Good Practice Guide for the post-fire management of ecosystems

nature conservation consultants

Cover photos by: A. Martinis (Zakynthos, July 2012)
and Bruce Marcot (PNW, 2007)

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Introduction

Fire is an environmental factor, which together with climate, landforms and soils, has operated over millions of years to shape the biodiversity of Mediterranean ecosystems. Fire is an integral part of many terrestrial biomes including the Mediterranean ones, but is also a major factor of disturbance. Natural fire regimes have been increasingly changed by man for many thousands of years, so that in many regions of the world human-caused fires have become more frequent than natural sources of ignition.

In the Southern European Mediterranean countries, the major driving forces behind this change in the fire regime are land abandonment and afforestation of former agricultural land, leading to fuel accumulation and landscape-level connectivity of flammable patches. In addition, climate change and land-use trends are expected to increase fire incidence in Central and Northern Europe, and new geographical areas (and forest ecosystems) where wildfires were infrequent are likely to become more fire-prone, as mentioned in Moreira et. al., 2012.

Fires are like no other disturbance because of the combination of effects they can have. The output of heat and smoke, the immediate reduction on plant and animal biomass, the rapid release of nutrients, the transformation of nutrient forms, and the change to local micro-environments are not reproduced by any other disturbance such as grazing, drought, flood, storms, landslides etc. Fires are an integral part of biological, geological, edaphic and atmospheric processes and they have a significant role to play in nutrient cycling and redistribution, gene transfer, biodiversity, succession processes, competition and other interactions within ecosystems.

According to Poirazidis et. al., 2012, Mediterranean ecosystems, due to a combination of natural factors and anthropogenic interventions, are characterized by high spatial heterogeneity. Wildfire is one of the main drivers for the current landscape mosaic and therefore most Mediterranean ecosystems show high resilience to wildfires.

When an ecosystem is disrupted by a wildfire, it can quickly suffer an intensive mortality of its dominant species, along with disruptions of its physical ecological structure and other damages. However, except in the case of rare, extremely intense fires, some plants survive the disturbance, and these can contribute to the post-fire regeneration that immediately begins.

In addition to social and environmental impacts, wildfires also produce considerable economic damages due to the huge amount of resources spent in fire suppression and prevention, the loss of commercial value of damaged wood products and the costs related to loss of public non-market services as referred in Moreira et. al., 2012.

Planning Post-fire Management

A common strategy for the management of burned areas, and other degraded lands, in the Mediterranean region was based on afforestation or reforestation with conifers, particularly since the nineteenth century. This traditional view ended up having a very low level of application, due to the cost of implementing it. In addition, changes in fire regime since the last decades of the twentieth century strongly compromised the effectiveness of this strategy.

Nowadays, the definition of the post-fire management approach depends on the expected ecosystem response and on the objectives determined for the management of the burned area.

Management concerns after a fire include minimizing erosion and its effects on aquatic systems, retaining adequate forest structure for fire-associated wildlife, capturing the economic value of the wood through postfire timber harvests (salvage logging), minimizing the likelihood of an insect outbreak among fire-stressed trees, reducing the potential for a severe reburn, and ensuring tree regeneration.(PNW,2007).

Post-fire regeneration processes differ among regions since different environmental factors play a critical role affecting regeneration patterns. According to Poirazidis et al, 2012 it seems that many environmental factors (like fire variability, patchiness of different successional states, geological substrate, ground slope, and woody vegetation cover) affect positively or negatively post-fire regeneration and finally define the post-fire patches of the new landscape. Other factors have also been found to affect the post-fire regeneration such as fallen wood and branches, obligate resprouter species cover (e.g., evergreen sclerophyllous shrubs and perennial grasses), legume species richness and abundance.

Post-Fire Management and Restoration steps

The first step in the post-fire management process is to ***evaluate the fire impacts*** which will be the key to evaluate how the ecosystem will respond.

The impact of a fire upon a site depends on fire characteristics (fire intensity, season, interval). It is therefore important to evaluate severity levels as soon as possible after fire and this can be done through field inspections and by using remote sensing at high resolution. This should be done in the first two weeks after the fire. Even before the fire it is necessary to ***map area vulnerability*** to wildfires and to identify priority areas for fire prevention, including soil information, topography, vegetation type and also the location of values-at-risk (infrastructures, buildings, valuable ecosystems). This will be very helpful not only to fire prevention but for post-fire management as well since it will help to prioritize the post-fire interventions.

