LIFE 07 NAT/GR/000286 “Restoration of Pinus nigra forests on Mount Parnonas (GR2520006) through a structured approach”

Guidelines for restoration of *Pinus nigra* forests affected by fires through a structured approach

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Contents

Summary

Black pine forests are among the most important forests of Greece due to their European importance, their rich flora and fauna and their environmental services. During the last years, an increase of wildfires and the burnt area has been observed, something that in the long term threats their conservation status since their natural regeneration is slow and becoming more difficult as long as fire danger increases and climate conditions turn to less humid and more warm. Black pine' s forest regenerate slow after fire because the species does not have serotinous cones and during summer, when fires frequently occur, cones are immature and as a result seed ripening from burnt trees is impossible. As a result, natural regeneration of the burned forest relies solely to the unburnt trees found either in "green islands" or isolated and scattered across the landscape. Artificial restoration is the only way to assist nature for the restoration of Black pine in areas where natural regeneration is not likely to appear in the next few years after the fire. Its success will be maximised if before a fire occur, a planning method having as core a step by step approach has been adopted. This step by step approach include 1) specification of selection criteria of areas prospective for restoration, 2) implementation of exclusion and ranking of areas prospective for restoration, 3) preliminary selection of areas for artificial restoration, 4) verification of the preliminary selection and 5) selection of restoration measures. Crucial element of this planning method is that it has to be part of the standard management planning for the forest. It includes safeguarding of personnel and means availability for its implementation, the rapid reaction against post-fire emergencies, mainly of erosion and the detailed assessment of the fire on which the implementation of the step by step approach is relied. The method also includes a monitoring programme for the evaluation of the method and its implementation procedures. Selection criteria are grouped into ecological and those related with abiotic features affecting suitability of each area for the Black pine re-establishment. Selection criteria can act as either exclusion or ranking of areas prospective for restoration. Exclusion criteria are the existence or the high possibility of natural regeneration and altitudes where climate is adverse for the survival of the seedlings. The ecological criteria and the way they increase the importance of an area are in hierarchical order are: 1) the representativity of the habitat type typical vegetation, 2) the inclusion of the area in Natura 2000 sites, 3) the inclusion of the area in a protected area, 4) the contribution to the conservation of important species and 5) the contribution to the re-establishment of connectivity between unburt forest remnants. Abiotic features that make an area more suitable for restoration are in hierarchical order 1) deep soil, 2) aspect favoring plant growth, 3) position on the slope favoring plant growth, 4) gentle slope, 5) geological substrate favoring plant growth. Areas prospective for restoration are ranked for each criterion and then according to the hierarchy between the criteria a catalog with the most suitable areas at the top is created. The sum of the top ranked areas for restoration which will be selected depends on the available resources. Selection of the area involves also technical criteria (aggregation and accessibility) so some top ranked areas may finally not selected. This preliminary selection is verified by field visit. The next step is the selection of the restoration technique between seeding and planting and their variants. One of the most important issues for a succesfull restoration is the permanent availability of adequate seed quantity ready to be disposed for seeding or for the production of seedlings.

Introduction

Until the mid-90's, post-fire management of mountainous forests of Greece was restricted to salvage logging and re-establishment through plantings or seedings in an *ad-hoc* basis when timber producing stands were burnt. In case where severe erosion could impact infrastructure, settlements, etc. some additional measures were taken, mainly small dams in the main courses originating from the burnt areas. Since then, an increase of wildfires and the burnt area has been observed (Arianoutsou 2007). By the end of the decade, after some devastating wildfires (e.g. Taygetos 1998[1]), the usefulness of a more systematic post-fire management approach became apparent (Konstantinidis 2001) and on site counter-erosion measures such as log erosion barriers and log checkdams became a common practice. Recently several reports (e.g. Arianoutsou 2007, Giannakopoulos et al 2009) stressed that wildfires are favoured by a temperature increase and precipitation decrease driven by climate change thus posing new threats to these forests.

Having these in mind and motivated by the post-fire management problems raised by the massive wildfires of 2007 in Peloponnese Greece, the Greek Biotope-Wetland Centre (EKBY) in cooperation with the General Directorate for the Development and Protection of Forests and the Natural Environment (GDF-Ministry of Environment) initiated the development of a structured approach for the restoration of Black pine forests. This approach intends to provide a standard prioritization method for selection of areas where artificial restoration of Black pine can be implemented. Existing knowledge, practical experience and awareness for the most critical post-fire problems of erosion allows efforts to be put on improvement of processes for the restoration of burnt Black pine forests. This is why the approach does not cover other issues regarding post-fire management such as silvicultural techniques used to support the post-fire natural regeneration or control of exotic invasive species, which are examined in the framework of COST Action FP0701-Post-Fire Forest Management in Southern Europe Barbati et al. (2009).

This report aims to present the rationale of the structured approach for the restoration of Black pine forests. In the first chapter basic information regarding the presence and the importance of Black pine forests in Europe and Greece are presented while in the second a review on the post-fire management apporaches in Europe and Greece is presented. The third chapter contain the step by step process for the selection of areas prospective to restoration, a structured approach as it is called with reviews on issues considered as critical for the post-fire management management and restoration. In the fourth chapter some additional issues are examined such as the importance of rapid response and the necessity of preparatory actions like vegetation mapping and maintaining of a seed stock. In the fifth chapter the demonstration implementation of the approach for the restoration of the burnt Black pine forests of Mt. Parnonas, in Peloponnese, South Greece is briefly presented.

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[1] Peloponnisos, South Greece. The same area was burnt again in 2007.

1. Black pine forests and fire

Black pine (*Pinus nigra* Arnold) is a species extending over more than 3.5 million hectares from western North Africa through southern Europe to Asia Minor and Crimea (Isajev et al 2004, Figure 1). In Greece, it is a rather common species grown from 500 to 1500 m a.s.l. depending on the latitude, and distributed from Peloponnese (South Greece) to Rhodope massif in the north of the country, including the islands of Thasos, Lesvos and Samos (Ganatsas 2010). It covers an area of more than 280.000 ha (Tsaprounis 1992).

