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Using thermal analysis to evaluate the fire effects on organic matter content of Andisols

J. Neris (1,2*), J.M. Hernández-Moreno (2), C. Jiménez(2), M. Tejedor(2)

(1) Swansea University, College of Science, Department of Geography, Swansea SA2 8PP. W Glam, Wales
(2) Departament of Soil Science and Geology, University of La Laguna. Astrófisico Fco. Sánchez Av 38071. La Laguna, Spain
*Corresponding author: jneris@ull.edu.es

Keywords

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Abstract

Soil organic compounds play a relevant role in aggregate stability and thus, in the susceptibility of soils to erosion. Thermal analysis (N_2 and air) and chemical oxidation techniques (dichromate and permanganate oxidation) were used to evaluate the effects of a forest fire on the organic matter of Andisols. Both thermal analysis and chemical methods showed a decrease in the organic matter content and an increase in the recalcitrance of the remaining organic compounds in the burned zones. Thermal analysis indicated an increase in the thermal stability of the organic compounds of fire-affected soils and a lower content of both labile and recalcitrant pools as a consequence of the fire. However, this decrease was relatively higher in the labile pool and lower in the recalcitrant one, indicative of an increase in the recalcitrance of the remaining organic compounds. Apparently, black carbon did not burn under our experimental conditions. Under N_2, the results showed a lower labile and a higher recalcitrant and refractory contents in burned and some unburned soils, possibly due to the lower decomposition rate under N_2 flux. Thermal analysis using O2 and the chemical techniques showed a positive relation, but noticeable differences in the total amount of the labile pool. Thermal analysis methods provide direct quantitative information useful to characterize the soil organic matter quality and to evaluate the effects of fire on soils.

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1 INTRODUCTION

Thermal analysis techniques have been widely used to study the mineral composition of soils, whereas their application to the organic compounds has been less common (Plante et al., 2009). In general, Andisols are characterized by high organic matter contents due its stabilization (by aggregates or organometallic complexes). However, this property may be widely affected by the occurrence of forest fires. Some authors have reported that wildfires usually produce a loss of organic matter and changes in its composition (De la Rosa et al., 2008, Duguy & Rovira, 2010) but there are not many studies carried out on Andisols.

2 OBJECTIVES

The main objective of this work is to study the effect of fire on organic matter pools of Andisols by means of thermal and chemical analysis.

3 METHODS

3.1 STUDY AREA AND FOREST FIRE DESCRIPTION

The study zone is located on the north side of Tenerife (27° 55’ and 28° 35’ N and 16° 05’ and 16° 55’ W), between 950 and 1250 masl Soils are mostly Andisols (Soil Survey Staff, 1999). A forest fire broke out in the north of the island on 30 July 2007, burning nearly 17,000 ha (Figure 1).

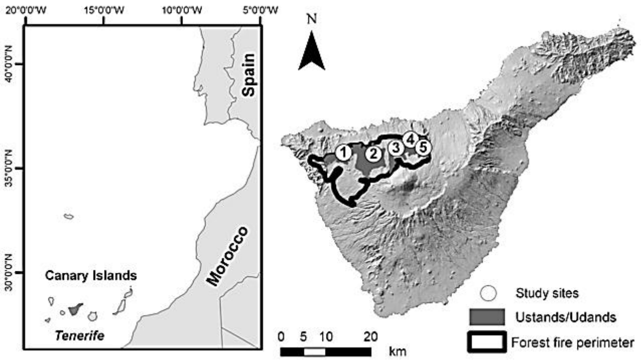

Figure 1. Location of the island of Tenerife and study sites.

3.2 EXPERIMENTAL DESIGN

Five sites were selected (Figure 1) all over Andisols, (Ustands/Udands) and under Canarian pine forest. Each site consisted of an unburned zone (U1 to U5) and a burned one (B1 a B5).

3.3 SOIL ANALYSIS

Three bulk soil samples were collected from the upper 5 cm at each zone. Thermal analysis (DTA and TG) was carried out by heating at 10 ^{o}C min^{-1} from room temperature to 900 ^{o}C under: flowing air and N_2. Soil organic C (SOC) was determined by dichromate oxidation (Walkley & Black, 1934). Active carbon (AC) was measured by permanganate oxidation (Weil et al., 2003).

