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Commentary from the U.S. Agroecology Summit 2023

Blending knowledge systems for agroecological nutrient management and climate resilience

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Agroecology links multiple ways of knowing in order to understand and manage farms as the ecosystems that they are—agroecosystems. Farmers often have deep, place-based knowledge of their agroecosystems that informs how to manage ecological interactions for multiple benefits. Many Indigenous practices sustained food production for generations without fossil fuel inputs, and traditional ecological knowledge is a valuable source of wisdom for adaptive management of agroecosystems. Other forms of ecological knowledge have been developed using Western scientific research approaches. Through the concept of the ecosystem, ecology applies systems thinking to understand complex relationships between organisms (including humans) and their environment across spatio-temporal scales. In practice, blending these ways of knowing has a wide range of interpretations and manifestations, especially in the past several decades, as agroecology has developed into a science, practice, and social movement. Embracing all three of these aspects, we argue that agroecology could more fully integrate traditional ecological knowledge and farmer knowledge with ecological science—including valuing where they overlap and their unique contributions (Kimmerer, 2013)—in support of food system transformation.

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We focus on the example of agroecological nutrient management in the context of climate change.

Ecology is a field that is well positioned for epistemological pluralism because it is distinct from the reductionist techno-science that has been a major cause of today's environmental and social crises. The industrial agricultural paradigm neglects ecological knowledge, instead prioritizing technological fixes that maintain yields in simplified production systems, typically using nonrenewable inputs such as chemical fertilizers. For instance, the singular focus on synthetic fertilizers for soil nutrient management has contributed to increased crop yields, but the synthesis and excess inputs of reactive nitrogen fertilizer are also major drivers of global change, most notably via greenhouse gas emissions and water pollution (Carpenter et al., 1998; Menegat et al., 2022). The reliance on concentrated and volatile markets for fertilizers and other chemical inputs also harms farmers. To move toward sustainable nutrient management, researchers must acknowledge that Western science offers one way of knowing among many knowledge systems and embrace collaborative approaches to practicing science with communities.

Ecological approaches to nutrient management harness ecological interactions to enhance internal nutrient cycling processes, thereby reducing inorganic nutrient inputs, soil degradation, and associated nutrient losses (Drinkwater & Snapp, 2023). This is a fundamental shift away from input-focused management toward management of crop and livestock diversity that enhances underlying nutrient reserves and biological communities in the soil. By reducing use of external inputs and increasing reliance on context-specific knowledge systems, this approach can increase both farmer agency and agroecosystem resilience, as well as yield stability. Understanding which management practices build up soil organic matter and nutrient reservoirs in different soil types and cropping systems is critical for informing transitions to ecologically-based nutrient management.

Indigenous and farmer knowledge have informed the development of diverse management systems that enhance soil fertility and nutrient cycling, as well as pest control, overall productivity, and many other demonstrated benefits (Carlisle, 2022; Kapayou et al., 2023). Ecological science can shed light on how these diverse types of crop rotations and intercropping systems provide specific functions, such as building soil organic matter and promoting nutrient release, linking these functions to distinct plants and plant traits (and their associated microbial communities) (Isaac et al., 2021). Although Western science is always a simplification of reality, ecology balances reductionism and holism to produce knowledge relevant to improving local management while building the generalizable understanding needed to adapt innovations to new contexts, including a changing climate. Fully blending these perspectives into a unique **agroecological nutrient management** approach would therefore benefit research, policy, and practice.

For instance, given the alarming rate of climate change, there is a need to understand the potential for carbon sequestration and net greenhouse gas mitigation in highly diversified and traditional farms, in order to inform effective policies and investments. A key part of climate adaptation and resilience for farmers will also involve careful management of biodiversity to reduce external inputs and buffer against extreme weather events. However, agroecological practices are currently highly heterogeneous across farms. Farmers who participate in agroecological networks can have management systems that vary from use of chemical inputs and low levels of crop and livestock diversity to highly diversified polycultures with little to no external inputs (Stratton et al., 2021; Teixeira et al., 2018). Furthermore, the ways in which agroecological nutrient management practices are implemented drives distinct outcomes. For example, some urban farms use excess compost inputs that cause nutrient surpluses, hydrophobic conditions, increased pest pressure, and reduced productivity (Gregory et al., 2016; Witzling et al., 2011). Diversified farms often purchase organic inputs such as manure or compost that may ultimately be derived from fossil fuels, depending on their sources. In many contexts, then, soil nutrient management practices on farms that practice agroecology can be improved to provide a broader suite of social and ecological benefits.

