Marginal Areas and Indigenous People Priorities for Research and Action

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1 Context

Business-as-Usual Is Not Working Marginal environments and the indigenous people who cultivate them have one thing in common – they are forgotten. Their soils and climates, crops and livestock, beliefs and knowledge systems rarely attract academic interest, policy studies or investment. Marginal environments refer to less-favorable agricultural areas (LFAAs) characterized by constrained agricultural potential and resource degradation attributable to biophysical and politico-socio-economic factors (Pender and Hazell 2000). Their low production potential is driven by rugged terrains, extreme weather conditions, poor soil and water quality, lack of socio-economic connectivity and limited exposure to agricultural intensification opportunities. In such regions, drought and erratic rainfall, salinization, and other factors present significant constraints for intensive agriculture. Marginal environments encompass all LFAAs and any favorable agricultural areas (e.g., areas not constrained by biophysical factors) with limited access to rural infrastructure and agricultural markets where cost-effective production is unfeasible (without additional support) under given conditions, cultivation techniques, and policy or

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macro-economic settings. The agricultural expertise of indigenous communities is often overlooked by decision-makers, who, instead, advocate interventions based on mainstream crops and external technologies. While such approaches have had demonstrable impacts on food security and poverty alleviation elsewhere, they often fail in indigenous communities where a vast range of crops are cultivated in diverse production systems and in marginal environments. As a result, agricultural yields in marginal areas continue to decline and the gap between the actual and potential yield of mainstream food crops widens (Mustafa et al. 2021; Chimonyo et al. 2020; Leakey 2020). Hunger, malnutrition, and poverty in indigenous communities continue to increase, as one in five people on the planet is malnourished (UN Environment Programme 2020).

We Need Diverse Food Systems An alternative to top-down technological packages is to approach the existential challenges that indigenous people face from their own perspectives and resources. However, the agrobiodiversity and associated knowledge systems that these communities have protected for millennia are under threat. Nearly 10% of all domesticated breeds of animals for food and agriculture are already extinct and another one million plant and animal species now face extinction (Brondizio et al. 2019). Many of these species are climate-resilient and nutritious crops. For example, millet and gluten-free grains such as amaranth, teff and quinoa are rich in vitamins, minerals, essential fatty acids, phytochemicals, and antioxidants, and crops such as finger millet, cowpea and bambara groundnut are also adapted to extreme weather (drought and heat stress) and poor soil conditions (Mabhaudhi et al. 2019a; Tadele 2018). While the genetic diversity found in indigenous farming systems could become the foundation for future agricultural and food systems, of over 30,000 edible plants, fewer than 30 species grown as monocultures now provide most of the food consumed by 7.8 billion people (FAO 2018). These mainstream crops monopolize agricultural research, investment, support and formal markets.

Languages Are the Basis of Knowledge From over 7000 languages, only six are spoken by half the global population (Eberhard et al. 2020). Roughly 40% of languages are now classified as endangered and as few as 600 might still be spoken in 2100 (Krauss 1992). For indigenous people, this represents not just a catastrophic loss of languages, but of cultural and ethnic identity and agricultural knowledge that, without a written record, has been conveyed verbally for generations. Where a language is unwritten, or its speakers are illiterate, the indigenous knowledge of a community, along with potential solutions to modern challenges facing humanity, are lost.

Climate Change and Sustainable Development Climate change threatens those least able to withstand its impacts. In 2015, UN member parties agreed to limit mean global temperature increases to 2 °C above pre-industrial levels (TheWorldCounts 2021). Predicted global heating is between 3.1 and 3.7 °C (Salawitch et al. 2017). The consequences of such increases and the frequency of extreme events will disproportionately impact indigenous people – since many already live in hostile and marginal environments. However, indigenous people are inheritors of a unique social and cultural identity, have a distinct historical continuity and traditional knowledge of how people have interacted closely with their environments, and have developed and passed on such expertise across many generations (Berkes 2008; Kingsbury 1998). It has been estimated that indigenous people have an approximate population of 476 million across 90 countries, with about 5000 distinct cultures, accounting for most of the world's cultural diversity (UN 2009).

