BROCHURE ON POST-FIRE VEGETATION AND SITE REGENERATION
RECOMMENDATIONS FOR POST-FIRE BIOMASS MANAGEMENT

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AND SITE REGENERATION
&
RECOMMENDATIONS FOR POST-FIRE
BIOMASS MANAGEMENT

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CENTRO STUDI ITALIANO
GEOMATICA
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1. Introduction

Mediterranean region in Europe covers approximately 900,000 km² representing approximately 40% of total Mediterranean basin, out of which forests take up approximately 19 million hectares. In Mediterranean region following factors represent driving factors for development of variety of forest ecosystems: topography, physiography, geology, precipitation and temperature regime, soil type and fire.

![Figure 1 Satellite image showing a large number of fires in Mediterranean, August 30th 2012](image)

The Mediterranean forest ecosystems are exposed to the variety of mostly negative effects that cause changes of temporary and/or permanent character. Historically Mediterranean forests were influenced by very early settlements and an intensive development of population. There are very few places in the world where influences and pressures of man on forests are so evident like in the Mediterranean. This is the main cause of deforestation, and as consequence the effects are shortage of water, inadequate agricultural production, extreme climatic conditions, strong erosive processes, etc. During the past, the main reasons of changes were extensive and uncontrolled grazing as well as conversion of forest areas to agricultural land. Significant problems of Mediterranean forests today are the untended forests in private ownership and abandoned agricultural land with no fire prevention at all (e.g. deserted olive orchards). Due to above mentioned reasons these areas are susceptible to fire.

Fire, caused by both anthropogenic and natural factors, plays a significant role in shaping ecology of the Mediterranean region. Most of this region is prone to fire due to dry and hot summers. Therefore, forest fire presents a natural driving factor in the Mediterranean region. Nevertheless, fires can also be often caused by human activities, railways and lightning. However, natural regime has been disturbed due to human influence and nowadays over 95% of fires are caused by human activity. Hence, forest fires occur more frequently and with higher intensity. Generally speaking, forest fire is a force of nature and represents uncontrolled and rampant spread of fire over the forest area. It can be categorized according the type, origin and level of caused damage. Three ingredients are essential for fire to occur: temperature, fuel and oxygen. These ingredients represent the so called “fire triangle” and if one of the ingredients is missing or removed fire will stop.

Natural traits of vegetation and favourable climatic conditions (temperature 27-32°C, relative air humidity 15-20%, wind speed 16-24 km/h and at least four weeks since last significant rainfall
[>0.25 cm rain/m²]) combined with the human error have made forest fires regular event with permanent negative effects in the Mediterranean (Fig. 2a and 2b). The economic value of burnt wood material is very small in comparison to the ecological and aesthetical values lost due to fire (soil, microclimate, oxygen, fauna, biodiversity, landscape, etc.).

Mediterranean forest ecosystems are in progression as a result of social trends in last two decades, such as rural depopulation, abandoning of the extensive animal husbandry and small-scale agriculture. Unmanaged forests present serious fire hazard, since they are very susceptible to fire and can facilitate the spread of fire on other managed forests or degradation stages (maquis, garrigue, scrub stand, ticket and bare karst).

Important trait of Mediterranean forests is their multi-functionality. Mediterranean forests are providing water and soil conservation, watershed protection, water cycle regulation, climate regulation, carbon sequestration, protection of biodiversity, recreation, embellishing the landscape, preservation of cultural and historical sites, sites for education and improving environmental consciousness, timber production (e.g. firewood, construction timber, charcoal), production of non-wood forest products (mushrooms, resin, fruits, cork, grazing, hunting, fishing, honey, medicinal and aromatic herbs).
Figure 2 Burnt area (a), number of fires (b) and average fire size (c) in Croatia from 2000 - 2012
Figure 3 Burnt area [in yellow whole burnt area and in black only forest burnt area] (a), number of fires (b) and average fire size (c) in Italy from 1970 - 2010 (Source: Incendi Boschivi 2010 volume completo; CFS)
2. Ecological factors for post-fire vegetation regeneration

Two natural forest formations represent the main traits of Mediterranean forests, the Mediterranean sclerophyllus forests and scrub and the Thermophilus mixed deciduous broad leaved forests. First being mixed forest of holm oak and manna ash (*Orno-Quercetum ilicis* H-ić/1956/1958 – Forest type: Mediterranean evergreen oak forest), and second is the association of downy oak and oriental hornbeam (*Querco-Carpinetum orientalis* H-ić 1939 - Forest type: Thermophilous deciduous forest).