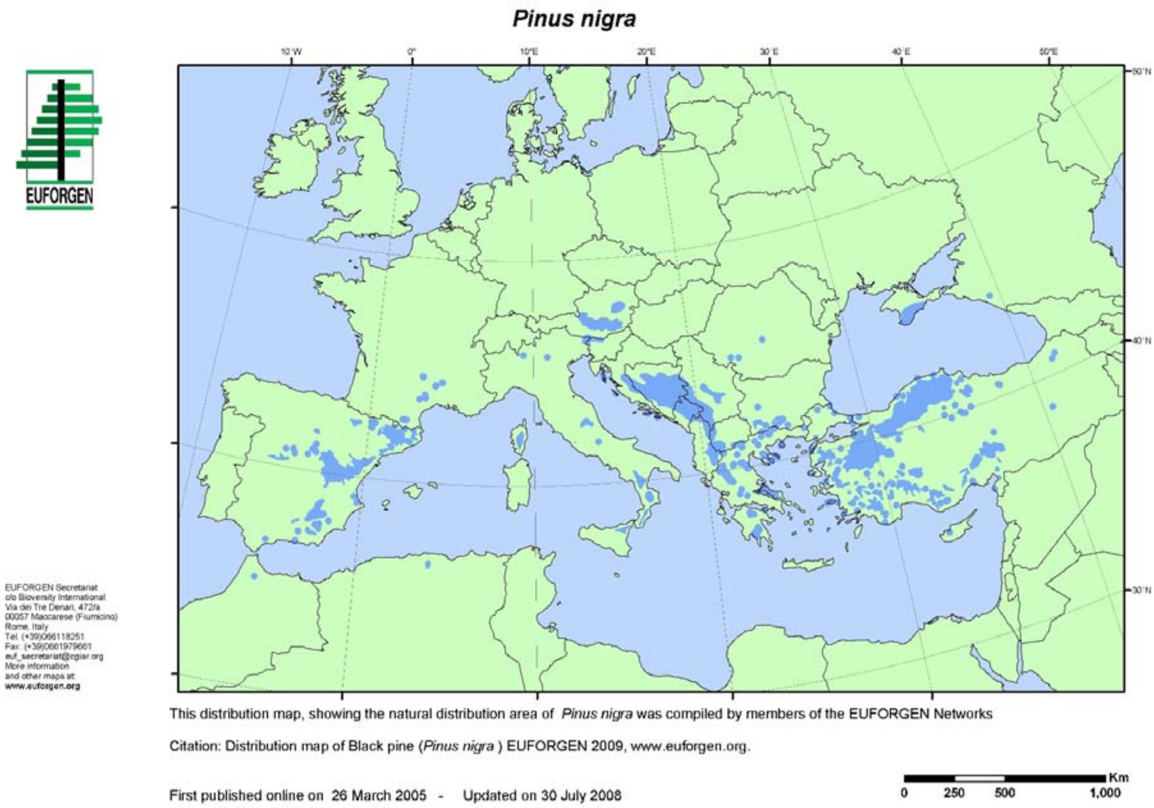

Figure 1. Distribution of Pinus nigra according to EUFORGEN (2009).

Black pine is a semi-light demanding species, resistant to wind and drought, and adapted to a variety of soil conditions (Zaghi 2008). In Greece, Black pine mainly forms even-aged forests as a result of past wildfires and in mixed stands with fir (*Abies cephallonica* and *Abies borissi-regis*) and beech (*Fagus* sp.) where as a pioneer species occupied grasslands or mountain agricultural land abandoned after WW II (Dafis et al. 2001). These forests are of high economic importance for timber production (Tsaprounis 1992) as in other countries of Southern Europe (Isajev et al 2004) while they host a variety of rare and protected animal species such as Cinereous vulture (*Aegypius monachus*) (Poirazidis 2003) and Brown bear (*Ursus arctos*) (Kanellopoulos et al 2006, Chrysopolitou and Chatzicharalambous 2008). They constitute the priority habitat type "(Sub-) Mediterranean pine forests with endemic black pine" included in Annex I of the Habitats Directive (92/43/EC).

Black pine has a medium tolerance to fire. Ground fires cause no damage to mature trees because they are protected by a thick bark (Fernandes et al 2008, Fule et al 2008) while the bare soil created after the fire favours an abundant natural regeneration. In contrast, crown fires which frequently occur in Southern Europe during summer burn the trees together with their immature cones since

Black pine seeds ripen in early autumn, from September to October (Skordilis and Thanos 1997). In other words, the species does not have serotinous cones with a seed bank that is released after a crown fire(Trabaud and Campant 1991, Tapias et al 2001). As a result, natural regeneration of the burned forest relies solely to the unburnt trees found either in "green islands" or isolated and scattered across the landscape (Ordonez et al 2005). In this case, seeds have been observed to disperse in a distance of 100 m with densities depending on topography, wind direction and the tree height (Ordonez et al 2006).

2. Post-fire management and restoration of Black pine forests

Post-fire management of forests poses several challenging issues to forest managers all over the world. In the US, post-fire management is implemented with a two-phase approach. The first phase involves the mitigation of erosion, the prevention of floods and other destructive phenomena and is called BAER (Burnt Area Emergency Response) (Napper 2006, US-DOI 2006). The second phase involves the consideration of actions for the long term restoration. Decision making during the second phase is based on a thorough assessment of fire's impacts (Lutes et al 2006). This assessment may include the socioeconomic impacts as well. Despite this well established approach, long term actions for restoration are implemented mostly on a case by case basis, while there are several issues including the necessity of salvage logging that are still debated [see, for example, Noss and Lindenmayer (2006), Baldini et al. (2007)]. At the same time, several reports indicate that the lack of expenditure monitoring cannot justify the proper use of funds (Hill 2003, Nazzaro 2006).

For Europe, a preliminary review of post-fire management by Barbati et al. (2009) reveals that several aspects of post-fire management have not been addressed, such as the evaluation of fire damages in economical terms, the emergency (short-term) actions that should be applied, the management of burnt trees, etc. European Forest Action Plan[2] acknowledges the problem by asking the support for restoration of forests damaged by natural disasters and fire as well as the grouping of member states to study particular regional problems related to forest management. Nevertheless, the two-phase approach seems that is gradually adopted and developed especially in the countries of South Europe.

In a review paper on setting goals and priorities for post-fire restoration projects in east Spain, Vallejo (2006) suggests protection of soils (the core objective of BAER) should be of highest priority and all other conservation actions can be scheduled later. In Spain and in particular in the region of Valencia a model predicting the possibilities of natural regeneration helping identifying areas more vulnerable to fires and with a higher priority for artificial restoration has been developed (Vallejo 2010). Also, a circular that explains how wood should be logged in areas affected by forest fires is being used in Comunitat Valenciana (Comunitat Valenciana 1994). This circular refers to criteria for salvage logging such as slope, geological substrate, risk of falling trees or rocks, disturbance of natural regeneration and erosion avoidance. In case that the burnt area is larger than 50 ha the circular requires documentation of the proposed handling of burnt trees.

