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Biocultural Diversity for Food System Transformation Under Global Environmental Change

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Biocultural diversity is central to the nutrition, resilience, and adaptive capacity of Indigenous and traditional peoples, who collectively maintain the longest ongoing human experiences with the provision of food under environmental change. In the form of crops and livestock and associated knowledge on their cultivation and use, food-related biocultural diversity likewise underpins global food security. As food system transformation is increasingly recognized as an urgent priority, we argue that food security, sustainability, resilience, and adaptive capacity can be furthered through greater emphasis on conservation, use, and celebration of food-related biocultural diversity. We provide examples from the Parque de la Papa, Peru, a "food biocultural diversity neighborhood" which through advocacy and partnerships based around its diversity, has both enhanced local communities and contributed to food security at a much larger scale. We outline collaborative actions which we believe are important to up- and out-scale food biocultural diversity neighborhood successes. Further research and knowledge sharing are critical to better document, understand, track, and communicate the value, functions, and state of biocultural diversity in food systems. Expanded training and capacity development opportunities are important to enable the interchange of experiences and visions on food, health, sustainability and resilience, climate adaptation, equity and justice, and livelihood generation with others facing similar challenges. Finally, strengthened networking across food biocultural diversity neighborhoods is essential to their persistence and growth as they increasingly engage with local, national, and international organizations, based on shared interests and on their own terms, across five continents.

Keywords: sustainable food systems, farmers' rights, crop wild relatives, crop diversity, climate change adaptation, agrobiodiversity

BIOCULTURAL DIVERSITY AND NEEDED TRANSFORMATION OF THE GLOBAL FOOD SYSTEM

The food we eat connects us to those who cultivated it, to the seeds they planted, and, ultimately, to the diverse peoples and places around this planet where the crops and livestock that nourish us originated (Khoury et al., 2016). All of us are the beneficiaries of processes that began for the most part 4,000–12,000 years ago, when many different cultures around the world became increasingly interdependent with the plants and animals they interacted with, through the biocultural processes of domestication (Larson et al., 2014).

These co-evolutionary processes have continued through to the present day in geographic centers of origin of agriculture, now commonly called "primary regions of (crop and livestock) diversity," resulting in tremendous variation in cultivated species, varieties and breeds, and underlying genetic and phenotypic diversity, as well as myriad cultural uses and customs around them (Bellon et al., 2005, 2017; Baltazar et al., 2015). This biocultural diversity—defined here as "dynamic, place-based aspects of nature arising from links and feedbacks between human cultural diversity and biological diversity" (Bridgewater and Rotherham, 2019)—provides the foundation for Indigenous and traditional peoples' nutrition, as well as the resilience and adaptive capacity of their food systems (Kuhnlein et al., 2009).

Cultivation and use practices both maintain and further evolve this diversity, with exchange and gene flow among domesticated (and occasionally also with wild progenitor) forms encouraging the development of new variation, and continued cultivation and selection leading to local adaptation (Bellon, 1996; Louette et al., 1997; Jarvis and Hodgkin, 2002; Allinne et al., 2007; Mercer and Perales, 2010; Rojas-Barrera et al., 2019). These traditions embody the longest ongoing human experiences with the provision of food under environmental change, including, due to commonly being in mountainous and other areas of great ecological diversity, significant stresses, shocks, and extremes (Arce et al., 2018; Argumedo et al., 2020; FAO Alliance of Bioversity International CIAT, 2021).

Food-related biocultural diversity—in the form of crops and livestock and associated knowledge on their cultivation and use—has dispersed from its primary regions of diversity to the far reaches of the planet, as humanity itself has spread around the world and become more interconnected (Khoury et al., 2016). Virtually all cultures now produce, trade, and eat a highly varied assortment of plants and animals, most of which were originally domesticated and diversified in distant lands. In their new homes, these foods have further evolved to meet local needs, conditions, and tastes, contributing to food security and nutrition, agricultural livelihoods, and cultural identities. Yet these food systems also remain connected to and dependent on primary and other regions of diversity, including for the genetic resources used in crop and livestock breeding to address productivity, pests and diseases, new markets and products, and other challenges and opportunities (Hoisington et al., 1999; Gepts, 2006).

