

EFFECT OF A WILDFIRE ON VOLCANIC SOILS UNDER PINE FOREST AND BROOM SCRUB IN TENERIFE (CANARY ISLANDS)

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Abstract

The effect of a wildfire at Fasnía (Tenerife, Canary Islands) on physical and chemical properties of soils under pine forest and broom scrub was investigated. Soils were mostly *Vitrandic Xerorthents*, and the fire spread over approximately 150 ha. Soil samples were collected in burned and non-burned locations, and at different distances from randomly selected individual plants. Some soil properties (pH in water and in 1N KCl, and electrical conductivity) varied significantly due to the fire in both plant communities, whereas available Mg content showed differences only attributable to the plant community. The clay content and the percentage of ammonium oxalate-extractable Fe were significantly different only under non-burned pine forest. Soil andic properties and some closely related parameters (organic C content, soil pH in NaF, P retention capacity and ammonium oxalate-extractable Al) were not significantly affected by heating or the plant community composition. Finally, available P, Ca and K increased slightly in burned soils as compared to non-burned ones. Sample location was never significant for any parameter. Provided the capacity of both plant communities to regenerate after an intense wildfire, the Fasnía case can be regarded as an ecological fire, with foreseeable positive effects and minimum damage to soil and the surrounding environment.

Additional Keywords: wildfire, plant community, soil properties, volcanic soils.

Introduction

In the Canary Islands, pine forests and other plant communities have been naturally affected by wildfires for centuries, although the incidence of man-caused fire episodes has increased during the last decades. Fires are known to modify abruptly soil properties and processes (DeBano et al., 1998) and their effects have been usually considered as negative for soils and the natural environment. Nowadays, wildfires are recognized as a main ecological factor whose impact on forest ecosystems is not necessarily negative, especially when soils are enriched with nutrients released from the burning living tissues and soil losses by erosion are limited (Höllermann, 2001).

In July 1997, a wildfire spread over a mountain zone at Fasnía (Tenerife, Canary Islands), covering approximately 150 ha and affecting basically pine forest and mountain broom scrub vegetation (Figure 1). Soils at the area are volcanic (which is the common rule in the Canarian archipelago), scarcely developed (AC-type profile), stony, medium-to-coarse textured, and rich in glass fragments (*Vitrandic Xerorthents*), in spite of which plant coverage can reach very high values. The area's climate is dry and cool (the affected zone rises between 1700 and 2100 m a.s.l.). Both Canarian pine (*Pinus canariensis*) and Teide broom (*Spartocytisus supranubius*) are highly calorific fuels, due to their content in resins and precursors of volatile, flammable compounds.

The aim of this paper is to evaluate the effect of fire in both pine forest and broom scrub, by measuring selected soil physical and chemical properties in burned and non-burned sites. The possible influence of sample collection site (whether close to the charred stem or in bare soil among individual plants) has also been investigated.

Materials and Methods

Field Sites

Four zones were sampled in the affected area (Figure 1): pine forest, broom scrub, burned and non-burned. In each zone, three 10 x 10 m plots were randomly established. In each plot, three surface (<10 cm) soil samples were collected, as follows: (i) close to the charred stem (where heat release is supposed to be more intense), at the edge of ash circles indicating the former diameter range of the living plant, and (iii) at bare soil with no growing plants before the fire. In non-burned zones, samples were collected at approximately the same distances from the stems as in burned plots. Therefore, a set of 36 soil samples were collected.

