Post-fire management

Vallejo, VR, M. Arianoutsou, and F. Moreira (2012) Fire Ecology and Post-Fire Restoration - Approaches in Southern European Forest Types. Ch.5 in F. Moreira et al. (eds.), *Post-Fire Management and Restoration of Southern European Forests*. Managing Forest Ecosystems 24. Springer.

Major topics in Mediterranean ecosystem post-fire management

- Soil protection to reduce erosion risk
- Salvage logging
- Forest restoration vs. forest conversion
- Active versus indirect restoration
- The management of herbivory
- Fire and alien species
- Pests and diseases

Soil protection to reduce erosion risk

- Soil erosion is one of the most damaging post-fire processes, because of the combined effects of direct soil heating and temporary loss of protective vegetation cover.
- Water erosion may produce onsite loss of soil productivity and offsite siltation and flooding. Soil losses will be irreversible at the ecological time scales if they exceed soil formation rates, which are low in Mediterranean regions.
- Reducing soil erosion and runoff risk should be the first priority in post-fire management.
- The major determinants of soil erosion risk are topography (slope grade and length), rainfall intensity, soil erodibility (related to soil properties), plant cover (including litter), and artificial erosion control measures, like slope terracing.

Soil protection to reduce erosion risk

- At the landscape and hillslope scales, fire severity is usually quite heterogeneous in space and not very high at the soil level for surface and crown fires, which are the most common in the Mediterranean Basin.
- In severely burned areas, plant cover recovery rate controls how long after fire the soil will be exposed to the direct impact of raindrops and to high water erosion risk.
- Modelling these factors will allow identifying areas exposed to high soil erosion risk, as a basis for planning post-fire soil protection actions.