Post-fire landscape: mosaic of burned and unburned areas
(source: PNW, 2007)

Based on the fire impacts evaluation through GIS, maps and on site visits as mentioned before, the following ***emergency interventions*** are suggested:

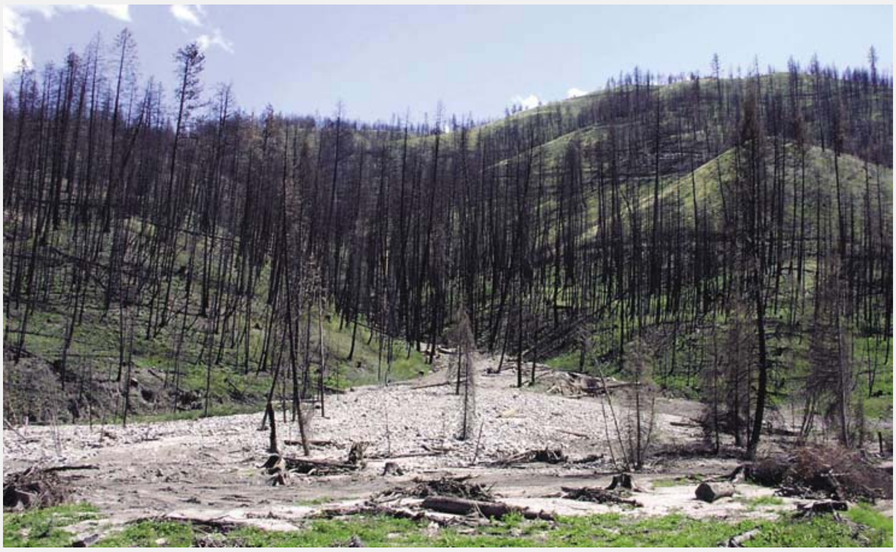
Direct interventions mainly aim to stabilize the affected area, prevent degradation processes and minimize risks for people, conservation principles, natural or cultural resources. These interventions mainly aim at soil protection to avoid ***soil erosion*** and decrease water runoff and risk of flooding, to decrease risks to people and property (e.g.

hazard from falling burned trees), or to the prevention of tree pests and diseases. They should be undertaken as soon as possible, at most a few months after the fire, and preferably before the first autumn rains especially for the Mediterranean region.

Heat from fire can alter the chemical properties of the soils and the availability of nutrients. The specific effects depend on the temperature and duration of the heat. Low-intensity fires may result to nutrients increase whereas with high-intensity fires soil fertility usually is diminished for up to 5 years.

Also, after a fire, the timing of runoff may change and sedimentation may increase. Loss of streamside vegetation may increase water temperatures and there may be less down wood available to provide structure and habitat in the streams. Especially in riparian areas a severe fire heats the water and changes its chemistry, resulting to fish and other aquatic organisms killing. Like the terrestrial wildlife, aquatic species have also experienced disturbance over time. A habitat change that may be negative in the short term, like a slope failure that increases sedimentation, may provide beneficial habitat in the long term by increasing the amount of wood in streams and variation in the channel structure.

Usually after a fire the **water runoff** increases because of the soil that become temporarily impervious to water and because there is less groundcover and fewer trees to absorb it. As a result, the timing of waterflows within aquatic systems can change, with greater variation between peak and low flows.



After a fire, water runoff can increase, filling waterways with sediment and woody debris.

(PNW, 2007)

Sedimentation and erosion also increase with greater runoff. Changes in water yield are greatest in the first few years after fire and decrease over time as vegetation regrows. That is why the interventions should be direct in cases of severe fires.

Forest roads are the largest source of erosion and sedimentation after wildfires. The greatest erosion occurs during the first year or two after construction. New roads constructed soon after a fire, combined with the natural post-fire increase in streamflow and overland flow have the greatest impact on water quality.

In these cases activities that may reduce the delivery of sediment to streams include aerial seeding to help a slope revegetate more quickly and thus reduce chance of erosion, installing larger culverts with the capacity to handle increased runoff, building structures to trap sediment such as silt fences, riprap, and gabions (wire baskets filled with rocks) and stabilizing stream channels with large woody materials, hay bales, or check dams.

Installing sediment barrier traps
(Source: Managing post-fire soil erosion in the mount Lofty Ranges, S. Australia)

Culverts that were put in to handle a certain amount of waterflow may be insufficient with increased runoff after a fire. The woody debris and sediments being washed down may clog the culvert during storms, leading to culvert failure and greater erosion. After a fire, existing culverts may need to be upgraded to handle the greater flow, and racks may need to be installed at the culvert intake to prevent clogging.

