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Application of thermal analysis to measure the spatial heterogeneity of organic matter degradation after wildfire: implications for post-fire rehabilitation treatments

Agustin Merino (1), M. Teresa Fonturbel (2), and Jose A. Vega (2)

(1) Departament of Soil Science and Agricultural Chemistry, Escuela Politécnica Superior, University of Santiago de Compostela, Spain, (2) Forest Research Centre, Consellería de Medio Rural. Xunta de Galicia. P.O. Box 127. 36080. Pontevedra, Spain

Severe wildfires can cause drastic changes in SOM content and quality with important implications for soil conservation and global C balance. Soil heating usually leads to loss of the most labile SOM compounds (e.g. carbohydrates, lipids and peptides) and to generation of aromatic substances. However, these fire-related damages are not uniform over large areas, because of the spatial heterogeneity of different factors such as fire type and environmental conditions. Rapid diagnosis of soil burn severity is required to enable the design of emergency post-fire rehabilitation treatments.

The study was conducted in soils from NW Spain, an Atlantic-climate zone that is particularly prone to wildfires. Intact soil cores (forest floor and uppermost mineral soil layer) were taken from a soil developed under granitic rock and subjected to experimental burning (in a bench positioned at the outlet of a wind tunnel). Soil temperature during fire was monitorised and five visual levels of soil burn severity (SBS) were recorded immediately after fire. Solid-state 13C CP-MAS NMR spectroscopy analyses were performed in an Agilent (Varian) VNMRS-500-WB spectrometer. The samples were analyzed by differential scanning calorimetry and thermogravimetry (TGA/DSC, Mettler-Toledo Intl. Inc.). The analyses were performed with 4 mg of samples placed in open aluminium pans under dry air (flow rate, 50 mL^{-1}) and at a scanning rate of 10 ºC min^{-1}. The temperature ranged between 50 and 600 ºC.

In the organic layer, the temperature reached during fire influenced the formation and characteristics of charred material. These materials showed an increasing degree of carbonization/aromatization in relation to the increase of temperature during burning. Burning also led to compounds of higher thermal recalcitrance (increases in T50 values -the temperature at which 50% of the energy stored in SOM is released-). However, values recorded in some samples were lower than those measured in highly polycondensed aromatic compounds.

In the mineral soil, large reductions in SOM content were found in both moderate and high SBS (up to 70 %), whereas important effects on SOM quality were only associated with high SBS. NMR analysis revealed these changes as losses of O-alkyl, alkyl and carboxylic structures and increases of the aromatic structures (up to 50 %). In both organic and mineral soils the DSC analysis revealed decreased combustion heat released up to 375 ºC, and increased T50.

Relationships between thermal properties and chemical-shift regions in the NMR helped provide a better understanding of SOM quality after wildfire. The results also show that thermal analysis can be used as a rapid tool to assess the different degrees of SOM degradation, in areas where the complex heterogeneity of the fire damage requires different emergency post-fire rehabilitation treatments.