POTENTIAL USE OF THE NATURAL ABUNDANCE OF STABLE CARBON ISOTOPE (^{13}C) FOR SOIL ORGANIC MATTER TURNOVER

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Soil organic matter (SOM) is essential for soil ecosystem function and services. Turnover of SOM is important for increasing soil organic carbon (SOC) stock and stabilizing climate. Soil organic matter is composed of soil microbes, decaying material from dead plant and animal tissues, fecal material, and products formed from their decomposition. The levels of SOC influenced by the interactive effects of a series of ecosystem processes, of which photosynthesis, respiration, and decomposition play key roles. The ratio of carbon isotopes ^{12}C, ^{13}C, and ^{14}C, which differs in natural materials, can be used to trace the pathway and flow of carbon in the global C cycle from the atmosphere to vegetation, soil organic carbon pool, and the soil biota with the use of either natural abundance of ^{13}C or labeling methodologies (Figure 1).

Photosynthesis is fixation of atmospheric CO_2 into plant biomass. The SOC input rates are primarily determined by the root biomass of a plant but also include litter deposited from plant shoots. Soil C results directly from the growth and death of plant roots and indirectly from the transfer of carbon-enriched compounds from roots to soil microbes.

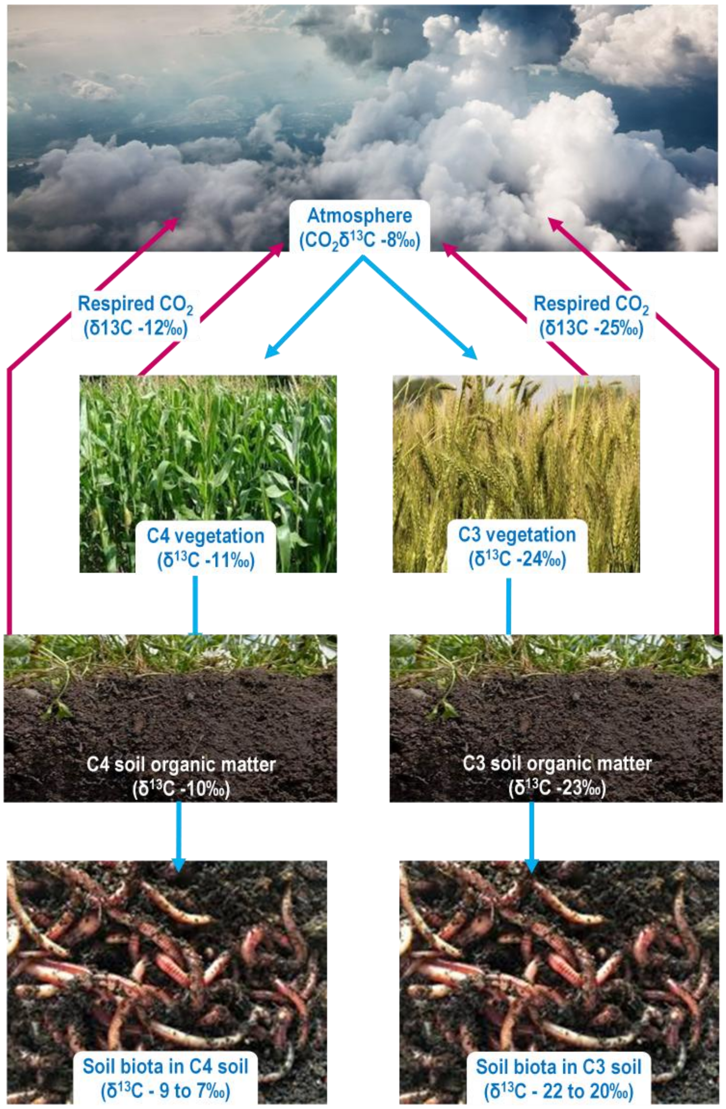

Figure 1. Schematic diagram depicting the distribution and variation of $\delta^{13}C$ values in the terrestrial ecosystem and atmosphere, the C3 and C4 vegetation represent wheat and maize, respectively.

