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One Earth

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Perspective

Against the odds: Network and institutional pathways enabling agricultural diversification

Jennifer Blesh,[1,*] Zia Mehrabi,[2] Hannah Wittman,[3] Rachel Bezner Kerr,[4] Dana James,[3] Sidney Madsen,[4] Olivia M. Smith,[5] Sieglinde Snapp,[6] Anne Elise Stratton,[7] Mohamed Bakarr,[8] Abram J. Bicksler,[9] Ryan Galt,[10] Lucas A. Garibaldi,[11] Barbara Gemmill-Herren,[12] Ingo Grass,[13] Marney E. Isaac,[14] Innocensia John,[15] Sarah K. Jones,[16] Christina M. Kennedy,[17] Susanna Klassen,[3] Christian Levers,[18] Laura Vang Rasmussen,[19] and Claire Kremen[20]

[1]School for Environment and Sustainability, University of Michigan, 440 Church St., Ann Arbor, MI, USA
[2]Department of Environmental Studies, University of Colorado Boulder, Boulder, CO, USA
[3]Centre for Sustainable Food Systems and Institute for Resources, Environment and Sustainability, The University of British Columbia, Vancouver, BC, Canada
[4]Department of Global Development, Cornell University, Ithaca, NY, USA
[5]Center for Global Change and Earth Observations and Ecology, Evolution, and Behavior Program, Michigan State University, East Lansing, MI, USA
[6]Department of Plant, Soil, and Microbial Sciences and Center for Global Change and Earth Observations, Michigan State University, East Lansing, MI, USA
[7]Sustainable Use of Natural Resources Department, Institute of Social Sciences in Agriculture, University of Hohenheim, Stuttgart, Germany
[8]The Global Environment Facility, Washington, DC, USA
[9]ECHO International, Inc., North Fort Myers, FL, USA
[10]Agricultural Sustainability Institute and Department of Human Ecology, University of California, Davis, Davis, CA, USA
[11]Universidad Nacional de Río Negro and Consejo Nacional de Investigaciones Científicas y Técnicas, Instituto de Investigaciones en Recursos Naturales, Agroecología y Desarrollo Rural, Río Negro, San Carlos de Bariloche, Argentina
[12]Sustainable Food Systems Program, Prescott College, Prescott, AZ, USA
[13]Department of Ecology of Tropical Agricultural Systems, University of Hohenheim, Stuttgart, Germany
[14]Department of Physical and Environmental Sciences and Department of Global Development Studies, University of Toronto Scarborough, Toronto, ON, Canada
[15]Department of Agricultural Economics and Business, University of Dar es Salaam, Dar es Salaam, Tanzania
[16]Alliance of Bioversity International & CIAT, Parc Scientifique Agropolis II, Montpellier, France
[17]Global Science, The Nature Conservancy, Fort Collins, CO, USA
[18]Department of Environmental Geography, Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
[19]Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark
[20]Institute for Resources, Environment, and Sustainability, Department of Zoology, Biodiversity Research Centre, The University of British Columbia, Vancouver, BC, Canada
*Correspondence: jblesh@umich.edu

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SUMMARY

Farming systems that support locally diverse agricultural production and high levels of biodiversity are in rapid decline, despite evidence of their benefits for climate, environmental health, and food security. Yet, agricultural policies, financial incentives, and market concentration increasingly constrain the viability of diversified farming systems. Here, we present a conceptual framework to identify novel processes that promote the emergence and sustainability of diversified farming systems, using three real-world examples where farming communities have found pathways to diversification despite major structural constraints. By applying our framework to analyze these bright spots in the United States, Brazil, and Malawi, we identify two distinct pathways—network and institutional—to diversification. These pathways emerge through alignment of factors related to social and ecological structure (policies, institutions, and environmental conditions) and agency (values, collective action, and management decisions). We find that, when network and institutional pathways operate in tandem, the potential to scale up diversification across farms and landscapes increases substantially.

INTRODUCTION

Continued simplification of agricultural landscapes is causing biodiversity loss, soil and water degradation, erosion of local knowledge systems, and climate change,[1,2] destabilizing the global supply of nutritious food.[3] Global and national trends in the diversity of traded commodities (e.g., corn, palm oil, soybeans, wheat) have increased in the last decades,[4] as indicated by an increasing number of crops contributing to domestic food supplies.[5] Yet, these trends should not be confounded with actual farm- or landscape-level biodiversity, which has declined around the globe.[6–9] Simultaneously achieving the cross-disciplinary targets of the "Zero Hunger" United Nations Sustainable Development Goal (SDG 2) as well as global targets on climate

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Box 1. Definitions of terms related to diversified farming systems

Agrobiodiversity, agricultural diversity: the varietal and species diversity used directly or indirectly for agricultural production and food, including harvested crops, livestock, and fish, and wild biodiversity, such as tree products or wild animals or fish, as well as non-harvested species that support agricultural production (e.g., soil microorganisms, pollinators).
Agroecology: a scientific discipline, suite of farming practices, and social movement transforming food systems toward sustainability.
Agroecosystem: an ecosystem managed for production of food, feed, fuel, or fiber, including interactions between biotic and abiotic components and flows of energy and matter. The scale of an agroecosystem can vary depending on the research question but is most often considered to be a field or farm.
Associated biodiversity: the subset of agrobiodiversity that includes organisms that support agricultural production and is not directly managed by farmers (e.g., the soil food web, herbivores, natural enemies, pollinators).
Diversified farming systems; diversification practices: the use of planned crop, fish, and livestock diversity, which influences associated biodiversity across scales. Example practices include agroforestry, cover crops, crop rotation complexity, intercropping, integration of crops and livestock, landscape complexity, native habitat retention, organic amendments, riparian buffers, rotational grazing of livestock, and varietal diversity.
Farming system: the land area owned or farmed by a particular farming household, including managed areas and surrounding habitats.
Food system: the set of activities linking people to food, spanning production, distribution, access, and consumption.
Functional diversity: the diversity of functional traits present in an agroecosystem.
Functional trait: characteristics of an individual organism that determine its effect on or response to the environment.
Planned diversity: the diversity of domesticated species selected by farmers (e.g., crops, livestock, fish, etc.)

change and biodiversity loss will require transforming simplified agricultural systems to help reverse these diversity declines.[10–12]

We define diversification of farming systems as intentional management to increase the diversity of agricultural plants and animals and non-agricultural biodiversity from field to landscape scales.[13] Such systems can be viewed as transitioning or transformed. The process of transitioning farm management systems takes resources and experience, often proceeding through recognized phases in which diversification efforts emerge and eventually result in system transformation. Transformation represents system redesign; for example, from managing simplified monocultures to managing high levels of crop and livestock diversity.[14]

The benefits of farming system diversification are supported by fundamental principles from research on biodiversity and ecosystem functioning[15,16] as well as experiments and observational studies in agricultural systems[17,18] and regional or national trends.[19,20] These studies show that use of diversification practices (e.g., cover crops and agroforestry; Box 1) supports ecological interactions that increase ecosystem services, such as improved crop yields, soil organic carbon storage, pest and disease control, and increased resilience to drought and other shocks. At the landscape level, diversified farms create a more biodiversity-friendly matrix that can provide multiple benefits, such as pollination, habitat for wildlife, and improved water quality.[21] Diversified farming systems can also increase farmers' and consumers' access to a diverse selection of foods and markets, potentially improving food and nutrition security locally and the quality of human diets through direct (i.e., growing more diverse species or varieties) and indirect (e.g., generating income to purchase food products that enhance diets) mechanisms.[22–24]

Over the last 150 years, macro-scale, or structural, factors related to political and economic forces have driven increasing specialization, simplification, and adoption of industrialized technologies on farms as well as an increase in farm size in many countries.[25] In contrast, public policies or laws that promote diversification practices in agricultural landscapes are not widespread,[26] nor is investment in development of seeds, crop mixes and rotations, and equipment to promote profitable diversified farms in specific contexts.[27,28] These structural conditions influence the "odds" of diversification—the balance of enabling and constraining factors—so that many diversification efforts now struggle against the odds.

In this paper, we draw on two well-established frameworks, social-ecological systems and the multi-level perspective (MLP), to identify pathways to diversified farming systems that overcome major structural constraints. Briefly, a social-ecological systems perspective[29–31] recognizes that farming practices and outcomes are shaped by a complex suite of factors, including ecosystem processes, infrastructure and technologies, markets, institutions, knowledge, social norms, and attitudes and behaviors. The MLP[32] identifies driving forces that facilitate sustainability transitions within social-ecological systems, shedding light on processes that interact and align across three distinct levels to spread innovations.[33] Within the MLP, the "niche" level is where innovations, such as farm diversification, often emerge and develop; the "regime" is the dominant social-ecological system (e.g., policies, institutions, and norms of simplified agriculture); and the third level is the wider "exogenous context" (i.e., trends or shocks that create windows of opportunity for transitions).[33,34]

Inspired by the literature on social-ecological systems and the MLP as well as our experience working across global contexts on transitions to diversified farming systems, we developed and applied a conceptual framework to identify novel interactions between structural and behavioral factors that permit the expansion of diversified farming systems. We applied our framework to analyze three "bright spots"[35,36]—cases in the United States Midwest, southern Brazil, and northern Malawi—that span disparate farming system types and socioeconomic

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Table 1. Social and ecological characteristics, main structural barriers to diversification, and primary diversification pathway of the three case studies

	United States Corn Belt	Southern Brazil	Northern Malawi
Climate	temperate	humid subtropical	subtropical
Soils	high fertility	moderately weathered	weathered, low fertility
Human development index (HDI) 2019	0.926	0.765	0.483
Average farm size, ha (±standard deviation)	530 (±460)	35 (±41)	0.82 (±0.60)
Cropping systems	grain, livestock	horticultural, mixed crop-livestock	grain, tubers, vegetables, tobacco, coffee, poultry
Dominant markets	export, national	local, regional, export	subsistence, export
Structural barriers	federal subsidies, concentrated input and output markets	federal subsidies, land use consolidation	colonial history, input subsidy program, concentrated input and output markets, neo-colonial development structures
Diversification pathway	network	institutional	network
Diversification practices	cover cropping, mixed crop-livestock, rotational grazing	cover cropping, intercropping, agroforestry, rotational grazing	legume intercropping, agroforestry, indigenous grains

Data are from surveys and field work conducted by the author team in the case study regions.[37–46]

conditions, which we selected to illustrate the broad utility of our framework (Table 1). While many traditional and Indigenous farming communities have maintained crop and livestock diversity (and are working against the odds and should be recognized as such), here we focus on specific cases where clusters of farmers have departed from regional trends toward simplified production to make a transition to diversified farming systems. We describe barriers and pathways to diversification in these three contrasting cases and identify links across them. Our analytical approach advances knowledge of specific mechanisms that increase resources to facilitate diversification in diverse global contexts. Building on insights from these case studies, we identify policy directions to help support and scale transition processes and transformation of farming systems.

