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REVIEW

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Crop species diversity: A key strategy for sustainable food system transformation and climate resilience

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Abstract

The global food system's reliance on a few species threatens food and nutritional security. Species diversification, including indigenous species, is a viable option to address this issue. Diversity enhances food systems' resilience against climatic and economic shocks. It offers resources for improved breeds and allows farmers to mitigate risks. However, successful diversification demands collaboration among farmers, researchers, academics, professionals, retailers, consumers, and policymakers. This review analyzes the role of crop species diversity in food system transformation, focusing on monoculture vulnerabilities, diversification benefits, indigenous species' role in nutrition and food security, and the importance of integrated policies and multi-stakeholder collaborations. We advocate for interdisciplinary research, participatory approaches, and supportive policies to foster diverse, resilient food systems that ensure food security, biodiversity conservation, and enhanced social well-being amidst global challenges. While acknowledging the importance of diversity in animal species for food security, the focus of this review is on crop species diversity and its potential to transform food systems.

KEYWORDS
diversification, food system, nutrition, resilience, species, transformation

1 | INTRODUCTION

Achieving global food security is a formidable challenge in the face of population growth, dietary changes, pandemics, conflicts, dwindling supplies of natural resources, land degradation, and changing environmental conditions. The Food and Agriculture Organization (FAO) reports that an alarming 2.4 billion people worldwide experience moderate to severe food insecurity each year (Food and Agriculture Organization [FAO], 2023). As market volatility and rising inflation persist, these numbers are projected to increase, undermining the significant progress made towards achieving the Sustainable Development Goals (SDGs) (Yuan, 2021). To meet this growing demand, food production systems must adapt and evolve.

Capitalist food production models, exemplified by the Green Revolution in India and contract farming in Africa, have prioritized yield maximization at the expense of ecological health and traditional food cultures (Kenner & Segal, 2023). This focus on high-yielding crops, some of which are genetically modified leads to increased reliance on pesticides and synthetic fertilizers, which can have negative impacts on native species and ecosystems (Malatji, 2020). Additionally, these models can push farmers towards cash crops, even if these crops are not appropriate and well-suited to local diets or have a detrimental environmental impact, as seen with cotton and tobacco in Africa. Contract farming, another form of capitalist food production system, exacerbates this issue by pressuring small-scale farmers to prioritize commercially viable crops over traditional, more adapted options (Tadele, 2023). This shift has resulted in increased exploitation of farmers by corporations, a decline in crop biodiversity, and greater food insecurity within communities.

The growing concerns about the vulnerabilities and sustainability of the monoculture system of farming have prompted a critical re-examination of current practices within the industry. Multiple studies have shown that agrobiodiversity can enhance agricultural productivity, resilience, and adaptability (Bravo-Peña & Yoder, 2024). Agrobiodiversity encompasses the diversity of crop species and varieties, livestock species and breeds, beneficial wild plants, and pollinators. Evidence from research and development projects over the last decades has strongly indicated that agroecosystems with diverse species are better positioned to thrive under current conditions and adapt to changing environments (Waha et al., 2018).

Despite this compelling evidence, there remains a notable gap in research specifically exploring how species diversity contributes to achieving food security. Addressing this gap is vital for developing practical strategies to bolster food security in diverse agricultural contexts. This review paper offers a comprehensive exploration of how crop diversity is crucial for enhancing global food security. Additionally, we include quotes from speakers who are also authors of the paper who took part in the CATAPULT symposium.

2 | CURRENT STATE OF SPECIES DIVERSITY IN THE GLOBAL FOOD SYSTEM

Out of approximately 400,000 globally identified plant species, humans have historically used only 7000 crop species for food (Antonelli et al., 2020). Nevertheless, our contemporary reliance is disproportionately placed on only a small fraction of these species. A mere 170 species are cultivated for food on a significant scale (Adesete et al., 2023). The FAO reports that 75% of the world's food comes from 12 crops and 5 animal species. This is attributed to the dominance of capitalist models that prioritize profit maximization, leading to the prevalence of a small number of staple crops like maize, rice, potato, and wheat (Grote et al., 2021). This focus on monocultures has displaced indigenous food species and traditional agricultural practices, a trend heavily influenced by the green revolution (Patel & Raj, 2013).