Basic degradation stages of Mediterranean evergreen oak forest are: macchia/maquis and garrigue; while regarding the downy oak (*Quercus pubescens* Willd.) forest these are: coppices of downy oak, scrub of oriental hornbeam and manna ash, Christ thorn, thickets as well as vegetation of grassland and bare karst.


Succession processes can be classified as primary or secondary according to the site where succession is taking place. Primary succession is taking place on the area where there was no previous vegetation and secondary on the area where ecological succession was interrupted by human or natural disturbances (logging or fires). In case of secondary succession the regeneration of vegetation is significantly faster. Destruction of forests is accompanied with destruction of soil; therefore succession (complete regeneration of the forest) takes much longer and requires significant effort. Third case is the human influenced transformation of plant association (succession of plant association) represented by introduction of new species which may or may not cause the extinction of some of autochthonous species.

On habitats prone to frequent forest fires many plants have fire-resistant seeds and roots able to sprout and shoot directly after the fire, which allows fast population regeneration. High temperature represents a “trigger mechanism” for germination. Therefore, seed of some species adapted to these habitats cannot germinate if it was not previously exposed to fire. Those species are mostly Mediterranean pioneer pines with ability to self-regenerate after the fire.

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3 Ibidem
4 Ibidem
In case when forest association without the ability to self-regenerate is burnt down the vegetation transformation will certainly occur. The same may happen when young pioneer pine association or climax vegetation community is burnt down. In both cases vegetation will struggle to regenerate. In some cases, species forming climax community can regenerate, but they form degradation stage preceding the climax community, while fire “favours” species adapted to fire suppress otherwise dominant species.

If there is no immediate action after the forest is burnt down, the soil will erode leaving only bare karst behind, and without human intervention it will take centuries for forest to develop to the point prior to fire. Course of regression of downy oak plant association is presented by figure 4, while the figure 5 presents course of forest vegetation progression and regression processes of two fundamental climax associations in EU-Mediterranean and sub-Mediterranean area.

Figure 4 Scheme of the course of forest regression under the anthropogenic influence: Managed forest (1) is gradually transformed in forest with thinned layer of trees and developed shrub layer (2) then into degradation inter-stage with equal share of trees and shrubs (3). Share of trees is decreasing and shrubs and bushes are dominating. Scrub stand remains for some time (4), however, with further regression, gaps in canopy are formed and only few trees are left (5), eventually thicket and bare karst appear (6).
3. **Strategy for post-fire vegetation regeneration & criteria for post-fire biomass management**

This chapter introduces two key issues for post-fire management in the Adriatic Region that are soil protection and improvement of the resilience/stability of the forest ecosystems.

### 3.1. Soil protection

Soil erosion is among the most damaging post-fire processes. Soil degradation and erosion risk may be greatly enhanced by fires through the combined effect of direct soil heating and temporal loss of protective soil cover. Moreover fire has negative impact on both, physical and chemical soil features. Physical properties are deteriorated through loss of humus, organic matter and soil structure. Actually, on sites barren by fires, soil becomes heavy, dry, has lower permeability and brakes easily. Chemical soil properties are less affected even though water erosion may produce onsite loss of chemicals and productivity. Therefore, if vegetation is completely or partially lost, special care has to be taken for avoiding erosion due to torrents, wind, heath and other causes, as elaborated further in section 4.2. Soil protection measures.
3.2. Enhancing resistance and stability of forest ecosystems

Trees, bushes and herbs occurring in managed and unmanaged forests, different degradation stages, parks and gardens in Mediterranean are highly flammable in case of fire. Besides high flammability, many species are able to regenerate in a short time span (less than a year). Serious problem occurs if fire takes place repeatedly, in short time frame (every few years or even year after a year) on the same site. In this case, vegetation is degraded into a lower degradation stage and species number and diversity decreases too. Decreased diversity of plant communities results in higher fire hazard.