Of the seventeen UN Sustainable Development Goals (SDGs), SDG1 commits the world to *eradicate poverty in all its forms,* and SDG2 to *end hunger, achieve food security and improved nutrition and promote sustainable agriculture* (UN 2021). This entails moving from an economic definition of poverty (lack of income) and hunger (lack of food) to a multidimensional concept involving sustainable livelihoods, healthy diets, knowledge of food heritage and agricultural systems and the agency of communities to make their own decisions. A more articulate and inclusive notion of poverty and hunger eradication means achieving sustainable livelihoods, better nutrition and greater resilience of *all* communities, including indigenous people, to climate shocks.

2 Approach

The consolidation of mainstream agriculture, the decline of species and associated knowledge and the climate crisis all call for a different approach for indigenous people living in hostile environments. In such circumstances, it is they, not us, who are the experts. The challenge is how research can help these communities become agents of change and co-owners of innovations to help secure sustainable livelihoods and healthier lifestyles. Rather than being seen as passive recipients of external technologies, indigenous people need fair and equitable partnerships with research, education, extension, and private institutions that recognize human rights as the basis for sustainable food systems. This means that, wherever possible, the development of agricultural products, value chains, markets and food systems should remain under the jurisdiction of indigenous communities in terms of benefits, intellectual property, labor conditions, and negotiating power. This includes the contribution of underutilized or 'forgotten' crops and their knowledge systems to food security, balanced diets, income generation, agricultural diversification and better use of marginal lands.

3 Evidence

Knowledge Diversity Marginal environments are biogeographically distinct, and their communities are culturally diverse. For indigenous people to secure sustainable livelihoods and healthier lifestyles, we need research approaches that suit the particularities of regions and people and knowledge systems that provide the best options for different circumstances. This requires complementary skills to address systemic challenges to the whole food system, rather than just its components and networks from which viable options can be considered, evaluated and delivered by indigenous people in their own localities.

Knowledge Partners While there are many knowledge systems for mainstream agriculture, we are not aware of any integrated system that relates specifically to marginal environments and indigenous people. However, a number can be adapted to these circumstances by research institutions with expertise in different biogeographical regions. For example, Crops For the Future (CFF) has developed *CropBASE* as a global knowledge base for under-utilized crops (Mohd Nizar et al. 2021), their suitability (Jahanshiri et al. 2020), economic potential and nutritional values in different environments. Along with its partners in the Association of International Research and Development Centers for Agriculture (AIRCA), CFF has proposed a Global Action Plan for Agricultural Diversification (GAPAD) (Association of International Research and Development Centers for Agriculture 2016). The International Centre for Integrated Mountain Development (ICIMOD) facilitates the *Global Framework for Climate Service* (ICIMOD 2021). to collate, curate, and share data so as to support robust planning and policy decisions for climate resilience in mountain regions. The International Center for Biosaline Agriculture (ICBA) has developed integrated drought management, monitoring/early warning systems, vulnerability and impact assessment and mitigation for crop diversification with under-utilized, stress-tolerant crops for food, feed and biofuel (ICBA 2021). The UKN *Centre for Transformative Agricultural and Food Systems* is building resilient, sustainable and healthy food systems for climate-resilient agriculture to improve human wellbeing and livelihoods in semi-arid regions of sub-Saharan Africa (UKZN 2021).

Impact Pathways The Global Forum for Agricultural Research and Innovation (GFAR) is building collective actions to improve the livelihoods of poor farmers, including those in indigenous and other communities living in marginal areas, by enhancing the market value of forgotten foods and the crops from which they derive, intervening in supply chain bottlenecks and mobilizing small producers as co-innovators. By recognizing the rich local knowledge behind forgotten foods, GFAR members seek sustainable avenues for a community-centered, pro-poor transformation of food systems and the reorientation of research and innovation governance. For this, GFAR is co-ordinating a *Collective Action on Forgotten Foods* and a *Manifesto for Forgotten Foods* that explicitly calls for novel research and innovation systems (GFAR 2017).

4 Indigenous Food Systems and Knowledge: Challenges in Diverse Settings

Biogeographical and Cultural Diversity While each marginal region and indigenous community is unique, some themes and challenges link them. Common research and innovation approaches can be shared and applied across environments.

Here, we consider food systems in four biogeographical regions representing a significant proportion of the world's marginal land area, indigenous people and agricultural biodiversity. We then identify innovations, investment opportunities, priorities, and proposed actions to help transform indigenous peoples' food systems in marginal areas through agricultural diversification beyond mainstream crops and systems.

