire of 2008 (Bastounopoulou, 2010a). Finally, an increase in the number of days with high risk of fire initiation is expected due to both the increases in the number of days with maximum air temperature above 35^o and the number of hot nights per year, as well as the decrease in the expected precipitation due to climate change (Bastounopoulou, 2010b).

All of the above mentioned facts, in regard with the implementation site, along with the major fire impacts previously discussed, were the crude guidelines for the development of the project's interventions. Scopes of the project were determined to be the cross evaluation of both the effectiveness of the applied restoration interventions and their economic viability. As outlined previously most post-fire management practices are addressing problems in regard with erosion and tree capital loss, while the most serious impacts on soil fertility and disturbance of the hydrological cycle are left untreated. Therefore also a discreet target of the project was the holistic approach of the restoration efforts, aiming to propose solutions for the disturbance of the water and soil nutrient elements cycles. Thus well-established restoration techniques should be coupled with innovative ones and measurable results should be produced in order to cross evaluate their effectiveness.

All of the well established techniques, namely logging, log barriers and planting, were surveyed in order to have a preliminary proof of their effectiveness and viability. Logging was the only one excluded, as it requires extensive human labor and presents also crucial counter active to restoration effects. Bird species in severely burned conifer forests depend heavily on the abundant standing snags for perch sites, nest sites, and food resources (Hutto, 2006), moreover, salvage logging has been found to reduce bird species abundance by 50% and richness by 40%, approximately (Castro et al., 2010). Beside those adverse effects on bird biodiversity, harvesting and slash logging results also in significantly higher seedling mortality (Vega et al., 2008), and has been found the least effective among forestry operations (Barberis et al., 2003). Planting interventions, though have not a proven functionality (Beghin et al., 2010, Gonzalez-Ochoa et al., 2004), were adapted mostly because of the natural presence of *Cupressus semperivirens* which, in contrast with *Pinus brutia,* does not regenerate easily and if such an intervention was not included an alteration of the original forest's character should be expected. Log barrier interventions were dictated because of the preliminary study results, which outlined erosion as the major threat in the implementation area, but also by their proven functionality (Shakesby, 2011), though this functionality is much depended upon the twofold difference in the soil water-holding capacity (Wolgermuth et al., 2001)

Decisions on the innovative interventions could not be based on extencive experimental data. Drivers for those decisions became the environmental needs as recorded through post-fire impacts identification and the available to the greater implementation area resources. The first input to this decision making proccess suggested the implementation of fertilization, in order to overcomme the decrease in both soil's organic matter and macro nutritional elements, and irrigation to overcomme the inreased water runoff and the decreased soil's water holding capacity. Locally available resources, on the other hand are the ones that limit down the possibilities, with water availability being the crucial parameter. Under this perspective the reuse of the products from municipal sewage plant of the city of Rhodes was promoted as the most influencial and easily adoptable within the Mediterranean region, if proven safe and effective. Though there are scarce records for use of sewage sludge in post-fire management (Larchevêque et al., 2010), the sideeffects of this application to other environmental parameters, beside plant growth, has not yet been investigated. The same goes with wastewater which has been extensively investigated as an alternative source for agricultural irrigation purposes (Botti et al., 2009, Ham et al., 2007, Westrell et al., 2004) but never again in post-fire forest restoration.

3. RESULTS

The aforementioned procedure generated an experimentation scheme consisting of 4 interventions, cross-complied, following the scheme presented in Figure 4, thus forming a 4X4 experiment within which the following interventions are included:

Anti-erosion Interventions. The anti-erosion method of choice is to create log land-barriers. (Figure 2)
Soil Improvement Interventions. This will utilize sewage sludge from the waste treatment facilities of the city of Rhodes (Figure 3) in order to enrich the damaged soil, with organic matter.
Planting Interventions. In order to enrich the local floral potential, planting will be implemented by the use of *Pinus brutia, Cupressus sempervirens* and *Juniperus* sp. propagated by local seeds and in density of almost 3.000 plants per ha.
Irrigation Interventions. This new and innovative method will apply almost 2 tons of wastewater per ha, provided by the waste treatment facilities of the city of Rhodes, through a surface application system in order to avoid environmental impacts during its removal.