Consequentially, the approach to regeneration of burnt forest associations in Mediterranean depends on the type of vegetation self-regenerating after the fire and the amount of soil left on the site. Such diverse conditions demand development of different silvicultural approaches to restoration of burnt sites which are conducted throughout the rotation of the stand: i) Reforestation ii) Forest tending (cleaning and thinning) and iii) Regeneration (natural or artificial).

4. Short term silvicultural measures

Different restoration measures are carried out according to the vegetation status (degradation stage, ability to self-regenerate, damage inflicted to the vegetation) and soil condition (amount of soil, level of erosion and susceptibility to erosion). Silvicultural measures for protection and restoration of vegetation and soil are divided accordingly:

- Sanitary cut of remaining vegetation (salvage logging)
- Soil protection measures.

4.1. Sanitary cut of remaining vegetation

This measure is mostly related to felling and removal of remaining trees and shrubs after the fire. The objective is to achieve the best possible conditions for natural regeneration, growth and development of the new plants. New vegetation can develop from remaining stumps (basal shoots), remaining seeds on the site and from natural seed dispersal of species surrounding the burnt area by air (anemochory) or animals (zoochory). The harvested wood should be extracted and sold if it can be done in cost-effective way. Remaining wood biomass should be chipped, laid on the ground and distributed over the whole site. This way it protects the seedlings and soil, at the same time allowing development of the plants over the whole area (Figure 6).

If the remaining biomass is piled or gathered in windrow (Figure 7 and 8), decomposition is hindered, thus the remaining biomass will be potential fuel for future fires and is de facto an everlasting fire hazard.

In Italy, salvage logging (harvesting of commercially valuable dead or damaged wood) has been a controversial question. In the Table 1 are listed the most commonly argued pros and cons of conducting salvage logging very soon after a fire.
Table 1 The most commonly argued pros and cons of conducting salvage logging (Italian case)

<table>
<thead>
<tr>
<th>Potential benefits</th>
<th>Potential negative impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ To obtain some economic benefit of charred logs;</td>
<td>✓ Logging has detrimental effects on seedling growth;</td>
</tr>
<tr>
<td>✓ To avoid boring insect pests (e.g. <em>Scolitydae</em>);</td>
<td>✓ Microsites around burned trees favour regeneration and pine seedling germination;</td>
</tr>
<tr>
<td>✓ To improve pine germination (if logging is immediate) and avoid damage to regenerated pines;</td>
<td>✓ Salvage logging reduces forest breeding birds and their seed dispersal activity which is critical for late successional species; also reduces deadwood associated fauna;</td>
</tr>
<tr>
<td>✓ Trees naturally falling down (usually 2–3 years after fire) expose tree crown to erosion;</td>
<td>✓ Dragging charred logs may produce soil surface degradation and soil erosion – rill erosion</td>
</tr>
<tr>
<td>✓ Risk of accidents by falling trees in inhabited areas;</td>
<td></td>
</tr>
<tr>
<td>✓ To reduce landscape visual impact</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 Reconstruction of forest-fire site: burnt material is chipped and pressed down to the ground

For these reasons one of the first decisions to take after forest fires is how to manage the affected wood. Harvesting of commercially valuable dead or damaged trees is the most common practice, on condition that burned wood has enough economic value (considering also eventual public economic aids) to pay for the logging operations and to yield some benefit to the forest owner.

The timber value drops continuously as time goes by after the fire due to wood decay, thus the forest owner is interested in logging as soon as possible to maximize economic benefit.

In practice, for large fires it is almost impossible to rapidly harvest all burned forest area, therefore priorities should be established and this gives time for planning and allows for introducing ecosystem conservation criteria, in addition to the immediate economic value.

Commonly, it is not advisable to immediately remove the burnt wood, since its removal contributes to increased risk of soil erosion, because the after fire exposed soil is more vulnerable to erosion.
This negative effect is greatly reduced if the felling of burned trees is postponed until a protective vegetation cover is established, which in many cases occurs within the spring following to fire. In case of large fires we must consider the possibility of planning a timetable for removal of dead wood, starting with the areas with a lower risk of erosion.