CONCEPTUAL FRAMEWORK FOR DIVERSIFICATION PROCESSES

Through a series of workshops and meetings between 2019 and 2021, we developed a conceptual framework to assess processes that support or constrain farming system diversification and related outcomes for food security and environmental sustainability (Figure 1). The aim of this framework is to enable an integrated assessment of patterns and distributions of farming system diversity, the suite of factors influencing diversification transitions and transformation, and the social-ecological outcomes that accompany diversification when it occurs. Through a participatory and iterative process, our interdisciplinary team of scholars and policy advisors, working across domains of land management and biodiversity conservation in North and South America, Asia, and Africa, incorporated the knowledge and perspectives of a global stakeholder advisory group. We then further elaborated and revised the framework through two additional virtual meetings and multiple asynchronous exchanges with the stakeholder group over a 1-year period. This group included 18 members representing a range of (1) academic, governmental, and non-governmental institutions, including farmer and international donor organizations; (2) subject expertise, including agricultural diversification, global change, economics, and ecology; and (3) region-specific knowledge.

The conceptual framework is illustrated in Figure 1. The outer wheel of the framework includes four categories of factors related to social and ecological structure: political economy (e.g., trade and distribution of wealth and power), governance (e.g., markets and policies), environment (e.g., soil type, climate, and topography), and culture (e.g., social norms within the dominant regime), all of which often reinforce, or lock in, simplified production systems. For example, a small number of companies control commodity crop production and flows and accumulate wealth in food systems.[47,48] Horizontal and vertical integration of supply chains, supported by national policy incentives and government subsidies, has created economic inequities and an increase in agricultural specialization.[25] Similarly, corporate influence over research and development, which focuses on input-dependent, simplified agriculture, deepens this path dependency.[27,49,50] These structural barriers increasingly constrain individual farmers' ability to engage in diversification practices on their farms,[51] yet researchers often neglect these large-scale constraints.[51,52]

Instead, most of the literature on adoption of diversification practices has emphasized individual-level factors that may explain farmers' management decisions,[52] such as typologies of attitudes, behaviors, and values;[53–55] sociodemographic variables (e.g., education level and income);[52] perceptions of risk;[56] and other farm characteristics (e.g., land tenure). However, the importance and effects of these factors vary across contexts so that they are not always significant predictors in models of adoption.[52,57] Consequently, there is growing awareness of the importance of institutional factors and structural barriers to farm diversification[51,52] as well as the need to integrate quantitative and qualitative approaches to understanding them.[30]

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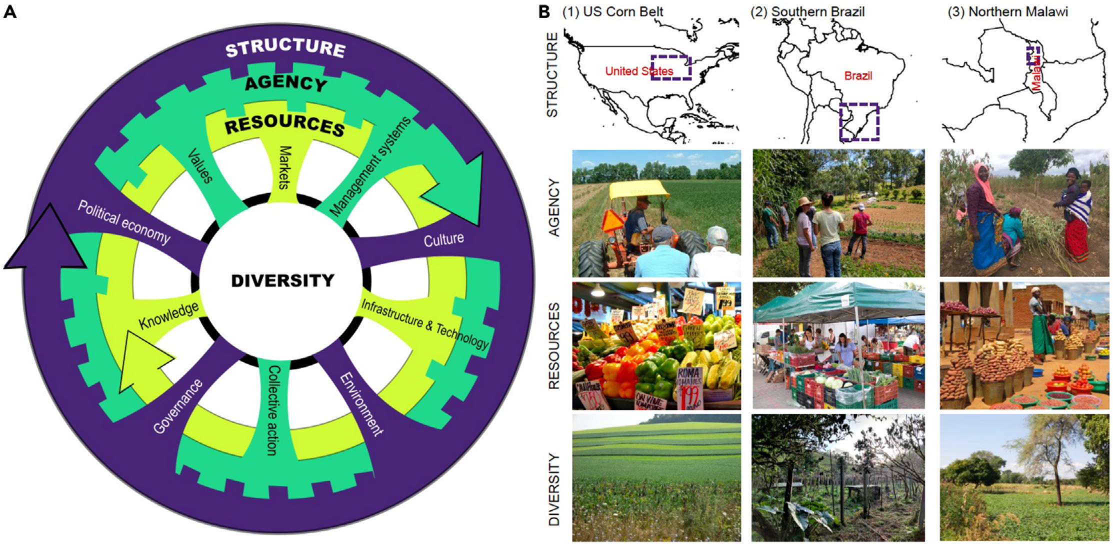

Figure 1. Conceptual framework for farm diversification

(A) Conceptual framework incorporating interactions between structure, agency, and resources that together constrain or enable diversified farming systems, which have important consequences for biodiversity, ecosystem services, human health, nutrition, and well-being.

(B) Schematic to illustrate specific examples of factors across these interacting levels in the three case studies: structure (governing boundaries in the case study regions), agency (photos of the farmer networks described in each case), resources (photos of local and regional markets), and farm diversity (from left to right: perennial alfalfa in strips with row crops, an agroforestry-mixed crop livestock system, and a mixed crop field with pigeon pea, cow pea, and acacia).

Despite structural constraints, the exercise of agency and innovation by farmers and other actors (i.e., building on the attitudes, values, and actions of individuals and their social networks) produces niches or pathways to diversification and its attendant social[58,59] and environmental[16,18] benefits (Figure 1, middle wheel). These diversification practices are most often initiated ''from the bottom up'' through the growth of grassroots efforts by farmers, consumers, and their networks to advance environmental sustainability or social justice goals.[60,61] However, actors within the dominant regime can also introduce innovations, especially in response to bottom-up pressure or exogenous changes, such as climate change or pandemics, which might pressure institutions to reorient around farm diversification. This structural change can facilitate broader-scale mechanisms for diversification.[62]

This framework therefore emphasizes how factors related to agency and structure can align and interact to mobilize resources (Figure 1, inner wheel) that increase the odds of agricultural diversification. Important resources include access to land, capital, and markets; knowledge, skills, and social networks; and technology and infrastructure to plant, harvest, and process diverse crops and livestock products (including seeds, equipment, and labor).[37,52,63,64]

Finally, ecological functions on farms are governed by crop, livestock, and associated diversity at field, farm, and landscape scales (Figure 1; Box 1). Agricultural diversity is a continuum, influenced by several interacting dimensions of management systems, including use of crop and livestock diversity (and associated diversity, such as pollinators, soil microorganisms, etc.) across scales.[13] Other key dimensions that influence agricultural diversity are soil disturbance through tillage or other mechanical operations and use of external inputs.[65] Transitions to diversification will also manifest differently (e.g., riparian buffers, crop rotations, intercropping, grazing, or agroforestry; Box 1; Figure 1B) depending on the type of farming system and broader social and ecological contexts. Together, these social-ecological system interactions produce outcomes that also range along gradients: from food insecurity to food security,[23,24] unjust to just livelihoods,[58,66] and environmental pollution to provisioning of ecosystem services.[21] By applying our framework to understand the multi-level interactions that facilitate agricultural diversification and associated outcomes in distinct contexts, we show how multiple factors across scales align to increase resources to transform farming systems.

CASE STUDIES OF PATHWAYS TO DIVERSIFIED FARMING SYSTEMS

In this section, we illustrate how interactions between agency and structure have increased agricultural diversity in three distinct contexts—the United States Corn Belt, southern Brazil, and northern Malawi—against the odds. We summarize evidence from these three cases, which were selected from sites where our author team has conducted long-term, on-farm research using interdisciplinary and participatory research methods.