In Portugal, the two-phase approach has been included in the National Forest Strategy (Direcao-Geral-dos-Recursos-Florestais 2007). In the chapter on the restoration and rehabilitation of forests affected by fire, restoration actions are divided into short-term aiming at reducing risks and тo the long term ones aiming at restoration of forest ecosystems and their productivity.

For Cyprus, Ioannou and Papageorgiou (2007) report that burnt mature stands

[2] http://ec.europa.eu/agriculture/fore/action_plan/index_en.htm

are left to natural regeneration. If the natural regeneration fails after a period of 3-5 years, artificial restoration is applied using either planting or seeding. In the case of immature stands, artificial restoration is applied immediately after the fire. In general, the success of natural regeneration after fires is very high, especially in the *Pinus halepensis subsp. brutia* stands.

In Greece, legislation dictates the burnt areas should be compulsory declared for restoration by excluding all uses, including grazing for several years. Also, in an attempt to minimise disturbance of natural regeneration, it suggests that restoration measures should be taken within three years after the fire. However, the lack of a comprehensive system for post-fire management has been recognised during the last decade focusing mainly on forests with serotinous species such as Aleppo pine (*Pinus halepensis*) (Konstantinidis 2001). After the devastating fires of 2007 in Peloponnese, post-fire management re-emerged as a central issue mainly because besides the great environmental impacts people were also killed and the first integrated approaches were proposed. Such an approach was designed and implemented in the burnt areas around ancient Olympia by the Institute of Mediterranean Forest Ecosystems and Forest Products Technology (Lyrintzis 2007). This project is distinguished because a) it proposes interventions based on a detailed impact assessment of the wildfires and b) it follows a clear two-phase arrangement of the restoration efforts, that of direct interventions to address emergency or short-term risks and that of mid-term restoration operations.

For Italy, Beghin et al. (2010) report that emphasis is placed on suppression rather than restoration, with a consequent unbalanced allocation of resources and priorities. Post-fire management activities commonly involve salvage logging operations, sometimes followed by plantations. Erosion stabilization measures are also adopted when necessary. Salvage logging is not applied as a way of minimizing the economic impact of forest fires, since this harvesting activity has usually no or little economic revenue given the low merchantability of salvaged wood, the complex topography and the reduced accessibility of burnt forests. He also points out that restoration activities after major wildfire events are strongly subject to budget constraints.

An important step to the development of a robust post-fire management strategy is expected by the Cost Action FP0701 on "Post-Fire Forest Management in Southern Europe", a network of researchers and practitioners working in the field of fire ecology and forest management from all around Europe. COST FP0701 aims at developing and disseminating scientifically-based decision criteria for post-fire management, applicable from the stand-level to landscape-level planning.

In this framework, it is not surprising that the restoration particularities of the burnt Black pine forests attracted little attention. The growing occurrence of large fires after 1990 motivated researchers to publish several papers addressing a variety of issues, particularly in Spain, such as vegetation succession after fire (Rodrigo et al 2004), natural regeneration dynamics (Ordonez κ. ά. 2005), and restoration techniques (Vallejo et al 2006). Nevertheless, a more comprehensive operational approach on post-fire management and restoration has not been presented.

In Greece, after large fires in Black pine forests, especially in those that produce timber,, restoration efforts are organised in two phases. During the first weeks after fire emergency soil stabilization measures with contour felled logs and construction of checkdams are being usually implemented. These measures are implemented following a technical study that contains a basic ecological assessment including the erosion risk, the area usually burnt per forest type and the volume of timber affected. Erosion and flood risk assessments are usually conducted empirically. There is no obligation for a thorough assessment of fire's impacts. During this period decisions regarding salvage logging are also taken, again in an empirical way, mainly based on timber demand and logging costs.

During the second phase, in the first winter after the fire, the necessity of artificial restoration is examined. As a starting point, the restoration of the whole burnt area is considered but the final decision for artificial restoration is based on the probability of seedlings' survival, the productivity of the soil, the estimated long term erosion risk and the available funding.

In several occasions, data regarding each of these criteria are lacking and estimations or empirical approximations are used. Forest restoration studies rarely consider the restoration of the whole forest ecosystem or the landscape implications. Usually, forest restoration studies focus solely on the re-establishment of the forest vegetation. Restoration planning tailored to facilitate forest dwelling species movement is also rarely applied. When available resources are limited, the selection of the areas to be restored is based on soil suitability and technical criteria such as proximity to roads. Implementation of these criteria is usually based on expert judgment and not on an objective system of ranking and selection. Nevertheless, the necessity of more integrated studies based on detailed ecological as well as economical assessments has been recognised (Petrogiannis 2001). Furthermore, the emergence of the phenomenon of large quantities of burnt timber after large fires raised questions about its management (Georgilas 2001) and stimulated the development of a decision support system (Xanthopoulos et al 2001).

3. Developing a structured approach for post fire Black pine restoration

In principle, post-fire management should be included in the whole management planning of every forest area (Moreira κ.ά. 2012). In such a case, restoration is one of the management measures aiming at achieving specific management objectives regarding burnt areas (Vallejo 1999). In the real world, forest managers usually have to decide without an "at hand" background work (Alloza and Vallejo 2006) and in a very short period they have to adopt new or alter existing management objectives in order to meet, for example, restoration budgets. At the same time, a proper restoration programme must also consider large scale conservation issues such as financial, technical, legal and other limitations (Vallauri et al 2005a) thus making the decision process more difficult. More specifically the approach was developed to accomplish the following general objectives and principles:

- Conservation of the area covered by Black pine forests that belonged to the priority habitat type "(Sub-) Mediterranean pine forests with endemic black pine" before the fire.
- Restoration and, if possible, improvement of the conservation status of the priority habitat type.
- Creation of suitable habitats for the movement of the forest dwelling animals among forest patches.
- Enhancing the resilience of Black pine forests to climate change by adapting its management as summarised for Mediterranean by Resco de Dios et al. (2007) from CBD/SBSTTA 7 Recommendation VII/6: (1) preservation of the pool of natural species and genetic variability of forests, (2) networking protected areas or natural ecosystems by creating ecological corridors or by maintaining appropriate ecological components in associated areas to allow natural migration of ecosystem elements, (3) reduction of forest fragmentation caused by anthropogenic activities, (4) restoration of degraded lands, (5) description of best management practices that will maintain or enhance adaptive capacity or resilience of ecosystems, e.g., establishment of wooded ecotones and buffer zones in order to allow ecosystem replacement.
- Application of the principles of ecological restoration as described by the

Society of Ecological Restoration International (Society for Ecological Restoration International Science & Policy Working Group 2004) and the Guidelines for Developing and Managing Ecological Restoration Projects (Clewell et al 2005).