Modern economic and agricultural development, globalization, urbanization, and other forces have led to the dominance of certain foods in the global food system, especially high starch, sugar, protein, and fatty foods, and have driven increasing homogeneity in food supplies worldwide (Khoury et al., 2014). This has contributed to reduced rates of undernutrition, but, in combination with widespread changes in lifestyle, has also led to increasing overweight and obesity as well as diet-related non-communicable diseases globally, and has not resolved persisting micronutrient deficiencies (Popkin, 2006; Pingali, 2007; Kearney, 2010). The industrialized production, transport, and marketing systems organized around these foods create daunting sustainability and equity challenges, with agriculture now being the world's largest terrestrial ecosystem and among the most significant contributors to environmental degradation, climate change, and biodiversity loss globally, and with health and ecological impacts disproportionately affecting marginalized populations (Béné et al., 2019; Rockström et al., 2020). These forces have likewise led to widespread and ongoing losses in food-related biocultural diversity, including crop landraces and traditional livestock breeds as well as their wild relatives (Khoury et al., 2021).

A key pathway to greater food security and nutrition, sustainability, resilience, and adaptation outcomes in food systems is therefore through diversification, including of food products as well as processes and actors (IPES-Food, 2016; Bioversity International, 2017; HLPE, 2017, 2019; FAO, 2018a,b, 2019a; Hunter et al., 2020a; Vermeulen et al., 2020). While consultations and dialogues on food system transformation are ongoing, including currently as part of the processes of the United Nations Food Systems Summit (UNFSS), the Convention on Biological Diversity (CBD)'s post-2020 Global Biodiversity Framework, and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), there is concern that Indigenous and traditional peoples' food systems, knowledge, and biocultural processes are not receiving the acknowledgment and attention they deserve (Argumedo et al., 2020; FAO, 2021; Nature Editorial Board, 2021). This must change.

In this Perspective piece, we—a group of Indigenous and non-Indigenous researchers and activists with longstanding collaborations around biocultural diversity—argue that food system transformation can be furthered through greater emphasis on conservation, use, and celebration of food-related biocultural diversity. We provide examples from the Parque de la Papa, Peru, a "food biocultural diversity neighborhood" which through community action, advocacy, and partnerships based around its diversity, has both enhanced local communities and contributed to food security at a larger scale. Finally, we outline collaborative actions which we believe are important to up- and out-scale food biocultural diversity neighborhood successes. These include further research and knowledge sharing, expanded training and capacity development, and strengthened networking.

SAFEGUARDING, USING, AND CELEBRATING FOOD-RELATED BIOCULTURAL DIVERSITY

To achieve greater food security and nutrition, sustainability, resilience, and adaptation in this era of global environmental change, we suggest that further attention must be paid to safeguarding, creatively using, and celebrating the food-related biocultural diversity that sustains humanity.

Safeguarding: Conserving and Accessing Food-Related Biocultural Diversity

International recognition of the importance of safeguarding the world's food-related biocultural diversity has increased over recent decades (FAO, 2002, 2010, 2015, 2019b; Convention on Biological Diversity (CBD), 2010; UN, 2015; Díaz et al., 2020). Despite the wider awareness in high level policy and technical fora, much of the variation which persists in farmers' fields and in wild and semi-wild places remains vulnerable to erosion and even extinction, including traditional and local knowledge (FAO, 2019b; Khoury et al., 2021). While *in situ* diversity is constantly changing due to environmental pressures and human preferences, significant declines over many decades are cause for alarm (Khoury et al., 2021). This diversity is only partially safeguarded in *ex situ* conservation repositories, such as national, regional, and international genebanks, and is therefore not fully conserved for long-term preservation, nor readily accessible to crop and livestock breeders (Gepts, 2006; FAO, 2010; Castañeda-Álvarez et al., 2016).

To continue to meet unique local needs, bolster the resilience and adaptive capacity of agricultural communities, and to evolve alongside biotic and abiotic pressures, crops and livestock must be acquired, cultivated, selected on, and exchanged by local peoples (Berthaud, 1997; Fenzi and Bonneuil, 2016; Bellon et al., 2018). To support these processes, further strengthening of locally managed *in situ* conservation methods is needed. Emphasis on the conditions and processes that foster diversity is essential—including informal trade and exchange systems—particularly through Indigenous and traditional farmer-led efforts (Brush, 2004; Thomas et al., 2012; Stenner et al., 2016; Bellon et al., 2017; Halewood et al., 2021). These can be further supported through a wide range of external approaches, for example diversity inventories and fairs, agrobiodiversity zoning and crop diversity park systems, community seedbanks, specialized markets, participatory evolutionary breeding, and payments for agrobiodiversity conservation services (Tapia, 2000; Narloch et al., 2011; Graddy, 2014; Vernooy et al., 2017; Fadda et al., 2020). Tools and approaches appropriate to location and culture should be identified based on inclusive processes (de Haan, 2021).