We argue this can be achieved through an integrated and participatory approach to researching and understanding agroecosystems. Rather than subjugating Indigenous knowledge to Western science, a collaborative approach would recognize that traditional knowledge and the practices of Indigenous communities, in many cases forcibly displaced from their land, form the basis of many practices now being investigated using Western scientific methods. As a cautionary example, some scientists have recently become enamored with the potential of a specific trait identified in a traditional maize variety to support free-living nitrogen fixing bacteria (Van Deynze et al., 2018). The reductionist approach is to study the nitrogen-fixing bacteria in isolation, aiming to identify methods that enable it to grow in association with hybrid maize varieties and other crops for possible commercialization. An agroecological approach would engage the communities who have been improving this land race for generations to better understand its ecology and history, including the broader agroecosystem context within which it was improved. For instance, this approach could inform how to adapt these systems to changing climates. An ecosystem approach would also carefully assess the benefits and tradeoffs of enhancing maize (or non-legume) nitrogen fixation relative to integrating legume crops and cover crops into rotations or intercrops with maize. In some contexts, integration of legume crops not only provides more nitrogen fixation capacity than associative nitrogen fixing bacteria are likely to provide, but they simultaneously support other ecological functions and improve household nutrition (Bezner Kerr et al., 2007).

As many agroecologists have argued, to fully blend ecological and farmer knowledge, research questions and priorities should be developed in partnership with communities and consider the broader sociopolitical context. Scientists must be trained in the politics of knowledge production and serve as respectful partners who listen closely and approach participatory research with humility. La Vía Campesina sees agroecology as a form of political resistance to "an economic system that puts profit before life," (La Vía Campesina, 2015, para. 6). Agroecological research must therefore also attend to political questions because improving agroecological practices requires supportive policy and market conditions, and access to knowledge and other resources such as land and seeds. A blended approach would allow scientists and communities to carry a more diverse set of tools and management strategies forward through joint discovery, while also considering who will benefit from or control these discoveries. Researchers can therefore help shift resources to marginalized communities while supporting broader, structural changes to food systems.

To advance this collaborative vision for research, academic institutions need to develop new curriculum and training approaches. Scholars from disciplines such as political ecology and agroecology increasingly call for research to understand how the interplay between structure and agency can foster farming system transformation (Blesh et al., 2023). A related concept—critical ecology—explicitly identifies how historical legacies of oppression and injustice have been drivers of ecological change (Denzin et al., 2008; Patterson et al. 2023). We also realize that if we are white and highly educated, we should be extremely cautious about imposing models of change onto other groups (Roman-Alcalá, 2022). A key role for those of us who are white academics is therefore to help make this cultural change in our institutions—for instance, ensuring that conceptual frameworks such as political ecology are integrated into the curriculum. To this end, we also need better training for students to become scholar-activists who understand oppression and systems of injustice, take time to understand others' worldviews, and use their positions to help make structural and political changes to redistribute resources.

It is important to recognize that the political struggles within agroecology are inextricably connected to material, biophysical conditions; that is, real relationships between organisms—including humans—and their environments. As a result, a more complete understanding of this biophysical complexity, and blending Western, traditional, and other farmer knowledge systems, will support better soil and agroecosystem stewardship. A participatory and pluralist research approach would thus combine the strengths that ecological science contributes to agroecology, such as mechanistic understanding, prediction, and systems thinking with farmers' place-based knowledge of crop varieties, soils, and climate conditions. Realizing this goal would expand transitions to agroecological nutrient management that increase farmers' resilience to climate change and support current and future generations.

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