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Timothy Crews,
The Land Institute, United States

*CORRESPONDENCE
Jennifer Blesh
jblesh@umich.edu

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Editorial: Ecological Nutrient Management as a pathway to Zero Hunger

Jennifer Blesh[1]*, Marney E. Isaac[2,3], Meagan E. Schipanski[4] and Steven J. Vanek[4]

[1]School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, United States, [2]Department of Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, ON, Canada, [3]Department of Global Development Studies, University of Toronto Scarborough, Toronto, ON, Canada, [4]Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO, United States

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Editorial on the Research Topic
Ecological Nutrient Management as a pathway to Zero Hunger

The second United Nations Sustainable Development Goal (SDG 2, or *Zero Hunger*) integrates five ambitious targets for agricultural sustainability, social equity, and human health (Figure 1; UN, 2015). Embedded in these targets are key ecological processes in agroecosystems, such as water and carbon (C) storage, nutrient cycling, and pest regulation. By contributing to social and ecological system resilience, these processes help to safeguard the future production of nutritious food (Blesh et al., 2019). The SDG 2 targets also include conservation of cultivated and wild species of plants and animals, and equitable access to critical resources for agricultural production, such as land, credit, markets, and knowledge. This Research Topic provides key interdisciplinary examples of social-ecological systems approaches required to achieve SDG 2.

A recent confluence of shocks—COVID-19, climate change, and the Ukraine-Russia conflict—have deepened food insecurity and hunger, making SDG 2 an even more urgent humanitarian priority. Although these crises have motivated calls to strengthen an industrial approach to agriculture that deepens reliance on non-renewable resources (e.g., USDA, 2022), they have fortunately also invigorated proposals to expand resilient and sustainable agroecosystems that better fulfill the broad and interconnected targets of SDG 2 (e.g., McGreevy et al., 2022). For instance, rising input prices from spikes in the price of fertilizer made from natural gas are a main driver of rising food costs, and thus food insecurity.

Globally, nitrogen (N) and phosphorus (P) are the nutrients that most often limit crop yields, yet widespread use of soluble N and P fertilizers contributes to climate change *via* greenhouse gas emissions, and to water pollution, both of which, in turn, threaten future food production and human health. The simplification of production systems, and the continued singular reliance on synthetic fertilizer inputs for nutrient management, have disrupted nutrient recycling and depleted stocks of soil organic matter (SOM) on farms, and increased N and P losses to the environment. This soil degradation, in combination with crop varieties bred to require inorganic fertilizers, undermines the achievement of SDG 2. In this Research Topic, we focus on Ecological Nutrient Management (ENM) as a holistic approach to managing agroecosystems to sustain crop production while reducing dependence on synthetic inputs.

This Research Topic brings together 12 papers on ENM as a pathway to Zero Hunger to summarize the state of the science, highlight opportunities and barriers to the expansion of ENM, and identify research needs to support its expansion. To frame the collection, Drinkwater and Snapp introduce five key principles of ENM. Each principle connects—directly or indirectly—to the targets of SDG 2, demonstrating how ENM is a mechanism for realizing the multifunctional goals of SDG 2 that link agriculture, environment, and human health (Figure 1). By increasing agrobiodiversity and reducing the need for purchased inputs, ENM increases ecosystem health while advancing social equity through greater farmer autonomy. Crop and livestock diversity can also support access to diverse markets, buffer against risk, and improve the quality of diets through multiple pathways (Powell et al., 2015; Jones, 2017).

Build SOM and nutrient reserves

Drinkwater and Snapp review recent scientific advances in the understanding of SOM stabilization, and interactions in the