To be better safeguarded against climate change and other human-caused as well as natural disasters, to be available for the innovation of crop and livestock species around the world, and to provide a historical record of biocultural diversity under global environmental change, this diversity also needs to be maintained in *ex situ* conservation repositories with the capacity to openly distribute it to breeders, researchers, educators, and farmers (Hoisington et al., 1999; Gepts, 2006; Khoury et al., 2021). To provide the necessary protections for these resources, safety backups of this diversity should also be made (Westengen et al., 2013). As with *in situ* food-related biocultural conservation efforts, these *ex situ* systems can be bolstered, in this case through the development and dissemination of improved methods and practices, and through more reliable support for essential activities and infrastructure.

It is also critical that *in situ* and *ex situ* approaches are better integrated such that resources usefully flow in both directions (Westengen et al., 2018; Ceccarelli and Grando, 2020; Fadda et al., 2020). Genebanks maintain many varieties and breeds that are no longer found on farms in regions where producers are facing increasing climate-related and other challenges, and where formal seed/breed systems are scarce or non-existent. *Ex situ* facilities should serve much more than is currently the case as providers to communities, to restore diversity lost in the past, and to distribute novel diversity, as requested. Likewise, *in situ* conservation initiatives could serve as sources for the periodic collection of germplasm. In all cases, conservation and distribution of diversity should proceed as inclusive processes, based on mutual trust and benefit, and following community agreements as well as national and international frameworks on equitable access and benefit sharing (FAO, 2002; Convention on Biological Diversity (CBD), 2014; Halewood et al., 2020).

Creative Use: Enhancing Livelihood Opportunities Based on Food-Related Biocultural Diversity

Indigenous and traditional agricultural communities in primary and other regions of food-related biocultural diversity have persisted to the present day despite loss of access to land and other natural resources, and numerous other intentional and unintentional actions which have disrupted their traditional ways of life (Garnett et al., 2018; FAO, 2019b). These communities have been impacted by economic and agricultural development and associated policies, including the industrialization of production and subsidized cultivation of staple crops in developed regions, combined with trade agreements which undermine local competitiveness. Often located in mountainous and other environments with extreme topography, such communities are also some of the most directly impacted by shifts in temperature and precipitation patterns resulting from climate change. While there is increasing awareness in global fora of equity issues related to Indigenous and traditional peoples (IFAD, 2009; UN, 2014; FAO, 2019b), and in some countries legislation has been enacted that acknowledges the rights of Indigenous peoples to their traditional livelihoods, in practice there remains much to be done to redress historical injustices, secure access to land and other resources, and open a greater range of opportunities for such communities in the food and agriculture sectors.

In this context, Indigenous and traditional agricultural communities adapt to changing livelihood challenges and opportunities through innovative use of food-related biocultural diversity. This is accomplished through ongoing introduction,

management, exchange, selection and improvement of crops and livestock, adjustments to agricultural practices and systems, and the development of new markets (FAO, 2021). External support for livelihood opportunities based on the use of food-related biocultural diversity can be accomplished through a wide range of existing and experimental tools and processes, such as through diversity-sensitive food procurement initiatives (De Schutter, 2014, 2015; Valencia et al., 2019; Swensson et al., 2021) and community-based development and marketing of value-added products, including those promoted with biocultural branding (Swiderska et al., 2019; AGUAPAN, 2020; FAO Alliance of Bioversity International CIAT, 2021).

Celebration: Awareness-Raising Around Food-Related Biocultural Diversity

Redressing the historical imbalances that have disadvantaged Indigenous and traditional agricultural communities and undervalued the food-related biocultural diversity they have generated and continue to maintain also necessitates reframing this diversity as a central community asset.