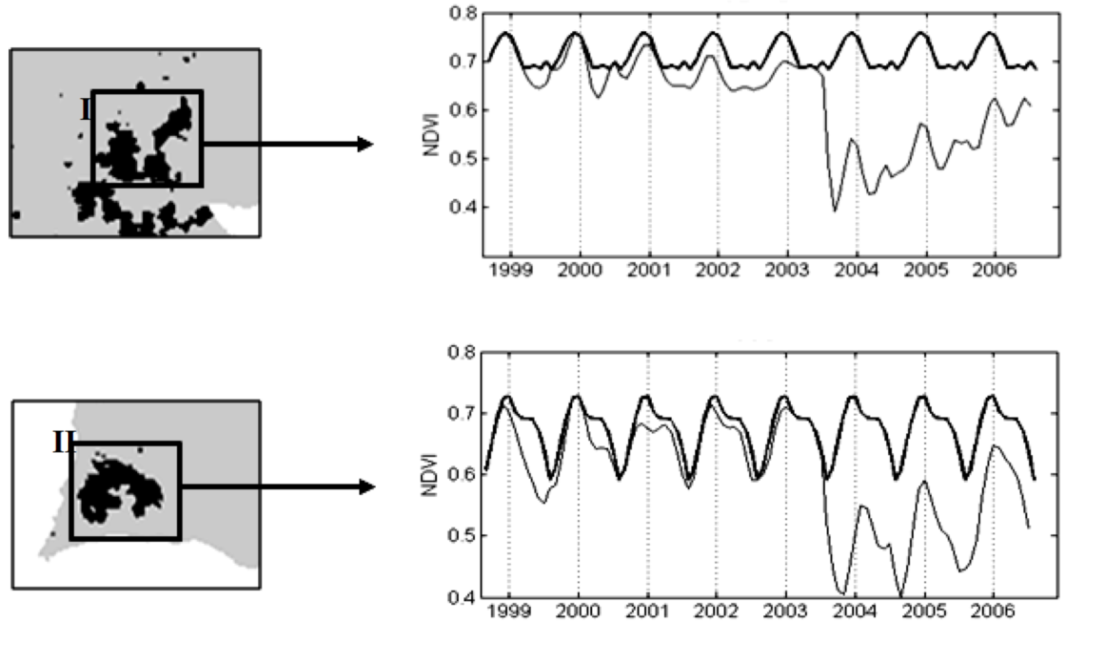
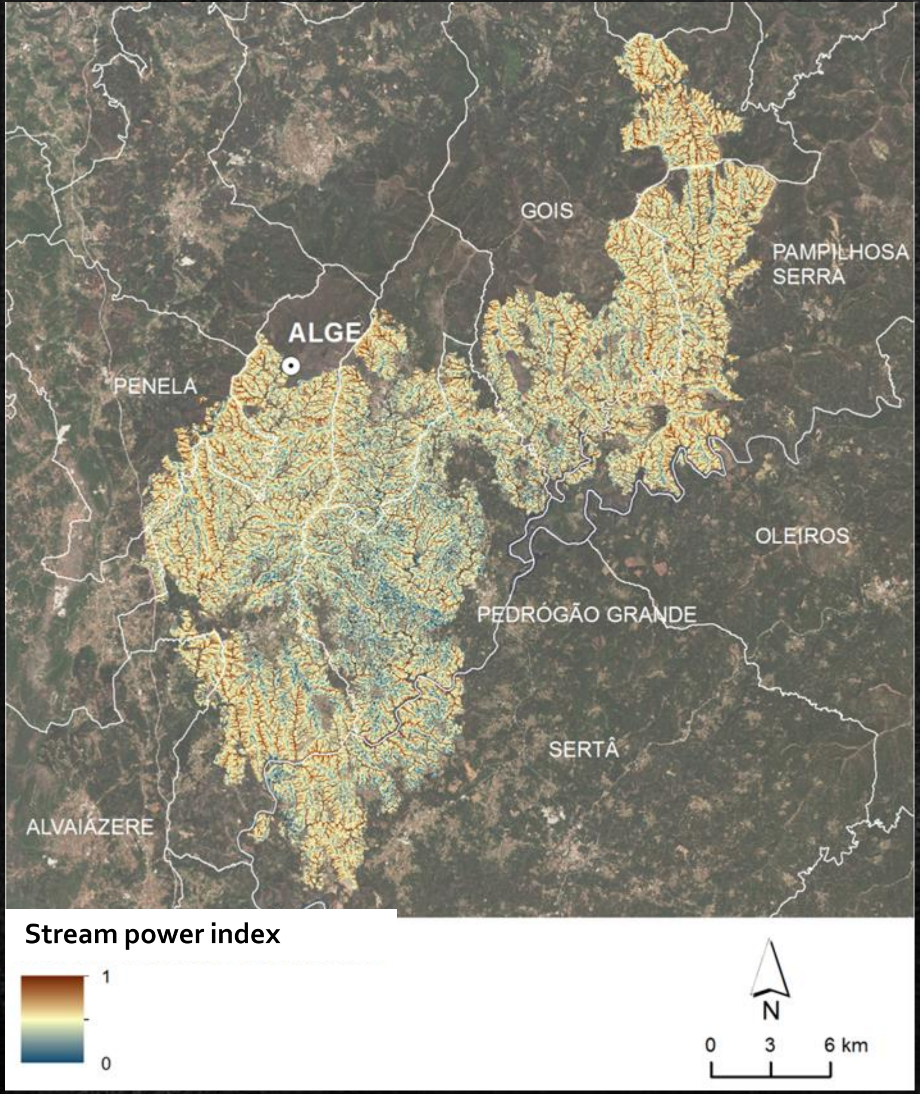