Figure 7 Reconstruction of forest-fire site by gathering of burnt material into strips

Figure 8 Recovering of forest-fire site by piling up the burnt material in 2001 (In the upper right side - forest stand after natural regeneration in 2014)
Felling of the logs one year after the fire minimizes adverse effects on the burned area (felling after two years would result with the downfall of individual trees with more adverse effects on the soil), where the resulting wood material can be used as a biomass for bio-energy, for consolidation of slopes, hydraulic arrangements or as a mulch of the seedling bed.

However it is advisable to retain some dead or damaged standing trees in Mediterranean coniferous forests (*Pinus halepensis* and *P. brutia*, as well as *P. nigra* and *P. sylvestris*), because they can facilitate the renewal, especially if removal of the branches/boughs with cones is avoided.

Furthermore, it is important to retain some snags (a standing, dead or dying tree) in order to keep birds nesting in the forest and other biodiversity components.

### 4.2. Soil protection measures

First step in post-fire soil protection is cutting and chipping of remaining biomass followed by its distribution over the whole site in an effort to prevent drying of the soil as well as the water and wind erosion.

On steep slopes and soft soils the use of felled logs for setting up dams or contour barriers are also effective post-fire management practices for reducing physical soil erosion and degradation.

Afterwards, possibility for natural regeneration has to be estimated according to the site conditions. If natural regeneration is not possible, vegetation has to be regenerated artificially (sowing of the seeds or planting of the seedlings). It is recommended that the burnt area is covered with all types of vegetation (trees, shrubs and herbs) as soon as possible. Trees and shrubs are binding deeper layers of soil while herb roots are preventing surface erosion. If natural regeneration is enhanced with artificial measures, formation of mixed stands is recommended and planting of species with following properties:

- Trees and shrubs with sparse crown
- Species which are accumulating minimal dead biomass
- Deciduous species
- Non-resinous species
- Succulent plants
- Drought resistant species with deep roots and thick leaves
- Plants with thicker woody stems.

To be effective seeding and planting should be applied shortly after the fire and before the heavy autumn rains, which means that areas vulnerable to erosion must be identified and restored as soon as possible.

### 5. Mid-term and long-term silvicultural measures

After the implementation of reconstruction measures, future natural course of development has to be monitored. Future natural course of development implies: growth of main tree species, growth of shrubs and herbs. Monitoring is needed for the assessment of stand characteristics which is the basis
for identification of appropriate future measures. Following measures can be implemented in the future according to the stand characteristics and regeneration success:

- Natural regeneration (stand is left to self-regenerate)
- Assisted natural regeneration
- Combined natural and artificial regeneration

5.1. Natural regeneration

It is traditionally accepted that Mediterranean plant communities have a high resilience to fire, meaning that the composition and structure of burned communities is restored very quickly, and the burned ecosystem cannot be distinguished after a few decades from the pre-disturbance state. However, recent studies indicate that Mediterranean basin forest communities and their dominant tree- or shrub species show different responses after large fires. Thus, forests of seeder species that produce few seedlings after fire and have limited long distance dispersal ability are replaced by other vegetation types.

Numerous studies confirmed that more intense wildfires decrease resprouting capability, as they probably cause the physical destruction of the bud-bank part, damage superficial roots or affect the physiology of the stump. In addition, the particular moment of the year when fire occurs can also critically influence resprouting. Certainly, most wildfires in Southern Europe occur during the hottest and driest season of the year (summer). Nevertheless, whether a fire occurs at the beginning or at the end of summer may be critical.

Natural restoration is a viable solution if the stand still possesses sufficient capability for self-regeneration. Therefore human intervention is not required when there is adequate number of trees in the stand for undisturbed and proper development of the stand and for soil and site conservation. After the fire all biomass has to be utilized, burnt trees are felled and harvesting residue piled. Deciduous species can self-regenerate from remaining stumps, roots and remaining seeds, while conifers self-regenerate only from the remaining seeds.