By adopting these objectives and principles the approach resolve the problem of adopting new or alter existing management objectives. Focusing on Black pine the particularities of species natural regeneration had to taken into account. Natural regeneration solely depends on remained unburnt trees and after the first 2-3 years seedlings face competition from the fully recovered understorey vegetation. This means that the forest manager has about two years after the fire to decide and plan restoration where it is needed. Other issues that were also considered were the low integration of GIS into forest management by the Greek forest services, the problem of insufficient personnel and the absence of detailed data such as species distribution, soil properties, etc. For these reasons, the approach is designed to be based on data usually included in the forest management plans, and implemented with average computer infrastructure and personnel skills as well as with limited stuff. The result is a step-by-step selection method of prospective areas for artificial restoration through a set of exclusion and ranking criteria. The step by step approach in decision making in forest management is a widespread practice (Hampton et al 2003) which takes into account alternatives thus increasing the reliability of results and restoration success. The steps are:

1. Specification of selection criteria of areas prospective for restoration
2. Implementation of exclusion and ranking of areas prospective for restoration
3. Preliminary selection of areas for artificial restoration
4. Verification of the preliminary selection
5. Restoration measures

Step 1. Specification of selection criteria of areas prospective for restoration

The selection of criteria was made after taking into account the biology of the species, its importance to fauna species as well as the national and EU legislation and recommendations published by the Society of Ecological Restoration (Society for Ecological Restoration International Science & Policy Working Group 2004) and the Pan-European Guidelines for Afforestation and Reforestation that were jointly adopted by the Ministerial Conference on the Protection of Forests in Europe and the Pan European Biological and Landscape Diversity Strategy Bureau (FOREST EUROPE 2008).

The criteria are either exclusion (A and B) or ranking (C through G) and they are applied with this sequence. Exclusion criteria prevent a) disruption of desirable post-fire ecological processes, such as areas with abundant natural regeneration and b) selection of areas for artificial restoration with disadvantages for artificial restoration (e.g. harsh climatic conditions). Ranking criteria attribute priority for restoration to areas with the best opportunities for a) successful re-establishment of the Black pine trees and b) achievement of the favorable conservation status of the species depending on Black pine forests.

A. Abudance of natural regeneration

Natural regeneration should always be protected and if possible promoted. In the case of Black pine forests, if the density of seedlings exceeds or is expected to exceed 1 plant/m^2 no artificial restoration should be implemented in this area (Βέργος κ.ά. 1995{Ordonez, 2004 #124).The part of the burnt forest excluded is composed from areas where the fire has burned only the forest floor, areas with scattered live trees and a buffer zone around unburnt "islands" as well as along the interface of burnt and unburnt forest (Ordonez et al 2005). In these areas, soil disturbing interventions such as fellings and log retrieval have to be finished before the seed dispersal which occurs from February to April (Skordilis and Thanos 1997). This is especially important since recolonisation is more successful within the first two years after the fire when understorey vegetation has not been fully recovered and the competition with saplings is low.

B. Potential lower distribution limit of the species
Areas with altitude lower than the limit of the natural distribution of Black pine forest in the region should be excluded. This exclusion limit can be increased if the areas near the lower distribution altitude are marginally suitable or there are projections for adverse climate change in these areas. Isolated trees or scattered clumps of trees in low altitudes are not taken into account. In the effort to delineate the local distribution of Black pine forest, old forest maps can also be used. In case that historical distribution to lower altitude is documented, the reasons for this recession of the species should be considered in the decision for the lower altitude.

The areas remained after the exclusion of areas where Black pine is expected to be restored naturally and areas with adverse climatic conditions, are ranked with the following criteria with the order that are presented here:

C. Representativity of the habitat type typical vegetation
Representativity is one of the features of the habitat types included in Annex I of the Habitats Directive used for the assessment of their conservation status at local and national level. According to the Explanatory notes of the Natura 2000 Standard Data Form (OJ n° L 107 1997) representativity gives a measure of 'how typical' a habitat type is according to the Interpretation Manual of European Union Habitats (European Commission DG Environment 2007). Thus, areas where the habitat type "(Sub-) Mediterranean pine forests with endemic black pine" had high representativity before the fire have should have higher priority for restoration. According to the abovementioned explanatory notes, representativity has four classes: A for excellent representativity, B for good representativity, C for significant representativity and D when habitat type is present on the site in question in a non-significant manner. It is important to point to the fact that habitat types of Annex I of Habitat's Directive are assessed for their conservation status wherever they appear and no only within the limits of Natura 2000 sites. Therefore it is expected that at least a general idea of the representativity for each area can be gained from the monitoring of the habitat types held every six years according to Article 17 of Habitat's Directive.

D. Inclusion of area in Natura 2000 sites or protected areas
In case that a large fire starts within or expands into the limits of protected areas and Natura 2000 sites, its effects on the conservation of species, the habitat types themselves and the integrity of the Natura 2000 site should be examined. Such burnt areas should have priority since their restoration will increase the added value for nature and natural resources. Furthermore, Habitats Directive calls for their restoration. In particular, article 6(1) calls for restoration of the disturbed natural habitats to a favourable conservation status. Black pine forests correspond to the priority habitat type "(Sub-) Mediterranean pine forests with endemic black pine".

E. Contribution to the conservation of important species

Prospective areas are evaluated for their contribution to the conservation of important species (protected endemic or threatened species according to the European and national legislation). Detailed species distribution maps are required for this criterion. The higher the number of important species favoured by the restoration of the area the higher this area is ranked.

F. Re-establishing of forest connectivity

Fragmentation is considered as one of the most important threats for European forest ecosystems affecting also the conservation status of several species (Lindenmayer and Fischer 2006, Kettunen et al 2007, European Environment Agency 2008). Therefore, restoration planning should also aim at a forest landscape structure that promotes connectivity (Sayer et al 2004, Lindenmayer and Fischer 2006, Meinke et al 2009) mainly through corridors as described by Lidicker (1999). The basic idea is that an area prospective for artificial restoration should be ranked higher based on its contribution to structural or functional connectivity between the intact areas of the forest or between these areas and other ecosystems favouring dispersal of forest dwelling species. Lindenmayer and Fischer (2006) suggest that this evaluation should be based on the biology of the species to be favoured and to the habitat particularities for each species in the burnt area. In case that these data are insufficient or nonexistent the only solution is to use expert opinion. Given that species accounts and their distribution are limited in Greece we propose an estimation method based on expert opinion in order to reduce subjectivity of the ranking. In particular, we adopt the suggestion by Jacquemyn et al (2003) that restoration of forest habitats adjacent to existing woodland is the best option because it ensures higher dispersal probabilities. In our approach, prospective areas that can serve as intersection nodes (Forman 1995) are ranked higher than areas that simply link patces, while areas with no contribution are ranked last (Figure 1).