United States Corn Belt

The United States Corn Belt in the upper Mississippi River Basin illustrates how bright spots of diversification can emerge and thrive even within a highly industrialized and simplified agricultural region. In many sub-watersheds of this region, 90%–95% of total land area is in corn and soybean production,[67] while diversified farming systems are rare.[8,68] For instance, only 3%–8% of harvested cropland includes cover crops in rotation.[69] The loss of species diversity in the Corn Belt has reduced

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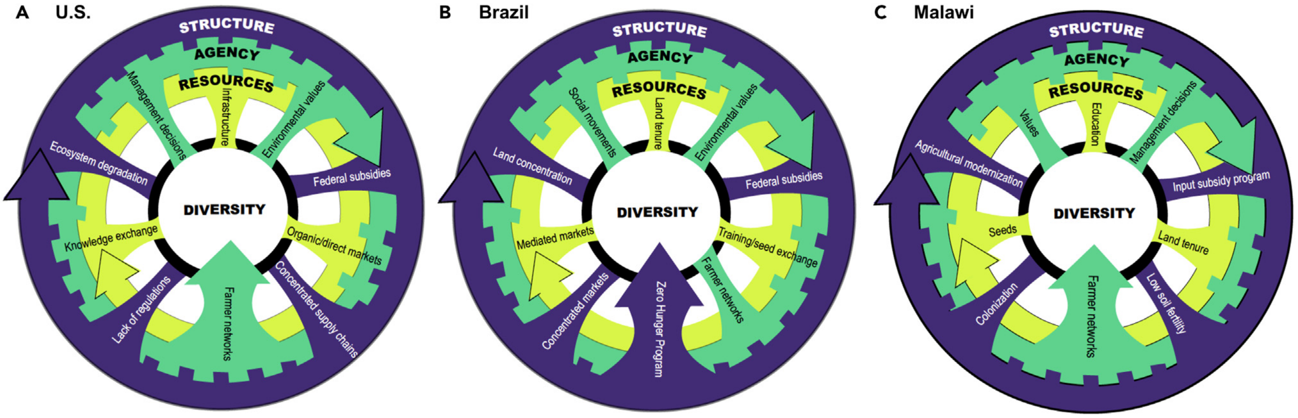

Figure 2. Case studies of diversification bright spots

(A) Our conceptual framework applied to the United States Corn Belt. In this highly simplified landscape with large structural constraints to diversified farming systems, a network pathway (agency: farmer networks) is the dominant mechanism by which farmers increased resources (e.g., processing infrastructure, new markets, knowledge) for agricultural diversification.

(B) Southern Brazil. In this family farming landscape, an institutional pathway (structure: policy change), which emerged from grassroots organizing, increased access to resources (e.g., access to land, training, seeds, and new markets) and enabled a large group of farmers to diversify.

(C) Northern Malawi. In this smallholder farming landscape with little institutional support for diversified farming systems, a network pathway (agency: community network) was the dominant pathway by which farmers increased resources (e.g., access to land, knowledge, and seeds) for agricultural diversification.

ecosystem functions required to sustain productivity, such as complex trophic interactions and soil nutrient cycling. Instead, high-yielding commodity crops now depend on fossil-fuel derived inputs, leading to unintended but widespread ecological and social consequences, including the persistent hypoxic zone in the Gulf of Mexico,[67] soil erosion,[70] and the decline of rural communities and local economies.[71]

Structural constraints to diversification

A confluence of political-economic, governance, socio-cultural, and environmental factors has led to extreme specialization in the United States Corn Belt (Table 1; Figure 2A). This transformation started with colonization by Euro-Americans and displacement of Native Americans in the mid-1800s. Following World War II and the start of the Green Revolution, policies encouraged use of synthetic inputs. Shifts in federal subsidies and insurance products in the Farm Bill (an omnibus law with a suite of agricultural and food programs) encouraged farm consolidation and simplification along with extension, credit, and other supports only for a few commodity crops.[72,73] Regional environmental conditions, including flat topography and former prairie soils, also facilitated land clearing and subsequent loss of biodiversity.[74]

Beginning in 2005, new federal policies encouraging ethanol production—the Renewable Fuels Standards—have consolidated these trends. Approximately 35%–40% of United States corn now goes to ethanol production.[75] Increasing demand for corn and rising but unstable corn prices drive farmers to reduce crop diversity and capture economies of scale. Other legal factors reinforce simplification, such as a lack of regulation of non-point source pollution or of habitat clearing or retention in agricultural landscapes.[26] Weakening of anti-trust regulations has further concentrated input industries and commodity markets, creating power imbalances.[47] For instance, in 2011, just three firms (ADM, Corn Products International, and Cargill) controlled 87% of all wet corn milling in the United States,[25] and in 2018, the top four seed companies controlled 67% of the global seed market.[48] Consequently, most farmers only have access to seeds that grow best in simplified stands with inputs of synthetic chemicals,[76] and they now have limited access to markets for crops such as small grains and dry beans.[37] Development of the World Trade Organization and trade agreements such as the North American Free Trade Agreement (NAFTA) have exacerbated corporate concentration in global food systems.[77] These institutions co-evolved with new cultural norms and attitudes about agriculture, such as valuing the esthetics of ''clean'' and weed-free monocultures, and a competitive culture around achieving high yields, even above profitability.[38,78] Policymakers, particularly those who draft the Farm Bill, also focus on the need for intensification to ''feed the world,'' even though more than 50% of regional crop production is sold for livestock feed (and 89% of those feed calories produced are unavailable for human food supply).[79] Taken together, these factors produce large structural constraints to diversification.

Pathways to diversification

In a context that promotes specialization, a small subset of farmers dispersed throughout the United States Corn Belt have nonetheless increased the diversity of their cropping systems. They use practices that can mitigate the environmental impacts of monocultures, including diversified organic farming,[80] mixed crop and livestock production,[81] rotational grazing of livestock,[82] ''strips'' of native prairie plants,[83] and diverse rotations with continuous soil cover through cultivation of winter small grains and annual cover crops in the off season.[39,56] Behavioral variables positively associated with farm diversification include positive stewardship attitudes and awareness of conservation programs.[52,57]

This bottom-up innovation on clusters of farms has co-evolved with and mobilized off-farm resources,[37] such as formation of new knowledge networks and organizations that increase financial capacity and access to information.[84] For example, Practical Farmers of Iowa (PFI) supports farmers' transitions to diversified management.[37,72,85] Formed in 1985, the network facilitates

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on-farm, participatory experimentation and horizontal knowledge exchange, especially through field days and conferences. Through these events, participants share technical information and spread new narratives promoting diversification as a ‘‘practical’’ way to support agricultural resilience and sustainability. The organization also works to increase access to financing, infrastructure, and markets to reduce the risks of diversifying rotations with crops such as small grains.[86]

To diversify in this landscape, farmers creatively blend knowledge and resources from the dominant regime with the new knowledge systems and infrastructure they are developing through grassroots networks like PFI. They integrate information from commodity groups, Land Grant universities, extension agents, and technical service providers with on-farm experiments to develop new management systems.[37,38] They mitigate financial risks of transitioning through strategies like re-integrating crop and livestock production to increase enterprise diversity, transitioning to certified organic production to access price premiums, and enrolling in Farm Bill conservation programs such as the Environmental Quality Incentives Program (EQIP), a working lands program that can support an array of diversification practices.[87]

In turn, farmers’ engagement with the institutions that primarily support simplification is slowly creating structural change within the dominant social-ecological regime,[37,88] with spillover effects that can facilitate transitions for a larger number of farmers. For instance, in the late 1980s and early 1990s, new research and extension programs focusing on organic and sustainable agriculture proliferated at Land Grant universities.[89] In 2015, a new ‘‘whole farm’’ insurance product became available through the US Department of Agriculture (USDA), which is designed to support diversified crop and livestock producers and address limitations of former commodity-focused policies.[90] Pressure from grassroots groups also contributed to a large increase in cost-share payments for practices like cover cropping. EQIP payments to farmers planting cover crops, for instance, increased from $15 million in 2009 to $56 million in 2014 and 2015.[91] Still, commodity programs in the 2018 Farm Bill that support dominant monocultures receive approximately 2.4 times more funding than the federal voluntary conservation programs, limiting the ability of the latter to influence adoption of diversification practices.[92] In summary, often driven by attitudes and values related to the health of the environment and rural communities, farmers in the Corn Belt are building networks that provide social and professional support for diversification. This network pathway has, in turn, created new organizations and participatory research and increased social pressure for important, if still limited, changes within the dominant regime (Figure 2A).

Southern Brazil

Brazil’s settler colonial history has shaped farm diversity in its southern region, which encompasses the states of Paraná, Santa Catarina, and Rio Grande do Sul. Prior to Portuguese settlement, Indigenous peoples in this area (including the Guarani and Kaingang) cultivated traditional crops such as cassava and hunted, fished, and gathered edible forest products. In the 17th and 18th centuries, the Atlantic Forest was cleared by settlers for mining exploration and for large-scale cattle and coffee production, furthering Indigenous dispossession and simplifying a complex agricultural landscape with expansion of commodity monocultures.[93] In the 19th century, a new wave of European immigration occurred as the Brazilian government aimed to populate the region, with tens of thousands of predominantly Germans and Italians with a cultural history of cooperativism settling the land.[94,95] Farmers of European descent adopted mixed crop-livestock systems with crop rotations that combined South American staples, such as cassava, beans, and maize, with European forage crops, such as oats and vetch. The subtropical climate in southern Brazil allows farmers to grow an array of horticultural products and raise livestock across multiple growing seasons per year. The scale of farming in this region also tends to be smaller than in other rapidly industrializing regions of Brazil (e.g., the center west) because of constraints imposed by the varied, hilly topography and land distribution practices related to agrarian reform and family farm succession.[96] Today, agricultural management systems in this region are influenced by interactions between global and regional markets, government policies, and strong grassroots organizations.

Structural constraints to diversification

As European-descended farmers passed on their land to their children over generations, parcels of land grew smaller, while other farmers became landless or found themselves in precarious labor contracts on plantations.[97] From 1964 to the mid-1980s, following global shifts to Green Revolution practices, the Brazilian military dictatorship and subsequent governments promoted agricultural specialization and subsidized technologies, such as synthetic pesticides and fertilizers.[98] As a result, mixed crop-livestock systems fell out of practice across much of the region by the late 1980s.[99] A parallel rise occurred in large-scale soybean production and concentrated animal feeding operations for regional and export markets, particularly in the plains regions of Santa Catarina and Rio Grande do Sul.[100] Government subsidies disproportionately accrued to export crops, supporting cultural narratives around agricultural modernization and Brazil’s identity as an ‘‘agricultural powerhouse,’’ which emerged as Brazil expanded agribusiness production to boost economic growth through exports.[101] These factors interacted to create a regime that favors land concentration, industrial practices, and large-scale commodity production while hindering diversification practices (Figure 2B).