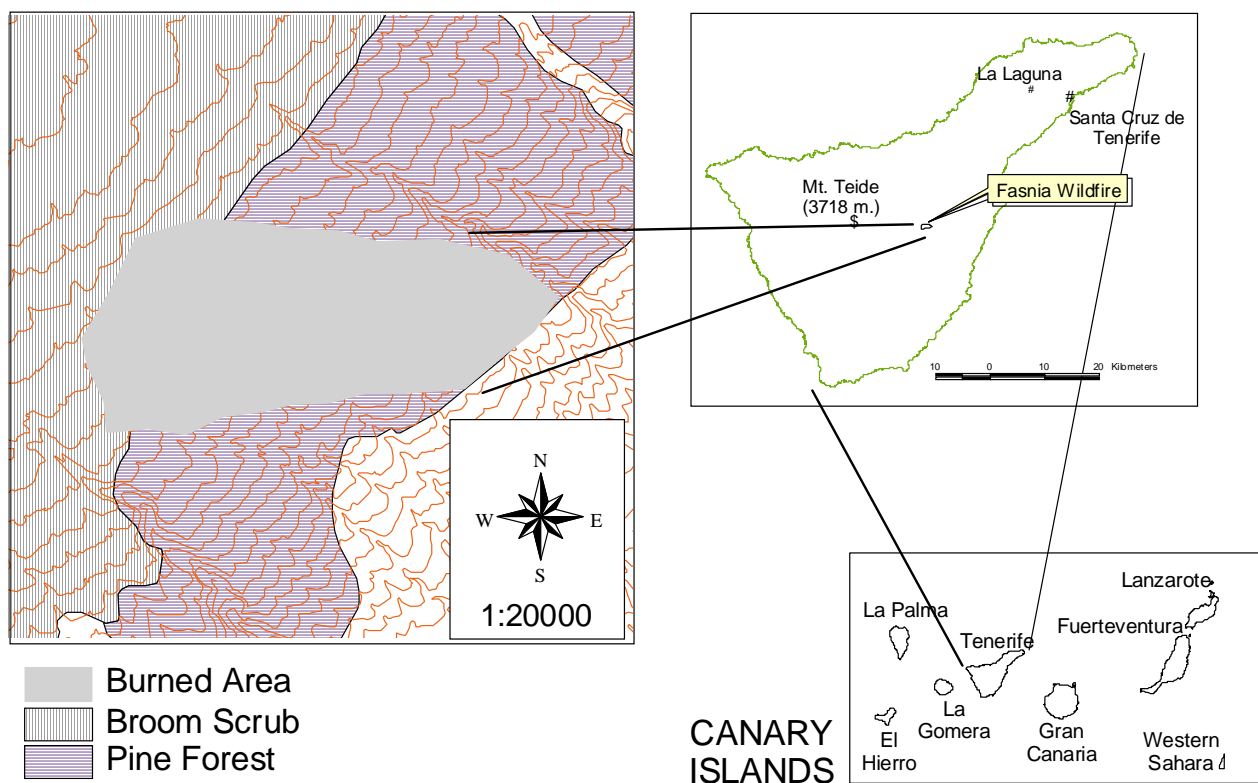


Figure 1. Location of the Fasnía wildfire.

Laboratory analysis

Soil samples were air-dried and sieved to pass a 2-mm mesh. The analysis performed include: pH (in H₂O and in 1N KCl, 1:2.5 soil-to-liquid ratio), pH (in 0.5N NaF, 1:50 soil-to-solution ratio), electrical conductivity (saturated paste), clay content (densitometry), available P (extracted with 0.5M NaHCO₃), organic C content (1N K₂Cr₂O₇ oxidation and further titration with 0.5N (NH₄)₂Fe(SO₄)₂), P retention capacity (Blakemore et al., 1981), NH₄-oxalate-extractable Al and Fe (Blakemore et al., 1981), available nutrients and C.E.C. (neutral 1M NH₄-acetate).

Statistical analysis

Averages for soil parameters were compared applying ANOVA test. Duncan's *post-hoc* test was applied whenever statistical differences were found. Statistical analysis was performed using the SPSS v.10 package for Windows™.

Results and Discussion

Influence of sample collection place

The values for many soil parameters increased (or decreased) with the distance from the plant stem or the zone of maximum ash deposition (data not shown), following a different pattern according to the plant community or the fact of being burned or not. For instance, soil pH in water (non-burned soils) was higher between plants (i.e. far from the plant stem) in broom scrub, whereas the opposite trend was observed in pine forest. However, there was no definite trend for this parameter in burned soils under broom scrub, whereas in pine forest, pH values continued to be higher in points closer to the plant. Only the clay content showed no spatial trend at all. In any case, ANOVA tests showed no significant differences ($\alpha = 0.05$) due to the point of sample collection in any plant community.

Influence of plant community and burning

Tables one and two show the average values for all the parameters studied in both burned and non-burned plant communities. Asterisks indicate those average values being significantly different ($\alpha = 0.05$) from the rest. Thus, for instance, soil pH (H₂O and KCl) was significantly higher for burned soils relative to the non-burned samples, which also stands for electrical conductivity (E.C.). This fact has been widely reported in the literature (Rundel, 1981; Kutiel and Naveh, 1987; Almendros et al., 1990) and is attributed to the soil enrichment in alkali and

alkaline-earth cations released from plant tissues in the form of ashes, that determine a rise in pH values, as well as a decrease in both actual and potential acidity (see pH values in KCl).

Table 1. Average values for soil properties (I)

Plant Community	pH (H ₂ O)	pH (KCl)	Available P	Clay	E.C.	Ca	Mg	Na	K	C.E.C.
Burned Broom Scrub	6.53* (0.48)	5.55* (0.52)	12.07 (5.45)	17.16 (7.00)	1477* (657)	4.62 (2.60)	0.81 (0.36)	4.79* (1.28)	2.31 (0.61)	21.02 (4.95)
Non-burned Broom Scrub	5.77 (0.28)	4.74 (0.28)	14.05 (9.80)	14.49 (3.15)	768 (374)	4.21 (1.94)	0.77 (0.33)	1.23 (0.26)	1.67 (0.33)	23.79 (4.53)
Burned Pine forest	6.77* (0.28)	5.95* (0.44)	21.44 (17.83)	17.84 (3.95)	1372* (647)	7.07* (2.60)	1.42* (0.31)	3.64* (3.18)	2.20 (0.89)	22.64 (4.42)
Non-burned Pine forest	5.96 (0.35)	4.92 (0.28)	9.43 (7.1)	21.81* (7.26)	685 (88)	5.33 (1.04)	1.39* (0.35)	4.51* (0.6)	1.80 (0.25)	24.13 (4.06)

Units expressed as follows: mg.kg⁻¹ (Available P), percentage (Clay content), S.cm⁻¹ (electrical conductivity), cmol.kg⁻¹ (available cations and C.E.C.). Standard deviations in brackets.