Example of new culvert put in next to the old one in order to increase capacity (*source: Final report of the U.S. Government Technical Team to Greece)*

If timber is harvested, woody debris, or slash, following a harvest operation may be spread on the ground to provide immediate ground cover. (PNW, 2007)

Also, logging may be suitable where accelerated soil erosion and increased soil compaction are unlikely to occur and where there will be no impairment of hydrologic and soil biological integrity as mentioned in Beschta et. al., 2004.

Log erosion barriers *(source: Final report of the U.S. Government Technical Team to Greece)*

On the contrary, ***salvage logging*** may be especially detrimental in those watersheds where only a few large trees or snags remain following fire. Large wood has multiple roles in the ecological recovery of disturbed aquatic ecosystems. Salvage logging conducted in or near riparian zones or streams diminishes the source of large wood important for stream structure and function. Post-fire wood inputs are important in creating physical habitat, recycling nutrients, and providing structural components during stream and riparian recovery, according to Beschta et al., 2004.

On the other hand, there are a lot of scientists and experts arguing that because soils and soil productivity are irreplaceable in human time scales, post-fire management practices that compact soils, reduce soil productivity, or accelerate erosion should not be undertaken or allowed to continue. The recovery of organic matter in soils, which is essential to the recovery of soil productivity in areas with moderate- to high-severity burns, can be accomplished efficiently and inexpensively by leaving burned areas undisturbed. (Beschta et al., 2004)

Furthermore, logging may be the solution for the prevention of pests' outbreaks. It is observed that after a fire an ***outbreak of insects*** attack fire-damaged trees. In some cases the physical damage from insects and decay fungi introduced by insects kills the trees, which become fuel for another fire. There are numerous factors that influence the chance of an insect outbreak in a burned area: It should be taken into consideration the general tree health before and after the fire, soil moisture, the stand density and species composition, since bark beetles (common species observed in cases of insects outbreaks) tend to be species specific, so as pure stands are more vulnerable to such an attack than mixed stands. (PNW, 2007).

Salvage logging as a post-fire management action is a controversy issue for its consistency to the ecosystem restoration after fire and is therefore discussed in more detail in the following section.

After the emergency interventions, some ***indirect interventions*** should be scheduled according to the fire affected biomes and the level of fire severity.

First of all the ***post-fire harvest of trees*** should be accurately planned according to the specific characteristics of the burned area.

In the past, logging of fire-affected forest stands often occurred with little consideration of potential ecological consequences. It is the most commonly applied forestry practice mainly for economic reasons.

The effects of post-fire logging depend on the intensity of each of these actions, whereas the timing of the harvest, method for removing trees, and the size of the harvested area all have different potential effects on the forest as it regrows. It is considered that logging within the first year causes the least damage to tree regeneration, and incidentally this is when the wood has higher commercial value.

Post-fire salvage logging also affects plant species composition and forest succession through changes in microclimate and mechanical damage to regenerating plants and soils.

(Source: Managing post-fire Habitat for Birds in Sierra Nevada)

It is observed that logged areas had significantly lower understory biomass, species richness, species diversity, growth, and survival of both tree and shrub species. Such logging can also have detrimental effects on the microhabitats of organisms associated with recovery and early successional vegetation.

The multiple ecological roles of large trees and their high probability of survival support the need to retain them in burned areas. Post-fire salvage logging, based primarily on economic values, typically removes only the largest trees and, by reducing total fuel loads, can supposedly reduce the severity of a subsequent fire. With regard to future fires, perhaps a more important concern of post-fire logging is its influence on fuel composition, particle-size distribution, and site microclimate. After a fire regenerated understory vegetation and fine wood debris (slash) begin accumulating as ***surface fuel.*** The woody debris created during a timber operation is another consideration. Without treatment, slash becomes an immediate fuel source**,** even if it protects the soil surface from erosion. On the other hand, slash treatments can damage tree seeds and seedlings through ground disturbance and prescribed fire. If another seed source is not nearby, this can have a long-term effect on the development of the forest. Logging slash can contribute to future fire behavior. The flammability of shrubs and perennial species depends on their density and moisture content. At the same way, the quantity and depth of fuel and moisture levels are all factors in fire behavior. In other words, logging can contribute to future fire behavior, but whether slash will be a problem for a future fire, depends on the contribution of slash to fire behavior, in the context of the whole system.