Arid (Drylands, Biosaline Soils and Coastal Regions) The importance of traditional food systems, especially in drylands, where indigenous people reside, cannot be over-emphasized. Indigenous people often hold a historical link between environmental heritage and food systems (Kuhnlein et al. 2013). Recent agricultural interventions have widely acknowledged the role of the indigenous knowledge of local people in the development of food systems in drylands. Effective and sustainable utilization of their cultural heritage regarding food systems can support environmental services, food preservation and food storage. Integration of various knowledge systems in co-innovation and co-production can transform traditional food systems, including food sovereignty, to avoid future hunger and malnutrition (Huambachano 2018; Pingault et al. 2020).

Despite the harsh environmental conditions in drylands, some indigenous food crops have exhibited outstanding performance and unmatched adaptation (Mabhaudhi et al. 2019a). Plant physiological adaptation to environmental stress has been a subject of intense research on dryland crops. Plant responses such as photosynthetic rate alteration, leaf area reduction, stomatal conductance regulation and waxy-substance production have been reported (Hasegawa 2013; Van Zelm et al. 2020). Drought evasion, albeit at the expense of biomass accumulation, has also been studied for many indigenous food crops. Similarly, rhizosphere microbiota (bacteria and fungi) cultivation has resulted in improved adaptation to water and nutrient stresses (Prasad et al. 2019). The application of microsymbionts and the rhizobiology associated with this innovation has explained, in part, the mechanisms of adaptation to stress by plant roots. Rhizobacterial nutrient solubilization, mobilization and salt mitigation using Azotobacter spp. has been found to increase synergy from inoculation (Srividhya et al. 2020). Mycorrhizal associations have also increased nutrient abstraction from the soils by 30%. Thus, co-inoculation with various species such as *Anthrobacter sp*., *Bacillus sp*., *Paenibacillus sp*., *Pseudomonas sp*., and *Rhizobia sp.* yielded between a 50% and 70% increase in nutrient uptake and use while enhancing photosynthesis and systems defense (Barriuso et al. 2008). Secretion of root exudates and stimulation of lateral root branching increased phosphorus uptake in the soil (Weih et al. 2018).

Both water- and nutrient-use efficiency are a function of the plant phenotype, management, and root architecture. Molecular marker-assisted breeding has made some inroads into the characterization of polygenic effects in relation to dryland environments. There is evidence that water-use efficiency (WUE) increases with water deficit, but not beyond 40% of irrigation requirement (Yu et al. 2020). The combination of high WUE and nutrient-use efficiency (NUE) in indigenous crops can improve yields. Recent developments in integrated drought monitoring and early warning systems have shaped mitigation options for smallholder farmers. With the adoption of controlled environment farming to produce vegetables, indigenous farmers will have the capacity and means to boost production and save about 90% water requirement (Eigenbrod and Gruda 2015). Research that introduces, evaluates, and adapts under-utilized crops for dietary diversification in marginal environments is underway. Several crops with proven tolerance to salt, salinity and/or water stress have been studied in drylands. So far, crop diversification has focused on cereals, legumes, fruit trees and fodder crops. There is evidence of improved crop yields, increased popularization of nutrient-dense crops and fodder suitable for drylands. Examples of dryland food crops include fruit trees (date palms), types of millet (finger-, pearl-, proso-, fonio-millet), pseudo cereals (amaranths, buckwheat, and quinoa), cereal grass (teff), pulses (chickpea, faba bean, pigeon pea lentil and groundnut), halophytes (Cumin, Salicornia, and Colocynths) and oilseeds (mustard, sesame, sunflower, safflower, and rapeseed). These crops have high nutritional values and are adaptable to harsh growing conditions. The genetic diversity among these crop species has been preserved and limited to the communities where they were being cultivated, e.g., teff in East Africa (areas around Ethiopia and Eritrea). Commercialization of these crops will contribute significantly to sustainable food and nutrition security.

Indigenous food systems face natural and anthropogenic extinction. While breeding techniques have advanced, only a handful of indigenous crops have received the required promotional support to facilitate widespread utilization.