4 RESULTS AND CONCLUSIONS

The main characteristics of the soil thermal behaviour in air and N_2 are summarized below for different temperature ranges. In figures 2 and 4, representative thermograms are depicted.

4.1 THERMAL ANALYSIS IN AIR: 50-200 ^{o}C

According to the DTA thermograms (Figure 2), an endothermic process occurs at this temperature range, related to the loss of adsorbed water. DTG curves show an endothermic peak (Endo0) at about 100 ^{o}C (82.7 ± 5.4 ^{o}C). No differences were observed in temperature peaks and soil weight loss between unburned (1.3 ± 0.2 %) and burned zones (1.2 ± 0.2 %). As expected, statistical analysis suggests that Endo0 is correlated to the content of clay and silt, but no other relations were found (Figure 3).

4.2 THERMAL ANALYSIS IN AIR: 200-380 ^{o}C

Thermograms (Figure 2) indicate the presence of an exothermic peak (Exo1) at a temperature about 330 ^{o}C (333.2 ± 31.3 ^{o}C). Its presence has usually been ascribed to the burning of labile organic matter (Plante et al., 2009; De la Rosa et al., 2008). This first exothermic event decreases or almost disappears in burned samples

As other authors have reported (Duguy & Rovira, 2010), temperature peak increases in burned soils (353.7 ± 32.3 ^{o}C) compared to unburned ones (312.7 ± 10.8 ^{o}C). This may be due to the increased stability of the organic compounds. Soil weight loss is noticeably higher in unburned soils (12.5 ± 1.2 %) than in burned ones (6.7 ± 1.8 %). This result represents a total and relative decrease in the amount of labile carbon of burned samples as a consequence of the fire action. Regression analysis shows that the weight loss in the labile peak is related to both the AC and SOC.

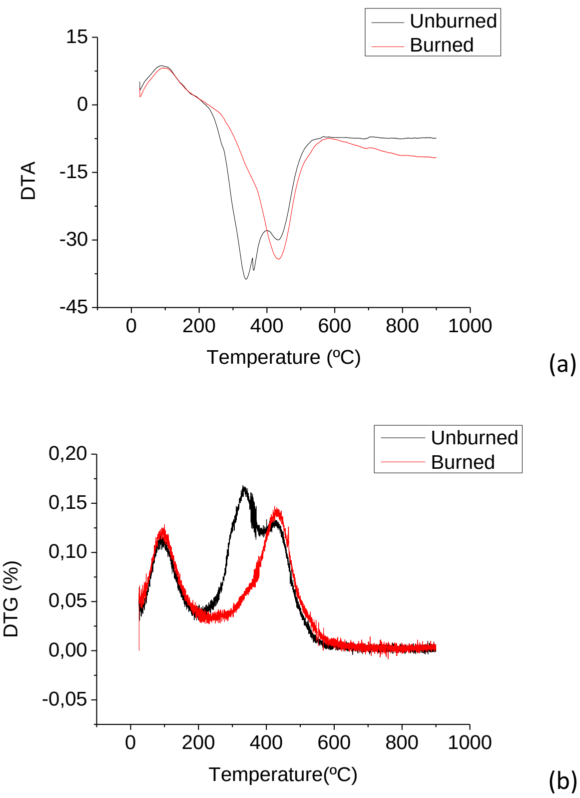

Figure 2. Example of air DTA (a)and DTG (b)thermogrames.

4.3 THERMAL ANALYSIS IN AIR: 380-500 °C

The presence of an exothermic peak at a temperature about 400 °C (406.5 ± 23.2 °C) is observed. This peak has generally been attributed to the loss of recalcitrant organic matter (Plante et al., 2009; De la Rosa et al., 2008). According to other authors (Duguy & Rovira, 2010), temperature peak decreases in burned soils (413.5 ± 29.0 °C) compared to unburned ones (399.4 ± 15.5 °C) although a large variation in the results were observed. Soil weight loss is slightly higher in unburned soils (7.6 ± 1.4 %) than burned ones (6,1±2,6 %). However, its relative amount is clearly lower in unburned soils (35.7 ± 3.1% and 43.8 ± 10.1% of the weight loss in unburned and burned soils). These results show the decreased in organic matter content, but also an increased recalcitrance of the organic compounds in the burned soils. Statistical analysis shows that the sum of the weight loss in the labile and recalcitrant peak is related to SOC.

