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SPECIAL SECTION: MOLLISOLS DEGRADATION AND EVOLUTION UNDER DIFFERENT MANAGEMENT PRACTICES AND CLIMATE CHANGE

Foreword: Degradation and evolution of Mollisols under different management practices and climate change

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Mollisols are inherently productive and fertile soils that are extensively distributed on the steppes of North America, South America, Ukraine, and Northeast China. All of those regions are major grain production regions of the world. Mollisols have been undergoing anthropogenic soil degradation and dehumification (loss of stable aggregates and organic matter). They are suffering from acidification due to extensive cultivation without sustainable management and overuse of chemical fertilizers. The degradation of Mollisols could lead to dire environmental consequences, alter the relationships between agroecosystems and their environment, and affect the sustainability of agroecosystems. A comprehensive understanding of Mollisols' characteristics and resilience, evolution patterns, and their biotic and abiotic controlling factors is urgently needed. This knowledge will not only illustrate the current status and evolutionary properties in Mollisols but also provide a scientific basis for developing the theoretical foundation and practical management approaches to promote the development of soil and agronomic sciences. In the past few years, much attention has been paid to the protection and sustainable utilization of Mollisols around the world. Efforts are being dedicated to refining agricultural management practices and policies regarding ecosystem restoration. Agricultural management practices, such as reduced soil tillage, rational fertilization, crop rotation, and crop residue or livestock excreta management, enhance the sustainability and resilience of agroecosystems in Mollisol regions.

This special section of the *Soil Science Society of America Journal* includes eight peer-reviewed papers, with six field studies and two laboratory incubation experiments. Those papers address the biogeographic distribution of N-related microbes, and the current research on the effect of agricultural management practices on soil hydraulic properties, nutrient cycling, and biotic and abiotic mechanisms in Mollisol-based agroecosystems. Collectively, these articles provide a systematic understanding of the ecosystem characteristics and resilience, and C and N cycling patterns in Mollisol agroecosystems. They also identify controlling factors that will shed light on the optimization of sustainable management and utilization of Mollisols.

A brief summary of the studies in this special section is provided below:

- Denitrifiers control the stepwise reduction processes of NO_3^- to N_2 in global N cycles. Among these, the reduction

Abbreviations: AOC, aggregate-associated carbon; iPOC, intra-aggregate particulate organic carbon; OC, organic carbon; SOC, soil organic carbon; SOM, soil organic matter.

of NO_2^- to NO is the rate-limiting step, catalyzed by two types of nitrite reductases encoded by cytochrome cd1 NIR (*nir*S) and copper-containing NIR (*nir*K) genes. However, little research has been focused on the biogeographic distribution patterns and potential for niche differentiation of *nir*S and *nir*K at spatial scales. Based on 26 soil samples collected across the Black Soil zone of northeast China and high-throughput sequencing, the *nirS*-type and *nirK*-type community diversity, biogeography, assembly mechanisms, and taxa interactions were investigated (Hu et al., 2021). They found that environmental factors (especially soil pH) played a critical role in driving the biogeographic distributions of denitrifying communities across the Black Soil zone of northeast China. The assembly processes governing the biogeography of denitrifying communities were largely dependent on dispersal limitation, which was more remarkable in the *nirS* community. Moreover, soil acidification, with soil pH ranging from 4.0 to 4.5, simplified network structure and compelled denitrifiers to cooperate with each other in contrast with other soil pH ranges.