Indigenous and traditional agricultural communities are increasingly raising local and regional awareness about their biocultural diversity with practices such as community inventorying and traditional monitoring (**Figure 1**), food biodiversity fairs and seed exchange events, and school garden programs (Cocks et al., 2012; Centro Internacional de la Papa (CIP) et al., 2015; Ministerio de Agricultura y Riego (MINAGRI) et al., 2017). The development of locally appropriate dietary and nutrition guidelines and formal education programs have also demonstrated success as supportive processes (Hunter et al., 2020a,b). To expand these efforts, we see substantial potential in media, product development, festivals, and other initiatives aimed at better connecting communities to consumers, with focus on championing the links between delicious food and biocultural traditions (Chefs' Manifesto, 2018; Crop Trust, 2019; Hunter et al., 2020a). National examples of these include the agrobiodiversity and gastronomy linkages promoted by Peruanos Unidos por la Cocina y la Alimentación (PUKA) in Peru, and Movimiento de Integración Gastronómica (MIGA) in Bolivia (Biocultural Diversity and Territories Platform for Sustainable Inclusive Development, 2021).

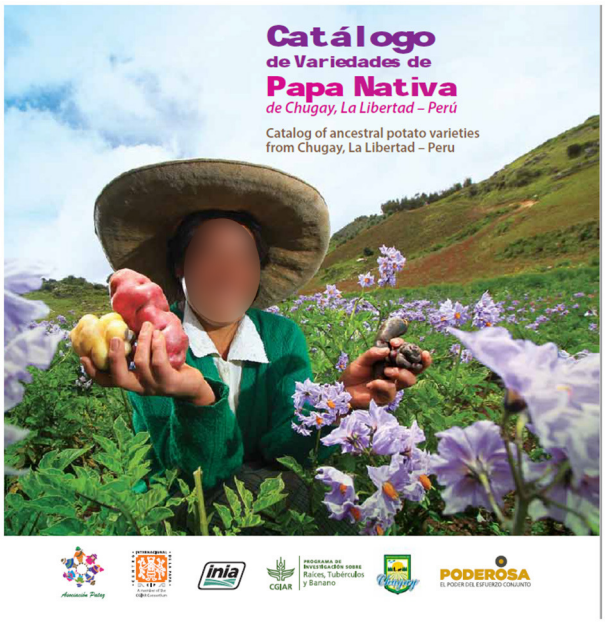

FIGURE 1 | An example of a published community landrace diversity inventory for the district of Chugay, Sánchez Carrión province, La Libertad department Peru (Centro Internacional de la Papa (CIP) et al., 2015). Baseline-level documentation of crop diversity and associated knowledge is intended to facilitate agrobiodiversity monitoring, geographical indication, biodiscovery, and local education. Image by Asociación Pataz.

Parque de la Papa—A FOOD BIOCULTURAL DIVERSITY NEIGHBORHOOD INITIATIVE

The Parque de la Papa (or Potato Park) (https://parquedelapapa.org/), located in the primary region of diversity of that crop in the Andes mountains of Peru, is an initiative that is demonstrating the potential of community action, advocacy, and partnerships around food-related biocultural diversity. The Parque, encompassing more than 10,000 hectares, was established in 2000 by six Quechua communities around Cusco as a Biocultural Heritage Landscape (Argumedo, 2008, 2012; Argumedo and Stenner, 2008; Asociación ANDES, 2016; Swiderska et al., 2020). More recently, the Parque is being envisioned as a "food biocultural diversity neighborhood"—a defined geographic region where community members work together to conserve, use, and celebrate their food-related biocultural diversity.

While the Parque was organized around, and celebrates, potato diversity, it's communities also maintain diverse maize, quinoa, bean, and various Andean root and tuber crop varieties, as well as alpaca and other livestock, through locally developed holistic management approaches (Asociación ANDES and the Potato Park, 2015; Agroecology Fund, 2020). The communities advocate for practices that conserve natural resources, as alternatives to extractive mining and other industries.

An enormous amount of potato diversity—more than 1,365 cultivated and wild types—is conserved by farmers in and around their fields in the Parque, some of which has been acquired over the past decade through a collaboration with the International Potato Center (CIP). This diversity is also conserved and supported locally through a community seed bank, seed multiplication center, and greenhouse facilities. True seeds have been deposited by the communities of the Parque in the Svalbard Global Seed Vault as an additional safety backup. This deposit directly by Indigenous communities/organizations was a first for the Svalbard initiative. These collaborative, inclusive, integrated efforts represent promising models for conservation, continued evolution, and access to potato diversity both for local communities and for plant breeders and farmers around the world (Agroecology Fund, 2020).