Another concern about post-fire logging is its effect on ***water quality.*** Fire and logging both reduce the amount of living vegetation available to take up and store water, which alters the hydrology of an area. Fire may cause greater changes in annual water yield than logging because more understory vegetation is killed and consumed. Thus, after both events, the quantity, timing, and quality of water flows can change.

Photo of dead surface fuels; note there is a lack of growth both on the lower branches of the trees and on the ground, due to little light being able to penetrate through the woodland canopy *(Wildfire Guidance manual)*

Also, the removal of green trees can negatively affect the ***wildlife*** and especially species that nest or forage in tree canopies. Species that are associated with open canopy stands may benefit from post-fire logging in dense stands. (PNW, 2007). In general, logging is a drastic habitat change and it is considered to have major effects on the species living in burned areas. In fire-prone regions, understanding the response of species to fire is a major goal in order to predict the effects on biodiversity according to V.Bros et al., 2011. Usually wildlife species of the Mediterranean ecosystems have evolved with historical fire patterns and have ways to cope with the fire. Burrowing mammals for example or arthropods can escape fire damage by remaining underground, while larger mammals can move away from the fire. However, the responses of organisms to post-fire practices are expected to vary according to species –specific differences in habitat requirements. For example, the removal of both dead and live trees negatively affects most wildlife habitat: fish, aquatic amphibians, and macroinvertebrates are likely affected by the removal of snags from the landscape, mainly near streams, because large logs in streams tend to create their habitat. High levels of sediment in a stream can bury fish and amphibian eggs and the stream structure used by aquatic life. In addition, studies carried out on birds show a reduction in the number of forest species living in logged areas compared with those in unlogged one, because of the removal of snags that provided them food and nesting.

On the contrary, burned areas and the snags they contain are the primary habitat for some species. Dead and dying trees are hosts to insects that are important food for wildlife, including birds, small mammals, and even bears. Snags are vital for primary cavity-excavating birds that nest in them and for secondary cavity-nesting birds and small mammals that cannot excavate their own cavity. (PNW, 2007) In addition, mammals that favor open areas benefit from the changes created by fire. Studies have shown that changes in small mammals' communities during vegetation succession are correlated with changes in vegetation composition and, particularly, structure. The relationship between fire events and small mammal diversity in natural communities is controversial. Several studies showed a decrease in the abundance of some species immediately after fire whereas in other studies it is recorded a reduced abundance in areas that are regularly burned, based on Briani, D.C. et al., 2004 study.

Beschta et al. (1995) recommend that "salvage logging should leave at least 50% of standing dead trees in each diameter class" They also indicate that proportional retention is needed because of the important graded inputs that a mix of large wood contributes to streams over the extended post-fire recovery period. These recommendations emphasize the importance of retaining the oldest and largest trees, both live and dead, in post-fire environments.

To sum up it seems that salvage logging is a post-management action that should be applied in specific cases, taking into account all the factors discussed above and the particular characteristics of the area and the fire occurred, whereas it should be prohibited on sensitive sites, including riparian areas, moderately or severely burned areas, fragile soils, steep slopes, roadless areas, watersheds where sedimentation is already a problem, where significant impacts to early successional vegetation may occur, and sites where accelerated surface erosion or accelerated mass soil erosion are likely to occur., as mentioned in Beschta et. al., 2004.

The first option of the indirect restoration techniques addresses to the management of the burned area through ***natural regeneration***

Plant species vary greatly in the strategies they have evolved to survive wildfire, and to regenerate afterwards. Often, the below-ground tissues of certain plants can survive the fire even though the above-ground biomass was killed by combustion or scorching, and the regeneration may then occur through stump or root-sprouting. Other plants may survive the fire as long-lived seeds that are buried in the forest floor, and are stimulated to germinate by post-fire environmental conditions. A few conifers maintain their seedbank in persistent, aerial cones, which are stimulated to open by the heat of the burn, so that seeds are released to the fire-prepared seedbed immediately afterwards. In other cases, species may invade the burned site, by dispersing from unburned communities nearby. Plant succession consists mainly of the regeneration and development through the respective life cycle of the species present before fire, as a process of secondary auto succession. In the absence of another wildfire, or some other catastrophic disturbance of the stand, the post-fire secondary succession often restores an ecosystem similar to the one present prior to the fire.

In the Mediterranean ecosystems constituting a large portion of the terrestrial vegetation of Greece, fire acts as an integral part of their evolutionary history, having shaped their adaptive traits. They characterized by high spatial heterogeneity and wildfire is one of the main drivers for the current landscape mosaic.