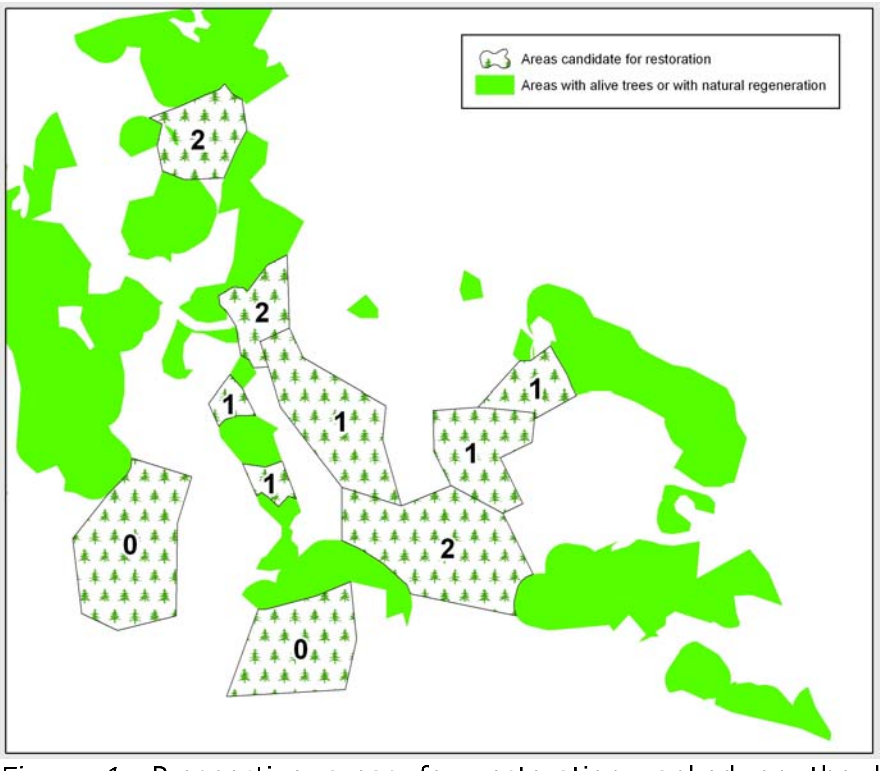

Figure 1. Prospective areas for restoration ranked on the basis of their contribution to the ere-establishment of forest connectivity [0: no contribution, 1: medium (link patch), 2: high (intersection node)].

G. Abiotic features of the prospective areas

Abiotic features and especially soil moisture is of profound importance for plantings (Ντάφης 1986). For areas prospective for restoration in Black pine forests, soil moisture is affected mainly by soil depth and aspect. This is because of the prolonged xerothermic period which can reach up to 75 days per year, especially in South Greece (Mavrommatis 1980) and the shallow soils prevailing in forest soils (Papamichos 1985). Deep soils allow roots to develop faster during the first year after planting and exploit moisture stored in deeper layers. For soil depth nine classes are used according to the Greek Soil Taxonomy (Δασκαλάκης κ.ά. 1989). Aspect is an important factor affecting air temperature. Southward aspects tend to have higher air temperatures since they receive higher amounts of solar radiation during the day (Apostolidou 2007). Aspects are ranked from more to less favorable: N, NE, NW, E, W, SE, SW, S.

Step 2. Implemetation of exclusion and ranking

All areas prospective for restoration are arranged in a table with the respective values for each of the above mentioned criteria in columns as seen in table 1. Abudance of natural regeneration is represented by the value of seedlings per square meter. Thus 1 stands for 1 seedling/m^2, 2 for 2 etc. Altitude of each area can be either its mean altitude or the area-weighted mean altitude. For representativity 2 stands for excellent, 1 for good and 0 for significant representativity. If more of 50% of an area is included within the limits of a Natura 2000 site its respective value is 1, else 0 and the same applies for protected areas. The number of species for which an area is important is the value in the respective field. Values for forest connectivity are: 0 for no contribution, 1 for medium (link patch) and 2 for high (intersection node). Abiotic features have values from 9 to 1 with 9 corresponding to deep soil and 1 to rock. Aspect take values from 8 to 1 with 8 corresponding to north and 1 to south.

The criteria are arranged from the most to the less important and the exclusion criteria A and B are the first applied (Table 1). Areas subject to criteria A and B are excluded from all future process. For the remaining of the areas a "suitability index" is formed by combining the values of criteria C to G as shown in table 1. Suitability indices for objective decisions in restoring ecosystems have been used in relevant restoration attempts (Antti and Otsamo 2006). Then by sorting the areas for this index from greater to lower values, the areas with higher priorities are top ranked (Table 2). Alternatively the areas can be ranked by subsequent sorting for each criterion from A to G.

Table 1. Example of the creation of a suitability index of prospective areas for restoration before ranking. In this case the lower altitude limit was set up to 850 m.

Area code or stand	Area (ha)	Nat. regeneration	Altitude	Represent ativity	Natura 2000	Protected area	Conservation of species	Forest connectivity	Soil depth	Aspect	Suitability index
		A	B	C	D1	D2	E	F	G1	G2	C/B/D1/D2/E/F/G1/G2
042	26,451	0.2	1050	2	1	1	0	2	4	6	2110246
043c	12,614	0	1050	1	1	1	0	2	4	3	1110243
048a	11,975	0	1075	0	0	1	0	1	8	5	0010185
047b	4,3014	0	1125	2	1	1	0	1	8	9	2110189

Table 2. The prospective areas for restoration of Table 1 after ranking.

