Origin and dynamics of some labile and stable carbon fractions in the subsoil of French forests: the case of particulate organic matter and pyrogenic carbon

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In temperate forests, soils contain a significant part of the ecosystem carbon (C) stock that can be subjected to C losses upon global changes. In forest soils, particulate organic matter (POM) is a major contributor to the labile C pool and its dynamics can significantly influence the overall total soil organic carbon stock. At the same time, pyrogenic carbon (PyC) is ubiquitous in forest ecosystems and is considered to be part of the more stable C fraction. PyC may leave the soil surface where it forms or is deposited, either through degradation or transfer within the profile, where it can contribute significantly to POM. Both PyC and POM have been overlooked in the subsoil.

We isolated the POM fraction of both the mineral topsoil (0–10 cm) and subsoil (40–80 cm) of 52 French forest sites, using a size- (> 50 μm) and density- (< 1.6 g·cm−3) fractionation scheme. These sites presented a diversity of soil class (dystric Cambisol, eutric Cambisol, entic Podzol) and vegetation type (deciduous, coniferous). First, we determined the POM chemical composition and thermal stability using elemental analysis and Rock-Eval thermal analysis. In a 22 forest sites subset, we estimated the quantity and molecular composition of PyC in both the topsoil and subsoil with the benzene polycarboxylic acids (BPCA) method. Then, we assessed how depth, soil class and vegetation type influenced POM chemistry and thermal stability and PyC quantity and quality in these temperate forest soils.

Depth, soil class and vegetation type were all important factors influencing POM chemistry and thermal stability. Variations in POM chemistry and increase in thermal stability with depth suggested different POM input sources for the topsoil and subsoil and an increased biogeochemical stability of POM in the subsoil. Compared with the POM fraction in dystric Cambisols or entic Podzols, POM in eutric Cambisols presented chemical and thermal properties suggesting that it was more decomposed, yet less thermally stable. These differences were mostly observed in the subsoil. POM from deciduous plots was significantly more thermally stable than from coniferous plots, suggesting a higher biogeochemical stability for POM in deciduous forest soils. While PyC content decreased with depth, its proportion to total soil organic carbon remained constant and even tended to increase. The BPCA pattern indicated that more condensed structures were found in the subsoil. Finally, POM thermal stability correlated positively to PyC proportion (Spearman = 0.76 and 0.58 in the topsoil and subsoil, respectively).

This study highlights the variations in POM chemistry and thermal stability existing within and among soil profiles and the role of depth, soil class and vegetation type in these variations. It appears that if POM can be regarded as a labile carbon fraction in soils, its lability varies depending on the ecosystem (soil, vegetation) and depth considered, and can also be influenced by the presence of PyC. The latter transfers through the soil profile, probably as soluble fraction, and tends to accumulate in the subsoil, specifically in Podzols.