Figures 9 and 10 show natural regeneration experiment on a burnt area in an Aleppo pine stand.

Figure 9 Experimental plot 2 years after the forest fire (left photo) and 6 years after the fire (2005)
5.2. Assisted natural regeneration

After-fire remaining trees are worthwhile to disseminate seeds over the area. In areas where the number of plants is insufficient, regeneration has to be enhanced with planting of additional seedlings or sowing of seeds. Further monitoring is recommended and reduction of number of stems and shoots if needed. Stand cleaning is done according to the negative selection criteria meaning that only trees displaying negative morphological characteristics (bent, sick, with oversized crown etc.) are removed. After cleaning, coniferous stands are pruned. Pruning increases canopy base height, thus reduces the possibility of a crown fire and of significant damages.

In Italy in broadleaved forests the best alternative to manage and ameliorate post-fire stands of resprouted (multi-stemmed) individuals is reputed to be their gradual conversion into either stored coppices (i.e. coppices in which they remain only one or two stems per stool) or eventually, if sexual reproduction may be encouraged, to high forests. This process involves the selection and elimination of resprouts (i.e. thinning the shoots on the stool) in order to reduce competition among the selected ones, raise the shoot canopy and boost sexual reproduction also through mechanical clearing of all surrounding vegetation (shrubs) in the area. Moreover, this practice has been argued to increase the potential of forest for wood production, livestock grazing, hunting and other alternative uses, while preserving their protective function and reducing the risk of wildfires. A selection thinning treatment is applicable when dominant and suppressed shoots can be distinguished and if wisely conducted it may enhance the structure and ameliorate the growth of broadleaved forests.
5.3. Combined natural and artificial regeneration

After implementation of short-term regeneration measures (vegetation cutting and soil protection), further stand development is monitored. Afterwards, first silvicultural measure carried out in deciduous stand is clearing. Clearing allows growth and development of morphologically better trees, also good mixture of species has to be maintained to improve stand resistance and stability. In later stand development stages thinning has to be performed due to need for stand density reduction. If needed, firebreaks are constructed or, if already constructed, maintained and cleaned from vegetation.

Artificial regeneration in Mediterranean implies removal of weeds and other undesirable vegetation, fencing, ripping and planting of saplings. Sites near roads, without significant karst areas or patches of private property are recommended. Selected site should resample a square to rationalize fencing costs. In practice reality is different. There are lots of kilometers of roads passing by sparse areas with some kind of vegetation where fencing is the main limiting factor (Figure 11). Fencing protects the saplings from grazing and trampling by cattle and game. New experiments and new approaches to karst afforestation are in favor of cylindrical protectors made out of wire mesh which are fixed with large stones. Basic idea is to provide individual protection to each and every sapling. They are especially recommended for large scale afforestation. Special feature of this technique manifests in parallel provision of two services by the afforestation site. Until the pine stand is fully developed (canopy is closed) it can function as a pasture and as an afforestation area. Moreover, other important advantages of this approach are: there is no fencing of the complete afforestation area (complete belt area along the road can be used for afforestation), increased economic viability of the roads allowing more creative road construction; easier and simpler supervision during the conducting of silvicultural and harvesting tasks (stand treating: planting of saplings, fertilization, weeding, thinning, felling, assortments extraction etc.); afforestation site is multifunctional which is important for forestry and rural development. Figures 12-14 present such experiment.
Figure 13 Black pine sapling (2+0) planted without wire mesh protector. Stick near the sapling serves as a location mark in case of destruction of sapling. Planted in 2011 and photographed two months later. Sapling is visibly marked by grazing.

Figure 14 Black pine sapling (2+0), planted in 2011 with wire mesh protector, photographed in 2014. Growth and development of the sapling is visible, sapling will outgrow the protector in 2 to 3 years when the protector will be removed and re-used in another site.

In Italy cylindrical plastic shelters are commonly used as an alternative to wire mesh protector (Figures 15 and 16).