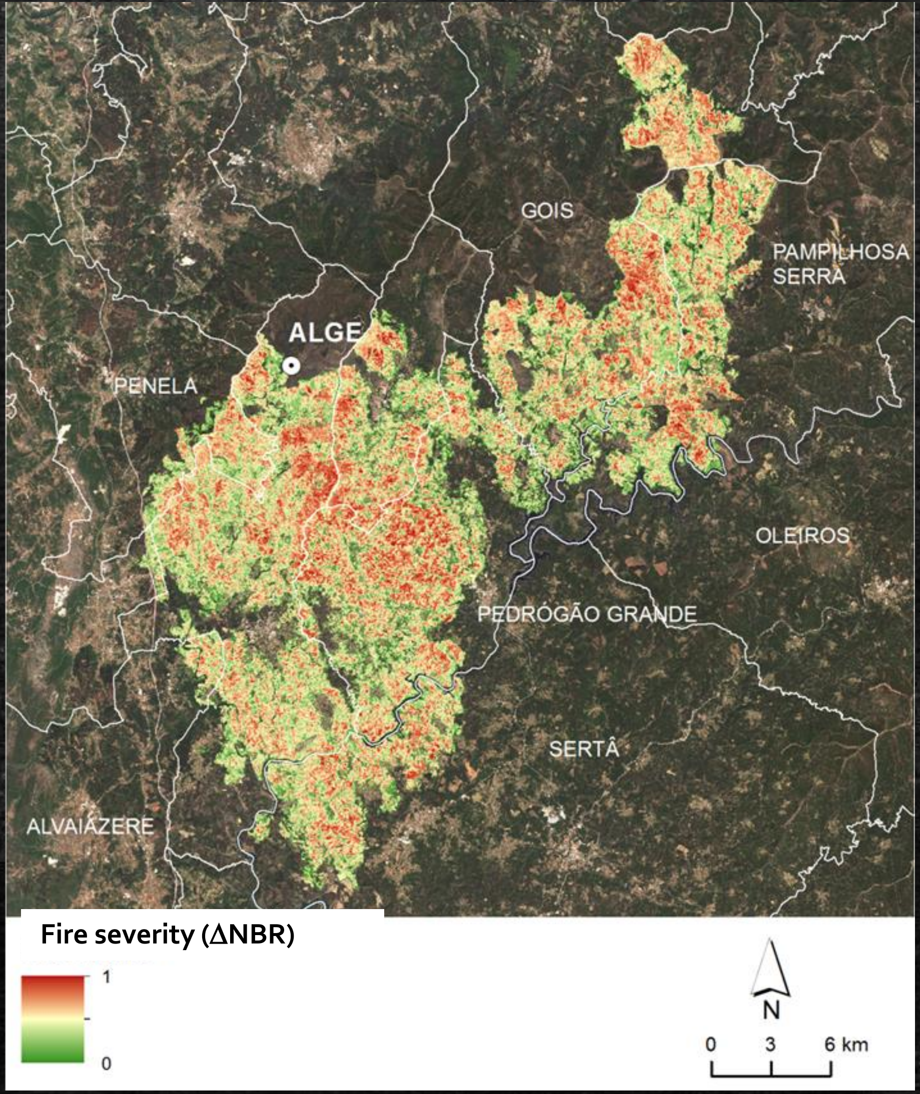