Pathways to diversification

To overcome these structural barriers, social movements and farmer networks in southern Brazil have developed a growing niche of diversified farming systems. As the government redemocratized in the late 1980s, land inequality and recognition of the negative environmental and health externalities associated with an industrial agricultural paradigm contributed to the organization of the Landless Workers Movement (Movimento do Trabalhadores Rurais Sem Terra [MST]), which advocates for agrarian reform and more sustainable forms of agriculture. Today, two social movements in southern Brazil are global models of grassroots change toward improved social equity and diversity in agricultural systems: the MST and the farmer network Ecovida, which promotes farm diversification through agroecology.[60,94] Ecovida is a decentralized network for farmer-to-farmer agroecological certification that began in 1998 in two municipalities in the state of Rio Grande do Sul and has since grown to include an estimated 5,000 family farms in nearly 200 municipalities across all three states of southern Brazil.[64] Diversification is a cornerstone of Ecovida's peer certification process, and research has identified high levels of crop and livestock diversity and low input-use intensity on farms in the network.[40,41]

Concerns about the impacts of agrochemical use on environmental and human health remain strong factors motivating farmers in the Ecovida network.[60,102] As a result, farmers increasingly value diversification practices that support reduction of synthetic inputs (i.e., practices that boost soil fertility and control pests and diseases through non-chemical means), including agroforestry, legume intercropping, and cover crop mixtures.[41] At local and regional meetings, Ecovida farmers share knowledge about diversification practices and maintain and increase the genetic diversity of crops and other native species through seed exchanges. Further enabling these efforts, a growing urban demand for sustainably produced foods has led to new marketing opportunities for Ecovida producers,[103] reflecting the importance of regional rural-urban relations in sustainability transitions.[104]

The election of President Luiz Inácio Lula da Silva ("Lula") in 2003 created an important opening for structural changes in support of farm diversification. Responding to the demands of grassroots movements, the Worker's Party government consolidated food security, nutrition, and family farming policies in the Zero Hunger policy platform and increased financial incentives and credit for organic and diversified farms.[42,105,106] Targeted public food procurement mechanisms, including the national school meal program (Programa Nacional de Alimentação Escolar, PNAE), played important roles in increasing market access for diversified farmers in southern Brazil and improving food security.[40,42,106] At the national scale, Zero Hunger policies influenced improvements in food production, poverty reduction, and increases in natural vegetation, especially through programs that provided credit to family farms.[107]

Interacting ecological, social, and economic forces related to agency and structure contributed to the emergence of a diversification bright spot in southern Brazil. Support from civil society organizations facilitated the development of participatory agroecological certification networks such as Ecovida and helped farmers in the network access government-sponsored marketing programs that strengthen family farming and encourage organic management practices.[40,42] Southern Brazil also has historically high rates of implementation of national social and agricultural support programs, which has increased access to credit and infrastructure relative to other regions of Brazil.[108] Actors within other agricultural institutions, such as the Santa Catarina state agricultural agency, Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), also spurred research on innovations for soil conservation and increased farming system diversity in response to the negative effects of soil erosion from simplified agriculture in steep terrain.[99] This institutional pathway (Figure 2B), which resulted from the alignment of grassroots organizing and a progressive administration, has scaled support for diversification.

Although political retrenchment following the 2016 political coup has dismantled or de-funded much of the national policy framework that supported farm diversification,[109] existing networks of farmers, consumers, and civil society organizations in southern Brazil have doubled down on efforts to advocate for diversified agriculture at local and state levels.[110] For instance, organizers in the city of Florianopolis shifted their focus to local bills and election of a progressive leader to promote the right to food and agroecology at the municipal scale.[111] Thus, as the institutional pathway narrowed in recent years, collective action again grew increasingly important for maintaining the momentum for change, showcasing how the interplay between network and institutional pathways can enable durable transitions.

Northern Malawi

Agricultural diversity is positively associated with diverse diets for the majority of Malawi's population, which relies on agriculture for food and livelihoods.[112,113] The rain-fed fields of smallholder farms are characterized by nutrient-poor soils. Working less than 2 hectares of land with hand hoeing, farmers grow an average of 2.3 field crops per household.[114] The most commonly cultivated crop is corn, but other cereals, like finger millet, are also grown for food and fermented products,[115] and other cash crops include tobacco and coffee in the northern region. Households also meet subsistence needs and livelihoods by cultivating beans, peanuts, sweet potato, cassava, pumpkin, tomato, onion, cabbage, leafy greens, and fruit trees.[43] Pulses such as pigeon pea, peanut, and soybean are consumed and sold, and contribute to soil regeneration. In some regions, farmers historically practiced mixed crop-tree systems featuring natural fallows and harvesting from forests.[116] Only about one-third of smallholder farmers own ruminants, such as goats, sheep, and cattle, although the majority keep chickens or other small birds.[112] In part because of out-migration of men,[117] women contribute an estimated half of farm field labor.[118] Women influence crop choice and in many cases foster crop genetic diversity by sharing seeds through kin and friendship networks,[119] but they often lack decision-making control over land use and income.[120]

Structural constraints to diversification

The dominant regime, which is characterized by declining agricultural diversity, must be understood through the context of the colonial history of Malawi and contemporary agricultural policy and institutions (Figure 2C).[121] Land tenure in rural communities is customary in northern Malawi, accessed through chieftaincies based on kinship, yet the state maintains ultimate control over land.[122] Colonial and post-colonial policies facilitated acquisition of tobacco, cotton, and tea estates for white settlers and political allies,[123] and contemporary changes to land policy exacerbate land inequities and conflict by permitting private land sales to international buyers.[122] From the 1960s, intensification of corn production has been a key tenet of agricultural modernization.[115] Development initiatives promoted simplified cropping systems, increased input use, and market integration.[7] As a result, intensified, continuous cropping has come to dominate arable land use in much of Malawi,[124] diverse farming systems have declined countrywide,[9] and Malawi has been declared a leading player in an "African Green Revolution."[125]

Input subsidy programs have increased access to fertilizers and modern corn varieties for most smallholders. The National Seed Policy of Malawi emphasizes support for the formal seed sector,[126] which is dominated by multinational companies, and

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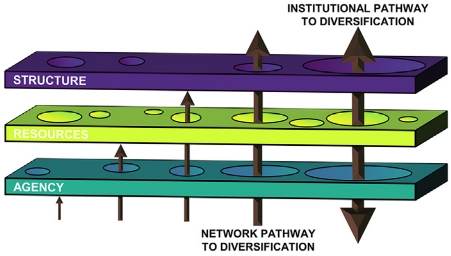

Figure 3. Network and institutional pathways to diversification
Diagram depicting network and institutional pathways to agricultural diversification. When social and ecological factors related to structure, agency, and resources align, "flowthrough" occurs to enable farm diversification. Description of arrows from left to right: (1) agency for diversification is lacking; (2) agency is present, but resources constrain diversification; (3) bottom-up processes hit a ceiling because of structural constraints, so diversification does not occur or is limited; (4) network pathway, in which farmer agency and collective action increase access to resources and enable clusters of farmers to overcome some of the structural barriers to diversification; and (5) institutional pathway, in which significant institutional and structural change expands diversification bright spots through spillover effects. The bidirectional arrow (5) indicates that innovations can be initiated by grassroots efforts or by actors within the dominant regime (which often occurs in response to bottom-up pressure or exogenous trends). Both pathways (arrows 4 and 5) can operate simultaneously and may be mutually reinforcing.

largely ignores informal exchange of traditional open-pollinated seed varieties. While the subsidy served as an important political tool in gaining rural support for the ruling party,[121] it has not led to substantial gains in crop productivity[127] or enhanced household nutrition, income, or resilience to extreme weather.[128]

Pathways to diversification

Industrialized agriculture is being challenged in Malawi by engaged citizens, farmer organizations, and academics who have demonstrated the shortcomings of the fertilizer subsidy program.[9,127] Proposed alternatives include a movement to decentralize agricultural research and extension systems by focusing on farmer-led agricultural development models,[129] which built on the rise of civil society and local governance beginning with multiparty elections in 1994.[130] However, efforts to enhance local control over extension systems in Malawi often run into bureaucratic and institutional barriers.[121]

A bright spot for diversification has emerged from efforts of the Soil, Food, and Healthy Community (SFHC) organization.[43] This community-led farmer network was formed in northern Malawi by Ekwendeni Hospital staff in 2000 because of concern about the level of food insecurity and malnutrition in surrounding villages.[131] Community engagement has supported a range of agricultural diversification initiatives over two decades, including legume intercropping, agroforestry, and production of indigenous grains such as finger millet, reaching more than 10,000 households in over 200 villages.[44,63] Farmers, researchers, and community health staff developed a curriculum that addresses nutrition, gender equity, agroecology, and resilience to climate change through participatory approaches, including use of drama and hands-on learning.[45]

This diversification niche is centered on community engagement on topics of farmer empowerment, equity, and nutritional education. The network's efforts have resulted in farmer-to-farmer experimentation, teaching, and sharing to develop agricultural systems that support food security, healthy diets, and greater social equity.[132] This capacity building has increased farmer preferences for diversified farming systems, including cultivation of diverse crop species and varieties, livestock integration, and use of compost and other soil health innovations.[43,63] Community-based education, in turn, has supported improved health outcomes, well-being, income gains, and broadening of dietary diversity.[44,46] This case study illustrates a network pathway (Figure 2C) in which farmer experimentation and knowledge exchanges, combined with attention to equity and other community concerns, facilitated increased diversification. The broader relevance of this approach is shown by recent uptake and further co-development of the curriculum with positive impacts on nutrition and gender equity in Singida, Tanzania.[133]

PATHWAYS FORWARD

Against formidable odds, clusters of farmers and other actors are maintaining and developing bright spots of agricultural diversification in distinct contexts around the world. By applying our conceptual framework to three cases of transitions to diversified farming systems, we identify common, yet often overlooked, structural barriers that can lock in simplified production systems. In the United States, corporate power and productivist priorities dominate the design and implementation of the Farm Bill; in southern Brazil, corporate power coupled with federal subsidies drive land use consolidation; and in Malawi, hierarchical governance supports corporate power that dominates input and seed supply chains. In all three cases, these structural barriers (Figure 1; Table 1; Figure 3) demonstrate how industrial food systems, which disproportionately benefit from government support,[50] do not facilitate diversified farming systems and the social[24,58,59,66] and environmental[16–18] benefits they provide.