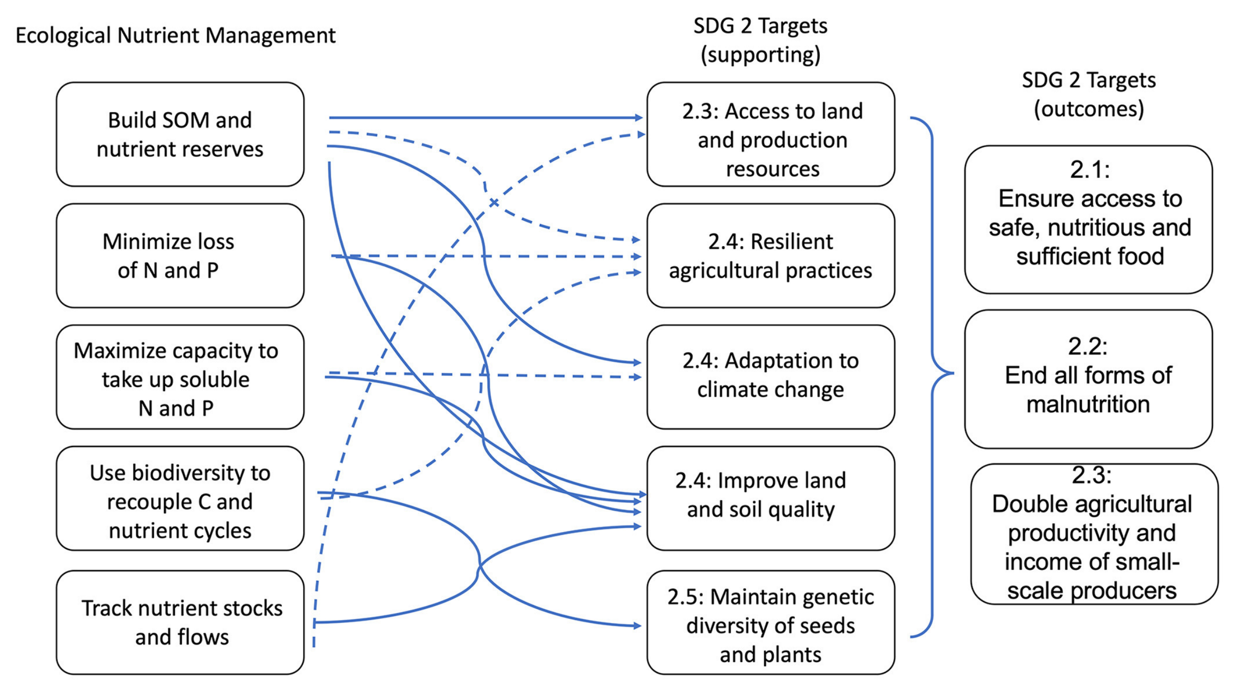

FIGURE 1
Conceptual diagram showing pathways that link Ecological Nutrient Management (ENM) to the 5 targets of the second Sustainable Development Goal (SDG 2, Zero Hunger). In their review, Drinkwater and Snapp introduce five key principles of ENM **(left side)**: (1) build soil organic matter (SOM) and associated nutrient reserves; (2) minimize the soluble pools of nitrogen (N) and phosphorus (P) that are vulnerable to loss; (3) maximize the capacity for agroecosystems to take up and cycle soluble nutrients; (4) increase biodiversity to maximize the presence of growing plants and recouple C, N, and P cycles; and (5) use mass balances to assess net nutrient stocks and flows over multiple growing seasons. We show the links between these principles and the five SDG 2 targets, which are organized into two columns, "supporting" and "outcomes." This distinguishes the components of the five targets that are intended to support high-level outcomes for SDG 2, shown at the far right of the diagram. Solid arrows show direct links between ENM principles and supporting targets of SDG 2, while dashed arrows show indirect links. These links include: ***Building SOM and nutrient reserves*** directly improves production resources and soil quality, and indirectly contributes to resilient systems by enhancing nutrient cycling and provisioning, reducing the need for external inputs, and buffering agroecosystems against drought and flooding. ***Minimizing losses of N and P*** directly improves land and soil quality by maintaining nutrient stocks in soils, and indirectly increases the resilience of agricultural practices by increasing the efficiency of nutrient inputs and reducing pollution of surrounding ecosystems. ***Maximizing agroecosystems' capacity to take up soluble N and P*** directly improves land and soil quality *via* nutrient storage and increased productivity, and indirectly supports climate change adaptation by reducing farmers' reliance on expensive, non-renewable inputs. ***Increasing species and functional diversity*** to recouple C with nutrient cycles directly maintains or increases crop diversity, and indirectly increases resilience by increasing productivity, buffering against market shocks, and increasing the capacity for adaptation to climate change. Using mass balances to ***track net nutrient stocks and flows*** directly improves land and soil quality by reducing nutrient surpluses and identifying deficits; it also indirectly increases farmer knowledge that improves management practices.

rhizosphere (i.e., the zone of soil closest to plant roots) that supply nutrients to crops, with a focus on ENM in smallholder systems in sub-Saharan Africa. Building SOM is also important for restoring soil quality in the Global North and can be realized most quickly by cultivating perennial species on farms. Mosier et al. and Martin and Sprunger discuss perennial cropping systems that could be adopted in the near term to restore degraded soils, while Crews et al. study a highly transformative perennial management system that involves intercropping a forage legume with a perennial cereal crop.