Fig. 4. Time series of NDVI (grey curves) spatially averaged over the two selected large fire scars, located in Region I (upper panel) and in Region II (lower panel), respectively. Black curves represent the Gorgeous Years (GY) of vegetation, given by the annual cycles of maximum NDVI for each month over the considered period.

Gouveia, C., DaCamara, C. C., & Trigo, R. M. (2010). Post-fire vegetation recovery in Portugal based on spot/vegetation data. *Natural Hazards and Earth System Sciences*, 10(4), 673-684.

Soil protection to reduce erosion risk





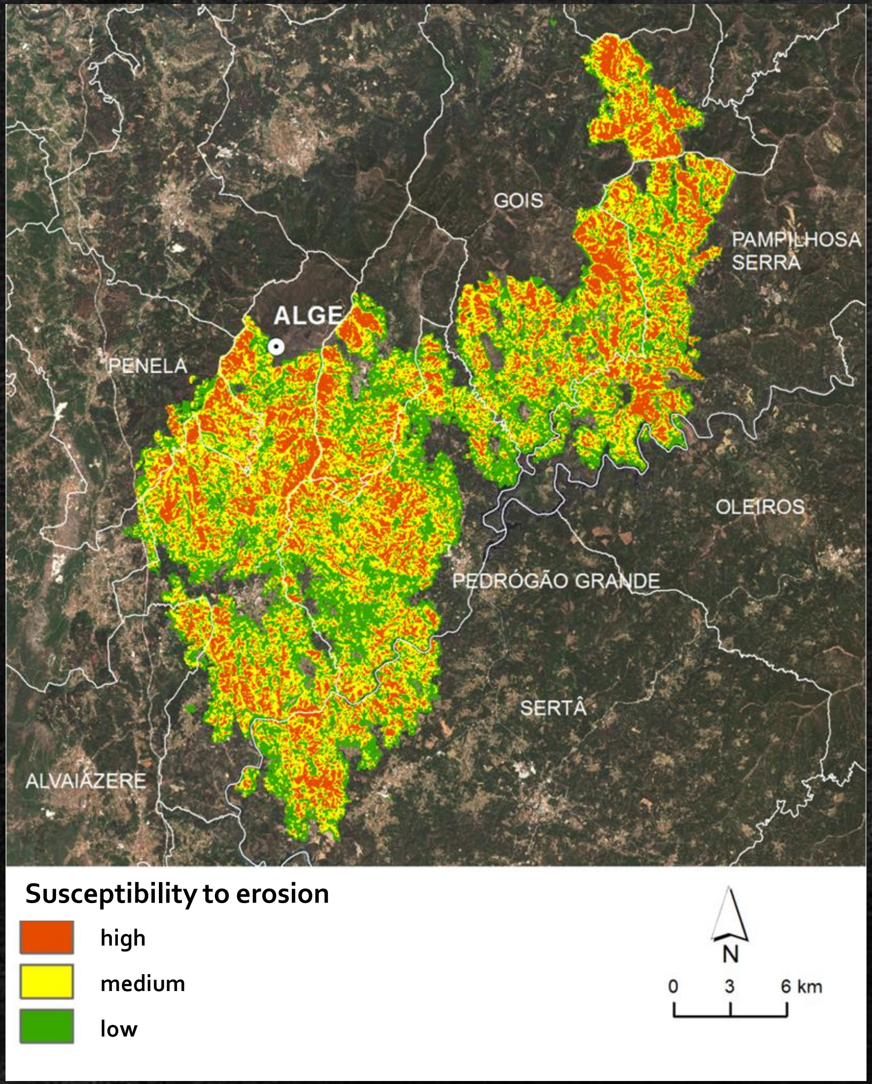
- Stream power index (SPI) takes into account data on watershed area and slope gradient:

$$SPI = \ln (CA * \tan S)$$

where CA (contributing area) is the watershed area upstream from the pixel and S is the slope at the pixel).

- Fire severity is given by the fire-induced difference in the Normalized Burn Ratio (ρNIR-ρSWIR / ρNIR-ρSWIR) .
- The map reflects the change in NBR between June 4 and July 4, 2017.

Soil protection to reduce erosion risk



- The map of susceptibility to erosion combines stream power index and fire severity.
- Susceptibility to erosion is higher in locations with steep slope, an extensive contributing area and high fire severity.
- This type of map is useful to prioritize emergency mitigation and rehabilitation measures.
- Monitoring rates of post-fire vegetation recovery may assist management decidions over a longer time span.

Soil protection to reduce erosion risk

- From the post-fire management perspective, the most critical factor affecting soil erosion risk that is susceptible of manipulation is plant/mulch* cover.
- In Southern Europe, high intensity rainfall is most likely by early Autumn. Therefore, for summer fires there is a high erosion risk right after the fire, when plant cover is low and heavy rains tend to occur.
- The main issues to consider when defining where to apply emergency measures include fire severity, presence of water-repellent soils, mapping of effective soil cover, areas at risk for flood or debris, river bank stability assessment, potential erosion or sedimentation and water quality deterioration, and status of infrastructures, like roads and bridges.

***mulch**: a layer of protective organic material applied to the surface of soil, such as wood chips, bark chips, or straw.