After a fire, the most obvious change is that of the composition and relative abundance of annual herbaceous plants, followed by that of herbaceous perennials. As succession proceeds and the canopy closes, herbaceous vegetation is either restricted to small openings, as in the case of phryganic ecosystems and to a lesser degree in coniferous forests, or remains dormant in the soil in the form of seeds waiting for the next fire to come.

Photo by Shai Levy/Flash90 (http://israel21c.org)

According to Arianoutsou, 1998, the specific regeneration behavior of the plants is related to their physiological traits and is strongly influenced by fire regime. Information on plant life histories summarizes in the following points:

- Woody seeding species forming soil seed banks exist in all stages of phrygana, in relatively high numbers. Among these species rockroses are the most prominent. Resprouting woody species also occur throughout the successional cycle of phrygana

- In the evergreen sclerophyllous shrublands though, only sprouting shrubs like kermes oak, lentisc, occur throughout the fire cycle.

- In pine forests sprouting and seeding shrubs can be found in either stages, but in very different numbers and cover.

- In the early successional stages, resprouters are competing with young tiny pine seedlings and seedlings of the other taxa. As the canopy closes, the understorey taxa are diminished in number and relative cover.

- Herbaceous species are present in the early successional stages of all three vegetation types, but they become less and less abundant as succession proceeds.

- Sprouting herbaceous perennials occur mainly at the early stages in the evergreen sclerophyllous shrublands and pine forests.

On the other hand, the behavior of the sprouters and seeders is different, applying in different fire regimes:

- The relative success of seeders depends on the availability of openings in the post f-fire regenerating vegetation since they can exploit these areas and they have greater possibility to establish themselves away from competition from the respouters, because of the dormant seed bank they have formed in ground. This pattern is mainly observed in long fire intervals while in short ones the opposite is recorded.

- Sprouters pose a competitive pressure on the seeders during post-fire regeneration, which has to do with exploitation of the moisture available, which means that the more humid the environment, the less gaps are available to seeders.

Furthermore, according to studies it seems that seed germination in the field occurs after the first rains in most of the seeding woody species of the burned phryganic ecosystems during the first-post-fire year. Seed germination is not only enhanced by fire in many species but it results in significantly higher densities in some cases, whereas light quality has been found playing important role in seed germination of specific species. During the first post-fire year a decrease in seedling density of woody taxa has been observed, and no remarkable seed germination has been shown for these woody species during the second post-fire year, while it seems that seed germination exists for several herbaceous species. As a result it could be said that fire plays an important role not in seed germination, since it happening anyway, but in massive seed germination as a result of the creation of a micro-environment favorable for germination. Therefore, concerning the woody phryganic species it seems that germination is regularly and continuously occurring, possibly after the 1^{st}-2^{nd} post-fire year resulting to mixed-aged stands. The same occurs for the herbaceous species, being different in that they reach their reproductive maturity in the first year after the fire.

Abies pinsapo and Quercus alpestris mixed forests 4 years after fire. Naturally recovering vegetation of oak resprouts and companion shrubs.
(Source: Arianoutsou, M., et al., 2012. Ch.11 by Jose Antonio Carreira, University of Jaen)

In the evergreen sclerophyllus formations, almost all plants of the woody species are respouters, resulting to single-aged communities.

Pine forests are a more complicated case. "Pine seeds germinate in a wave during the first post-fire year and almost no seedlings are observed during the second year" according to Arianoutsou 1996. Germination in unburned pine forest is rather scarce and it occurs in gaps. Fire causes a massive seed release from the cones, the opening of which is induced by high temperatures developing during fires. The increased seed germination may be a result of the more favorable light conditions because of the existence of more open areas, since its germination is light-controlled.

All evergreen sclerophyllous species of the understorey regenerate vegetatively, actively posing an interspecific competition upon the young pine seedlings.

Herbaceous annuals also germinate, while most perennial herbs resprout.

Gradually, as the canopy of the forest closes, the understorey taxa are restricted but they become more abundant again at the more mature stages, when the tree floor starts to thin out due to senescence (in the absence of fire) (Kazanis, D., Arianoutsou, M., 1996).

None of the Mediterranean plants of Greece seems to be strictly dependent upon fire for its recruitment. It is well established for pines that fire enhance massive population recruitment but they are not expected to be extinct in the absence of fire. On the contrary, it may happen in frequent fires, at intervals shorter than the minimum time which is necessary for full regeneration maturity since pines are long-lived species with extended juvenile periods.

