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Preface

Preface: Special issue SOM 2015

1. Introduction to the special issue Soil Organic Matter 2015: From structure to functions

Soils around the world are spatially heterogeneous environments that contain approximately 2300 Gt of carbon in various forms (Stockmann et al., 2013). As such, they represent the world's most important terrestrial carbon sink that exceeds the amount of carbon stored in phytomass and the atmosphere (Scharlemann et al., 2014). At the same time, soils are the central resource for food production of a rapidly growing world population (McBratney et al., 2014). To better predict soil organic matter (SOM) storage and turnover, but also to safeguard the productivity of soils as a natural resource, we need a comprehensive understanding of SOM nature, function, turnover, and stabilization. Therefore, we cannot overstate the need of novel approaches that pay particular emphasis on SOM vulnerability to agricultural management practices (i.e. tillage, crop selection, erosion control, biochar as soil amendment etc.), forestry and to climate change.

In 2007, the first International Symposium on Soil Organic Matter was held in Poitiers, France, followed by meetings in Colorado Springs (USA, 2009), Leuven (Belgium, 2011), and Nanjing (China, 2013). Since the symposium in Poitiers, fundamental progress has been made concerning cutting edge techniques to characterize the nature of organic matter and its sequestration in soils, leading to the novel perspective that SOM cycling and stabilization is mainly an ecosystem property (e.g. Sollins et al., 1996; Schmidt et al., 2011). However, a comprehensive understanding of SOM dynamics in terrestrial ecosystems remains still challenging due to the complex interactions of biogeochemical and physicochemical processes controlling of SOM stabilization and turnover at different spatial and temporal scales. In an effort to bring together scientists working on different aspects of this important topic, the 6th Symposium on Soil Organic Matter was organized in Göttingen in 2015. This special issue highlights important work presented during this symposium, as well as research developed as a result of the ensuing scientific discussion.

2. Overview of the special issue: Novel insights in soil organic carbon dynamics, cycling and storage

Organic matter significantly affects water holding capacity, nutrient cycling (especially nitrogen, phosphorus, sulphur and micronutrients), aggregate stability, and buffering capacity of agricultural soils (Rao et al., 2017). Sustainable management of SOM resources in agroecosystems is therefore a decisive factor to maintain or even increase the productivity of soils to meet the increasing demand for food and fodder and to ensure food security in future (Rao et al., 2017). Major sources for C and nutrients in agricultural soils are rhizodeposition, manure and mineral fertilization. In addition, above- and belowground biomass, remaining after harvest or incorporated as mulch, contribute quantitatively to organic matter input. Hence, several articles in the special issue focus on residue amendments (above- and/or belowground) and nitrogen (N) fertilization practices in agricultural soils to increase SOM storage, and to decrease greenhouse gas (GHG) emissions, and priming effects (PE). For Sub-Saharan soils under Sudano-Sahelian conditions, PE could not explain SOM losses after several additions of crop residues, and higher straw input rates did not induce additional PE (Yemadje et al., in this volume). Furthermore, SOM mineralization enhancement was also not explained by multiple rewetting events, only the first wetting cycle created a mineralization flush (Yemadje et al., in this volume). The authors concluded that SOM depletion in Sudano-Sahelian soils with wetting-drying cycles and crop residue addition is rather a consequence of rapid SOM and crop residue mineralization under optimal soil moisture conditions than an effect of repeated PE and/or mineralization flushes after rewetting. Moreover, the intensity of PEs does not appear to reflect differences in residue input quality (Shahbaz et al., in this volume). Priming effects were similar for leaf, stalk and root residues. Only at elevated addition levels, PE increased less for root residue addition compared to stalk and leaf amendment (Shahbaz et al., in this volume). Generally, the proportion of residues physically protected within aggregates and consequently SOM stabilization decreased with increasing residue input (Shahbaz et al., in this volume). The results of Meng et al., in this volume reveal that priming effects in intensively managed calcareous soils of northern China can be even more reduced when addition of maize straw is combined with N fertilization. The reasons behind this effect are not completely clear, yet. Ammonia toxicity, inhibiting microbial decomposers (Clay and Clapp, 1990), repression of white rot fungi degrading straw lignin by high N levels (Williams et al., 2016), immobilization of N during straw decomposition (Chen et al., 2014), and microbial N-mining (Craine et al., 2007) might be relevant mechanisms.