At the same time, our framework enables a novel analytical approach to identify the most influential pathways for transitions toward agricultural diversification and sustainability in distinct global contexts (Table 1). In each case, with support from a range of actors in the food system, groups of farmers are managing diversity from field to landscape scales to restore ecological interactions and associated functions that promote their livelihoods and well-being. Together, these role models for change demonstrate two replicable and interacting pathways that shift resources to farmer-led innovations and facilitate agricultural diversification.

The first, a network pathway, is the primary mechanism that facilitated the emergence of bright spots in the United States and Malawi. In this pathway, the agency of individual farmers and their collective action through social networks increased access to key resources for diversification, including knowledge and skills, land, seeds, equipment, processing infrastructure, and markets. In the United States midwest, the formation of farmer networks was motivated by attitudes and values about environmental stewardship, as epitomized in the ideological foundations of organic agriculture. In this region, political-economic constraints to diversification, such as government subsidies to support commodity crop production, mean that the total number of diversified farms is still small, and thus their ability to influence environmental sustainability at scale is limited. However, the United States case also demonstrates how

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farmer- and community-driven action can intersect with and help promote limited structural changes to move farming systems toward sustainability. In the Malawi case, soil infertility, food insecurity, and child malnutrition were overarching concerns that motivated the formation of new grassroots networks linking farmers and the health care system. Through community education and participatory research, access to and consumption of diverse and nutritious food crops increased along with building soil fertility. Efforts to address gender inequities in agriculture and food systems, specifically the needs and concerns of women farmers, also facilitated diversification.

The Brazil case exhibits a second, institutional pathway to diversification in which significant structural change occurred with the convergence of bottom-up pressure from social movements and a progressive government. In this bright spot, a strong network pathway enabled niche innovation that was initiated by actors in grassroots networks, which eventually led to institutional innovation within the dominant regime. In this example, the national government established markets for public food procurement programs that explicitly targeted diversified and organic crop production. In Brazil (as in all three case studies), industrial agriculture is heavily subsidized, and market prices do not reflect the true costs of input-intensive production systems.[50] Diversification thus required government intervention through an ensemble of policies, programs, and institutions that restructured markets to provide public goods from agriculture,[42] including institutional models for food access, such as school meal programs. The Brazil case shows the potential for interplay between network and institutional pathways to foster diversification.

Network and institutional pathways can therefore operate simultaneously and be mutually reinforcing (Figure 3). The cases show how transitions from simplified to diversified farming systems involved the development of new narratives, attitudes, and production practices; formation of knowledge networks; investment in new infrastructure; and institutional changes. Together, grassroots networks and formal institutions (which are often slower to evolve) can alter the power relations that produce structural barriers, creating openings for broader transformation. Because those benefitting from the current regime do not often have incentives to change it, these pathways are most likely to progress along a continuum from network (agency) to institutional (structural) change, which is associated with an increasing scale of impact. In Brazil, progression along this continuum was most advanced across the three cases, reflecting alignment of agency and structural factors that produced substantial policy support for diversification. It is also important to note that there may be additional pathways to diversification not identified in our three cases. These bright spots were purposefully selected based on our team's long-term, on-farm research, which spans contrasts in socioeconomic and climate conditions and farming system scales and types. However, many more cases could be explored with our framework to further refine knowledge of pathways to farming system diversification.

Dynamic, multi-level interactions between agency and structure are a key mechanism of transformative change, in part through spillover effects that expand the reach of bright spots.[31,33] For instance, in the United States, dynamic interactions between farmer networks, small changes to Farm Bill conservation and insurance programs, and development of new markets and supply chains are creating opportunities for a wider group of farmers to diversify their rotations. There has also been a growing influence of consumer demand for organic, local, and sustainably produced food, which is a force that could ultimately pressure the dominant regime to transform. In Malawi, changes to governance, reforms such as decentralized extension programs, and participatory research on diversification have reinforced each other and supported the growth of civil society.[129] Farmer networks have grown with support from educational efforts and external researchers, allowing scaling up, while rising costs of purchased agricultural inputs provide opportunities for change. In Brazil, farmer networks and social movements played an important role in motivating and designing progressive federal food systems policies. Although these national programs in Brazil diminished under the administration elected in 2018, they show how the presence of strong network and institutional pathways can produce larger spillover effects, increasing the scale of diversified farming systems (Figure 3), especially in regions with effective policy implementation. Overall, the three cases show that creating a supportive structural context that promotes expansion of local initiatives can be accelerated when civil society groups, such as farmer organizations, nongovernmental organizations (NGOs), and social movements, apply pressure to the dominant social-ecological system.

Finally, the need for structural change also applies to research institutions and the institutions that finance research. Scientists have a key role to play in shifting power imbalances by conducting interdisciplinary and participatory research on farming systems, such as the approaches used in our three case studies. Rather than thinking of current governance systems and inequities as inevitable, scholars can co-develop research with communities and other partners to foster the joint goals of human and ecosystem health. Experience shows that, to be effective, these research efforts should be inclusive of diverse stakeholders, particularly those whose voices and knowledge systems (e.g., non-western, traditional) are marginalized and oppressed.[10,45] The increasingly important influence of structural constraints on individual decision-making[51] and the dynamic multi-level interactions in the three cases also demonstrate the need for whole-systems and long-term research approaches that consider factors related to agency and structure.

Policy implications

Diversified farming systems are critical for achieving the multidimensional targets of SDG 2, Zero Hunger, with co-benefits for other SDGs, including nature-based solutions to tackling global climate change and loss of biodiversity.[10,12,134,135] Yet, because diversified farming systems are often neglected in policy and research programs, they still face barriers to scaling up. The bright spots we describe here, which demonstrate the feasibility of diversified farming practices despite structural barriers, provide insights that can inform broader policies to accelerate needed farming systems transformations.[50,135] We offer the following broad-scale policy recommendations related to the specific network and institutional mechanisms for diversification

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identified in the case studies to foster environmental sustainability, public health, and social equity:

- Improve anti-trust laws and policies to reduce the excessive corporate power that creates large structural barriers to diversification and to prevent increased supply chain vulnerabilities associated with the concentration of agribusinesses and food systems governance;
- Implement targeted cost-share payments for increasing diversity at field, farm, and landscape scales, particularly in the early years of transition, while ecosystem functions are still being restored and extra labor and other resources may be needed;
- Support the development of structured markets that link goals for environmental sustainability with goals for food and nutrition security and social equity—for example, public procurement for public nutrition programs (i.e., in schools and hospitals) or local businesses and markets;
- Increase farmers' access to land, infrastructure, and other resources for managing diverse crops and livestock through improved tenure systems, support of local knowledge and seed exchange in rural contexts, and financial support mechanisms, particularly for improving gender equity;
- Encourage corporate social responsibility norms and tracking systems that support diversified supply chains;
- Address legal barriers through improved laws and policies regulating environmental pollution and requiring retention of some native habitat in agricultural landscapes;
- Invest in participatory, social-ecological systems research and education, increasing opportunities for co-creation and design of farming systems to ensure sovereignty and sustainability of transformative efforts through local leadership.

These recommendations are synergistic. For instance, our analysis identifies the reinforcing interactions between network and institutional pathways that produce win-win outcomes and increase the scale of transitions. In each case study, we identified either a network or institutional pathway as the main mechanism of diversification, yet both pathways work together. These bright spots demonstrate that expanding the presence of diversified farming systems will require grassroots organizing and institutional change to erode structural barriers and mobilize key resources for diversification.

Given increasing external pressures to transform agricultural systems, including climate change, human pandemics, consumer interest in sustainable diets, and movements for social justice, there are new windows of opportunity for widespread transitions to diversified farming systems. The coronavirus disease 2019 (COVID-19) shock and Ukraine-Russia conflict have confirmed that simplified production systems and consolidated supply chains lack adaptive capacity,[136] leading to tragic co-occurrence of unprecedented food waste and rapid rises in food insecurity.[137] In contrast, diversified farming systems increase resilience,[31] including buffering against extreme weather events caused by climate change.[138] It is therefore critical to support efforts to build new coalitions (e.g., across actors with rural and urban interests) that can advocate for the transformative policy changes outlined here. Together, researcher-practitioner partnerships focused on understanding transition pathways and outcomes can help foster the transformative change necessary to scale farm diversification and social and environmental sustainability.

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AUTHOR CONTRIBUTIONS

Conceptualization, all authors; methodology, Z.M. and C.K.; visualization, S.M., O.M.S., and J.B. with input from all authors; writing – original draft, J.B. with contributions from H.W., D.J., A.E.S., R.B.K., S.M., S.S., Z.M., C.K., and R.G.; writing – review & editing, all authors.