Relying heavily on a limited number of species poses substantial risks, as shocks to their production can have cascading effects, leading to widespread food insecurity and economic downturn (Sonking, 2020). For example, the emergence of *Fusarium wilt* of monoculture banana (Ismaila et al., 2023) and *Spodoptera frugiperda* (fall armyworm) in monoculture maize in sub-Saharan Africa (Kansiime et al., 2023) demonstrates the significant impact of such vulnerabilities. Monocultures repeatedly extract the same nutrients from the soil leaving it depleted whereas diverse agriculture mimics nature's system of using a diversity of nutrients and returning nutrients to the system through diverse organic matter. In addition, monocultures driven by large corporations often focus on quantity over quality, disregarding dietary needs. In Africa, the historical promotion of cash crops like cacao, coffee, and tobacco exemplifies this pattern. While intended to boost economic growth, these systems leave smallholder farmers marginalized while multinational corporations make profits (Bernstein, 2010).

> A disease spreading in one of the few species that the global food supply lies on can wipe out a large proportion of food supply and leave some of the most vulnerable populations food insecure.
>
> (S. Bhagwat)

Despite the identification of 7000 edible plant species, there is little public knowledge regarding their nutritional content, leading to some being marginalized in the conventional food systems (Antonelli et al., 2020). Furthermore, a majority of these species thrive naturally without human intervention. This means such species are only used by communities who understand their importance and are able to forage them. The practice of foraging and consuming such species is deeply rooted in indigenous knowledge systems, a heritage still maintained by some communities. This traditional wisdom and practice, derived from a profound understanding of ecosystems and seasons, serves as a repository of invaluable information that has sustained communities for generations.

Indigenous knowledge on local plant species is recognised as an underused resource in community development (Son et al., 2021). The significance of indigenous knowledge is complex, ranging from the preservation of plant, tree, fungi, and animal species, sustainable management of natural resources, and community resilience practices for coping with natural disasters to improved health and well-being through traditional medicine and nutrition (Domingo et al., 2023). However, the importance and preservation of this knowledge varies widely. Consequently, gaps in public understanding regarding these edible species underscore an increased risk of failing to establish a sustainable food system. The urgency of this challenge is accentuated by the intensifying erosion of native or indigenous species, driven in part by extensive monoculture practices that dominate modern agriculture. The consequences are profound, including loss of biodiversity, soil and water degradation, increased vulnerability to pests and diseases, increased food and nutritional insecurity, and a diminishing pool of species capable of withstanding potential threats posed by climate change.

Currently, the *FAO Strategic Framework 2022–2031* marks a crucial shift, acknowledging that the broader context extends beyond mere production to encompass vital considerations such as nutrition, environmental impact, and overall well-being. Achieving global food security demands addressing these multifaceted concerns. Despite this framework, a three way disconnect between culture, food and the environment is still evident (Figure 1). The traditions in non-intensive agriculture are in contrast with commercial mass production on which the current food system heavily relies. Moreover, the intensification of agriculture does not consistently align with environmental conservation efforts, prompting the proposition of technological solutions to safeguard the environment.

The intricate relationship between biocultural diversity and local food production practices is a critical consideration in the quest for a sustainable and secure global food system. This diversity, inherent in the interplay between culture and biodiversity, presents both challenges and opportunities that must be addressed. Thus, developing strategies that not only boost production but also foster nutritional well-being, environmental sustainability, and improved quality of life requires a deep understanding of this web of relationships.

To bridge this disconnection between culture, food, and the environment, there is a need for connecting environmental factors (e.g., climate) with social factors, especially

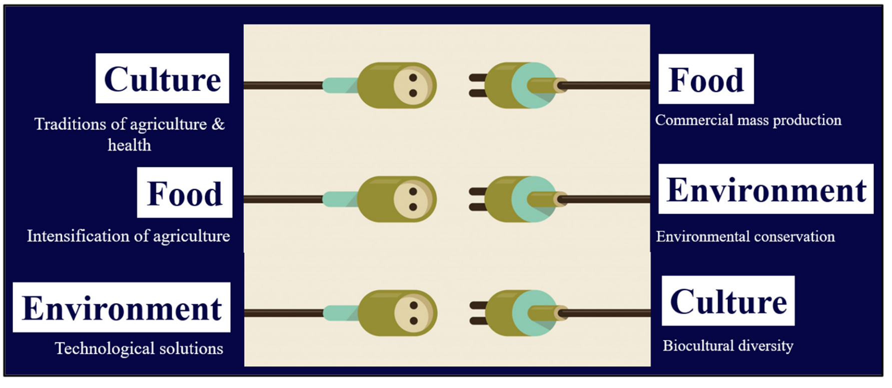

FIGURE 1 Disconnection between culture, food and the environment in food systems (CATAPULT Symposium, 2023).

intersectionality (age, disability, ethnicity, and gender). Currently, these factors are looked at separately, however, integrating them enables transformative change through combined top-down and bottom-up approaches. This holistic approach can lead to increased resilience to climate change impacts, enhanced food security, greater farming diversity and reduced vulnerability (Hellin et al., 2022). Crucially, community engagement is vital for the success of these efforts (Ng'endo & Connor, 2022).