Semi-Arid (Seasonally Dry, Rainfed, Impoverished Soils) Semi-arid regions are a subtype of environment with an aridity index (ratio of total annual precipitation to potential evapotranspiration) between 0.20 and 0.50 (Lal 2004). These regions are characterized by mean annual precipitation between 200 and 700 mm (Gallart et al. 2002), often with stormy character, clustered in alternating seasons. A complex range of topography, biodiversity and variability in rainfall and microclimatic conditions has meant frequent exposure to droughts and floods, with grievous implications for agricultural production, ecosystem services and social and cultural relations. The food system context across semi-arid sub-Saharan Africa (SSA) is one of significant environmental, political, socio-economic and cultural diversity. However, the region is regarded as being among the world's most food-insecure (Umetsu et al. 2014; Sutherland et al. 1999). Compounding threats, such as climate change, environmental degradation and increasing populations, have left many marginal communities vulnerable to food and nutritional insecurity (Mugari et al. 2020). This insecurity is further compounded by globalization and the homogenization of the food system, both of which have relegated many African indigenous crops, which are suited to these environments, to the status of neglected and under-utilized species (Chivenge et al. 2015).

Across SSA, food systems rely primarily on the staple food crop production of a few major crops and a few minor or endemic food crops (including under-utilized species) (Leff et al. 2004). Cereal staple crops such as maize, sorghum, wheat and pearl millet are grown and consumed extensively by rural farmers across the region

(Lal 2016; van Ittersum et al. 2016; Hadebe et al. 2017; Bvenura and Sivakumar 2017). However, rural farmers also rely on indigenous crops and associated knowledge systems to ensure their food security (Mabhaudhi et al. 2019b). They augment field crop harvests with different types of seasonal edible wild fruits, vegetables, and roots identified, harvested and processed using indigenous knowledge.

Rural farmers, usually women, are generally regarded as the custodians of under-utilized indigenous and traditional crops and the knowledge of their cultivation and use. It is generally recognized that, although indigenous food plants have, in the past, played an important role in the diet of African communities, the industrialization of food systems and formalization of markets has resulted in a decline in the use of African indigenous and traditional food crops. Also, in most cases, the promotion of Green Revolution technologies has inadvertently exacerbated inequalities and food insecurity. For example, in the 2000s, and after the massive roll-out of hybrid technologies, evidence from Rwanda (Dawson et al. 2016) and Ghana (Vercillo et al. 2020) showed significant growth in agriculture's contribution to the GDP. However, this was accompanied by greater inequalities and food insecurity for rural communities.

On the other hand, reports suggest that under-utilized crops offer a pathway to a more sustainable and equitable agricultural system for SSA, capable of addressing several SDGs related to socio-economic and socio-ecological wellbeing (Mabhaudhi et al. 2016). Researchers argue that one of the unintended outcomes of the global agro-industrial food system has been the replacement, and subsequent relegation, of under = utilized indigenous and traditional crops through the introduction of exotic and (now considered) "major" crops that were often higher-yielding, but also more input-intensive. This has led to the neglect of traditional crop species that had previously formed the basis of local indigenous food systems, which were resilient, sustainable and healthy.

Despite the lack of support, many smallholder farmers use indigenous crop species as nutritious foods that support cultural and ecosystem services. Many of these crops are favored in local markets for both household consumption and as medicines (Chandrasekara et al. 2016). Using traditional methods and knowledge, farmers select, harvest, store and trade indigenous crop varieties that possess desirable nutritional, medicinal and pharmaceutical properties (Dansi et al. 2012). Decades of research have shown that indigenous crops and associated knowledge-systems can improve food and nutritional security in marginal environments. However, it is important to identify traditional tools and strategies that can help address production constraints within marginal farming communities when integrated with modern and digital technologies.

Humid (Tropical, Rainforests) Tropical rainforests are home to many indigenous people and serve as a lifeline for many forest-dependent communities. While not all are indigenous, indicative estimates show that, globally, there are approximately 1.3 billion forest-dependent peoples (Chao 2012). Their food systems are complex chains of production, distribution, consumption, recirculation of food refuse, and the acquisition of trusted foods and ingredients from other populations built on a diversity of local or traditional practices for ecosystem management. These practices include multicropping, resource rotation, succession management, landscape patchiness management, and various methods of managing unpredictable ecological surprises (Whyte 2015; Berkes et al. 2000). Social mechanisms behind these practices include adaptations for the generation, accumulation, and transmission of knowledge; the use of local stewards and rules for social regulation; mechanisms for cultural internalization of traditional practices; and the development of appropriate world views and cultural values (Wiersum 1997; Kuhnlein and Receveur 1996). Resources are collectively managed, relying on group decisions, often by consensus and involving elders (Garí 2001). As the result of a constant struggle between modernization and survival, indigenous peoples have developed flexible strategies to maintain relatively stable and sustainable food systems that are biodiverse, resilient, and long-serving. While there is ample variation in the practices of each indigenous community living in the humid tropics, they share certain similarities in adaptive management. These include an emphasis on feedback learning, the treatment of uncertainty and unpredictability and resilience mechanisms that confer obvious advantages over conventional "modern" productive models (Toledo et al. 2003; Wilson and Woodrow 2009; Goldsmith 2012).