Soil protection to reduce erosion risk

- Slope treatments stabilize the burned areas by preventing or mitigating the negative effects of fire. The most used techniques include mulching , erosion barriers (Fig. 5.4), scarification, slash spreading, planting and seeding, control of invasive species and protection of special sites and habitats.
- Stream and channel treatments are used to reduce or mitigate water control and quality, trap sediment and debris and maintain stream and channel characteristics.
- The application of an organic layer of mulch, either alone or combined with seeding native grasses, is an effective rehabilitation option on steep slopes with low plant cover and high erosion risk, as it is aimed at reducing rain splash, surface flow, soil crusting and compaction, thereby increasing infiltration.
- In burned pine forests on steep slopes and soft soils, log dams or contour-felled barriers may be also effective post-fire management practices for reducing physical soil degradation and erosion

Soil protection to reduce erosion risk

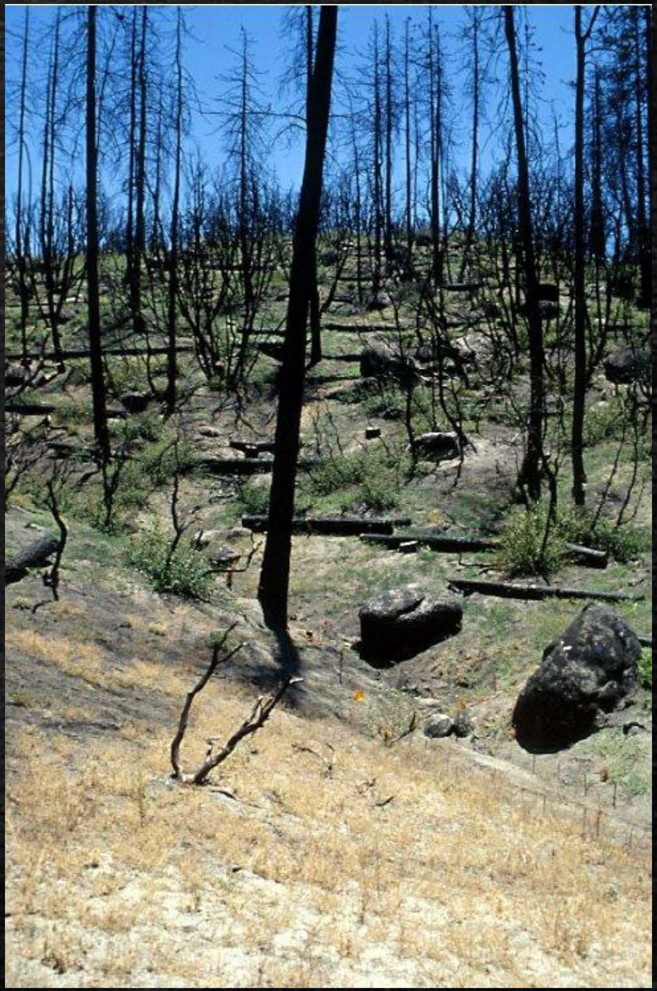
- Straw mulch provides immediate ground cover and protects the soil from erosion and loss of nutrients. Mulch can reduce downstream peak flows by absorbing rainfall and allows prewetting of water repellent soil. Straw helps to secure seeds that are stored in the soil, or applied as an emergency treatment. Straw mulch on burned areas helps maintain a favorable moisture and temperature regime for seed germination and growth.

Figure 10—Straw broadcast from a helicopter provides fast soil cover.

Napper, C. (2006). Burned area emergency response treatments catalog. US Forest Service, San Dimas Technology and Development Center. Watershed, Soil, Air Management 0625 1801—SDTDC

Soil protection to reduce erosion risk

- Log erosion barriers (LEBs) are used in timbered areas with moderate- and high-burn severity where hillslope erosion rates are increased significantly from the fire.
- LEBs (contour felled logs, log terraces, or terracettes) are logs placed in a shallow trench on the contour. LEBs trap sediment if laid in a bricklayer pattern on the hillslope.
- The potential volume of sediment stored is dependent on slope, size, and length of the felled trees, and proper implementation. LEBs with soil end berms trap more sediment.
- LEBs reduce erosion by shortening slope length, providing surface roughness, improving infiltration, and trapping sediment.