4.4 THERMAL ANALYSIS IN AIR: 500-900 °C

Some authors have reported the presence of a third exothermic peak in the region of 500-650 °C related to the most thermal stable organic matter such as black carbon (De la Rosa et al., 2008). In this study this region was extended to 900 °C to incorporate a shoulder observed in N_2-DTG curves which arose from 600 to 900 °C. Thermal analysis under air showed no peaks in this region and soil weight loss was less than 1% on average which involves only the 5% of the soil loss. Apparently, black carbon did not burn under our experimental conditions. No statistical relations were found between this peak and the analysed soil properties.

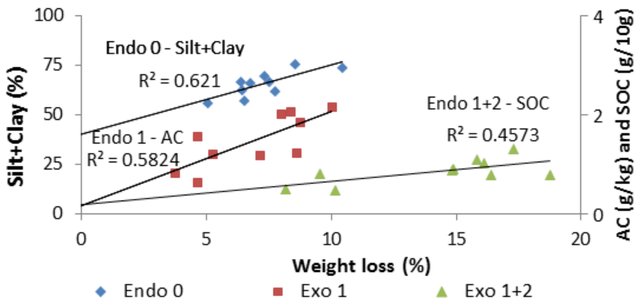

Figure 3. Relation between DTG and soil properties.

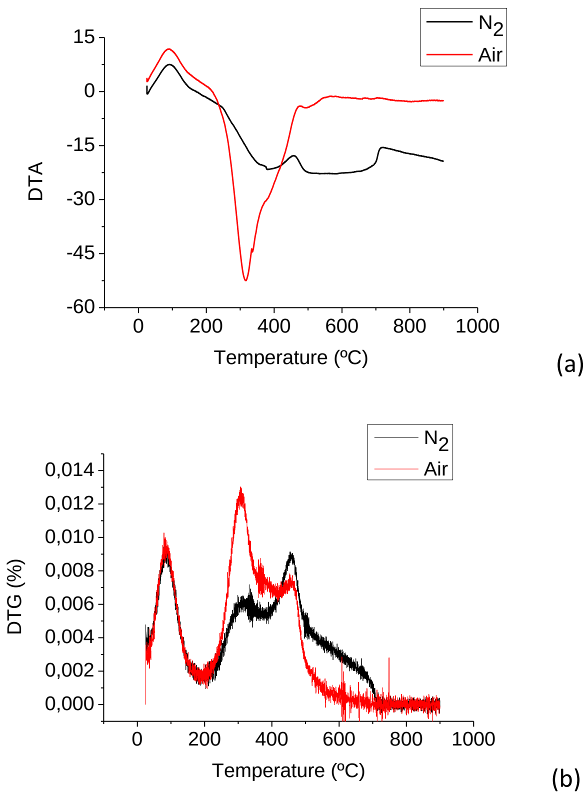

Figure 4. Example of air DTA (a)and DTG (b)thermogrames.

4.5 DIFFERENCES BETWEEN AIR AND N_2 THERMAL ANALYSIS

Peak temperatures shifted to higher values in Endo0, Exo1 and Exo2. Specifically, temperature increased by 28.5 °C in Exo2 in unburned and 43 °C in burned soils. This result suggests an increase of thermal stability under N_2 of the labile and especially the recalcitrant pool. In general, the total weight loss in the range 50-900 °C under air and N_2 fluxes is similar. However, data shows a redistribution of the organic pools comparing N_2 and air methods. Air DTG shows a higher labile pool than N_2 curve. This difference is counteracted by an increase in recalcitrant and refractory pools in burned and some unburned soils. In the remaining unburned soils, N_2 DTG curves show an increased of the refractory pool content that counteracts the decrease in the labile pool. This change can explain the shoulder observed in the 500-900 °C temperature range of some unburned soils (figure 3). The chemical and physical protection of organic matter in the aggregates of unburned soils and the lower decomposition rates under N_2 compared to air could explain why some labile compounds behave as refractory in N_2 thermal analysis.

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