Figure 2: Log barrier

Figure 3: Rhodes Waste Water Treatment plant

Four repetitions have been included, which are distributed within the burned Natura 2000 site, in three locations. The distribution of the 16 intervention parcels within each repeat is presented in detail through figures 5, 6 and 7. Each parcel covers an area of 1 ha, resulting this way to a repeat of 16 ha and total covered area of 64 ha. Though efforts were made to retain a tetragonal scheme for each parcel this was not achieved because of a single case in the “Ag. Isidoros” repeat, upon which the null hypothesis will be applied in order to minimize the experimental variation among the parcels.

The effectiveness of the applied interventions will be assessed based on two main categories of criteria. The first category of criteria will assess the cost of each intervention. Previous studies have assessed the cost of forest restoration (Espelta et al., 2003), however they did not include the specific intervention, which will be implemented in this project.

The second category of criteria for the assessment of the interventions will involve their ecological effects. Their efficiency will be evaluated by the use of certain indicators such as the population, density and height of new plants (Espelta et al., 2003), in the case of natural regeneration with the use of simulation models, Geographical Information Systems and satellite data. In addition to those modules, special concern has been given to biodiversity restoration impact, which will be monitored through the total number of taxa growing in each parcel, with direct focus on the ones of Table 2.

The comparative assessment of the interventions will be incorporated through multivariate analysis to deduce conclusions regarding the environmental safety, the economic sustainability and restoration effectiveness, of each intervention alone, but also of every possible among them, combination. Monitoring of the project’s outcomes will be also approached through the use of a GIS tool of remote sensing, which will allow the remote assessment of the interventions effectiveness. Coupling those results with the field acquired data will allow for the verification and the typification of the satellite spatial data.

The added value of this project lays in the fact that it aims towards a complete and combinatory study of the best practice options for the restoration of burnt natural areas, with the main result, a Best Practice Guide for the Restoration of Burned Mediterranean Forests, which will clarify issues regarding safety, cost and efficiency of practices applicable to the whole of Southern Europe and especially insular forest ecosystems. In addition, the aim of this project is to research on the safety and efficiency of new innovative practices for forest restoration, such as irrigation and fertilization, with the use of wastewater and sludge from a sewage treatment plant. Given that the water quality from the waste treatment plant remains consistent and safe, then at a later stage, a new more permanent irrigation network could be used as a fire prevention method.

Family	**Genus, Species**
Leuciscinae	*Ladigesocypris ghigii,* Gianferrari
Ranidae	*Pelophylax cerigensis,* Beerli, Hotz, Tunner, Heppich & Uzzell
Hylidae	*Hyla arborea (kretensis),* Ahl
Lacertidae	*Lacerta trilineata diplochondrodes,* Wettstein
	Lacerta oertzeni pelasgiana, Mertens
Accipitridae	*Buteo rufinus,* Cretzschmar
	Hieraaetus fasciatus, Vieillot
Falconidae	*Falco biarmicus,* Temminck
Cervidae	*Dama dama,* L.
Vespertilionidae	*Eptesicus bottae,* Peters

Table 1: Special interest faunal taxa in the area of implementation

Family	Genus, Species
Cruciferae	*Aethonema arabicum,* (L.) E. O. Schulz
	A. pogonocarpum, A. Carlstrom
	Erophila verna, (L.) Chevall. *sensu lato*
Caryophyllaceae	*Arenaria rhodia,* Boiss.
	Gypsophilla confertifolia, Hub.-Mor.
	Silene salamandra, Pamp.
	S. discolor, Sm.
Leguminosae	*Colutea insularis,* Browicz.
	Medicago heyniana, Greuter
Crassulaceae	*Rosularia serrata, (*L.) Berger
Hamamelidaceae	*Liquidambar orientalis,* Miller
Compositae	*Anthemis rhodensis.* Boiss.
	Carlina tragacanthifolia, Klatt
	Scorzonera elata, Boiss.
Campanulaceae	*Campanula hagielia,* Boiss.
	C. rhodensis, A. DC.
Primulaceae	*Cyclamen rhodium,* Gorer sensu lato
Boraginaceae	*Lithodora hispidula,* (Sm.) Griseb.
Labiatae	*Stachys cretica,* L. ssp. *smyrnaea* Rech. fill.
Thymelaeaceae	*Thymelaea tartonraira,* (L.) All.
Rubiaceae	*Galium canum,* DC. ssp. o*vatum* Ehrend.
Liliaceae	*Allium junceum,* Sm. ssp. *junceum*
	Fritillaria rhodia, Hansen
	Muscari weisii, Freyn
	Colchicum balansae, Planchon
	C. variegatum, L.