Coniferous cultures or stands which cannot be converted into autochthonous forest communities by means of self-regeneration are mostly regenerated with seedlings. Seeds of autochthonous plants are sowed under the overstory of the old stand when conditions are suitable in- and on the ground. Old stand is regenerated by regeneration cuts. Special care has to be taken of supporting and nurturing the emerging autochthonous vegetation.
6. Recommendation for biomass management

In Mediterranean ecosystems, particularly in new stands after the fires, fuelwood accumulates fast since biomass production is quick and decay is slow. This is common in many areas however, the rate at which such accumulation occurs varies depending on characteristics of the ecosystem and its environment. Prescribed burning, biomass utilization and grazing are the most applied measures that can maintain balance and reduce the probability of fire. As prescribed burning and grazing are measures that are outside of this WP some guidelines on biomass utilization will be summarised.

First should be emphasized that active forest management based on appropriate silvicultural practices is generally carried out in areas where are favourable economic conditions; or where the forest products have a higher value than the cost for managing the forest; or where these interventions are financially supported with specific funding.

The most common intervention of biomass management are:

- clearing of overgrown understory or shrub removal,
- trees thinning,
- pruning of lowest branches.

All these interventions are very useful to regulate the spatial (vertical and horizontal) distribution of biomass in the forest stands, for reducing the amount of the most dangerous fuel components (dead and fine fuels) and for creating gaps in the forest cover (crowns and understory), but they are also very expensive and therefore this treatments are applied at locations of special interest (e.g. urban-forest interface).

6.1. Overgrown understory clearings

Almost all forest fires start and spread at ground level (surface fire): in other factors being equal, the susceptibility to wild fires outbreak in absolute terms and the likelihood that surface fire turn into crown fires depends significantly on the presence, consistency and structure of the lower layer of the
vegetation (understory). In this sense, it may be useful to require their control with clearings not only along the roads (removing dried herbs and shrubs stories), but, in some cases, even within the forest where the human impact is stronger. Where appropriate and possible, the removal, to be useful, must be extended to a significant surface, starting from roads and firebreaks. In any case it should be avoided if possible to operating in summer, and even in spring in the driest stations.

6.2. Trees thinning

Thinning is needed in later development stages. Thinning is undoubtedly the most efficient silvicultural practice to reduce the likelihood of spread of a forest fire in the vulnerable forest stands (young conifer forests, young reforestation).

Potential positive effects of thinning are numerous: reduction of the amount of dry crowns, reduction of the amount of dry trees or trees in decay, increase of mechanical stability of the trees and consequently reduction of woody biomass and fuel on the ground, increase of the amount of green biomass in the understory due to improved light conditions, reduction of the amount of undecomposed litter due to reactivation of mineralization processes (increased contribution of light and heat), etc.

In addition, thinning, especially selective from the understory, also increases average distance between the crown and the soil, reducing this way the risk of fire passing from a surface to a crown. The thinning that is generally practiced is from below, with removal of trees which belong to dominant- and intermediate- story, in addition to those which are damaged or in poor health conditions.

Thinning intensity is determined by the stand age and forest cover.

6.3. Pruning

Besides shrub and understory clearing and thinning, pruning is also a very effective practice. A generalized pruning of the branches up to approximately 2m in height can ensure a good degree of fire prevention, at least in the case of stands with a prevalence of conifers, in particular by reducing the probability of transformation of surface fires into crown fires.

Pruning is performed with chain-saw with the objective to increase canopy base height (to lift the crown) and reduce the possibility of running fire passing into a crown fire. If there is a demand for harvested biomass it should be sold on the market, otherwise branches should be chopped up and laid over the ground to facilitate their decomposition.

7. Other defensive measures

Besides the above mentioned intervention measures, other defensive measures against the re-occurrence of fire and for facilitating the firefighting in case of re-occurrence of fire are important as well:
• Developing a positive attitude towards forest vegetation among local population;
• Training of experts for selection and implementation of preventive measures;
• Training of professional firefighters;
• Training of civil protection volunteers;
• Development of detailed firefighting plans;
• Construction of fire braking lines;
• Forest sanitation measures;
• Good surveillance and monitoring ensuring immediate detection;
• Appointment of the firefighting leaders;
• Appropriate equipment;
• Development of appropriate legal acts and their implementation.
Disclaimer

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