From the above it is evident that there are still a lot to research and know concerning the species replacement patterns. However all this knowledge is facilitating to the plants physiological traits in the post-period fire in order to determine the best post-fire management process.

It is also recommended the application of appropriate ***silvicultural techniques*** to support post-fire natural regeneration in order to promote faster achievement of the mature stages of development. These techniques could be applied mainly through favoring vegetative regeneration through stump undercutting and selection of shoots and through supporting the regeneration of new individuals through pruning and thinning to stimulate seeding, by giving more light and potential growing space to dominant branches and crowns of dominant standing trees, whose seed production is generally higher than the other trees.

It has already been mentioned that many environmental factors affect positively or negatively post-fire regeneration and finally define the post-fire patches of the new forested landscape. Large wildfires usually create a complex and highly heterogeneous post-fire landscape regarding the differences on the natural regeneration success. Reliable prediction models for post-fire vegetation recovery at regional scale, based on geographic information systems (GIS), are necessary in order to predict the aforementioned effects (Arianoutsou et al. 2011) and assign spatial reference to them. Therefore, the integrated ***GIS-based model*** that was developed recently (Poirazidis et al., 2012) proved to be a helpful tool. Such model can identify the natural post-fire regeneration of *Pinus halepensis*, becoming a useful tool for the application of restoration measures. It also has the capacity to predict and represent spatially, at a prefecture level, the regeneration patterns, taking into account not only the most important factors which influence post-fire forest regeneration and their interaction, but also the spatial autocorrelation of the forest regeneration dynamics, which consists a very useful tool for the post-fire management of the pine forests. The development of such models could significantly contribute to the post –fire management of the Mediterranean ecosystems.

Other significant interventions include the prohibition of activities that could alter the succession and delay the restoration by removing elements of recovery or enhance soil and water resources damages. The approach of seeding burned areas with non-native species, especially grasses is based on reducing onsite erosion, decreasing sediment runoff into streams, reducing noxious weed invasions, and increasing the availability of forage for grazing animals. Although the efficacy of seeding for accomplishing these objectives has not been well evaluated, results of studies show that seeding grasses in burned ecosystems can lead to long-term changes in ecosystem composition and structure, and this is the reason of including the ***banning of non-native species seeding*** in the post-fire interventions. Furthermore many studies have resulted that establishing a dense cover of seeded grasses, which decreases survival of woody plant seedlings, may cause long-term diminution of many important functional roles of species that shape ecosystem structure and productivity, wildlife habitat, and erosion control, whereas it is estimated that grass seeding has a low probability of reducing postfire erosion in the first season of erosion because any benefits of grass cover occur after the initial damaging runoff events.

All the above conclude that "seeding of non-native species should be avoided unless the pre-fire landscape has been severely degraded or dominated by alien or non indigenous species", as mentioned in Beschta, et al., 2004.

Furthermore one of the indirect interventions that in most cases should be applied is the ***prohibition of the grazing*** on the affected areas. It significantly damages soils, elevates erosion, thwarts vegetative recovery, contributes to invasions of exotic species, and degrades stream and riparian conditions.

Source: Managing Wildlife after the fire (Texas Parks & Wildlife)

On the contrary, as it is mentioned below, prescribed fires could be very useful in reducing the fuel and therefore the fire hazard.

To sum up, post fire livestock grazing is widely recognized as an inhibitor of soil recovery and plant succession delaying the general restoration of burned areas and it should not occur in burned areas, particularly riparian areas, until vegetation recovery has occurred.

The most essential step in post-fire management and the one that often omitted is ***monitoring and evaluation*** of the plans applied. This is the only way to gain understanding of ecosystems succession after fire through assessing whether objectives accordingly the appropriate restorations plan, were fulfilled or how possible is to attain them.

According to SER (Society for Ecological Restoration International Science & Policy Working Group (2004)), there are three strategies for conducting an evaluation: direct comparison, attribute analysis, and trajectory analysis. In direct comparison, selected parameters are measured in the reference and restoration sites. In attribute analysis, a set of desirable characteristics for the project result are defined at the beginning and the measured parameters are compared with this set. In trajectory analysis, data are collected periodically and trends examined to confirm that the project is following the intended trajectory.

In order to assess whether the objectives were fulfilled, the knowledge of the baseline situation is necessary, while the social impacts of any restoration project should also be taken into account, since beside the ecological objectives there are always social end economic objectives and implications.