Napper, C. (2006). Burned area emergency response treatments catalog. US Forest Service, San Dimas Technology and Development Center. Watershed, Soil, Air Management 0625 1801—SDTDC

Soil protection to reduce erosion risk

- Slash spreading involves felling, lopping, and scattering submerchantable trees and brush to provide soil cover.
- This treatment is intended for use in areas of high- and moderate-burn severity, areas burned but with available slash material onsite, soils with high erosion-hazard ratings.

Figure 16—Completed unit with slash spread uniformly.

Napper, C. (2006). Burned area emergency response treatments catalog. US Forest Service, San Dimas Technology and Development Center. Watershed, Soil, Air Management 0625 1801—SDTDC

Salvage logging

- After forest fires, one of the first decisions to take is how to manage the affected timber.
- Harvesting of commercially valuable dead or damaged trees (salvage logging) is the most common practice, provided burned timber has enough economic value to pay for the logging operations.
- Timber value continuously decreases as time passes after fire because of the wood decay, thus the forest owner is interested in logging as soon as possible to maximize economic benefit.
- For large fires, it is almost impossible to rapidly harvest all burned forest area, therefore priorities should be established.

Salvage logging

- Salvage logging is controversial.
- Table 5.1 provides a list of the most commonly argued pros and cons of conducting salvage logging as soon as possible after a fire.

Table 5.1 Argued pros and cons of salvage logging

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

[a](SAF 1996); [b]Amman and Ryan (1991); [c] Roy (1956); [d]Gayoso and Iroumé (1991); Beghin et al. (2010); [e]Ne'eman (1997); Ne'eman and Izhaki (1998); Bautista and Vallejo (2002); [f]Castro et al. (2009); [g]Cobb et al. (2010); [h]Poff (1989); [i]Terry (1994); Bautista et al. (2004)

Salvage logging

- Generic recommendations:
- Avoid short-term salvage logging on vulnerable soils, at least until a protective vegetation cover has developed (usually after the first post-fire spring).
- Retain some snags* in order to keep forest nesting birds and other biodiversity components.
- Selective logging in patches may combine economic and ecological benefits, avoiding sensitive soil erosion areas and generating mosaics that would optimize biodiversity.
- Monitor surviving weakened trees for the risk of pest outbreaks.
- Use branches as barriers or to produce mulching material (chipped wood) to protect spots with high erosion risk (e.g. gullies, road talus.

*Snag: a standing, dead or dying tree, often missing a top or most of the smaller branches.

Forest restoration vs. forest conversion

- Stand replacing fires offer the opportunity to consider alternative forest types to be promoted.
- For hardwoods, changing the dominant tree species is difficult even after a fire, as it may require uprooting the stumps. This is done, for example, to convert eucalypt plantations to another type of forest, or to a different type of land use, but is costly and has a heavy ecological impact on the soil.
- Forest conversion could be considered for breaking the horizontal continuity in homogeneous forests, usually eucalypt or pine plantations.
- For fire management planning, introducing patches of different forests types (e.g. promoting riparian vegetation along creeks) or even other land uses (e.g. agricultural areas or pastures) located in strategic areas may reduce fire hazard and help fire suppression.

Active versus indirect restoration

- One major decision in the post-fire management of burned forests, when the restoration of the former forest type is the main objective, is whether to use natural regeneration (indirect restoration), if it is present or predicted to occur, or active restoration (planting, seeding).
- There is strong political pressure for reforesting or afforesting burned areas in the Mediterranean region as soon as possible after a wildfire, and this has been a common practice since the late nineteenth century, particularly in conifer forests.
- Reforestation/afforestation may not be the best alternative in many cases and the current political and social paradigm of “compensating” areas burned with active reforestations in a similar or higher number of hectares should be abandoned.

