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So often over the past decades soil biologists have been faced with this difficult question: what have all the hours of research and the vast number of papers actually achieved for the benefit of agriculture and the stewardship of the environment? If you are a nitrogen fixing person, a phytopathologist or, nowadays, a bioremediationist you may have had a ready answer but, more often than not, the response involved bluster and hand waving and rather vague references to soil fertility, the source of useful microbes, and a better understanding of the processes that underpin 'life as we know it'. Not any longer! Soil biology researchers have found a cause: carbon dioxide, temperature and soil organic matter.

Variations in soil carbon sinks, pools and fluxes are likely outcomes of climate change. In addition, any increases in plant growth as a consequence of elevated atmospheric CO_2 levels and temperatures will impact on plant quantity and composition, plant litter deposition and decomposition, and a plethora of belowground biological activities. The local, national and global cycling of carbon and other essential elements has become of widespread and urgent concern as the climate shifts and the capacity of soil to act as a buffer is threatened. As a result, the multitude of biological factors that contribute to carbon, nitrogen and other biogeochemical cycles are under close examination; if ever there was a subject that needed high quality research and clear thinking this is it.

About 75% of the earth's organic C is contained in plant residues and soil organic matter (SOM). The plant material is subject to mineralization, initially targeting the sugars (e.g. glucose, fructose) and then, after the generation of extracellular enzymes, the cellulose, hemicelluloses and pectin. The soluble products of depolymerisation are transported into bacterial and fungal cells and metabolised. The direct outcomes of all this are increases in microbial biomass and activity and CO_2 evolution. The indirect effects are just as important: the generation of plant nutrients and the maintenance of constant fluxes of carbon and nitrogen in the biosphere.

Organic additions to soil can arise from micro- and macro-fauna and dead microbial cells as well as crop residues, compost, sewage sludge, etc. Another major and fairly constant input derives from growing plants and is comprised a vast number of root exudates. As a consequence, rhizosphere microbial enrichment is a major and ongoing contributor to flushes of activity measured in the root region. Of course, these surges may be short-lived and cease once the labile carbon has been metabolised. Furthermore, at a root zone scale, the flush may be closely associated with the growing root and, therefore, moving in space as the plant penetrates the soil. Whether these common events will eventuate in increased SOM decomposition is another matter and is the central theme of this Citation Classic redux.

In contrast to 'new' organic additions, native SOM is highly recalcitrant. This is because much of it has been derived from the partial degradation of lignin and the chemical and biological condensation of the aromatic products, as well as the synthetic activities of the microbial biomass that produce humic-like substances such as melanins. SOM also complexes and stabilises non-aromatic organics and is often bound to soil clays and sesquioxides and trapped within domains and aggregates that further enhance its longevity. The constancy of the SOM is important for all sorts of the chemical, physical and biological properties of a healthy and fertile soil. SOM also represents a long-term repository for carbon and nitrogen and the many factors that contribute to its turnover have occupied the literature for decades. Today, in our changing climate world, the importance of these processes is writ large: any shift towards persistent SOM carbon and nitrogen becoming a short-lived pool subject to flux is of great significance.

Soils that have been enriched as a result of fresh organic matter inputs have undergone changes in microbial numbers, diversity and function. The processes that give rise to the degradation of the more resistant of the plant residues will have been induced and up-regulated and there will be an increase in a large number of extracellular enzymes (some of them persisting long after the cell that produced them has re-assumed its resting state). The bacteria and fungi are said to have been 'primed' and once the new substrates have been exhausted may turn their attention to the mineralization of the otherwise persistent SOM. Comparing the release of CO_2 from labelled organic additions with that arising from native SOM breakdown gives a clear indication if any changes have been brought about by priming.

One projected outcome of the increase in CO_2 in the atmosphere is that plants will grow faster and bigger and that eventually the additional carbon will be sequestered in soil organic matter. Even if

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there were a strong priming effect it would be temporary and any increase in respiration losses would be offset by the accumulation of SOM. The counter argument is that the priming effect will enrich a microbial community that will then decompose the SOM and mineralise the stored C (and, of course, generate more CO_2). So, research aimed at distinguishing the many factors that lead to carbon and nitrogen deposition in soil and the constancy of the SOM pool is a hot and controversial topic.