Long term planning

Besides the post-fire management activities that could be implemented after a fire occurs, there are plenty of activities and strategies that could be applied as a pre-fire process.

Based on recent studies the main factor that affects the fires initiation and spread is the landscape use. The essential landscape planning aims to reduce fire hazard in order to produce landscapes that are less fire-prone. It is well known that factors such as weather, topography and land cover play a key role concerning the fire regime. Land-cover is strongly related to vegetation composition and thus flammability and is the only factor from the above that could be controlled. It is well established that agricultural areas and deciduous broadleaved forests are the least fire-prone landscapes whereas shrublands and pine woodlands are the most fire-prone areas. This knowledge could be very useful to managers in cases of wildfire initiation as it might be helpful in planning the suppression with less cost and less intense and severe impacts.

In general it is required dramatic changes in forest management practices and policies that relate to land use and fire management in order to reduce human impacts to ecosystems and allow natural disturbance regimes to retain or reestablish some of their historical influence in maintaining the diversity and productivity of regional landscapes. The definition of land use management rules and the design and implementation of policies to achieve specific landscape objectives contribute to eliminate the fire hazard of the specific area.

For example, prescribed fire or controlled occupational burning used often by shepherds to renew pastures can be useful tools to reduce fire hazard.

One of the most serious consequences of the abandonment of traditional practices is that villages in mountain areas, traditionally surrounded by a belt of farmland that acted as a landscape fuel break, nowadays have forests and shrublands in the vicinity of houses and other infrastructures, which greatly increase fire hazard.

Population decline, agricultural and pastoral land abandonment and policies promoting forest cover, particularly in former agricultural land, are the main driving forces of this process. This could be addressed through policies enabling the improvement of the socio-economic conditions of people leaving in rural areas and implementing rural development policies for reducing fire hazard, such as agriculture and livestock grazing.

Conclusions

The natural environment of Greece is characterized by a variety of types of Mediterranean ecosystems, which follow the corresponding variety of climate types. Having affected by the repeated action of fire, plant species in such Mediterranean ecosystems have developed special adaptations (traits) to deal with fire, ensuring their presence in space and time.

The time for reversion and restoration of Mediterranean ecosystems plant communities ranging from a few years for shrubland (phrygana and maquis) to three to four decades for pinewoods.

In general, the principal objectives of post-fire rehabilitation efforts should be to avoid additional damage, repair potential problems from fire suppression activities and enhance the reestablishment of native vegetation to provide soil cover and organic matter. Post-fire treatments should be implemented only when they are needed to facilitate ecosystem recovery and do not interfere with natural succession or to reduce human disruptions of natural ecosystem processes. Consequently, highly disturbed sites should be rehabilitated immediately following fires, as mentioned in Beschta et. al., 2004.

Post-fire treatments such as seeding of non-native species, livestock grazing, or salvage logging can alter succession and delay restoration by removing elements of recovery or by accentuating damage to soil and water resources. Instead, management priorities should aim at the prevention or minimization of activities that increase stress upon surviving native biota, disrupt the establishment of native species, or alter microclimates.

If the predictions for climate change are confirmed, it is expected a corresponding change in the fire regime, which in turn is expected to have significant impacts on natural ecosystems and post-fire restoration, especially for those that are not adapted to fire. Climate change induced by enhanced levels of greenhouse gases will alter the flammability of the landscape through its effect on the dryness and the amount of vegetation and litter, which becomes fuel in a fire. A hotter, drier climate will extend the fire season, or the period during the year when the vegetation is flammable. Climate change will also affect the ways in which ecosystems respond to fire. A drier climate will result in slower post fire recovery. Vegetation occurring in the moister parts of the landscape, including wetlands, riparian zones, rainforests and peat swamps are likely to be most adversely impacted if drying leads to increased frequency of fire, according to D.C. Briani et al., 2004. The post-fire management of ecosystems should be based on scientific knowledge to avoid actions that might have more serious consequences than the fire itself.

In landscapes altered by decades of resource extraction or fire suppression, however, the consequences of fire for forest ecosystems may be severe. Pre-fire restoration of ecosystem integrity is likely to be more effective than fire prevention or post-fire attempts at protection and rehabilitation of the stream channel.