Plant C inputs are the primary energy source for microorganisms. Through microbial processing and assimilation, they can be converted into microbial-derived C. This microbial-derived C can be physically protected in organo- mineral associations because of its close proximity and interactions with the soil mineral matrix. Therefore, it tends to be more stable than the unprocessed plant-derived C. Microbial products of decomposition, mainly from necromass and other by-products, contribute significantly to stable SOC. Therefore, partitioning SOC into the plant and microbial-derived C aids our understanding of the C formation pathways and the mechanisms of SOC stability/ persistence.

Soil organic carbon is the largest pool of terrestrial ecosystems and significantly affects global carbon cycling (Lal, 2004). The carbon dioxide (CO_2) derived from soil organic matter (SOM) decomposition is an important source of atmospheric CO_2. The CO_2 released from soil respiration enriches ^{12}C while the residual SOM enriches ^{13}C, relative to the substrate, because of carbon isotopic fractionation during SOM decomposition. Consequently, the isotopic fractionation affects the carbon isotope composition of atmospheric CO_2 because the released CO_2 finally goes into the atmosphere. Scientists who study global change incorporate carbon isotope data for tropospheric CO_2, derived from an international network of stations, into atmospheric circulation models. This step is used to calculate global carbon balance and analyze atmospheric carbon source/sink positions and quantities. Thus, understanding carbon isotope fractionation during SOM decomposition can help scientists to use carbon isotope data for atmospheric CO_2 in their studies of global carbon cycling.

The significant advantage of natural abundance methodologies is that studies can be carried out directly on samples collected from an experimental site. The prospects of using stable isotope of carbon (^{13}C) are listed below.

1. Priming effects on labile and stable soil organic carbon decomposition: The priming effect, which can be defined as the change in the mineralization of native SOM due to exogenous addition of substrates, has been observed in many studies (Lenka et al., 2019). Using ^{13}C labeled substrate or natural abundance of ^{13}C is the most widely used promising method for partitioning the total respired CO_2 into C derived from the substrate and native SOC.
2. Carbon use efficiency and storage in terrestrial ecosystems: stable isotope of C (i.e. ^{13}C) is used to quantify the plant and microbial carbon use efficiency. That may then translate to soil carbon storage.
3. Assessing soil carbon sequestration under climate and land-use variation.
4. The natural abundance of ^{13}C helps quantify the carbon sequestration pathways in arable lands.
5. Tracing of SOM stabilization pathways in aggregates under different soil management.
6. Temporal dynamics and vertical distribution of newly-derived carbon from a C3/C4 conversion in different land use.
7. Priming effects induced by glucose and decaying plant residues on SOM decomposition:
8. Stable isotopes of carbon and nitrogen help predict the belowground communities at a regional scale.
9. Mean residence time (MRT) of soil organic carbon under different soil management (e.g., residue, nutrient and irrigation).
10. It is an important tool to understand the deep soil carbon dynamics.
11. Carbon isotopes enable studying the soil ecosystem processes by tracing the flow of carbon, which will significantly improve the process-based biogeochemical carbon and nitrogen models used for predicting future climatic change.

Instrument Essential for Conventional Isotopic Analysis: Isotope Ratio Mass Spectrometer (IRMS) allows the accurate measurement of even minute differences in the abundances of different isotopes like $^{2}H/^{1}H$, $^{13}C/^{12}C$, $^{15}N/^{14}N$, and $^{18}O/^{16}O$. It is a specialized technique used to provide information about substances' geographic, chemical, and biological origins. However, recent advancements in science and instrumentation have enabled compound-specific isotope analysis using GC-IRMS (Gas chromatography-IRMS) to answer more precise questions in functional soil ecology. In conclusion, the use of stable isotopes should help to identify the keystone groups of soil biota involved in carbon fluxes to and from the soil and to quantify these carbon fluxes, which can then be implicitly included in global circulation models used for predicting climate change.

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