REFERENCES

1. Matson, P.A., Parton, W.J., Power, A.G., and Swift, M.J. (1997). Agricultural intensification and ecosystem properties. Science *277*, 504–509.
2. Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A., et al. (2015). Planetary boundaries: guiding human development on a changing planet. Science *347*, 1259855.
3. Ramankutty, N., Mehrabi, Z., Waha, K., Jarvis, L., Kremen, C., Herrero, M., and Rieseberg, L.H. (2018). Trends in global agricultural land use: implications for environmental health and food security. Annu. Rev. Plant Biol. *69*, 789–815.
4. Martin, A.R., Cadotte, M.W., Isaac, M.E., Milla, R., Vile, D., and Violle, C. (2019). Regional and global shifts in crop diversity through the Anthropocene. PLoS One *14*, e0209788.
5. Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L.H., and Struik, P.C. (2014). Increasing homogeneity in global food supplies and the implications for food security. Proc. Natl. Acad. Sci. USA *111*, 4001–4006.
6. Aguiar, S., Texeira, M., Garibaldi, L.A., and Jobbágy, E.G. (2020). Global changes in crop diversity: trade rather than production enriches supply. Global Food Secur. *26*, 100385.
7. Snapp, S. (2020). A mini-review on overcoming a calorie-centric world of monolithic annual crops. Front. Sustain. Food Syst. *4*, 540181. https://doi.org/10.3389/fsufs.
8. Aguilar, J., Gramig, G.G., Hendrickson, J.R., Archer, D.W., Forcella, F., and Liebig, M.A. (2015). Crop species diversity changes in the United States: 1978–2012. PLoS One *10*, e0136580.
9. Chibwana, C., Fisher, M., and Shively, G. (2012). Cropland allocation effects of agricultural input subsidies in Malawi. World Dev. *40*, 124–133.
10. Blesh, J., Hoey, L., Jones, A.D., Friedmann, H., and Perfecto, I. (2019). Development pathways toward "zero hunger". World Dev. *118*, 1–14.
11. Dury, S., Bendjebbar, P., Hainzelin, E., Giordano, T., and Bricas, N. (2019). Food Systems at Risk. New Trends and Challenges (FAO-CIRAD-European Commission).
12. Delabre, I., Rodriguez, L.O., Smallwood, J.M., Scharlemann, J.P.W., Alcamo, J., Antonarakis, A.S., Rowhani, P., Hazell, R.J., Aksnes, D.L., Balvanera, P., et al. (2021). Actions on sustainable food production and consumption for the post-2020 global biodiversity framework. Sci. Adv. *7*, eabc8259.
13. Kremen, C., Iles, A., and Bacon, C. (2012). Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. Ecol. Soc. *17*, art44.

Please cite this article in press as: Blesh et al., Against the odds: Network and institutional pathways enabling agricultural diversification, One Earth (2023), https://doi.org/10.1016/j.oneear.2023.03.004

14. Hill, S.B., and MacRae, R.J. (1996). Conceptual framework for the transition from conventional to sustainable agriculture. J. Sustain. Agric. *7*, 81–87.
15. Tilman, D., Isbell, F., and Cowles, J.M. (2014). Biodiversity and ecosystem functioning. Annu. Rev. Ecol. Evol. Syst. *45*, 471–493.
16. Isbell, F., Adler, P.R., Eisenhauer, N., Fornara, D., Kimmel, K., Kremen, C., Letourneau, D.K., Liebman, M., Polley, H.W., Quijas, S., and Scherer-Lorenzen, M. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. J. Ecol. *105*, 871–879.
17. Tamburini, G., Bommarco, R., Wanger, T.C., Kremen, C., van der Heijden, M.G.A., Liebman, M., and Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. Sci. Adv. *6*, eaba1715.
18. Beillouin, D., Ben-Ari, T., Malezieux, E., Seufert, V., and Makowski, D. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. Global Change Biol.
19. Nelson, K.S., and Burchfield, E.K. (2021). Landscape complexity and US Crop Production. Nat. Food *2*, 330–338.
20. Larsen, A.E., and Noack, F. (2017). Identifying the landscape drivers of agricultural insecticide use leveraging evidence from 100,000 fields. Proc. Natl. Acad. Sci. USA *114*, 5473–5478.
21. Kremen, C., and Merenlender, A.M. (2018). Landscapes that work for biodiversity and people. Science *362*, eaau6020.
22. 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 Secur. *7*, 535–554.
23. 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.
24. Bezner Kerr, R., Madsen, S., Stüber, M., Liebert, J., Enloe, S., Borghino, N., Parros, P., Mutyambai, D.M., Prudhon, M., and Wezel, A. (2021). Can agroecology improve food security and nutrition? A review. Global Food Secur. *29*, 100540.
25. Hendrickson, M.K. (2015). Resilience in a concentrated and consolidated food system. J. Environ. Stud. Sci. *5*, 418–431.
26. Garibaldi, L.A., Oddi, F.J., Miguez, F.E., Bartomeus, I., Orr, M.C., Jobbágy, E.G., Kremen, C., Schulte, L.A., Hughes, A.C., Bagnato, C., et al. (2020). Working landscapes need at least 20% native habitat. Conservation Letters *14*, e12773.
27. DeLonge, M.S., Miles, A., and Carlisle, L. (2016). Investing in the transition to sustainable agriculture. Environ. Sci. Pol. *55*, 266–273.
28. Isaac, M., Isakson, S., Dale, B., Levkoe, C., Hargreaves, S., Méndez, V., Wittman, H., Hammelman, C., Langill, J., Martin, A., et al. (2018). Agroecology in Canada: towards an integration of agroecological practice, movement, and science. Sustainability *10*, 3299.
29. Fischer, J., Abson, D.J., Bergsten, A., French Collier, N., Dorresteijn, I., Hanspach, J., Hylander, K., Schultner, J., and Senbeta, F. (2017). Reframing the food–biodiversity challenge. Trends Ecol. Evol. *32*, 335–345.
30. Wittman, H., Chappell, M.J., Abson, D.J., Kerr, R.B., Blesh, J., Hanspach, J., Perfecto, I., and Fischer, J. (2017). A social-ecological perspective on harmonizing food security and biodiversity conservation. Reg. Environ. Change *17*, 1291–1301. https://doi.org/10.1007/s10113-016-1045-9.
31. Zimmerer, K.S., Lambin, E.F., and Vanek, S.J. (2018). Smallholder telecoupling and potential sustainability. Ecol. Soc. *23*, art30.
32. Geels, F.W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Pol. *31*, 1257–1274.
33. Geels, F.W., Sovacool, B.K., Schwanen, T., and Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. Science *357*, 1242–1244.
34. Anderson, C.R., Bruil, J., Chappell, M.J., Kiss, C., and Pimbert, M.P. (2019). From transition to domains of transformation: getting to sustainable and just food systems through agroecology. Sustainability *11*, 5272.
35. Bennett, E.M., Solan, M., Biggs, R., McPhearson, T., Norström, A.V., Olsson, P., Pereira, L., Peterson, G.D., Raudsepp-Hearne, C., Biermann, F., et al. (2016). Bright spots: seeds of a good Anthropocene. Front. Ecol. Environ. *14*, 441–448.
36. Cinner, J.E., Huchery, C., MacNeil, M.A., Graham, N.A.J., McClanahan, T.R., Maina, J., Maire, E., Kittinger, J.N., Hicks, C.C., Mora, C., et al. (2016). Bright spots among the world's coral reefs. Nature *535*, 416–419.
37. Blesh, J., and Wolf, S.A. (2014). Transitions to agroecological farming systems in the Mississippi River Basin: toward an integrated socioecological analysis. Agric. Human Values *31*, 621–635. https://doi.org/10.1007/s10460-014-9517-3.
38. Blesh, J., and Galt, R.E. (2017). Transitions to agroecological nutrient management practices in the USA Corn Belt. In Agroecological Practices for Sustainable Agriculture, A. Wezel, ed. (World Scientific), pp. 85–126.
39. Blesh, J., and Drinkwater, L.E. (2013). The impact of nitrogen source and crop rotation on nitrogen mass balances in the Mississippi River Basin. Ecol. Appl. *23*, 1017–1035.
40. Valencia, V., Wittman, H., and Blesh, J. (2019). Structuring markets for resilient farming systems. Agron. Sustain. Dev. *39*, 25.
41. Stratton, A.E., Wittman, H., and Blesh, J. (2021). Diversification supports farm income and improved working conditions during agroecological transitions in southern Brazil. Agron. Sustain. Dev. *41*, 1–22.
42. Guerra, J., Blesh, J., Schmitt, A.F., and Wittman, H. (2017). Pathways to agroecology through mediated markets in Santa Catarina, Brazil. Elementa Sci. Anthropocene *5*, 67.
43. Snapp, S., Bezner Kerr, R., Ota, V., Kane, D., Shumba, L., and Dakishoni, L. (2019). Unpacking a crop diversity hotspot: farmer practice and preferences in Northern Malawi. Int. J. Agric. Sustain. *17*, 172–188.
44. Bezner Kerr, R., Kangmennaang, J., Dakishoni, L., Nyantakyi-Frimpong, H., Lupafya, E., Shumba, L., Msachi, R., Boateng, G.O., Snapp, S.S., Chitaya, A., et al. (2019). Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agric. Ecosyst. Environ. *279*, 109–121.
45. Bezner Kerr, R., Young, S.L., Young, C., Santoso, M.V., Magalasi, M., Entz, M., Lupafya, E., Dakishoni, L., Morrone, V., Wolfe, D., and Snapp, S.S. (2019). Farming for change: developing a participatory curriculum on agroecology, nutrition, climate change and social equity in Malawi and Tanzania. Agric. Human Values *36*, 549–566.
46. Madsen, S., Bezner Kerr, R., Shumba, L., and Dakishoni, L. (2021). Agroecological practices of legume residue management and crop diversification for improved smallholder food security, dietary diversity and sustainable land use in Malawi. Agroecol. Sustain. Food Syst. *45*, 197–224.
47. Howard, P.H. (2015). Intellectual property and consolidation in the seed industry. Crop Sci. *55*, 2489–2495.
48. Clapp, J., and Purugganan, J. (2020). Contextualizing corporate control in the agrifood and extractive sectors. Globalizations *17*, 1265–1275.
49. Lyon, A., Friedmann, H., and Wittman, H. (2021). Can public universities play a role in fostering seed sovereignty? Elementa Sci. Anthropocene *9*.
50. FAO; UNDP; UNEP (2021). A Multi-Billion-Dollar Opportunity - Repurposing Agricultural Support to Transform Food Systems (FAO).
51. Stuart, D., and Gillon, S. (2013). Scaling up to address new challenges to conservation on US farmland. Land Use Pol. *31*, 223–236. https://doi.org/10.1016/j.landusepol.2012.07.003.
52. Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P., and Singh, A.S. (2019). Adoption of agricultural conservation practices in the United States: evidence from 35 years of quantitative literature. J. Soil Water Conserv. *74*, 520–534.
53. Rogers, E.M. (2003). Diffusion of Innovations (Free Press).
54. Ajzen, I. (1991). The theory of planned behavior. Organ. Behav. Hum. Decis. Process. *50*, 179–211.
55. Foguesatto, C.R., Borges, J.A.R., and Machado, J.A.D. (2019). Farmers' typologies regarding environmental values and climate change: evidence from southern Brazil. J. Clean. Prod. *232*, 400–407.
56. Roesch-McNally, G.E., Basche, A.D., Arbuckle, J., Tyndall, J.C., Miguez, F.E., Bowman, T., and Clay, R. (2018). The trouble with cover crops: farmers' experiences with overcoming barriers to adoption. Renew. Agric. Food Syst. *33*, 322–333.
57. Floress, K., García de Jalón, S., Church, S.P., Babin, N., Ulrich-Schad, J.D., and Prokopy, L.S. (2017). Toward a theory of farmer conservation attitudes: dual interests and willingness to take action to protect water quality. J. Environ. Psychol. *53*, 73–80.
58. Bacon, C.M., Getz, C., Kraus, S., Montenegro, M., and Holland, K. (2012). The social dimensions of sustainability and change in diversified farming systems. Ecol. Soc. *17*, art41.
59. Sánchez, A.C., Kamau, H.N., Grazioli, F., and Jones, S.K. (2022). Financial profitability of diversified farming systems: a global meta-analysis. Ecol. Econ. *201*, 107595.
60. Mier y Terán Giménez Cacho, M., Giraldo, O.F., Aldasoro, M., Morales, H., Ferguson, B.G., Rosset, P., Khadse, A., and Campos, C. (2018). Bringing agroecology to scale: key drivers and emblematic cases. Agroecol. Sustain. Food Syst. *42*, 637–665.
61. Iles, A. (2021). Can Australia transition to an agroecological future? Agroecol. Sustain. Food Syst. *45*, 3–41.