Because of the variation in fire effects across the landscape, after a large fire, different management approaches may be taken within different portions of the burned area. Post-fire management includes full protection of soils, retention of large trees, and nurture of natural recovery processes. Conversely, available information indicates that the following post-fire activities are not likely to be consistent with ecosystem restoration: seeding non-native species, livestock grazing, installation of instream structures and logging of ecologically sensitive areas including roadless areas, riparian areas, and areas with moderate to severe burns.

However, it is well established that some of these post-fire approaches described above are likely to be even more effective if undertaken proactively before a fire.

BIBLIOGRAPHY

1. Arianoutsou M., 1998. Aspects of Demography Post-Fire Mediterranean Plant Communities of Greece. In: Ecological Studies, Vol. 136. Rundel et al. (eds.)Landscape Degradation and Biodiversity in Mediterranean –Type Ecosystems.
2. Arianoutsou, M., Leone, V., Moya, D., Lorreglio, R., Delipetrou, P. and de las Heras, J., 2012. Management of Threatened, High Conservation Value Forest Hotspots under changing Fire Regime. Ch.11 (257-291). In: F. Moreira et al. (eds.) Post-Fire Management and Restoration of Southern European Forests, Managing Forest Ecosystems 24.
3. Beschta, R., Rhodes, J., Kauffman, J., Gresswell, R., Minshall, G., Karr, J., Perry, D., Hauer, F., Frissell, C., 2004. Post-fire management on forested public lands of the Western United States. Conserv. Biol. 18, 957–967.
4. Beschta et al., 1995. Wildfire and salvage logging: recommendations for ecologically sound post-fire salvage logging and other post-fire treatments on federal lands in the west. Pacific Rivers Council, Portland, Oregon.
5. Briani, D. C. et al., 2004. Post-fire succession of small mammals in the Cerrado of Central Brazil. In: Biodiversity and Conservation 13: 1023–1037.2004 Kluwer Academic Publishers. Printed in the Netherlands.
6. Bros, V. Moreno-Rueda , G. & Santos X., 2011. Does postfire management affect the recovery of Mediterranean communities? The case study of terrestrial gastropods. Forest Ecology and Management, 261, 611-619.
7. Kazanis D, Arianoutsou M., 1996. Vegetation structure in a post-fire successional gradient of Pinus halepensis forests in Attica, Greece, Int J Wildland Fire, 6: 83-91.
8. PNW (Pacific Northwest Research Station), 2007. Managing Forest after Fire. Science Update, Issue 15.
9. Poirazidis, K.S., Zografou, K., Kordopatis, P., Kalivas, D.P., Arianoutsou, M., Kazanis, D., Korakaki, E., 2012. Annals of Forest Science 69: 519-529.
10. Moreira, F., et al., 2012. Setting the Scene for Post-Fire Management, Ch. 01 (1-19). In: F. Moreira et al. (eds.) Post-Fire Management and Restoration of Southern European Forests, Managing Forest Ecosystems 24.
11. Retana, J., Arnan, X., Arianoutsou, M., Barbati, A., Kazanis, D., and Rodrigo, A., 2012. Post-Fire Management of Non-Serotinous Pine Forests, Ch.07 (151-170). In: F. Moreira et al. (eds.) Post-Fire Management and Restoration of Southern European Forests, Managing Forest Ecosystems 24.
12. Rost, J. , Clavero, M., Brotons, L., and Pons, P., 2012. The effect of postfire salvage logging on bird communities in Mediterranean pine forests: the benefits for declining species. Journal of Applied Ecology. British Ecological Society.

13. U.S. Technical Team to Greece: Technical Collaboration Between the United States and Greece in Post-Fire Emergency Response. Final Report: October 2007.

14. Αριανούτσου, Μ., Καζάνης, Δ. 2012. Ο οικολογικός ρόλος της φωτιάς στα χερσαία οικοσυστήματα της Ελλάδας. Κεφ.8. (103-116) στο Α.Χ. Παπαγεωργίου, Γ. Καρέτσος και Γ. Κατσαδωράκης (επιμ. έκδοσης). Το δάσος: Μια ολοκληρωμένη προσέγγιση. WWF Ελλάς, Αθήνα.

15. Managing Post-Fire Habitats for Birds In the Sierra Nevada http://data.prbo.org/apps/snamin/uploads/images/fire/Managing%20Post%20Fire%20Habitat%20for%20Birds%20in%20the%20Sierra%20Nevada.pdf

16. Wildfire - Post-fire Succession - Species, Prairie, Ecosystem, and Plants - JRank Articles http://science.jrank.org/pages/7389/Wildfire-Post-fire succession.html#ixzz2CxxtfvkX

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