Maximize capacity to take up soluble N and P, and minimize nutrient losses

Several papers address mechanistic questions about ecological processes that store and cycle nutrients in agroecosystems, while exemplifying methods needed for robust understanding of ENM practices. Mosier et al. review mechanisms that stabilize soil C and retain N and P, while fostering the availability of these key nutrients. In an on-farm study in British Columbia, Norgaard et al. evaluate strategies to balance the stoichiometry of N and P in organic nutrient amendments to improve soil nutrient retention. Meanwhile, Martin and Sprunger move beyond traditional agronomic metrics of N availability in maize agroecosystems, such as extractable N and crop N uptake, to instead focus on plant-soil-microbial interactions (the microbial loop) that regulate organic N cycling. Finally, Isaac et al. review literature and global trait databases to assess the effects of crop domestication on root functional traits, and discuss implications for crop nutrient acquisition within the context of ENM. They emphasize the need for new crop breeding paradigms to support SDG 2, particularly Target 2.5 to maintain genetic diversity of domesticated crops (Figure 1).

Moving beyond the field and farm scale, two papers in this collection focus on recovering nutrients from urban areas and returning them to rural areas to improve soil fertility for crop production. The paper by Ryals et al. examines a number of potential ENM impacts (crop production, soil nutrient cycling and losses) of closed loop sanitation systems (EcoSan) with implications for regional circular nutrient economies. These systems couple household toilets with composting to recycle nutrients to food production. Harder et al.'s innovative proposal for regional scale modeling assesses food system scenarios that facilitate circular nutrient flows. The authors account for flows in interacting systems and sectors outside the region boundary, improving analyses that can inform how to reduce waste and use of external inputs on farms.

Track net nutrient stocks and flows

The application of nutrient mass balances in research and practice is another core principle of ENM that could help achieve the targets of SDG 2, such as improving the quality of soil and surrounding ecosystems by reducing nutrient surpluses and increasing farmer access to knowledge to improve the sustainability of nutrient management practices. Crews et al. demonstrate the value of collecting detailed N-flux measurements over a 5-year period to inform sustainable N management. Witcombe and Tiemann apply partial N balances to working farms to understand how farmers' management decisions affect the trajectory of soil fertility.

Use biodiversity to recouple C and nutrient cycles

The studies on perennial cropping systems, together with Perrone et al.'s experiment on overwintering cover crops, reinforce that legumes and perennials are essential plant functional groups for restoring soil fertility and building SOM, impacting multiple outcomes depending on their specific functional traits and how they are managed by farmers. These studies thus inform how to manage agrobiodiversity to recouple C and nutrient cycles. For instance, perennial legumes—whether harvested or not—can build soil C and N pools and enhance internal nutrient cycling and availability to crops (Crews et al.; Mosier et al.). Annual legumes, on the other hand, may not have a detectable effect on soil C and N pools if harvested (Witcomb and Tiemann), but they provide a healthy source of protein for human diets. In contrast, non-harvested legume cover crops are not consumed by people but can build multiple SOM pools (Drinkwater and Snapp) and increase soil N availability, even in cold northern climates that limit cover crop biomass production (Perrone et al.).

Zimmerer et al.'s study identifies multifunctional outcomes of crop diversification in Peru. The authors analyze social, political, and ecological factors influencing agrobiodiversity on smallholder farms and gardens, and their associated impacts on ENM. The authors define the concept of a "key agrobiodiversity-and-food space" as a management system with a high likelihood of having multiple positive outcomes related to SDG 2, particularly the targets for maintaining genetic diversity and improving human nutrition. In their study site, *Maizales*, or fields that combine maize with other crop species, are a "keystone" management system linked to enhanced agrobiodiversity, ENM practices, and food and market opportunities for smallholder farmers.

