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Mini Review

Impacts of Fire and Restoration Techniques on Soil Properties

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Abstract

The protection and conservation of burnt forest areas require specific actions in the short, medium and long term, that must be developed with a strong awareness of the local reality concerning climate, hydrogeology, social expectations and the economy. Recent studies show that the ecological effects of post-fire rehabilitation techniques must be considered and taken into account when defining forest management models since some options can increase the soil degradation level. Post-fire impacts on soil degradation extent and magnitude depend on the fire history, environmental conditions of the fire-affected area and human management. These interactions are very difficult to generalize because they are interdependent. Consequently, if we want to prevent future problems from today's solutions, it is urgent to assess the ecological consequences of the options applied and to ensure that they are included in the treatment of the decision-making process. The main objective of this mini-review is to summarize the fire effect on physic-chemical and microbial soil properties. Moreover, it is intended to describe some of the most common restoration techniques and their possible impacts on soil properties.

Keywords: Fire; Soil properties; Restoration; Changes in climate; Fire regime

Introduction

In the Mediterranean Basin, changes in climate and fire regime (increased recurrence and severity) reduce ecosystem services after fires, linked to changes in soil biota, by increasing soil degradation and losses in plant diversity [1,2]. High burn severity limited natural vegetation recovery, and reduced biological soil functionality. Soil resource is not renewable at human time scales and is fundamental to address future global challenges such as climate change, water scarcity, loss of biodiversity, human health, and food security [3].

Impacts of a fire on soils properties

Post-fire impacts on soil degradation depend on the fire history, environmental conditions of the area, and human management. Burned land, without organic matter, does not produce lumps and the soil loses its porosity. Thus, rainwater does not penetrate and eventually runs down the surface, grazing fields and pastures: it is erosion. Without porosity, soil ventilation is hampered. Chemical reactions stop, some of the minerals important for nutrition become toxic, plant metabolism becomes slow and vegetation grows poorly and weak. Under such conditions, even with high fertilization, crop productivity is poor. Soil dynamics depend not only on physic-chemical properties but also on micro-fauna and microbiological health because the return of vegetation after a fire is directly impacted by the activity of these organisms. These organisms are not only responsible for the decomposition of organic matter and the formation of humus, but also to close the biogeochemical cycles, allowing the availability of essential nutrients for plants [4]. In addition to the capacity of recycling plant and animal residues, microorganisms are able to degrade or even mineralize toxic compounds produced during the fires [5]. Moreover, microorganisms together with macro-invertebrates contribute to the soil texture, shaping the soil aggregates, contributing thus to adequate levels of soil permeability and aeration for plant growth [4]. Fires are known to disturb the composition and diversity of soil communities. The generated heat may kill the cells, reducing microbial biomass [6]. However, other indirect factors of fire, such as overall losses of soil C and N, pH, an increase of soil hydrophobicity and compaction, contribute to disturbing the microbial populations [7]. Bacteria seem to be more resistant to heat than fungi, and generally increase in relative abundance after fire [7]. Mycorrhizal fungi, which colonize the majority of land plants and provide them with access to soil nutrients, are highly negatively affected by fire [8]. Also, the macro-invertebrates populations are heavily disturbed by fire, with mortality reaching 100% depending on the proportion of organic soil consumed and taxa [9]. Disturbance of the microbial communities is inevitably reflected in the soil function, with alterations on the populations responsible for the degradation of soil polymers [10].

Impacts of restoration techniques on soils properties

Some types of post-fire interventions are salvage logging, site preparation (e.g. ripping), mulching (e.g. straw), seeding, erosion barriers, and channel treatments [11]. However, some interventions can increase soil degradation. Salvage logging, which is carried out in the period immediately after a fire, and the site preparation, can promote soil degradation (e.g. soil compaction, aggregate stability and organic matter loss, reduction of carbon sequestration) and have negative impacts on vegetation recuperation capacity [12]. On the other hand, mulching practices reduce soil degradation [11]. Organic amendments are more appropriate to restore soil nutrients. Overall, post-fire management options can trigger or reduce soil degradation in burned areas [11]. Soils restoration and protection is urgent, but its ecological suitability can only be achieved using methods that improve the natural ecosystem. Mulching has a high capacity to reduce overland flow and soil erosion [13] and increasing some major cation nutrients [11]. However, its impacts on soil organic matter (SOM) quality and quantity or in vegetation recovery continue poorly studied [14,15]. Since SOM is the most functional fraction of many soils and, hence, a widely used indicator of soil health and quality is important to increase the knowledge of this interaction. The soils restoration with stabilized organic wastes use as an amendment, such as compost, is not only sustainable, but is also expected to accelerate the restoration of burned soils ecosystem, due to the correction of unbalanced physic-chemical parameters, and because amendments may serve as inocula of microorganisms [16]. Nevertheless, studies involving fire impacts on soil properties in forest ecosystems are scarce [17] most studies evaluated the effect of short-term rehabilitation techniques on soil erosion and runoff, and some investigated how biotic components are affected when long-term restoration activities were applied. Few studies had integrated a physico-chemical and biological assessment of long-term restoration techniques. Thus, is important to study the consequences of fires on the soil properties, monitoring the physic-chemical, biochemical and microbiological parameters and the influence of long-term restoration techniques. The tools applied in adaptive post-fire forest management must increase soil health to improve the resilience of vulnerable ecosystems.

Conclusion

Fire can have major impacts on soil. Human intervention and the way that we manage areas affected by fires is crucial to lead to an increase or decrease in soil degradation. Sustainable measures such as mulching can improve soil conditions, contrary to salvage logging techniques that cause soil degradation. Overall, post-fire management options can cause or reduce soil degradation in areas affected by fires.

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Conflit of interest

No conflit of interest.

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