Active versus indirect restoration

- Reforestations are usually carried out through active restoration techniques such as plantation or direct seeding.
- **Planting is expensive** due to the costs of acquiring plant seedlings from nurseries, their transport to the burned area, site preparation (usually the highest cost), and other costs for equipment, fertilizers, tree shelters, replacement of dead seedlings, and human labour.
- **Soil preparation for planting** may increase the **risk of soil erosion**, and the **mortality rates** of planted seedlings, although quite variable, are **often higher than 50%.**
- **Direct seeding is less costly** and can be applied in extensive areas (e.g. aerial seeding), but the **success** (seed germination and plant establishment) is also usually **very low**.

Active versus indirect restoration

- These **active forest restoration techniques have low cost-effectiveness** and should be considered only when other options are not feasible, e.g. in areas where no natural tree regeneration is expected and where there are no mature trees in the vicinity that might provide seeds to naturally colonise the site in the medium term.
- Often, it would be much **more effective to explore the natural potential** characteristic of many Mediterranean species, i.e. **taking advantage of regeneration from seeds** left in the ground by the burned vegetation, **or from resprouting** of burned trees and shrubs.
- These passive (natural) restoration techniques have **lower costs and higher plant survival and growth rates** when compared to active restoration.

Active versus indirect restoration

- It would be preferable to make more extensive use of assisted natural restoration , based on the management of natural regeneration from seeds or resprouts.
- This may involve thinning, the selection of shoots, and the control of unwanted vegetation. The costs associated with assisted natural regeneration can be much lower when compared to active restoration.
- Evidently, the **decision** of opting by active or natural restoration will be **constrained by the type of pre-fire vegetation**, the ecosystem **response to fire**, and the **objectives** for the burned area.

The management of herbivory

- The beneficial effects of grazing and browsing are that they contribute to reduce fuel loads and thus, fire hazard. Fire and grazing are quite similar disturbances in several aspects of their impact on vegetation.

- Using animals (mainly domestic) in fuel management, sometimes called prescribed herbivory, requires knowing their feeding strategy.


“Sapper-goats” in Penacova, central Portugal.

- Browsers consuming woody species (shrubs and tree branches), e.g. goats or deer, are better suited for controlling shrubby areas than grazers, which consume mostly herbaceous vegetation (e.g. cows or sheep).

- Grazing animals can be used in post-fire management, when the objective is to reduce fuel loads (e.g. in fuel breaks, or in areas at the wildland-urban interface).

The management of herbivory

- Important factors to take into account to increase the effectiveness of grazing include:
  - (i) the selection of the animal species,
  - (ii) the selection of the grazing season and grazing period, and
  - (iii) the establishment of an appropriate stocking rate.
- Pastoral burning has been practiced in the Mediterranean for thousands of years, to suppress the unpalatable woody species to animals in favor of the herbaceous plants palatable to sheep and cattle.
- Herbivory can, however, be an important limiting factor when the post-fire objective is the regeneration of burned areas. After fire, the regenerating plants are particularly susceptible to animal consumption. The first species to emerge typically have high digestibility and are very attractive to herbivores.

The management of herbivory

- Resprouting species support well a slight consumption, but can be affected if there is repeated consumption of their terminal buds, essential to their growth in height.
- It may be necessary to invest in the protection of regenerating/planted plants. This can be done using three main different alternatives:
  - (i) reducing the animal population size;
  - (ii) protecting individual plants ;
  - (iii) fencing off herbivores from specific areas.
- The protection of individual trees is adopted when animals have access to regeneration areas or plantations. Various types of protections of variable prices and effectiveness are available. The most common is to protect each tree with a cylindrical wire mesh.
- Fencing may be a good option, depending on the size of the area to protect and on tree density. Generally, for larger areas and higher tree density, it is cheaper than the protection of individual plants.

Fire and alien species

- Alien species may be an important post-fire management issue in situations where fire promotes their occurrence, particularly if they become invasive and endanger the regeneration of native vegetation.
- Besides their impact on native diversity, when these new plant communities have different fuel properties that increase their combustibility, they may create a feedback loop where fire promotes invasive species, which increase fire hazard of the affected area.
- Mediterranean plant communities are rather resistant to biological invasions, as native species are likely to be good competitors under the strong selection regime imposed by humans on the Mediterranean flora. The multiple stresses of drought, fire and grazing also present limitations to prospective alien plant species to establish and to become invasive.