Area code or stand	Area (ha)	Nat. regeneration	Altitude	Represent ativity	Natura 2000	Protected area	Conservation of species	Forest connectivity	Soil depth	Aspect	Suitability index
		A	B	C	D1	D2	E	F	G1	G2	C/B/D1/D2/E/F/G1/G2
042	26,451	0.2	1050	2	1	1	0	2	4	6	2110246
047b	4,3014	0	1125	2	1	1	0	1	8	9	2110189
043c	12,614	0	1050	1	1	1	0	2	4	3	1110243
048a	11,975	0	1075	0	0	1	0	1	8	5	0010185

Step 3. Preliminary selection of areas for artificial restoration

Steps 1 and 2 can be implemented irrespectively of available resources for restoration. Step 3 is the step where the operational aspects of restoration such as available resources (funding, reproductive material) and technical features (e.g. accessibility of the areas) are taken into account.

Available resources (e.g. financial, seed stock) determine the total area that can be restored after taking into account the cost per hectare and the success of the restoration method (seeding or planting) to be applied. Seeding has lower cost per hectare but higher quantities of seed are needed. Thus in case that seed stock is low seeding can not be used as the main technique for the re-establishment of Black pines and the area to be restored is depending on the available funds for nursering and planting of seedlings. On the other hand, some highly ranked areas may be difficult to access. For the restoration of Black pine forests in Greece and after several contacts with forest managers two criteria for the selection of prospective areas for artificial restoration may be considered, a) aggregation of the areas for restoration and b) accessibility of the areas from the existent road network.

A. Aggregation of the areas. Selection of aggregated areas results at reduced costs of restoration since personnel and equipment do not need to relocate frequently. Aggregation also results in larger restoration patches which in the landscape context will reduce fragmentation (Forman 1995). This is compatible with the selection rationale of areas prospective for restoration.

B. Accessibility of the areas from the existent road network. Small distance from existing road network reduces the restoration cost since the transportation time for materials and equipment is reduced. By selecting areas adjacent to existing roads some funds may be reserved and used for additional restoration work. Also, further disturbance of the soil from opening new roads is avoided.

Implementation of step 3 allows the examination of different scenarios of combining areas and methods in order to reach the maximum area for restoration with the available resources. Those scenarios may also include implementation phases for the restoration of the whole burnt area taking into account the flow of funding.

This step ends with drafting a preliminary map with a respective table of highly ranked and operationally optimum areas for restoration.

Step 4. Verification of the preliminary selection

Step 4 involves the verification of suitability of the preliminary selection of areas for artificial restoration (Step 3). Here, the forest manager verifies on site that all areas selected have soil conditions suitable for artificial restoration (seeding or planting) and that access to the area from the road network has no obstacles such as fallen trees, rocks etc. Obstacles are considered for removal and if this is possible in the framework of restoration, special notes are kept in for the planning of the restoration work.

Step 5. Restoration measures

The restoration measures presented here are not the only possible that could be implemented for the restoration of Black pine forests. They are the most commonly applied.

To log or not to log

Management of the standing burnt trees is an important and controversial issue that must be addressed. Leaving standing burnt trees at place have advantages and disadvantages that should be taken into account. According to Baldini et al. (2007), general rules can not be applied; instead, local conditions and the overarching principles of soil protection and biodiversity conservation should drive decision making. Revenues from timber selling can be considered but only when the additional disturbance from logging works in the landscape do not have detrimental effects on biodiversity (Castro et al 2010). Detailed assessment of fire's impact on the forest in combination with historical data regarding post-fire natural regeneration can substantially assist forest managers.

Soil erosion is the most frequent and severe impact from post-fire logging. DellaSala (2006) and Baldini et al. (2007) report that it is unavoidable even when the least soil impact retrieval systems have been used. Felling for constructing log erosion barriers is widely used for erosion prevention. However, several researchers (e.g. Marques and Mora 1998, Robichaud et al 2008) have found that the actual contribution of log erosion barriers to erosion prevention is very poor; they are effective in reducing runoff and peak flow in small events, but not in large events. Their effectiveness is strongly affected by the implementation quality (Robichaud et al 2000). In all cases, moving logs from the forest can further disturb the soil, causing loss of nutrients and erosion (McIver and Starr 2000, DellaSala 2006) even when less soil disturbing methods are applied (Baldini κ. ἀ. 2007).

Lindenmayer et al. (2004) claim that burnt trees benefit biodiversity either left standing or felled and left on spot and conclude that "salvage harvesting activities undermine many of the ecosystem benefits of major disturbances". Also, Castro et al. (2010) found that salvage logging in pine forests in Spain significantly affected avifauna diversity and abundance and proposed no or carefully designed logging with combination of several treatments. In Greece, Spanos et al (2005) found that early logging reduced the impacts on natural regeneration while Raftoyannis and Spanos (2005) found that salvage logging and log barriers had no significant effect on the recovery of natural vegetation. In the case of felling, wood is decomposing faster thus improving the soil quality to the benefit of ground biota. However, fine wood may be highly flammable during the first years after felling (Donato et al. 2006) making salvage logging unsuccessful in reducing burn severity (Thompson and Spies 2010). When standing trees are felled in the subsequent years, they may damage seedlings, but they provide some shade (DellaSala 2006). Fernandez et al (2007) have also recorded positive relations between tree cover index and soil moisture. Post fire felling has detrimental effects to natural regeneration (DellaSala 2006, Baldini et al. 2007, Beghin et al. 2010).

Black pine re-establishment

Re-establishment of woody vegetation is usually the core of the restoration process and is basically dictated by the abiotic conditions of the area under restoration. Artificial re-establishment of Black pine can be implemented either by planting or by seeding, but both basic methods can be applied with various techniques. Selection of the re-establishment method (or methods) should consider advantages and disadvantages of each method not only during the implementation but also during the years to come, since each method and its particular technique needs different treatments in the future. Taking into account new aims for Mediterranean forests such as increase of carbon fixation and increase biodiversity, Pausas et al. (2004) proposed the following major generic objectives where the main goal is nature conservation: a) soil and water conservation; b) improving the resistance, and especially the resilience of ecosystems with respect to wildfires; and, c) increasing mature woody formations, both in forests and tall shrublands, depending on the environmental conditions of the site.

According to Dafis (2010), seeding is the most natural method of restoration and has many advantages when compared to planting. The most important is that young plants are able to adapt their root system to the local soil characteristics right from the start thus avoiding the transplantation shock when produced at the nursery. A much larger number of young plants per unit area are established and, consequently, the potential for natural selection becomes stronger. Pausas et al. (2004) indicate that seeding has also the advantages of low cost, low impact and easy application to remote locations. Among the disaadvantages, seeding demands large quantities of seeds and is highly dependent on the following weather conditions. Also, ants, mice and birds consume a significant portion of the seeds (Ordonez and Retana 2004 and Zwolak et al. 2010). Finally, as time from fire increases, understorey vegetation covers the ground and organic material is accumulated, seeding is less successful and needs site preparation by grazing, burning, ripping, etc (Espelta et al. 2003).

