Carbon flows by soil organic matter formation: A review based on 13C natural abundance

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Aggregation of mineral and organic particles is a key process of soil development, which promotes carbon (C) stabilization by hindering decomposition of plant and microbial residues. All microbial utilization and C stabilization processes lead to 13C fractionation and consequently to various δ13C values of organic matter in aggregate size classes, sand, silt, and clay-sized particles, as well as density fractions. Differences in δ13C within the aggregates and density fractions may have two reasons: 1) preferential stabilization of organic compounds with light or heavy δ13C and/or 2) stabilization of organic materials after passing one or more microbial utilization cycles, leading to respiring of 13C depleted CO₂ and heavier δ13C in remaining C. Assuming these two reasons, the new approach based on the natural differences in stable C isotopic composition between SOM fractions was proposed and tested on soils developed solely under C3 vegetation (arable, coniferous and deciduous forests) in boreal climate (Gunina and Kuzyakov, 2014). This approach assumes that: 1) 13C enrichment between the SOM fractions corresponds to successive steps of SOM formation; 2) 13C fractionation (but not the δ13C signature) depends mainly on the transformation steps and not on the C precursors. Consequently, 13C enrichment of SOM fractions allows reconstructing the SOM formation pathways. To prove these initial results we reviewed δ13C values of soils globally and focused on the i) estimation of the validity of this approach for soils developed under various climatic conditions and parent materials, and depending on fertilization, and ii) C flows not only between aggregate size classes and density fractions but also between various particle size classes of the soils (i.e. sand, silt, and clay) and iii) on revealing the intensities of natural 13C fractionation during the stabilization of litter C in aggregates, particle size classes, and density fractions. Results showed that density fractions were 13C enriched in the order: free particulate organic matter (POM) < light occluded POM < heavy occluded POM < mineral fraction, with the strongest increase between the light occluded and heavy occluded POM. The maximum 13C fractionation during stabilization of litter C in density fractions and aggregate size classes was < 2‰. Δ13C enrichment of the SOM fractions showed that the main direction of C flows within the aggregates and SOM fractions was from the macroaggregate-free POM to the mineral microaggregate fraction. Thus, despite some limitations, δ13C natural abundance approach based on 13C fractionation within individual steps of SOM formation is very useful and probably the sole approach to estimate C flows under steady-state without labeling.