Barriers to implementation of ENM

Several papers in the collection discuss the multi-level, social-ecological constraints to ENM. Nyamasoka-Magonziwa et al. conduct focus groups and survey 184 farm households in East Africa to understand economic, cultural, and environmental drivers of organic nutrient management. Their results highlight the importance of access to resources, gender dynamics, and land tenure in driving farm management decisions. Drinkwater and Snapp, Mosier et al. and Isaac et al. summarize key challenges to adoption of ENM on farms, such as a lack of financial incentives and markets for diversified cropping systems; policies that emphasize short-term productivity over long-term ecosystem resilience; the need for seeds bred for organic systems; and the need for greater dissemination of agroecological knowledge. These multi-scale barriers point to the need for democratic policies that conserve nature, provide fair prices for farmers, and ensure that all people have access to nutritious food.

Future directions for research and the SDGs: Taking ENM seriously

The papers in this collection highlight research needs that can help overcome barriers to implementation; specifically, supporting research on micro-scale mechanisms, embracing complexity in on-farm research, and designing cross-scale studies to close nutrient loops. Ecological mechanisms at the micro-scale that conserve C and nutrients in soil (e.g., interactions between plant roots, microbial communities, and soil mineralogy) are a complex scientific frontier of ENM that can build generalizable knowledge to adapt to local contexts. This line of inquiry could be extended to understand connections between soil nutrient management, crop nutrient status, and human nutrition. There is also a need for participatory, on-farm research to better understand the myriad factors that influence farmers' transitions to ENM. Such studies could zoom in on positive models of innovation to understand processes that facilitate ENM, and the associated benefits for the SDG 2 targets. Or, this work could identify how to phase out unsustainable forms of nutrient management (Geels et al., 2017). This collection also highlights the need for interdisciplinary, cross-scale studies to scale up innovative technologies such as perennial crops, which have promise for building SOM, conserving soil nutrients, and minimizing nutrient losses (Zhang et al., 2022). Additionally, new technologies and infrastructure for waste capture and recycling are needed to close loops between urban and rural spaces and reduce nutrient losses to the environment at landscape and regional scales.

The UN's Agenda for Sustainable Development resolves to achieve Zero Hunger by 2030, which is on the horizon. Continuing to incentivize an industrialized approach to agricultural nutrient management has not put us on a trajectory to achieving this goal and continues to exacerbate environmental and human health crises. This leads us to ask: when will we embrace the experiential and scientific evidence pointing to ENM as a pathway to ending hunger?

Author contributions

JB suggested the Research Topic and wrote the initial draft of this editorial. All authors contributed to conceptualization, writing and editing, and approved the submitted version.

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Conflict of interest

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References

Blesh, J., Hoey, L., Jones, A. D., Friedmann, H., and Perfecto, I. (2019). Development pathways toward "zero hunger". *World Dev.* 118, 1–14. doi: 10.1016/j.worlddev.2019.02.004

Geels, F. W., Sovacool, B. K., Schwanen, T., and Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. *Science* 357, 1242–1244. doi: 10.1126/science.aao3760

Jones, A. D. (2017). Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low-and middle-income countries. *Nutr. Rev.* 75, 769–782. doi: 10.1093/nutrit/nux040

McGreevy, S. R., Rupprecht, C. D., Niles, D., Wiek, A., Carolan, M., Kallis, G., et al. (2022). Sustainable agrifood systems for a post-growth world. *Nat. Sustain.* 1–7. doi: 10.1038/s41893-022-00933-5

Powell, B., Thilsted, S. H., Ickowitz, A., Termote, C., Sunderland, T., and Herforth, A. (2015). Improving diets with wild and cultivated biodiversity from across the landscape. *Food Security* 1–20. doi: 10.1007/s12571-015-0466-5

UN (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. New York, NY: UN.

USDA (2022). *USDA Makes It Easier for American Farmers to Grow Food, Ease Burdens for American Families*. Avaialble online at: https://www.usda.gov/media/press-releases/2022/07/12/usda-makes-it-easier-american-farmers-grow-food-ease-burdens (accessed October, 2022).

Zhang, S., Huang, G., Zhang, Y., Lv, X., Wan, K., Liang, J., et al. (2022). Sustained productivity and agronomic potential of perennial rice. *Nat. Sustain.* 1–11. doi: 10.1038/s41893-022-00997-3