Planting techniques may use bare-root or container seedlings. Bare-root seedlings have the advantage of low cost at the production phase and greater adaptive potential of their root system at the replanting site, but they demand much greater care in the extraction, packaging, transportation and planting phase. Also the time between extraction and planting must be limited in order to minimise transplantation shock. An important advantage of bare-root seedlings is the fact that quick and simple methods can be used for planting, such as planting with planting bar or pickaxe, provided that the soil conditions are suitable.

Container seedlings have been proved more suitable for areas with a dry Mediterranean climate mainly because they can be maintained for a longer time from the moment of extraction to the moment of planting, which allows for the prolongation of the planting period (Chirino et al. 2009). Additionally, container seedlings can be planted deeper than usual (Chirino et al. 2009) in areas where the surface soil dries frequently. On the other hand, container seedlings have the disadvantage of higher production cost and the possibility of root twisting, especially when their age is greater than two years. The transportation cost is also higher.

Another issue is the age of seedlings. One-year container seedlings as well as bare-root seedlings have the advantage of lower production, transportation and planting costs but they incur greater costs for protection, especially against competition with ground vegetation (Dafis 2010). Two-year seedlings have the disadvantage of higher production, transportation and planting costs (and in the case of container seedlings the risk of root twisting), but they require less post-planting care than the first year seedlings.

Increasing water availability

Water availability is one of the most critical issues that artificial restoration of Black pine is facing, especially in drought-prone areas (Dafis 1986, Vallejo 2010). Increasing availability of water can be achieved through reduction of evaporotranspiration and by increasing available soil water. Reduction of evaporotranspiration in a landscape-scale restoration project can be achieved by reducing soil and seedlings exposure to direct sunlight through shading. Shading is increased by dead organic material, plants that germinate or resprout (Castro et al. 2002) and by standing burnt trees. Therefore, careful consideration of all post-fire treatments with impacts to soil and vegetation is needed. Increase of water availability needs some costly interventions, usually during or just after planting or seeding. It can be achieved with a variety of methods including water-harvesting techniques, application of hydrogels or low cost irrigation solutions (Vallejo 2010). Water harvesting can be applied to plantings and spot or line seedings; it involves division of the slope into micro-catchments with the objective to slow surface runoff and channel water to plantings or seedings (Ferrándiz et al. 2006, Chirino et al 2009). Hydrogels have been also tested but their contribution to seedling survival seems to be variable (Pausas et al. 2004, Chirino et al. 2009). Low cost irrigation solutions are based on water collected from a variety of sources like permanent rivulets, rain or fog collectors (Estrela et al. 2009), storage into tanks from where it reaches plant root area through a small scale temporary irrigation network (usually made up of plastic pipes). Nevertheless, all watering solutions have some cost and they should be used in locations with strategic importance for the restoration project.

The mix of measures for increasing water availability should be decided on the basis of the intended restoration success of plantings or seedings, in combination with the available resources (time, labour, technical means, accessibility of the project area, etc).

Grazing control

Grazing of domestic animals, when excessive, is an important threat to natural and artificial restoration of burnt forests. Overgrazing not only threaten seedlings or planted trees but can also compact the soil (Papanastasis and Noitsakis 1992), initiating rill erosion and depletion of nutrients. In case where livestock grazing is a threat fencing of the restored areas should be applied.

4. Improving the approach's performance

Performance of the structured approach and restoration success can be enhanced by applying some complementary measures. These are:

- Launching the process immediately after the fire
- Impact assessment report
- Soil mapping
- Distribution of vegetation types, flora and fauna
- Road network
- Seed stock from the same provenance
- Nursering of plants not far from the area under restoration
- Monitoring

Launching the process immediately after the fire

Implementation of the structured approach should be initiated right after the fire. This is dictated by several components of the approach. The most important are:

- Estimation of areas where natural regeneration has high possibility (exclusion criterion)
- Necessary production time for Black pine seedlings

One of the exclusion criteria of a burnt area is the possibility of natural regeneration. Black pine seeds are dispersed from March to April, so forest managers should take advantage of the intermediate time interval to prepare a sampling scheme based on the mapping of live trees present in unburnt or lightly burnt islands or scattered in the landscape. The time needed for mapping of live trees depends on the extent of the burnt area and of the availability of satellite or other type of imagery that can significantly reduce mapping efforts (Lutes et al. 2006, Corona et al. 2008, Mitri and Gitas 2008, Veraverbeke et al. 2010). This process may face several obstacles such as difficulties in acquiring satellite images without clouds, large areas difficult to access and financial difficulties; so, any delays may, at the end, cause problems to the restoration.

In cases where plantings are necessary, production of Black pine seedlings needs at least 1 year from seeding which in Greece is suggested to be done in late autumn. It is apparent that a precise knowledge of the number of seedlings is not possible in advance. Nevertheless, if forest managers have some initial impact assessment data, they can provide rough estimates to the Directorate of Reforestations and Watershed Management which is the national authority for planning seedling production in forest nurseries. Gathering of these initial data can be done during the emergency assessment for soil stabilisation and flood control that usually takes place just after the fire.

Accordingly, if the approach is launched immediately after the fire, restoration can start two years after the fire. According to Vallejo (2010), the soil is less vulnerable and the plant cover has been regenerated to a minimum protective threshold after two years from the fire, while there is enough time to locate all areas with natural regeneration and exclude them from restoration.

Impact assessment report

Estimation of natural regeneration probabilities as well as assessment of impacts on flora and fauna (that are also taken into account during Step 2 of the approach) are suggested to be integrated into an impact assessment report that serves as the basis of all decisions regarding restoration needs, objectives and measures (Clewell et al. 2005). This report can be compiled in different stages according to the progress of the assessment. Apart from the regeneration probabilities, the impact assessment report is of crucial importance for a) providing the base data for ranking the prospective areas for their contribution to the conservation of important species and re-establishing of forest connectivity and b) drafting the restoration monitoring programme.

It is essential to recall here that the approach does not include assessment and planning of emergency response actions targeting protection of soils, flood control, etc. These are considered as already implemented. It has already been explained, that the objective of the approach is to provide a structured method for restoration. We acknowledge however that emergency interventions, such as logging may impact restoration. This is why we provide brief reviews regarding restoration measures aiming at broadening the perspectives of the forest managers during the post fire decision making, especially towards the issue of conservation of biodiversity.