Please cite this article in press as: Blesh et al., Against the odds: Network and institutional pathways enabling agricultural diversification, One Earth (2023), https://doi.org/10.1016/j.oneear.2023.03.004

62. Gonzalez de Molina, M., Petersen, P.F., Peña, F.G., and Caporal, F.R. (2019). Political Agroecology: Advancing the Transition to Sustainable Food Systems (CRC Press).
63. Kansanga, M.M., Luginaah, I., Bezner Kerr, R., Dakishoni, L., and Lupafya, E. (2021). Determinants of smallholder farmers' adoption of short-term and long-term sustainable land management practices. Renew. Agric. Food Syst. *36*, 265–277.
64. Niederle, P., Loconto, A., Lemeilleur, S., and Dorville, C. (2020). Social movements and institutional change in organic food markets: evidence from participatory guarantee systems in Brazil and France. J. Rural Stud. *78*, 282–291.
65. Zimnicki, T., Boring, T., Evenson, G., Kalcic, M., Karlen, D.L., Wilson, R.S., Zhang, Y., and Blesh, J. (2020). On quantifying water quality benefits of healthy soils. Bioscience *70*, 343–352. https://doi.org/10.1093/biosci/biaa011.
66. Wittman, H., Desmarais, A., and Wiebe, N. (2010). The origins and potential of food sovereignty. In Food Sovereignty: Reconnecting Food, Nature and Community, H. Wittman, A. Desmarais, and N. Wiebe, eds. (Food First), pp. 1–14.
67. David, M.B., Drinkwater, L.E., and McIsaac, G.F. (2010). Sources of nitrate yields in the Mississippi River Basin. J. Environ. Qual. *39*, 1657–1667.
68. Crossley, M.S., Burke, K.D., Schoville, S.D., and Radeloff, V.C. (2021). Recent collapse of crop belts and declining diversity of US agriculture since 1840. Glob. Chang. Biol. *27*, 151–164.
69. USDA (2017). Quick Stats (National Agricultural Statistics Service). http://nass.usda.gov.
70. Thaler, E.A., Larsen, I.J., and Yu, Q. (2021). The extent of soil loss across the US Corn Belt. Proc. Natl. Acad. Sci. USA *118*, e1922375118.
71. Lobao, L., and Stofferahn, C.W. (2008). The community effects of industrialized farming: social science research and challenges to corporate farming laws. Agric. Human Values *25*, 219–240.
72. Lighthall, D.R., and Roberts, R.S. (1995). Towards an alternative logic of technological change: insights from Corn Belt agriculture. J. Rural Stud. *11*, 319–334.
73. Barnett, B.J. (2014). The last farm bill? J. Agric. Appl. Econ. *46*, 311–319.
74. Cronon, W. (2009). Nature's Metropolis: Chicago and the Great West (WW Norton & Company).
75. USDA (2021). Economic research service. U.S. bioenergy statistics. https://www.ers.usda.gov/data-products/us-bioenergy-statistics/.
76. Douglas, M.R., and Tooker, J.F. (2015). Large-scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in US field crops. Environ. Sci. Technol. *49*, 5088–5097.
77. McMichael, P. (2009). A food regime analysis of the 'world food crisis'. Agric. Human Values *26*, 281–295.
78. Carolan, M.S. (2006). Do you see what I see? Examining the epistemic barriers to sustainable agriculture. Rural Sociol. *71*, 232–260.
79. Cassidy, E.S., West, P.C., Gerber, J.S., and Foley, J.A. (2013). Redefining agricultural yields: from tonnes to people nourished per hectare. Environ. Res. Lett. *8*, 034015. https://doi.org/10.1088/1748-9326/8/3/034015.
80. Delate, K., Cambardella, C., Chase, C., Johanns, A., and Turnbull, R. (2013). The Long-Term Agroecological Research (LTAR) experiment supports organic yields, soil quality, and economic performance in Iowa. Crop Manag. *12*, 1–13.
81. Liebman, M., Helmers, M.J., Schulte, L.A., and Chase, C.A. (2013). Using biodiversity to link agricultural productivity with environmental quality: results from three field experiments in Iowa. Renew. Agric. Food Syst. *28*, 115–128. https://doi.org/10.1017/s1742170512000300.
82. Sulc, R.M., and Tracy, B.F. (2007). Integrated Crop–Livestock Systems in the US Corn Belt (Wiley Online Library).
83. Schulte, L.A., Niemi, J., Helmers, M.J., Liebman, M., Arbuckle, J.G., James, D.E., Kolka, R.K., O'Neal, M.E., Tomer, M.D., Tyndall, J.C., et al. (2017). Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands. Proc. Natl. Acad. Sci. USA *114*, 11247–11252.
84. Baumgart-Getz, A., Prokopy, L.S., and Floress, K. (2012). Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. J. Environ. Manage. *96*, 17–25.
85. Bell, M.M. (2004). Farming for Us All: Practical Agriculture & the Cultivation of Sustainability (Pennsylvania State Universty Press).
86. PFI (2021). Practical farmers of Iowa small grains program. https://practicalfarmers.org/programs/field-crops/small-grains/.
87. Basche, A., Tully, K., Álvarez-Berríos, N.L., Reyes, J., Lengnick, L., Brown, T., Moore, J.M., Schattman, R.E., Johnson, L.K., and Roesch-McNally, G. (2020). Evaluating the untapped potential of US conservation investments to improve soil and environmental health. Front. Sustain. Food Syst. *4*, 236.
88. Carolan, M.S. (2006). Social change and the adoption and adaptation of knowledge claims: whose truth do you trust in regard to sustainable agriculture? Agric. Human Values *23*, 325–339.
89. Jacobsen, K., Niewolny, K., Schroeder-Moreno, M., Van Horn, M., Harmon, A., Chen Fanslow, Y., Williams, M., and Parr, D. (2012). Sustainable agriculture undergraduate degree programs: a land-grant university mission. J. Agric. Food Syst. Commun. Dev. 13–26. https://doi.org/10.5304/jafscd.2012.023.004.
90. USDA (2021). Risk management agency. Whole farm revenue protection. https://www.rma.usda.gov/en/Policy-and-Procedure/Insurance-Plans/Whole-Farm-Revenue-Protection.
91. GAO (2017). Agricultural Conservation: USDA's Environmental Quality Incentives Program Could Be Improved to Optimize Benefits (United States Government Accountability Office). GAO-17-225.
92. Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., and Baumgart-Getz, A. (2008). Determinants of agricultural best management practice adoption: evidence from the literature. J. Soil Water Conserv. *63*, 300–311.
93. Tranjan, J.F. (2016). Participatory Democracy in Brazil: Socioeconomic and Political Origins (University of Notre Dame Press).
94. Wolford, W. (2010). This Land Is Ours Now: Social Mobilization and the Meanings of Land in Brazil (Duke University Press).
95. Tarlau, R. (2019). Occupying Schools, Occupying Land: How the Landless Workers Movement Transformed Brazilian Education (Oxford University Press).
96. Schneider, S., and Niederle, P.A. (2010). Resistance strategies and diversification of rural livelihoods: the construction of autonomy among Brazilian family farmers. J. Peasant Stud. *37*, 379–405. https://doi.org/10.1080/03066151003595168.
97. Prado, C., and Macedo, S. (1967). The Colonial Background of Modern Brazil (Forma∼ ao Do Brasil Contemporâneo, Colônia, Engl.) Transl. From the Portuguese by Suzette Macedo.
98. da Costa, M.B.B., Souza, M., Júnior, V.M., Comin, J.J., and Lovato, P.E. (2017). Agroecology development in Brazil between 1970 and 2015. Agroecol. Sustain. Food Syst. *41*, 276–295.
99. Altieri, M.A., Lana, M.A., Bittencourt, H.V., Kieling, A.S., Comin, J.J., and Lovato, P.E. (2011). Enhancing crop productivity via weed suppression in organic no-till cropping systems in Santa Catarina, Brazil. J. Sustain. Agric. *35*, 855–869.
100. Warnken, P.F. (1999). The Development and Growth of the Soybean Industry in Brazil (Iowa State University Press).
101. Andrade, D. (2016). 'Export or die': the rise of Brazil as an agribusiness powerhouse. Third World Themat. TWQ J. *1*, 653–672.
102. Marques, F.C., and Oliveira, D. (2016). Agricultura Ecológica ao Sul do Brasil: de alternativa à contra-tendência. Íconos Rev. Ciencias Sociales, 87–106.
103. Escosteguy, I.L. (2019). Inovações Socias Na Promoção Da Agroecologia e de Redes de Civismo Agroalimentar Em Florianópolis-SC (Universidade Federal de Santa Catarina).
104. James, D., and Bowness, E. (2021). Growing and Eating Sustainably: Agroecology in Action (Fernwood Publishing).
105. Blesh, J., and Wittman, H. (2015). "Brasilience": assessing resilience in land reform settlements in the Brazilian Cerrado. Hum. Ecol. *43*, 531–546.
106. Wittman, H., and Blesh, J. (2015). Food sovereignty and Fome Zero: connecting public food procurement programs to sustainable rural development in Brazil. J. Agrar. Change *17*, 81–105.
107. Dyngeland, C., Oldekop, J.A., and Evans, K.L. (2020). Assessing multidimensional sustainability: lessons from Brazil's social protection programs. Proc. Natl. Acad. Sci. USA *117*, 20511–20519.
108. Medina, G., Almeida, C., Novaes, E., Godar, J., and Pokorny, B. (2015). Development conditions for family farming: lessons from Brazil. World Dev. *74*, 386–396.
109. Sauer, S., Leite, A.Z., and Tubino, N.L.G. (2020). Agenda política da terra no governo Bolsonaro. Revista da ANPEGE *16*, 285–318.
110. de Souza, J.C., da Silva Pugas, A., Rover, O.J., and Nodari, E.S. (2021). Social innovation networks and agrifood citizenship. The case of Florianópolis Area, Santa Catarina/Brazil. J. Rural Stud. https://doi.org/10.1016/j.jrurstud.2021.09.002.
111. Ferreira, G.C. (2019). Pelo direito à cidade: políticas públicas e hortas urbanas em Florianópolis. História Unicap *6*, 259–273.