However, the behaviour of nutrients follows diverse patterns in each case. Thus, available Ca increases significantly only in burned soils under pine. The differences for available Mg seem to be due to the nature of plants rather than to burning. Sodium levels are lower under non-burned broom scrub and, finally, neither the available P nor K contents vary significantly, although fire apparently released a great amount of available P from pine forest.

Cation-exchange capacity, organic C content or clay content have not been significantly affected by fire in any case. Together with nutrient behaviour, this leads to an enrichment of the exchange complex in basic nutrients, which is consistent with pH values in KCl. Base saturation percentage (S/T ratio) increases from 33% to 59% under broom scrub and from 54% to 63% in pine forest after burning. Schoenholtz et al. (2000) pointed out that the S/T ratio is more a valuable indicator of forest soils quality, just as those parameters on which depend basic processes in forest soils, such as pH and organic C content. Soil organic matter content has clearly decreased in both plant communities as a consequence of fire, but not to a significant degree (Table two). The combustion of organic matter is consistent with the increase in soil pH and E.C., as well as the enrichment in basic nutrients. It can be expected that the most labile organic fractions have decreased to a great extent, whereas the more stable and recalcitrant organic compounds (humic acids and humins) would have remained unaffected (Almendros et al., 1990).

Table 2. Average values for soil properties (II)

Plant Community	pH (NaF)	P Retention	Organic C	Oxalate Al	Oxalate Fe
Burned Broom Scrub	10.18 (0.43)	43.87 (12.73)	3.24 (1.42)	0.85* (0.47)	0.80* (0.08)
Non-burned Broom Scrub	9.97 (0.25)	34.55 (7.30)	4.56 (2.75)	0.67* (0.29)	0.74* (0.11)
Burned Pine forest	9.95 (0.20)	34.55 (7.30)	3.17 (1.37)	0.46 (0.17)	0.67* (0.12)
Non-burned Pine forest	9.84 (0.65)	45.95 (14.0)	5.17 (2.18)	0.99* (0.80)	0.004 (0.001)

All units as percentages (save for pH in NaF). Standard deviations in brackets.

Also, the average values for clay content would suggest the absence of important losses of soil material by runoff or wind erosion, which is noticeable in a zone where the average slope is about 10%. Several authors have reported important movement of fine particles after wildfires (Saá et al., 1994; Thomas et al., 1999 among many others). Apparently, this is not the case here. Therefore, it could be concluded that soil erosion has been limited, at least until the precise time of sampling. Imeson et al. (1992) reported that soil physical properties of burned soils developed on acid igneous and metamorphic rocks and having mor-type humus may improve immediately after the fire, to later undergo a collapse, because of pore filling by fine material, especially if the vegetation does not recover at short term. The apparent absence of soil losses by erosion is consistent with nutrient enrichment and also supports the idea, expressed above, that soil quality in the area studied in this paper has not been affected by fire.

Finally, soil andic properties (P retention capacity, soil pH in NaF and Al- and Fe-oxalate contents) have not varied significantly as a consequence of fire, or only up to a limited degree. P retention capacity has increased slightly in soil samples under broom scrub, whereas the opposite phenomenon happened under pine (Table two). Similar trends for broom scrub in Tenerife have been observed by Pérez and Notario (2003), but the variations in P retention were never significant. Oxalate-extractable Al has decreased in soils under pine forest after the fire, which could be due to a destruction of labile Al-humus complexes and further precipitation of Al. This is supported by the decrease in the organic C content (Table two), as well as P retention capacity, which is associated with this type of organo-metallic complexes in volcanic soils. Oxalate-extractable Fe has not varied significantly in soils under broom scrub, but a dramatic enrichment has been measured in the case of pine forest. This could be explained by: (i) a massive release from plant tissues as a consequence of fire, where it could have accumulated, and/or (ii) a different composition of parent rock material in the area, as basaltic rocks commonly alternate with more acid trachytic and phonolytic rocks, which are known to be poorer in Fe than basic volcanic rocks.

To sum up, soil parameters closely related to soil quality in forest environments (soil pH, organic matter content, S:T ratio and clay content) have remained unchanged, have increased or, in the worst case, have not decreased sharply (%Organic C), which yields adequate soil conditions for the recovery of both ecosystems. This recovery would depend largely on climatic conditions and on the potential of plants to resprout. In the case of Canarian pine, this capacity is widely known, so after a few years it would easily recover, but the re-establishment of Teide broom scrub to a comparable state as before the wildfire may require longer periods of time (Höllermann, 2001).

Conclusions

Fasnia wildfire at Tenerife island has been in general terms positive for the ecosystems affected, at least as revealed by the results of this work. The behaviour of the parameters studied does not support the idea of a catastrophic event, but rather an ecological wildfire that has mobilized nutrients without significant losses of soil constituents. No great error can be expected in this type of wildfires due to the sampling location with regard to plants.

Acknowledgements

The authors are grateful to Mr. V. Ramos Arteaga, for his valuable assistance during the sampling tasks.

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