The Parque has worked to enhance livelihood opportunities around its food-related biocultural diversity by developing local technological, market, and policy innovations based on traditional knowledge and biocultural heritage (Asociación ANDES and the Potato Park, 2015). These innovations—ranging from changing the areas and timing of potato cultivation, establishing a community seed bank, improving plowing and water retention methods, creating biocultural descriptors for potato varieties, developing microenterprises based on cultivated and wild plant products, establishing horizontal partnerships with scientists, and working with the Peruvian government to declare a National Day of the Potato—have significantly improved the food security and livelihoods of community members. Celebration of this diversity at local to national scales has resulted in the Parque being recognized as an Agrobiodiversity Zone by the Peruvian government (INIA, 2020) (**Figure 2**). Awareness of the value of local diversity and empowerment around its use has been such that the Parque has also become a provider of food to others in times of need. For example, communities donated one ton of potatoes to Cusco during the COVID-19 crisis in 2020, to support food-insecure migrants and other vulnerable groups (Local Futures, 2020).

ACHIEVING GREATER FOOD SYSTEM RESILIENCE AND EQUITY THROUGH SUPPORT FOR FOOD-RELATED BIOCULTURAL DIVERSITY

To achieve greater food security and nutrition, sustainability, resilience, and adaptation in this era of global environmental change through conservation, use, and celebration of food-related biocultural diversity, we outline below what we consider to be important, interrelated actions in collaborative research and knowledge sharing, training and capacity development, and networking.

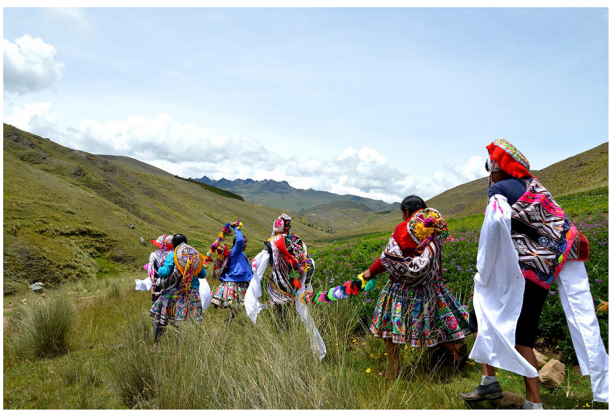

FIGURE 2 | Parque de la Papa community members celebrate the annual festival of "Papa Tinkay," a ritual offering to the flowering potato plants to bring a fruitful harvest (Agroecology Fund, 2020). Image by Asociación ANDES.

Collaborative Research and Knowledge Sharing

Despite awareness of the importance of, and threats to, food-related biocultural diversity in high level policy and technical fora, and the increasing variety of research, action, and advocacy tools designed to conserve, increase use, and celebrate this diversity employed at community levels, major gaps in understanding the significance of change in this diversity over time, and the best approaches to mitigate or reverse further losses, remain (Khoury et al., 2021).

A worldwide effort to take stock of the state of food-related biocultural diversity is urgently needed to provide a cross-cultural knowledge base to guide current and future initiatives. This knowledge base can only be adequately established through inclusive, multi-disciplinary and participatory processes, engaging Indigenous and traditional agricultural communities in and beyond primary regions of diversity. Strategies to bring together traditional as well as scientific knowledge and methodologies need further development to create a network of research sites/observatories, enabling collaborators to address complex questions related to food and nutrition, sustainability, resilience, adaptation, and livelihoods (Díaz et al., 2015, 2018). Importantly, food biocultural diversity neighborhoods and other such communities must have a stronger voice than in the past in communicating their perspectives to the global scientific and development communities (Nature Editorial Board, 2021). Such a knowledge base should inform conservation and development actions globally for decades to come.

Training and Capacity Development

Food biocultural diversity neighborhoods and other agricultural communities in regions of diversity are innovating stewardship models that explicitly maintain the biocultural processes which conserve and use diversity and provide livelihood opportunities. The Parque de la Papa has both slowed the loss of crop diversity *in situ* in its communities, and added new diversity obtained from *ex situ* repositories to the point where the communities now maintain arguably the most potato diversity per unit cultivated area in the world. Key to this success are the methods, tools, and processes collaboratively developed to implement and manage the diversity within a holistic landscape, based on a combination of Indigenous cosmologies, local use traditions, and scientific research.