Tropical rainforests cover only a small part of the earth's surface (about 7%), yet house over half the species of plants and animals on the planet (Lima et al. 2020). High deforestation rates result in a significant reduction in the area and geography of mature tropical forests and a loss of diversity of tropical forest species (UN DESA 2009). As a consequence, many native societies of the rainforest have already been destroyed, and those cultures that still exist face a grim future due to poor policies and practices (Ohenjo et al. 2006). Indigenous peoples experience extreme disparities compared with greater-than-global averages in obesity, undernutrition and micronutrient malnutrition, as well as other health gaps that are grounded in poverty and marginalization (Port Lourenço et al. 2008; Companion 2013; Davis and Wali 1994).

Conflicts of land tenure and assimilationist policies have compelled and compounded the migration of indigenous peoples to urban areas (Hansungule and Jegede 2014; Xanthaki 2003; Lin 1994). This exodus contributes to their inability to realize sustainable diets based on local species and traditional knowledge (Kuhnlein 2003; Dounias et al. 2007; Dounias and Froment 2011; Berbesque et al. 2014; Powell et al. 2015; van Vliet et al. 2015; Ickowitz et al. 2016; Crittenden and Schnorr 2017; Kraft et al. 2018; Bethancourt et al. 2019; Reyes-García et al. 2019; Fernández 2020). Consequently, their vast knowledge and guardianship of 80% of global species diversity is also diminished and lost (FAO 2017). Not only are forest-dwelling cultures losing their forests, they are also losing their next generations to whom they would pass on the traditional indigenous knowledge and practices built over generations. There is a critical urgency to act before the current living generation of knowledge-holders and the species that they have inherited are lost forever. Recognizing this importance, there have been sporadic efforts to document this knowledge, resulting in highly variable data that lack workability and comparability (Agrawal 2002; Ngulube 2002; Quek and Friis-Hansen 2011; Naming et al. 2010;

Shapi et al. 2011). This piecemeal approach highlights the need for a global knowledge base of indigenous species and systems and the design of systematic approaches and methods of data collection and observation. As well as the continuing efforts to reverse the dispossession and marginalization of indigenous peoples, the recognition of their roles and knowledge should be increasingly advocated, not only for the benefit of their own communities, but as part of a collective global public good.

Without the contribution of indigenous peoples to international health and sustainability targets, many of the United Nations' SDGs cannot be achieved, most notably SDG1 (zero poverty anywhere) and SDG2 (food security and improved nutrition). The design of sustainable food systems is also necessary in order to ensure the delivery of healthy, safe, and nutritious foods in both sustainable and equitable ways in an era of changing climates. In each case, the knowledge of indigenous communities can provide essential contributions to sustainable diets and climate-resilient food systems (Kuhnlein et al. 2019).

Mountains The mountains and uplands of the world are home to diverse food systems, each with its accompanying repository of indigenous knowledge evolved through generations of empirical experience. In the Hindu Kush Himalaya, rangelands constitute around 60% of the land use, and Yak herding, Angora goat and sheep rearing form the basis of food systems in large parts of the Tibetan Plateau and the higher altitudes (Miller and Craig 1996; Miller 1999). On the southern slopes, transhuman pastoral communities carry out seasonal migrations, their animals grazing in the high-altitude *Bugyals* (pastures) during summer and descending to lower altitudes during the cold winter months (Mitra et al. 2013). The food system of these communities is linked to mixed farming systems across their migratory routes, and food grains are predominantly obtained from farmers in exchange for milk products. Mixed farming systems with cereal-based agriculture and livestock rearing, intricately linked to forests, constitute the food system in the mid-altitudes of western Himalaya. These systems are built around upland cereals – buckwheat, millet, amaranthus - and legumes, complemented with milk and milk products. In the Eastern Himalaya and much of the uplands of Southeast Asia, shifting cultivation, with a rich diversity of cereals, legumes, tubers and leafy vegetables, together with small ruminants, piggery and poultry, constitutes the food system of diverse communities inhabiting the region (Ramakrishnan 1992; Rerkasem and Rerkasem 1995; Cramb et al. 2009; Mertz et al. 2009). Regenerating fallows and young forests also form important constituents of the food system of shifting cultivators (Delang 2006; Cairns 2007; Rodericks 2020). Small pockets of settled agriculture, predominantly consisting of wet terraces and complemented with animal husbandry, and intricate links with forests are also found in pockets of Eastern Himalaya, with the *Aji*-system of the Apatanis in Arunachal Pradesh, the *Zabo* system of the Chakesangs of Nagaland and the *Buun* system of the Khasis of Meghalaya being prominent agricultural systems in a landscape otherwise dominated by shifting cultivation (Kumar and Ramakrishnan 1990; Agarwal and Narain 1995; Sundriyal and Dollo 2013; Mulyoutami et al. 2009). Further south, in the uplands of Southeast