- Land use change highly influences soil organic C (SOC) fractionation and distribution in soil matrix. Conversion of cropland to grassland or forestland has the potential to sequester more C and change C allocation in varied C fractions. A 29-yr field experiment on Mollisols of Northeast China demonstrated that conversion of cropland to grassland and forestland increased OC accumulation in soil profiles, especially at the 0-to-40-cm depth (Hao et al., 2022). Long-term grassland restoration exerted greater impacts on the labile OC than recalcitrant OC fractions through larger OC inputs from plant roots. The labile OC fractions (dissolved OC, light C obtained from density fractionation) in 0-to-80-cm soil depth were significantly higher in grassland than in forestland and cropland. Meanwhile, land use effects on the recalcitrant OC fractions (heavy fraction, humic acid, and humin) were mainly observed in the 0-to-40-cm soil. Grassland restoration, with greater C sequestration potential and larger liable OC contents, may help improve soil quality more than forestland and cropland in this Mollisol region.
- Agricultural land use in the northern Great Plains of the United States has negatively affected soil health and associated ecosystem services through grassland conversion to cropland and a transition away from small-grain cropping systems to warm-season crops during the last 30 yr. Mitigating these effects requires the adoption of conservation practices. A study was carried out to quantify near-surface soil responses to crop diversity and intensity, cover crops, livestock integration under controlled experimental conditions, and land uses (dryland cropping vs. perennial agroecosystems) on a common Haplustoll soil in south-central North Dakota, USA (Liebig et al., 2022). They found that diverse and continuous cropping improved soil structure, nutrient supply potential, and biological habitat but increased soil acidification and soil NO_3–N accumulation under dryland cropping practices in the northern Great Plains. Cover crops had a negligible effect on soil condition and function, whereas livestock integration on cropland improved nutrient supply potential and biological habitat but impaired water intake into the soil. Compared with dryland cropping, soil conditions and functions were consistently improved under perennial agroecosystems.
- In the Argentinean Pampas region, decreasing physical quality of Mollisols has been observed due to simplified crop rotations. The effects of cover cropping management on soil water capture, transport, and storage as compared with different crop rotations with bare fallow were investigated in two different and representative Mollisols (one Typic Argiudoll and one Typic Hapludoll) of the Argentinean Pampas region (Villarreal et al., 2022). Cover cropping management in soybean [*Glycine max* (L.) Merr.] monocultures, as compared with crop rotations, increased the soil water capture only in Typic Hapludoll and improved the soil capacity of transport water in the Typic Argiudoll of the Argentinean Pampas region. Additionally, soybean monocultures reduced the soil's ability to capture, transport, and store water in Mollisols from the Pampas region, threatening their conservation function. The inclusion of cover cropping management during the fallow period in soybean monocultures could be an appropriate agricultural management strategy to improve water capture and transport in Mollisols of the Argentinean Pampas region, especially in a Typic Argiudoll.
- Soil tillage practices and the resulting increase in water erosion is one of the most important anthropogenic processes to drive soil nutrients and SOC turnover in agricultural land. A combination of field study and 30-d incubation experiment was conducted to explore the responses of surface soil nutrients and SOC turnover to different soil tillage and water erosion patterns in the Mollisol region of Northeast China (Li et al., 2022; Zhao et al., 2022). They found that water erosion played a greater role in controlling the distribution of dissolved OC than tillage erosion, whereas particulate OC distribution was more sensitive to tillage erosion. Mild erosion (averaging 17.4 t ha^{-1} yr^{-1}) could deplete microbial biomass and contribute to SOC mineralization, whereas intense erosion (averaging 54.6 t ha^{-1} yr^{-1}) may lead to a shift in microbial structure, thus promoting the dynamic replacement of SOC. In addition, soil tillage could promote the reaggregation of macroaggregates (>2 mm) by accelerating the turnover of the coarse (0.25–2 mm) intra-aggregate particulate OC (iPOC), leading to a lower concentration of aggregate-associated C (AOC). At the same time, runoff transformed larger aggregates

(>0.25 mm) into smaller particles (<0.25 mm) without catalyzing C turnover. Moreover, the fine (0.053–0.25 mm) iPOC was positively correlated with AOC within >1-mm soil aggregates for both soil tillage and runoff, suggesting that the loss of AOC during soil C turnover can be indicated by the changes in fine iPOC content.

- Crop residue return can prevent the degradation of cropland caused by conventional tillage practices in Mollisols. Meanwhile, additional N input from crop residue inevitably changes soil N pools. A 16-yr field experiment was conducted to evaluate soil N storage changes and the distribution of N in soil physical fractions in the Mollisol region of Northeast China (Zhang et al., 2022). The concentration of total N in bulk soil and physical fractions (light fraction, sand, silt, and clay) was measured. They observed that the distribution of N storage changes in physical fractions under residue return was affected by different tillage practices and cropping systems. In the 0-to-5-cm layer, total N content was higher in no-tillage than in moldboard plow, whereas the result was the opposite in the 10-to-20-cm layer. The stratification ratio of soil total N was greater under no-tillage. Compared with soil without crop residue return, residue return increased soil N storage by 6.4–24.9% in the plow layer. Continuous maize (*Zea mays* L.) increased the N storage in all physical fractions, whereas the decrease of silt-N storage was observed in soybean–maize rotation plots. Overall, residue return could enhance soil N storage, whereas the distribution of N storage changes in the light fraction and sand size fraction was influenced by tillage practices. The distribution of N storage changes in the silt and clay fractions was influenced by cropping system.
- The topsoil and subsoil are commonly mixed in the operation of deep tillage in agricultural soils. It is not yet clear whether the influence of crop straw on soil organic matter (SOM) mineralization in the mixed topsoil and subsoil is different from that in the sole topsoil or subsoil. To understand soil C sequestration, it is important to know how residue C is incorporated and distributed in SOC fractions in the topsoil, subsoil, and mixed soil. A 120-d incubation experiment with the addition of ^{13}C-labeled maize straw to the topsoil, subsoil, and their mixture of a typical Mollisol in Northeast China found that straw addition promoted SOM mineralization and induced a positive priming effect (Dai et al., 2022). The mineralization of SOM with straw addition was 122% higher in the topsoil than in the subsoil. After the 120-d incubation, 12–16% of straw C was mineralized as CO_2, contributing approximately 50–70% to the total CO_2 production. Straw C was also incorporated into SOM fractions, with 34, 7, and 59% in the light fraction, particulate OC, and mineral-associated OC in topsoil, respectively. This finding indicated that straw addition tended to increase C sequestration in both subsoil and mixed soil but increase C turnover in the topsoil compared with the subsoil.

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Na Li: Conceptualization; Methodology; Resources; Writing – original draft; Writing – review & editing. Lujun Li: Conceptualization; Methodology; Resources; Writing – original draft; Writing – review & editing. Xia Zhu-Barker: Conceptualization; Writing – original draft, Writing – review & editing. Yi Cheng: Conceptualization; Writing – original draft. Jun-Jie Liu: Conceptualization; Writing – review & editing. Scott X Chang: Conceptualization; Writing – original draft, Writing – review & editing.

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