Addition of straw or organic fertilizers is of particular concern in flooded rice systems, as the supply of readily decomposable carbon significantly increases CH_4 emissions (e.g. Pisante et al., 2015). Since mineral nitrogen fertilization increases the activity of methane-oxidising bacteria, the use of organic manures in paddy soils is often recommended in combination with mineral N addition (e.g. Uprety et al., 2012). Tariq et al. (2017) tested different fertilization treatments of paddy soils (N fertilizer only, maize straw + N fertilizer, and maize compost + N fertilizer) in combination with two different water regimes (midseason drainage, and early + midseason drainage). While under midseason drainage alone, straw amendment

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resulted in significantly higher CH_4 emissions compared to compost addition, CH_4 emissions of straw and compost amended variants were comparable for early + midseason drained soils (Tariq et al., 2017) and at the same level as treatments with no organic amendments under midseason drainage alone. The observed large mitigation effect of early + midseason drainage implies that the addition of complex organic matter sources to paddy soils might not necessarily pose increased risk to the climate when careful water control and adequate drainage management is guaranteed (Tariq et al., 2017). Another study in this special issue focuses on the effect of maize and soybean residue amendments to the emission of the GHG N_2O from sole cropped and intercropped agroecosystems (Bichel et al., in this volume). Monoculture versus intercropping systems of soybean and maize had no effect on N_2O emissions, however, the amendment of both types of residues, maize and soybean, always significantly reduced the N_2O emissions.

At the same time as efforts are being made to deepen our understanding about sustainable management of SOM in agriculture, there is also ongoing research on SOM cycling and sequestration in forest, silvo-pastoral, and grassland ecosystems. Especially the properties and dynamics of SOM in deep soils has been largely ignored for a long time but receives increasing interest in recent years (Rumpel and Kögel-Knabner, 2011), as high proportions of total SOM stored within a soil profile may be found in subsoil horizons despite low SOM concentrations (Batjes, 1996; Jobbagy and Jackson, 2000). Moreover, SOM in deep soil horizons is characterized by mean residence times of up to several thousand years and consequently contributes especially to long term carbon storage (Rumpel and Kögel-Knabner, 2011). Wordell-Dietrich et al. (in this volume) compared temperature sensitivity of SOM mineralization and priming effects after C addition of top- and subsoils taken from a forest site 35 km north-west of Hanover, Germany. Temperature sensitivity of SOM mineralization decreased with soil depth, indicating that subsoil carbon will be less affected by climate change compared to topsoil carbon, a finding that is of special relevance for future soil organic carbon and climate modelling (Wordell-Dietrich et al., in this volume). Moreover, organic carbon inputs to a level of up to 80% of original carbon content in the deepest soil horizon did not lead to positive priming effects in the deepest soil horizon, most likely due to a larger spatial segregation between decomposers and substrate compared to topsoils. The results of Wordell-Dietrich et al. (in this volume) indicate that carbon inputs into subsoils with low SOM content may increase soil organic carbon storage more effectively than topsoil SOM amendments. In another study, Cappai et al. (in this volume) could clearly show that the spatial tree distribution in silvo-pastoral ecosystems such as Mediterranean cork oak grasslands considerably contributes to the establishment of SOM and SON hotspots. They found the mineral-associated SOM fraction over-saturated in direct vicinity of the trunks, while the mineral-associated fraction outside of the crow projection area was saturated only to 65%. Moreover, also the other SOM pools (fPOM, oPOM and water extractable OM) decreased from the trunk towards open grassland patches. This highlights the key role of single trees and their litter input for the formation of local SOM hotspots, soil organic carbon stabilization and nutrient storage.

Besides subsoil C storage, the effects of climate change on SOM turnover in cold, winter-frozen ecosystems are also discussed in this special issue. Kurganova et al. (in this volume) quantified the impact of altered snow depth profiles on soil CO_2 efflux. In total, the reduction of snow cover depth reduced the cold-season CO_2 efflux from soil up to 2.5 times.

Besides studies on SOM cycling and storage in agricultural, forest and grassland ecosystems, methodological advances in SOM research have been in the focus of the 6th Symposium on Soil Organic Matter. Two articles in this special issue deal with pre-treatment procedures of soil samples for accentuating nuclear magnetic resonance (NMR) or diffuse reflectance infrared Fourier transform (DRIFT) spectra. Pretreatment with hydrofluoric acid (HF) caused inconsistent losses of various soil organic carbon species from different soil and sediment samples that could not be linked to distinct properties of the respective samples (Sanderman et al., in this volume). For many samples the selective loss of certain soil organic carbon species reached a degree sufficient to bias the interpretation of the NMR results. Consequently, the authors recommend to carefully consider the physicochemical environment and putative mechanisms if HF is used to characterize the mineral-stabilized SOM. Yeasmin et al. (in this volume) compared HF treatment, sodium hypochlorite (NaOCl) treatment and dry ashing with subsequent spectral subtraction to accentuate organic bands in differential DRIFT spectroscopy. Using a set of contrasting soil types, they could prove that HF treatment was more effective than the two other techniques by providing mineral interference free spectra and least affected organic bands.

In summary, the ten articles in this special issue provide insight into current trends and developments in the study of SOM. We hope this special issue will inspire further research on SOM and look forward to the 7th Symposium on Soil Organic Matter in Rothamsted, United Kingdom in 2017.

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