There is no denying that priming is a complex process and the results are varied and inconclusive. Some report no long-term changes in the SOM carbon reservoir, others that any loss is counterbalanced by additional inputs, whilst still others observe an actual increase in the sequestered carbon. Not surprisingly, plant species, age and health, the presence of mycorrhizae, pollutants, soil type, management, and climatic factors are highly influential as is the C:N ratio and the availability of all other micro- and macronutrients. Quantifying the various processes is further complicated (if that were possible!) by the recent suggestions that rhizodeposits and SOM are transformed by soil chemical and physical factors and that the affect of the microbial biomass may be less, in some circumstances, than previously assumed.

The biogeochemical and climate cycle modellers are well aware of the debate about the predicted changes to the SOM component of biosphere carbon. For the last half-century many mathematical models that attempt to describe the processes contributing to the dynamics of C and N flux have been developed. With predictions of further increases in atmospheric CO_2 as well as more frequent wetting and drying cycles and elevated temperatures, it is imperative that the modelling of the dynamic, complex and chaotic processes be based on sound science if it is to inform opinion and policy with regard to the impacts of climate change.

Ten years ago Yakov Kuzyakov, Jürgen Friedel and Karl Stahr published a review paper on the mechanisms and measurements of the priming effect. This was a phenomenon that had been mentioned intermittently in the literature since the 1920s, had a surge of interest in the late 1940s (Francis Broadbent and others) and, in the early 1950s, Bill Martin and his colleagues dubbed the process 'priming'. After this things went relatively quiet until the mid-1980s when papers by Jenkinson and the Rothamsted group redefined the process and interests in soil carbon and nitrogen fluxes and the processes involved took a giant leap forward. It is a measure of the increasing importance of the topic that 70% of the citations of the Citation Classic paper discussed here have come in the last five years and almost 60 in the last 12 months.

All three authors of the original paper have had (and continue to have) prominent and highly influential careers in soil science. Yakov Kuzyakov is now Professor for Agroecosystem Research at the University of Bayreuth having moved there in 2006 after a journey that took him *via* Moscow, Halle, Berlin, Hohenheim, Santa Cruz, Bangor and Müncheberg. He has an international presence and strong research contacts and collaborators in the U.K., U.S.A.' Russia and France. Yakov is also a frequent traveller to China where he holds a visiting professorship at the Chinese Academy of Sciences in Beijing.

Jürgen Friedel is currently Associate Professor at the University of Natural Resources and Applied Life Sciences in Vienna where his research activities are focussed on understanding the key contributors to soil fertility in order to inform and facilitate the optimisation of soil management in organic farming.

Karl Stahr has been at the University of Hohenheim since 1988 after periods in Berlin and Freiburg. He is Professor of Soil Science and Petrology and his research on soil genesis and mineralogy, land evaluation, aspects of the carbon and nitrogen cycle, and recycling of organic waste has established his prominent international reputation. His influence, and indeed presence, has been felt in parts of the world that reads like a gazetteer: Brazil, Ecuador, Argentina, Spain, Portugal, Egypt, Israel, Turkey, China, Somalia and Vietnam (the list goes on). His stamina (and frequent flyer miles) is the envy of many!

The subject of priming and its consequences has been, and continues to be, controversial and the subject of heated debate. The mechanisms are complex and the carbon, nitrogen and energy availability of various substrates, the biotic and abiotic drivers, the shifts between fast- and slow-growing microbes, and the possibly sequential impacts of r- and K-strategists in the decomposition of both fresh organic matter and SOM, are all discussed by Yakov Kuzyakov in this latest Citation Classic article.

The paper discussed in the article that follows is: Kuzyakov, Y., Friedel J.K., Stahr K. 2000. Review of mechanisms and quantification of priming effects. *Soil Biology & Biochemistry* **32**, 1485–1498. (cited 318 times).