Soil mapping

Detailed mapping of soil quality strengthens the accuracy of ranking of burnt areas and minimises corrections during step 4. It also allows the optimization of the selection of restoration measures.

Distribution of vegetation types, flora and fauna

After the fire, when the approach should be initiated, vegetation and the whole ecosystem is drastically altered. Therefore, judgments regarding representativity, importance of species, etc can only be relied on existing data normally derived from vegetation surveys, monitoring and mapping. These data should be up-to-date, a task that forest manager should have incorporated in the work plan for the area. This information will be also used as a reference for the impact assessment report and for the evaluation of restoration’s success.

Road network

Updated mapping of road network is particularly useful for the implementation of Step 3 of the structured approach, helping also other components of the restoration process such as monitoring, safeguarding of plantations, etc.

Seed stock

Artificial restoration of the Black pine forest depends solely on the availability of seeds, so it is of crucial importance that an adequate stock from each provenance is maintained ready for use. Black pine produces a significant number of seeds every two years and these seeds retain a 75% germination capacity for 2-4 years (Takos and Merou 1995). Therefore, forest managers should renew their stock every 2 years.

In seedings, a ratio of 0.8 kg/ha is needed dependent on the seeding technique (broadcast, spot etc). For plantings, each kilogram of seed gives approximately 30,000 plants. Taking into account that an average of 2,500 plants/ha are planted in Greece, each kilogram of seeds can produce plants for 12 ha. According to data collected by Kravvaritis (2010), the average burnt area of Black pine forests after wildfires is 1,270 ha. For an area like this, an average quantity of 105 kgr of seeds should be immediately available. This quantity equals to almost 4 m^3 or 3,465 kgr of cones.

In Greece, seeds must be properly registered by the Central Store of Forest

Seeds which is the national authority for certifying seeds of all kinds of planting in natural forests. It has the proper equipment for handling and storage of seeds.

Seedling quality

Seedling quality is a keystone for the restoration success in case of plantings. For restoration purposes in the Mediterranean ecosystems, Vallejo et al. (2006, 2010) suggest that seedlings should be able to withstand the transplanting shock and the first summer drought; they should be, also, capable of adapting to local climatic conditions such as summer stress, cycles of drought and still take advantage of the favourable climatic periods to achieve sustained growth. Seedlings originating from the area under restoration are expected to maintain these characteristics (Chatzistathis and Dafis 1989, Dafis 2010) and this is the reason why a local seed stock is necessary to be maintained. Nursering near the area under restoration is another technique or measure? helping seedlings to adapt to the local climatic regime along with standard nursering techniques such as preconditiong, use of amendments, etc.

Monitoring

Despite the knowledge on forest restoration that has been accumulated during the last decades there are still important gaps in knowledge (Barbati et al. 2009). One of the best tools to understand successes and failures are long-term monitoring and evaluation of restoration actions in Mediterranean landscapes (Vallejo et al. 2006). On the other hand, forest restoration is a costly process; it is essential that its contribution to the sustainable development can be based on sound scientific and economic arguments. Forest restoration is a long term process and its effectiveness is difficult to be evaluated during the initial implementation phase or even the first years after (Vallauri et al. 2005b). Often, its success is largely based on the subsequent actions including protection, thinnings, etc. For this reason, monitoring is nowadays performed in the context of adaptive management, ensuring that there is a feedback to guide the management of the restored area (O'Connor et al. 2005).

Monitoring programs should be tailored to the restoration project or programme and should be integrated to the monitoring scheme of the wider area in order to be part of the adaptive management cycle. (Vallauri et al. 2005b) suggest that monitoring indicators should be simple, measurable, reliable, relevant and timely.

5. Implementation of the approach in the burnt forests of Mt. Parnonas, South Greece

Impact assessment

One of the more devastating fires of the summer of 2007 occurred on south-eastern Peloponnese. The fire spread to an area of 5,788 ha affecting 1921.02 ha of the priority habitat type "(Sub-) Mediterranean pine forests with endemic black pine". This area accounts for 35.91% of the 5,350 ha of the habitat type in the SCI??. In particular, 227.33 ha where slightly burnt, 256 ha where moderately affected and 1452.5 ha were completely burnt. However, patches of surviving black pine trees remained that totaled 420.1 ha, which, as seed sources, served as forest regeneration centers. Two years after the fire, natural regeneration of black pine was observed in patches near surviving black pine trees and near edges between burnt and unburnt areas summing up to 341.24 ha. The natural regeneration appeared to be relatively abundant (1-2 plants/m^2) except in sites covered by dense grass vegetation.

Implementation of the approach and initial evaluation

All steps of the approach were implemented with success. During Step 2, the area under natural regeneration was excluded together with areas with altitude lower than 850 m reducing the total prospective area for restoration to 1144 ha. From these, 888.4 ha were estimated that could contribute to the re-establishing of forest connectivity. They were further ranked for their soil dept and aspect and the most suitable areas were selected amounting to 498.28 ha. From these areas, 291.33 ha were selected in Step 3 for artificial restoration during the period 2009-2013 (duration of the LIFE project). As an indication, 83% of them were in a distance less than 50m from the road network. These areas were verified as suitable with field work (Step 4) and a technical implementation study was conducted for the selection of the restoration measures (Step 5). Due to some preparatory work made by the Forest Service of Sparti, the only restoration measure that was necessary was the re-establishment of Black pine which was decided to be done with planting.

The time needed for the implementation was approximately 6 months including the time needed for the detailed ecological assessment of the fire. This time does not include the development of the approach. The personnel involved were one forester and one GIS specialist and some specialists for the plant and animal species depending on the forest. During this time regular consultations with the forest managers of the area took place. Nevertheless, the approach has been developed in such a way that it can be applied even without the use of GIS but this may affect the accuracy of steps 2 and 3. This was done because GIS technologies are not available yet to all local forest authorities.

The selection of areas for restoration revealed the lack of site quality mapping and detailed distribution maps of plant and animal species depending on Black pine forests in the area. These did not allow for a more detailed ranking of prospective areas.

As a first evaluation, the following comments can be drawn:

- The time and labor needed are within the potential of the Greek forest authorities.
- Assuming that fires occur until the end of August, the approach allows for the first restoration measures (e.g. seeding, production of the exact quantity of plants, etc) to be implemented early next spring.
- Geographical Information Systems can contribute substantially to speeding up the implementation of the structured approach and the quality of the deliverables but the approach can be implemented even without their use.

In conclusion, it can be supported that the step-by-step approach is a very useful tool in the hands of forest managers for restoration of Black pine forests.

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