

## Soil organic matter dynamics and isotopic studies

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The dynamics of soil organic matter (SOM) can be considered as well documented and quantified, when compared to that of other non living organic matter pools. The early-recognized role of SOM as a resource for food production has generated active research and modern experimentation as far back as the 18th Century. Furthermore, soil is of easy access, and the carbon fluxes entering the soil are of known nature and lend themselves easily to experimental control and isotope labelling. The current knowledge of SOM dynamics is synthesized in compartmental models such as those of Jenkinson *et al.* (1991) or Parton *et al.* (1993). Carbon dynamics in most soils of the world can be considered as having reached a near-steady-state regime, established between the continuous production of vegetal material, and its degradation by soil microorganisms. The models divide OM into discrete pools, which are essentially defined by their intrinsic life-times. Typically these pools are: easily metabolisable OM from plants and microorganisms (1–5% of soil C, life-time of a few months); coarse ligno-cellulosic remains from vegetal material (10–20% of soil C, 1–20 years); humified or preserved OM (40–90% of soil C, 10–200 years); long-life OM (10–50% of soil C, more than 1000 years). These models have a rather good local predicting value, but the empirical, quantitative knowledge of SOM dynamics they contain is still not fully related to the qualitative knowledge of carbon transformation in soils. The examination of these models thus raises important unresolved questions.

The first set of questions concern the state of OM in soils and the processes of its transformation. The reality of these pools is clearly assessed on a kinetic point of view, but still partly escapes to the physical identification. For instance two pools can be considered as not well characterized. The first is the most 'labile' one (with a life-time of a year or less), whose biodegradation governs the cycling of nutrients and ecosystem productivity. The other is the most stable pool of soil carbon (with a life-time of 1000 years or more). This pool defines by difference the pool that exchanges carbon with the atmosphere at the global change time-scale. Isotope tracers studies are necessary, if not inevitable, for the

investigation of the nature of these pools. In the last years, two isotopic techniques appeared of considerable interest to reach this goal. On one hand, the 'natural  $^{13}\text{C}$  labelling technique', which uses the natural difference in  $^{13}\text{C}/^{12}\text{C}$  between C4 plants and C3 plants, allowed the measurement of the age distribution of soil carbon and any separable fractions (Balesdent and Mariotti, 1996). On the other, the AMS  $^{14}\text{C}$  technique offered the possibility to follow the progressive incorporation of thermonuclear  $^{14}\text{C}$  between the 1950's and present on archived soil samples (Trumbore and Druffel, 1995). These techniques have allowed a good quantification of the different pools and of their life-times, but no clear and unique proposition of identification or separation has emerged. At present these methods can be coupled with chromatographic separation of either pyrolysis, oxydation or extraction products, and allow the investigation of soil carbon age distributions *at the molecular level*. New hopes can thus be put in the molecular characterization, if relevant, of SOM dynamics pools.

The second set of questions concern the forces that drive SOM dynamics. Many factors have been suggested as affecting SOM life-time, but have still not been hierarchised. Beside the effects of soil temperature, moisture, texture and nutrients, there is still a high variability of either SOM storage or SOM life-time, which has to receive mechanistic explanation. The amount of stable SOM for instance appears dependent on soil pedological characteristics: it varies from more than 50% of topsoil C in Mollisols to less than 10% in some Inceptisols or Spodosols. Similarly, cultivation is able to decrease SOM life-times by as much as one order of magnitude. The effects of soil minerals on OM protection, in interaction with pedoclimatic variables such as desiccation or aeration, or with land use, has been described for years under the vocable 'physical protection' of SOM (Oades, 1995). This old concept has been re-visited through modern methods (e.g. Golchin *et al.*, 1994 and Chenu *et al.*, this volume) and a consensus arose from such studies: the fate of OM is intrinsically linked with its localisation within the clay matrix and with the fate of microaggregates wherein OM is occluded. The structure of this matrix

and the climatic forces that tend to disturb it would then be more important than the intrinsic nature of SOM to explain its life-time. The difficulties encountered in the chemical characterization of OM pools could thus be partly explained by the physical protection, along with the great variety of processes involved in SOM transformation.

Further progress in the knowledge of SOM dynamics requires multiple techniques. It is easily predictable that this progress will arise from joined research efforts on common sites, which may ideally gather long term experiment data and samples, known carbon inputs, artificial and natural isotope labelling techniques.

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