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The temporal distribution of water-soluble nutrients from high mountain soils following a wildfire within legume scrubland of Tenerife, Canary Islands, Spain

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ABSTRACT

The concentrations of soil water-soluble elements (Ca^{2+}, Mg^{2+}, K^{+}, NH_4^+-N, NO_3^--N, SO_4^{2-}-S and P), pH and electrical conductivity (EC) were monitored over a 15-month period after a wildfire that burned nearly 7 ha of high mountain broom scrubland in Tenerife (Canary Islands). The results showed that the mean values of soil pH, EC and basic cations were significantly higher three months after the wildfire in the burned area than in samples collected at adjacent, unburned sampling sites, and gradually decreased thereafter. The nitric-N increased consistently and linearly in time after the wildfire in all the samples, more intensely inside the burned area. Mean ammonium-N levels were nearly constant in burned and unburned samples almost across the entire study period, and increased in the burned area fifteen months after the fire. Sulfate-S and P showed no significant variations based on sample status (i.e., burned or unburned) or sampling time, possibly because of their particular dynamics in volcanic soils. These results point to a limited loss of nutrients, therefore suggesting that the possibility of intense post-fire erosion will be low. The nutrient levels found by the end of the study period were high enough to support the re-establishment of vegetation; however, the effect of alien herbivores on broom seedlings could eventually lead to a progressive replacement of the legume scrubland in the burned area.

1. Introduction

In many terrestrial ecosystems, wildfires have regularly affected scrublands to become an essential agent for the seasonal re-establishment and growth of vegetation in them (Keeley et al., 2012), as already reported for chaparral (SW USA; Barro and Conard, 1991; Minnich and Franco-Vizcaino, 2009), maquis and garrigue (European Mediterranean basin, Lloret and Vila, 1997) and *fynbos* communities (South Africa, Van Wilgen et al., 2010; Rutherford et al., 2011).

In the Canary Islands (Fig. 1) wildfires mainly burn pine woodlands, dominated by Canarian pine (*Pinus canariensis* L.) (Climent et al., 2004; Escudero et al., 2000), but sometimes they spread beyond the upper limit of the Canarian pine forest belt (Notario, 2009), burning the mountainous legume scrublands that lie above 1800 m. In Tenerife, the main high-mountain shrub species is Teide broom (*Spartocytisus supranubius*), whose typically pillow-shaped mature individuals may reach as much as 3 m in height and 5–6 m in diameter. Other shrubby legumes (*Adenocarpus viscosus*, *Chamaecytisus proliferus*) and herbs (*Descurainia bourgeana*, *Erysimum scoparium*, *Pterocepahlus lasiospermum*, etc.), many of them endemic to the Canary Islands, and Teide broom constitute highly valuable, rich and dense communities. So far, and to our knowledge, the effects of wildfires on these high mountain scrublands have not been studied in detail. However, environmental managers and technicians have noticed that post-fire recovery of these scrublands may be hindered by long droughts and the pressure of non-native, invasive herbivores, namely wild sheep (*Ovis orientalis musimon*) and rabbits (*Oryctolagus cuniculus*) (Marrero-Gómez, personal communication).

Teide broom scrublands grow over volcanic, shallow, stony and poorly developed soils (Köhler et al., 2006; Rodríguez, 2014; Rodríguez et al., 2010), whose low degree of evolution may be explained by the scarcity of water and extreme temperatures in the area (Del Arco et al., 2006; Fernández-Palacios and De los Santos Gómez, 1996) that prevent the development of differentiated soils. Only in closed hydrological basins, the accumulation of fine mineral matter from the surrounding slopes gives rise to thick and relatively fertile soils (i.e., Fluvisols, Rodríguez, 2014); however, the main soil types in the area (Vitric Andosols, Leptosols, Umbrisols and Regosols) are generally nutrient-poor (Rodríguez et al., 2010).

In these environments, ash supplies from wildfires may constitute an important source of readily available nutrients. However, the "ash bed effect" (DeBano et al., 1998) is known to decrease with time, as ash nutrients are progressively removed from the soil by wind and/or overland flow and leaching (Bodí et al., 2014; Pereira et al., 2010). In the case of such removal, the effective post-fire recovery of vegetation would be at stake. This issue gains further relevance once we consider that we are