Asia, Forest Gardens complement shifting cultivation and wet paddy systems constituting an important part of food systems of upland communities in Indonesia (Mulyoutami et al. 2009).

Knowledge systems and traditional practices associated with food systems of indigenous communities are rich. They reflect a deep understanding of crop, soil and water dynamics and the functioning of the surrounding environment. Animal husbandry and rangeland management of pastoralists centered around rotational grazing suggest an understanding of the carrying capacity of rangelands and high-altitude meadows. The intricate link between agriculture, animal husbandry and forests found in western Himalayan mixed farming systems similarly reflect an understanding of the link among forest litter, animal dung, nutrient management and crop productivity. Indigenous knowledge of shifting cultivators suggests a robust risk management strategy and underlies the conservation and management of a wide diversity of crops, together with a range of landraces. Food systems of these communities also extend to fallow management and indicate an indigenous understanding of the food and nutritional value of wild edibles and animal products supported by regenerating fallows and forests. The indigenous knowledge of shifting cultivators also includes weed management and traditional knowledge of soil management practices, including an understanding of crops best suited to each soil condition. This indigenous knowledge base offers opportunities for developing solutions to several of the challenges arising out of land degradation and climate-induced stress emerging in present-day upland agriculture. Indigenous food systems and the knowledge associated with such systems are under threat today. With the transition to commercially important monocropping driven by markets and a policy promoting commercialization and homogenization, indigenous food systems are rapidly being replaced by cash crop plantations and commercial agriculture (Fox et al. 2009; van Vliet et al. 2012). The rapid erosion of agro-germplasm has serious consequences for ensuring food and nutritional security of the future, as many of the crops found in food systems of the mountains are not only recognized future smart crops, but also important as 'building blocks' for developing stress-tolerant, nutrient-dense crops of the future crucial for ensuring food and nutritional security and attaining Zero Hunger (Kadambot et al. 2021).

4.1 Innovations and Investment Opportunities

Current agricultural policies promote staple crops for mainstream agriculture in favorable areas. This has been at the expense of indigenous and under-utilized crops, many of which are well adapted to hostile environments and yield nutritious products. Many favored agricultural lands have reached their saturation potential, are often overexploited due to demographic pressure, and are increasingly impacted by climate change. If we are to nourish more people on a hotter planet, marginal regions will have to play a more significant role in food systems. However, the current promotion of healthier diets and sustainable food systems has excluded indigenous people, their crops and expertise. Evidence shows that where investment has been targeted at such communities and their food systems, they can enhance productivity, improve nutrition and reduce carbon emissions. The challenge is to link formal and local knowledge to identify which crops best suit specific environments, deliver desirable products and support sustainable and equitable livelihoods. This requires investment and policy support for innovations and technologies that can mainstream diverse value chains, their crops, products and knowledge systems.

4.2 Game-Changer Technologies and Innovations

The need is urgent. To achieve sustainable livelihoods, indigenous people in marginal areas need game-changer technologies in which they are the agents of innovation. This requires approaches that ensure the conservation, quantity, quality and value of products from forgotten crops to external markets. Innovations and technologies need synergies between researchers and indigenous communities as partners, not clients. The innovation process must allow for participatory and demand-driven approaches that stimulate and build upon farmer innovations and suit local circumstances. For this, indigenous communities need access to better knowledge systems, improved genetic material, integrated management practices and novel technologies across the whole value chain that provide routes to markets. Again, this requires long-term research support and an enabling policy environment at each stage of the value chain, rather than sporadic efforts at specific points along it.