Up- and out- scaling such models requires the advancement of systems of learning in creative environments in which different forms of knowledge can coexist. The Yachaykuychi (Rainbow of knowledge) Pluriversity, an outgrowth of experiences gained in the Parque de la Papa, is an incipient international, intercultural educational institution aimed at these goals (Asociación ANDES, 2021). Dedicated to the conservation, innovative use, and celebration of biocultural diversity, its vision is that all Indigenous peoples and smallholder farmers benefit from state-of-the-art research, tools, and training that embody multiple ways of knowing. To realize this vision, the Pluriversity is promoting and enabling partnership-driven, Indigenous-led research in interwoven food and agriculture topics, including the integration

of *in situ* and *ex situ* conservation, farming under climate change, Indigenous governance and agrobiodiversity management, and sustainable livelihood innovation.

To advance the aims of these training and capacity development initiatives, currently scattered research efforts and resources relevant to food-related biocultural diversity need to be compiled, with focus on the pressing priorities of Indigenous and traditional communities. Second, the perspectives of Indigenous and non-Indigenous experts need to be combined to help transform the way the public see and understand these communities and the diversity they safeguard. Further, existing investments in community-based biocultural diversity conservation research need to be bolstered by collaboratively designing and building core infrastructure for monitoring and data management. Finally, innovative training methods for Indigenous peoples, farmers, students, and scientists need to be created to prepare a new generation of researchers, leaders and activists able to bridge cultures, collaboratively address environmental challenges, and raise awareness of food-related biocultural diversity opportunities.

Training and capacity development through structures such as the Yachaykuychi Pluriversity, supported by local, national, and international organizations, will provide critical transformative processes through which biocultural knowledge systems surrounding food can be better recognized as the foundations of conservation and innovative use initiatives. Such activities will also provide a major medium by which communities can learn from the successes and challenges of others regarding safeguarding diversity and creating livelihood opportunities.

A Network of Food Biocultural Diversity Neighborhoods

Communities in the primary and other regions of diversity of crops and livestock typically maintain a varied range of domesticated species, and in addition collect wild foods to supplement their nutrition and livelihoods. This said, their food systems generally center on a few iconic foods, e.g., potatoes and quinoa in parts of the Andean mountains, maize and beans in Mesoamerica, and bananas and starchy roots and tubers such as yams and taro in the highlands of Papua New Guinea. A promising pillar around which to organize a network of food biocultural diversity neighborhoods, building on the many existing networks and initiatives of Indigenous, rural, and small-scale farmers, is therefore the conservation, use, and celebration of such emblematic crops and livestock.

A network based on the emblematic crop and livestock concept has recently emerged, inspired by the Parque de la Papa and hosted by the International Network for Mountain Indigenous Peoples (INMIP) (https://inmip.net/). This currently includes interested communities in China, Ethiopia, Guatemala, India, Kenya, Mexico, Papua New Guinea, Peru, and Tajikistan. Such a network, aligning with wider efforts, offers opportunities for substantive positive change in the primary regions of diversity, by providing focus for initial integrated conservation and use efforts, connecting communities based on shared needs and diverse experiences, and embracing local, national, and international collaborations.

The initial focus on integrated conservation and use, innovative livelihood, and celebration actions for emblematic crops and livestock can be leveraged in and beyond communities to benefit other, less well-known species and their stewards. In the spirit of the generosity of sharing of biocultural diversity that has characterized these communities for countless generations, the network can also play a key role in instigating dietary, sustainability, resilience, and adaptation innovations through interchange among and beyond communities, preferably with support from nutritionists, chefs, researchers, and others.

In emphasizing conservation, use, and celebration around food-related biocultural diversity, and in recognition of the rights and the roles of Indigenous and traditional communities, progress on the actions outlined here will substantially contribute to the Sustainable Development Goals, the CBD, and the ITPGRFA, among others. This focus on biocultural diversity and on the neighborhoods that nurture it is certainly not the only set of actions needed to create more secure, nutritious, sustainable, resilient, climate-adapted, and equitable food systems. However, it is a critical element of such systems and one where progress is being made.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

AA, CK, and HD wrote the first draft of the article. All authors edited, contributed to the article, and approved the submitted version.

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