Please cite this article in press as: Blesh et al., Against the odds: Network and institutional pathways enabling agricultural diversification, One Earth (2023), https://doi.org/10.1016/j.oneear.2023.03.004

112. Jones, A.D., Shrinivas, A., and Bezner Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. Food Pol. *46*, 1–12.

113. NSO (2020). The Fifth Integrated Household Survey (IHS5) 2020 Report (National Statistical Office. Government of Malawi).

114. Kankwamba, H., Kadzamira, M., and Pauw, K. (2018). How diversified is cropping in Malawi? Patterns, determinants and policy implications. Food Secur. *10*, 323–338.

115. Bezner Kerr, R. (2014). Lost and found crops: agrobiodiversity, indigenous knowledge, and a feminist political ecology of sorghum and finger millet in northern Malawi. Ann. Assoc. Am. Geogr. *104*, 577–593.

116. Moyo, B.H.Z., and Moyo, D.Z. (2014). Indigenous knowledge perceptions and development practice in northern M alawi. Geogr. J. *180*, 392–401.

117. Vail, H. (1983). The state and the creation of colonial Malawi's agricultural economy. In Imperialism, Colonialism and Hunger: East and Central Africa, R.I. Rotberg, ed. (Heath), pp. 39–87.

118. Palacios-Lopez, A., Christiaensen, L., and Kilic, T. (2017). How much of the labor in African agriculture is provided by women? Food Pol. *67*, 52–63.

119. Bezner Kerr, R. (2013). Seed struggles and food sovereignty in northern Malawi. J. Peasant Stud. *40*, 867–897.

120. Andersson Djurfeldt, A., Cuthbert Isinika, A., and Mawunyo Dzanku, F. (2018). Agriculture, Diversification, and Gender in Rural Africa: Longitudinal Perspectives from Six Countries (Oxford University Press).

121. Chinsinga, B. (2011). Seeds and subsidies: the political economy of input programmes in Malawi. IDS Bull. *42*, 59–68.

122. Peters, P.E., and Kambewa, D. (2007). Whose security? Deepening social conflict over 'customary'land in the shadow of land tenure reform in Malawi. J. Mod. Afr. Stud. *45*, 447–472.

123. McCracken, J. (1982). Peasants, planters and the colonial state: the case of Malawi, 1905-1940. J. E. Afr. Res. Dev. *12*, 21–35.

124. Anseeuw, W., Jayne, T., Kachule, R., and Kotsopoulos, J. (2016). The quiet rise of medium-scale farms in Malawi. Land *5*, 19.

125. Denning, G., Kabambe, P., Sanchez, P., Malik, A., Flor, R., Harawa, R., Nkhoma, P., Zamba, C., Banda, C., Magombo, C., et al. (2009). Input subsidies to improve smallholder maize productivity in Malawi: toward an African green revolution. PLoS Biol. *7*, e1000023.

126. GoM (2018). Government of Malawi National Seed Policy.

127. Messina, J.P., Peter, B.G., and Snapp, S.S. (2017). Re-evaluating the Malawian farm input subsidy programme. Nat. Plants *3*, 17013–17019.

128. Bezner Kerr, R., and Patel, R. (2014). Food security in Malawi: disputed diagnoses, different prescriptions. In Food Security and Development: Country Cases (Routledge), pp. 205–229.

129. Masangano, C., Kambewa, D., Bosscher, N., and Fatch, P. (2017). Malawi's experiences with the implementation of pluralistic, demand-driven and decentralised agricultural extension policy. J. Agric. Ext. Rural Dev. *9*, 185–195.

130. Hussein, M.K. (2017). Local governance in Malawi–sighs and sobs in district councils? Int. J. Soc. Sci. Humanities Invent. *4*, 3222–3230.

131. Kerr, R.B., and Chirwa, M. (2004). Participatory research approaches and social dynamics that influence agricultural practices to improve child nutrition in Malawi. EcoHealth *1*, SU109–SU119. https://doi.org/10.1007/s10393-004-0038-1.

132. Nyantakyi-Frimpong, H., Hickey, C., Lupafya, E., Dakishoni, L., Bezner Kerr, R., Luginaah, I., and Katundu, M. (2017). A farmer-to-farmer agroecological approach to addressing food security in Malawi. In Everyday Experts: How People's Knowledge Can Transform the Food System, p. 121.

133. Santoso, M.V., Bezner Kerr, R.N., Kassim, N., Martin, H., Mtinda, E., Njau, P., Mtei, K., Hoddinott, J., and Young, S.L. (2021). A nutrition-sensitive agroecology intervention in rural Tanzania increases children's dietary diversity and household food security but does not change child anthropometry: results from a cluster-randomized trial. J. Nutr. *151*, 2010–2021.

134. Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J., Smith, A., and Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philos. Trans. R. Soc. Lond. B Biol. Sci. *375*, 20190120.

135. Eyhorn, F., Muller, A., Reganold, J.P., Frison, E., Herren, H.R., Luttikholt, L., Mueller, A., Sanders, J., Scialabba, N.E.-H., Seufert, V., and Smith, P. (2019). Sustainability in global agriculture driven by organic farming. Nat. Sustain. *2*, 253–255.

136. Swinnen, J., and McDermott, J. (2020). COVID-19 and global food security. EuroChoices *19*, 26–33.

137. HLPE (2020). Impacts of COVID-19 on Food Security and Nutrition: Developing Effective Policy Responses to Address the Hunger and Malnutrition Pandemic.

138. Bowles, T.M., Mooshammer, M., Socolar, Y., Calderón, F., Cavigelli, M.A., Culman, S.W., Deen, W., Drury, C.F., Garcia y Garcia, A., Gaudin, A.C., et al. (2020). Long-term evidence shows that crop-rotation diversification increases agricultural resilience to adverse growing conditions in North America. One Earth *2*, 284–293.