Better Knowledge Systems Agricultural research is often confined to silos and excludes local knowledge. Indigenous communities need knowledge systems that integrate their own expertise and belief systems with evidence from scientific studies and predictive models. This requires novel approaches to data collection, collation and curation and digital technologies that can make knowledge available to end-users.

Improved Seed Systems Breeding approaches need to utilize the inherent genetic variability in local crops to develop widely adapted cultivars for diverse biophysical and socio-economic conditions. This requires new cultivars with improved yield potential without compromising nutrient density and climate resilience, breeding programmes that utilize technologies and approaches from major and model species and community seed-saving and selection approaches that conserve and enhance agricultural biodiversity.

Integrated Management To be cost-effective, productive and sustainable, crop management in marginal areas must both enhance productivity and reverse resource degradation. This requires technologies that increase access to water and nutrients and cultivars that are more efficient in water and nutrient use than major crops. Innovations for marginal areas will also need to be context-specific and include survival mechanisms that enhance climate resilience. For this, innovations must utilize an understanding of ecological processes and soil health, rather than dependence on external inputs for crop production.

Technologies to Markets Indigenous food systems are predisposed to production and market risks due to harsh biophysical and socio-economic shocks. New technologies are needed to improve harvesting, post-harvest storage, milling and drying so as to support economically viable value chains, and digital systems are needed to trace crops and verify their products from field to consumers. Risk-mitigating innovations that promote resilience will protect communities from climate shocks and enhance sustainability.

5 Priorities and Proposed Actions

Mainstreaming Diverse Value Chains Addressing climate change, food security and malnutrition are global priorities. However, without mainstreaming the crops, foods and knowledge of indigenous people in marginal areas, the SDGs cannot be achieved. If we are to move beyond a narrow focus on specific SDGs, mainstreaming efforts must focus on improving the livelihoods of poor farmers, especially women, by enhancing the value of their under-utilized crops and forgotten foods to local and global markets. This requires technological and policy interventions to overcome bottlenecks along the production and consumption chain that also address global mandates for environmental sustainability and biodiversity conservation. It also requires the transformation of research systems to mobilize small producers as co-innovators and sources of ingenuity.

Evidence-Based Policies Development of policies must address challenges and knowledge gaps in technological innovations, social inclusion and environmental and economic equity for indigenous communities. Most importantly, for marginalized communities to actively become part of mainstream economies, policy instruments must ensure equal access to digital innovations, capacity development, crop insurance and friendly financing and investment. Priorities should be informed by global knowledge systems that use digital technologies to link global scientific evidence with local indigenous knowledge of the cultural and traditional value of traditional crops beyond yield-for-profit alone. A key requirement is policy reforms that are explicit in their support for indigenous people, are based on a global evidence base and share best practices between biogeographical regions and indigenous communities.

Advocacy for Agency We need to raise awareness of the potential of under-utilized crops and forgotten foods. This requires recognition of the rich local knowledge of indigenous people as custodians of agrobiodiversity and greater self-awareness of communities to unlock their creativity as agents of change. By increasing their self-esteem, self-pride and self-confidence, indigenous communities can become active drivers of new technologies for which formal research and innovation systems are currently the decision-makers. Advocacy supported by evidence, policy and the agency of indigenous communities opens avenues for farmer-centered, pro-poor transformation of food systems and the reorientation of research and innovation to mainstream value chains and value-added products from under-utilized crops.

Collective Actions Integrated strategies must evolve around a framework that is all-inclusive, but context-specific. An integrated and holistic policy approach is necessary to advocate for collective actions with indigenous communities that engage research institutions, policymakers, farmers, consumers and other stakeholders to unlock the untapped potential of marginal agriculture. The GFAR Collective Action on Forgotten Foods (GFAR 2017), which explicitly includes a *Manifesto for Forgotten Foods*, is a major opportunity for indigenous communities in marginal areas to be part of a global effort to mainstream diverse value chains.

Coordinated Investment Time is of the essence. If indigenous communities in marginal regions are to become agents of change, they need coordinated investment, accessible finance, co-innovations, traditional knowledge, governance, evidence, and empowerment. Policies encouraging public and private investments and research and development for indigenous communities and marginal areas are imperative to improve the sustainability and resilience of their food systems. Public-Private-Partnerships offer an important opportunity to leverage resources, access new technologies and innovations and facilitate risk-sharing. However, a conducive policy environment and global commitment of resources are essential prerequisites if we are to deliver diverse solutions for forgotten people in forgotten regions.

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