Table 2: Special interest herbal taxa in the area of implementation

I	I+F	I+P	I+LB
F	F+P	F+LB	I+F+P
P	P+LB	I+F+LB	I+P+LB
LB	F+P+LB	I+F+P+LB	null

I=Irrigation, F=Fertilization, P=Planting, LB=Log Barriers

Figure 4 : Interventions distribution among each experimental repeat

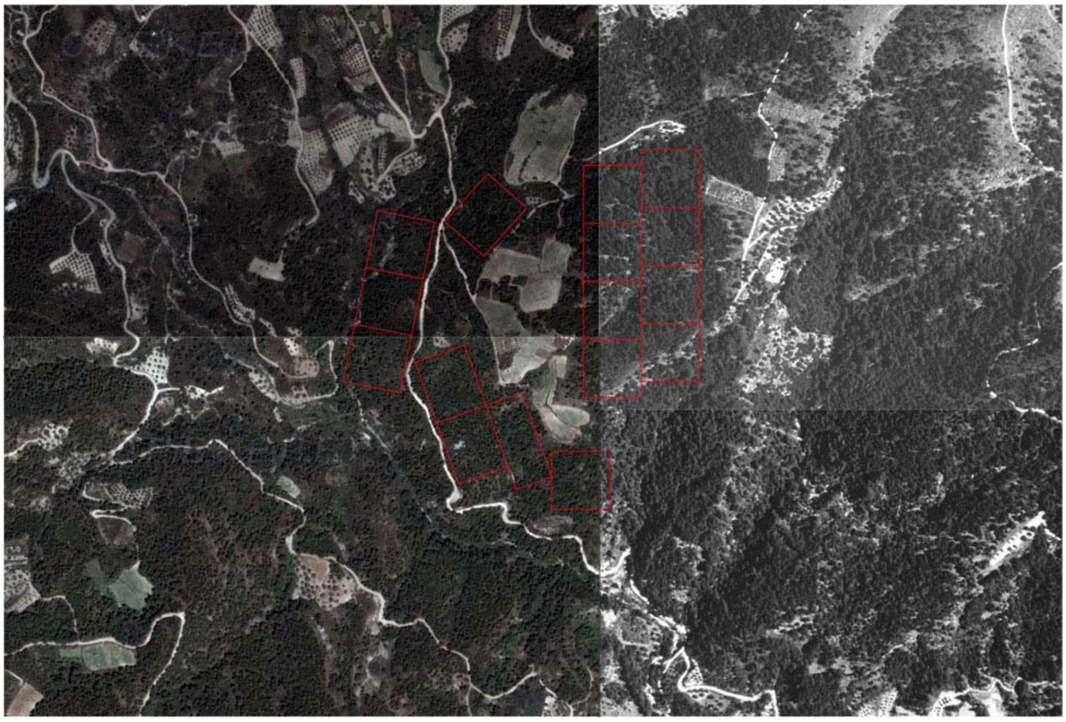

Figure 5: Agios Isidoros plots

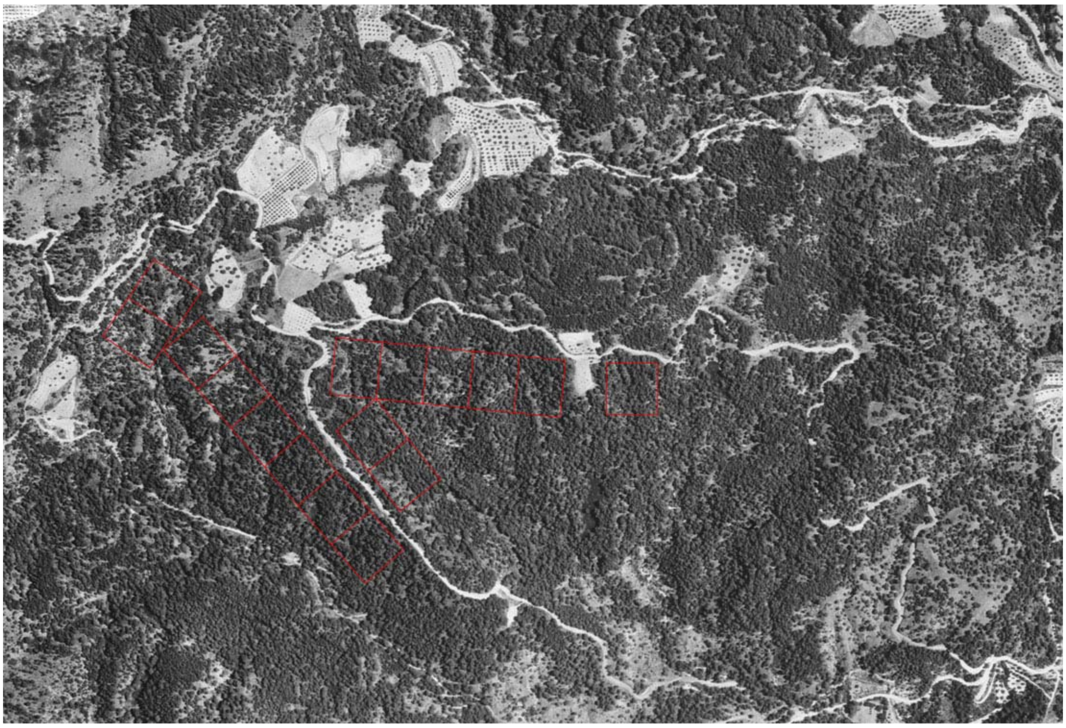

Figure 6: Laerma plots

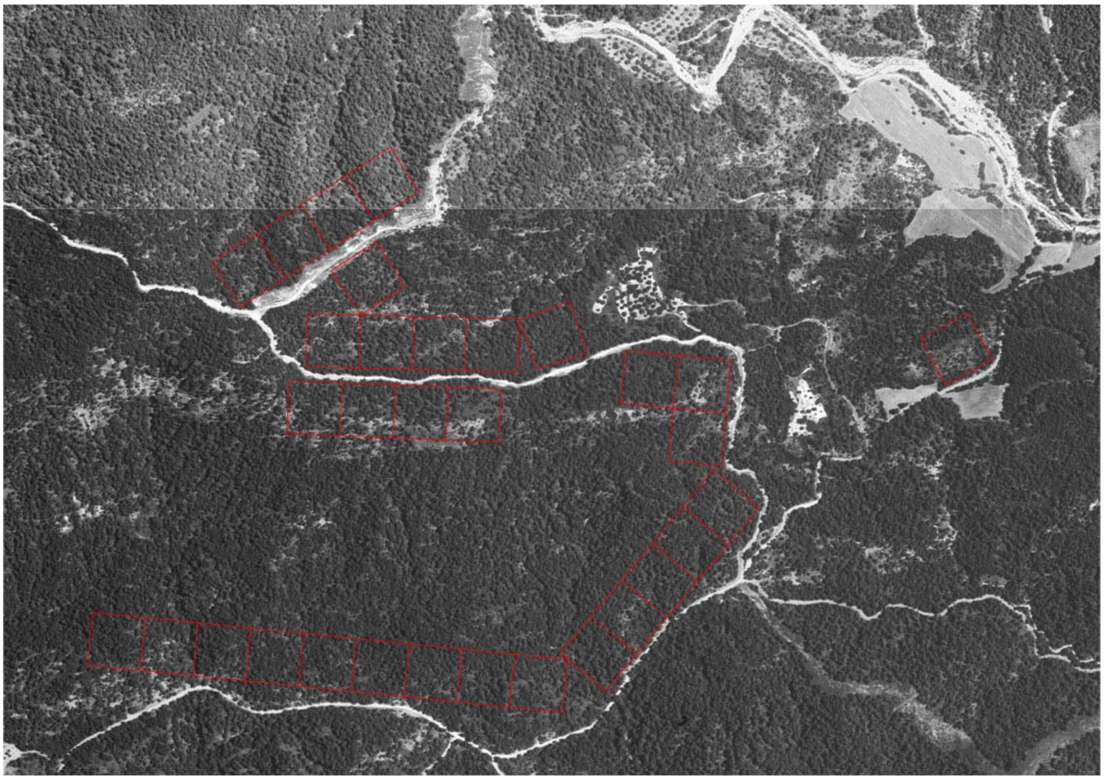

Figure 7: South Rhodes plots

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