Fire and alien species

- However, in areas of Southern Europe with less dry climates, invasive species are becoming a problem in burned areas. In northern and central Portugal, for example, the genera *Acacia*, *Hakea*, *Ailanthus*, are a growing concern for forest managers, as their prevalence in burned areas is notoriously increasing. The status of *Eucalyptus*, in this regard, is debated.
- In summary, fire does not seem to promote the occurrence of exotic plants in most of the Mediterranean ecosystems, as these systems are rather resilient to disturbance. Although aliens seem to prefer disturbed places to establish, they usually cannot cope with native species in dry environments.
- In most cases where alien plants have been recorded in natural systems, their presence was concentrated in mesic places where nutrient availability is often higher, which may explain why in specific regions with less xeric environments, such as central and northern Portugal, exotic species are becoming a major problem in post-fire management.

Hakea sericia

Pests and diseases

- There are two basic mechanisms through which fire and pests or pathogens interact. One is the mortality or weakening of trees by fire and the subsequent promotion of damaging insect and pathogen populations.
- The second is through the mortality of trees caused by these agents, which contributes to dead fuel accumulation and increased fire hazard. However, there is not much information available on the relationships between wildfires and tree insect pests and pathogens in Southern Europe.
- Pines are the target of a variety of bark beetles that can cause tree death, branch dieback and reduced productivity. Pine beetles of the subfamily *Scolytinae* (mainly the genera *Ips*, *Orthotomicus*, and *Tomicus*) are considered a major problem in burned pine forests.

Pests and diseases

- The pine processionary caterpillar, *Thaumetopoea pityocampa*, is considered the most destructive forest insect pest throughout the Mediterranean Basin. It is a tent-making caterpillar that feeds gregariously and defoliates various species of pine and cedar.

- These species may cause intense defoliation with consequent tree weakness and even death. This might contribute to fuel accumulation, increasing fire hazard.

- Eucalyptus longhorned borers of the genus *Phoracanta* (*Coleoptera: Cerambycidae*) are serious borer pests of eucalypts, particularly those planted outside their natural range, e.g. the eucalyptus plantations in Portugal. *Phoracantha* species tend to attack damaged or stressed trees.

- *Gonipterus scutellatus* (*Coleoptera: Curculinoidae*) is an exotic weevil infesting eucalypt plantations. The nematode *Bursaphelenchus xylophilus* (pine wilt nematode) was found in Portugal for the first time in 1999 and is a major threat for the maritime pine (*Pinus pinaster*) forests.

- Trees weakened by fire will become more susceptible, thus increased problems are expected. On the other hand, trees weakened or killed by these pathogens may increase fire hazard.

Key messages

- Post-fire emergency rehabilitation actions should be applied to burned forests showing high erosion and runoff risk, with slow natural plant recovery rate.
- The forests more prone to post-fire erosion are pine forests with an understory dominated by obligate seeders.
- Mulching is one of the more effective techniques to decrease erosion risk.
- Salvage logging has economic and ecological benefits but also negative impacts. General recommendations are: avoiding dragging logs in vulnerable soils, retain some snags for biodiversity purposes, monitor surviving weakened trees for the risk of pest outbreaks, and use charred wood for soil protection where there is high erosion risk.
- Forest conversion after fire could be considered for fire prevention and for landscape renaturalization.

Key messages

- Although active reforestation/afforestation is the usual action taken by policy makers and forest administrations, in many cases assisted natural restoration is more efficient and cost-effective.
- Grazing animals contribute to reduce fuel load and fire hazard. However, herbivores may also limit the post-fire vegetation recovery.
- Alien invasive species are not much favored by fire in xeric Mediterranean environments, but in some moister areas they are becoming an increasing problem for post-fire management.
- Pests and diseases may increase dead fuel accumulation, and consequently fire hazard. Fire may facilitate pest outbreak, especially for pine bark beetles.