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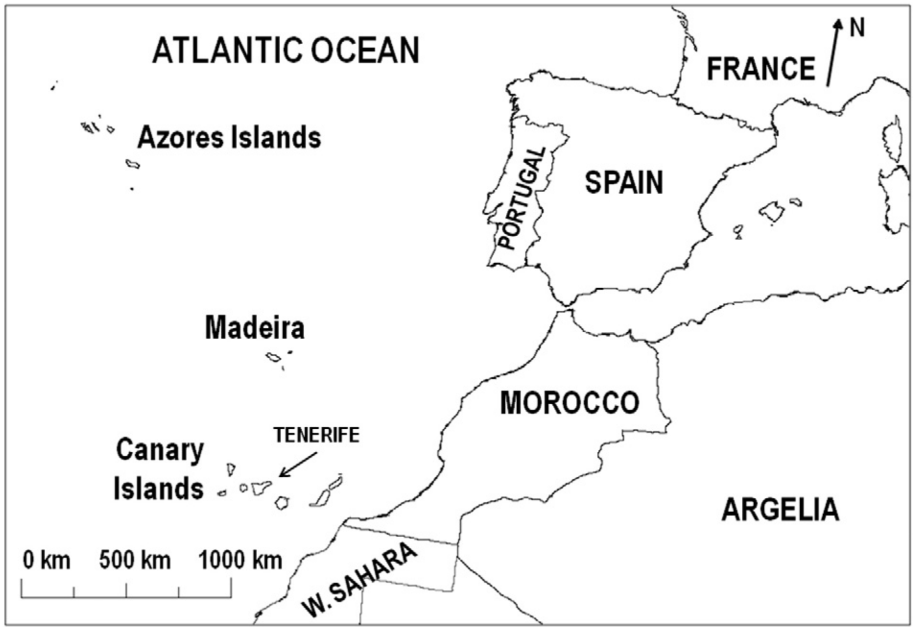

Fig. 1. Geographical location of the Canary Islands.

just starting to understand the natural mechanisms governing the dynamics of soil nutrients in these ecosystems (Rodríguez, 2014; Rodríguez et al., 2010). One way to investigate this is to determine the concentrations of soil water-soluble nutrients, as they depend on the amount and properties of the ashes released to soil after a wildfire (Bodí et al., 2014; Pereira et al., 2012). In previous papers (Notario et al., 2007, 2008), our research group studied the effects of a wildfire that occurred on 13th June 2003, close to a peak called Pico Cho Marcial, which burned nearly 7 ha of Teide broom scrub. Several N fractions, as well as organic C and soil nutrients were measured shortly after the wildfire. In this research, we monitored the levels of water-soluble nutrients along a fifteen-month period, so as to elucidate whether they were effectively lost after the fire event. Based upon this extended study, the consequences for the unique vegetation of this ecosystem are being made.

2. Materials and methods

2.1. Environmental factors and fire event

The Pico Cho Marcial (PCM hereafter) wildfire occurred in the heights of Güímar (Tenerife, Canary Islands) from 13th to 14th June 2003, and burned a Teide broom scrubland (*Spartocytisetum supranubii*) (Rivas Martínez et al., 1993) over volcanic soils that have been classified as Lithic xerorthents (Soil Survey Staff, 2010) or Umbric Leptosols (IUSS, 2007). The burned area can be enclosed inside a rectangle with UTM coordinates 28R Cs 354560 3134920 (NW) and 28R Cs 354960 3134620 (SE). The elevation of the study area ranged from 2130 to 2240 m with predominantly southeast-facing slopes and an average gradient of 25%. According to image analysis, plant coverage consisted primarily of Teide broom and was approximately 75% prior to the wildfire. The climate in the area is cold in winter (average temperatures usually lower than 5 °C) and warm in summer (average temperatures close to 30 °C), with a sharp thermal contrast throughout the daytime (≥10 °C), regardless of the season (AEMET, 2012). Water supplies in the area come mostly from snowfall, and usually range between 300 and 700 mm, although snowfall events have become more infrequent, probably as a consequence of the global warming, that has increasingly become evident in the Tenerife summit in the recent decades, as shown by Martín et al. (2012).

As indicated above, the PCM wildfire started on 13th June 2003, and spread for approximately one day until it was definitely controlled and extinguished. The fire had a nearly ellipsoidal perimeter, with a northwest to southeast major axis (Fig. 2) and enclosing a 7.1 ha surface. A post-fire examination of the broom plants in the affected area suggested that fire severity was highly variable, as could be inferred from their different degree of consumption (Notario et al., 2007), whereas herbs and small shrubs were entirely burned.

2.2. Field work

The geographical location of the wildfire and the sampling grid are shown in Figs. 1 and 2. Once the fire perimeter was traced in the field using a GPS device, a regular 45-point sampling grid was designed to determine the location of sample collection. Sampling sites were located in such a way that two adjacent sites were separated 40 m in longitude and 50 m in latitude. Thirty-six sampling sites were located inside the fire perimeter and the remainder in the adjacent area around it. Surface (0–5 cm in depth) soil samples were gathered after removing the coarsest charcoal fragments and/or plant debris and stored in plastic bags. Ashes, if present, were collected together with the burned soil. The samples were then air-dried for 48 h and sieved to pass a 2-mm mesh. Four samplings were carried out 3, 8, 12, and 15 months after the fire event.

2.3. Laboratory analysis

Soil:water extracts were obtained after adding 25 ml of distilled water to 5 g of sieved soil, and a shaking-centrifuging-filtering sequence, as previously described by Marion et al. (1991) and Notario et al. (2007, 2008). Chloroform (0.5 ml) was added to the extracts to prevent microbial growth.

The following properties were measured in the extracts: pH and electrical conductivity (EC) with suitable electrodes (Radiometer PHM-82 and CMD210, respectively), NH_4^+-N and P by UV–VIS spectrophotometry, measuring the absorbance of the respective complexes with potassium iodine mercuriate (Nessler reagent, Jackson, 1958)