In light of these considerations, we propose an urgent need for the transformation of the current food system. This transformation can involve a transition from industrial monoculture to multifunctional farming landscapes, changing from dependence on a few species to embracing a diverse range of species. This approach could help in building a food system that is productive and attuned to the broader ecological and cultural context, fostering a sustainable and inclusive future (Figure 2).

3 | WHY SPECIES DIVERSITY IS KEY FOR FOOD SYSTEM TRANSFORMATION

The importance of species diversity in the context of food system transformation cannot be overstated, as it underpins the very foundation of our agricultural ecosystems. In this section, we explore the key reasons why species diversity is critical for driving the much-needed transformation of our food system.

3.1 | Fostering local economies and cooperative practices

Species diversity plays a pivotal role in shaping our economy, environment, health and society as illustrated in Figure 3a,b. A food system where diversity is foregrounded, can provide multiple positive benefits. Amid the prevailing dominant influence of large corporations and globalized interests in the current food system, a diversity-centric approach can pave the way for localized food economies. This is because diversity of species enhances ecological resilience and also becomes a catalyst for cooperative models of production, distribution, and consumption, thereby lessening the dominance of centralized powers.

Diverse crop species and cropping systems are fundamental to the development of community-supported agriculture initiatives, which exemplify the positive impacts of species diversity on local economies. Community agriculture initiative programs, as demonstrated by Smith et al. (2020), involve direct partnerships between farmers and consumers. By incorporating a variety of crops, these initiatives offer consumers diverse and seasonal produce while providing farmers with a stable market. This direct and cooperative relationship strengthens local economies by ensuring fair prices for farmers, knowledge sharing and fostering community engagement in the food system.

The emphasis on species diversity also aligns with agroecological practices that often underpin cooperative farming models. Agroecology emphasizes working with natural processes, promoting biodiversity, and incorporating traditional knowledge. A study by Holt Giménez and Shattuck (2011) highlights the role of agroecology in supporting cooperative practices, as it empowers local communities to manage resources collectively, share knowledge, and engage in collaborative decision-making. This approach not only contributes to sustainable farming but also strengthens the social aspects of communities.

3.2 | Safeguarding against shocks and resilience

Species diversity is essential for transforming our food system, providing resilience against climate and economic

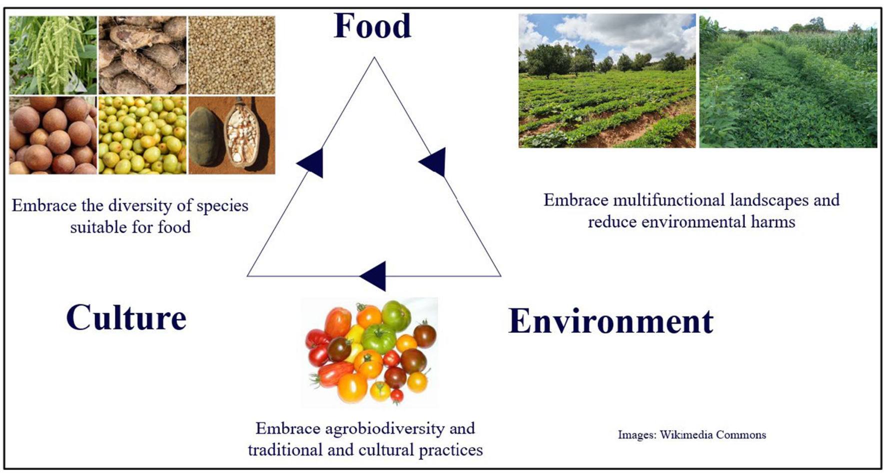

FIGURE 2 Reconnecting culture, food and the environment for a sustainable food system (*CATAPULT Symposium, 2023*).

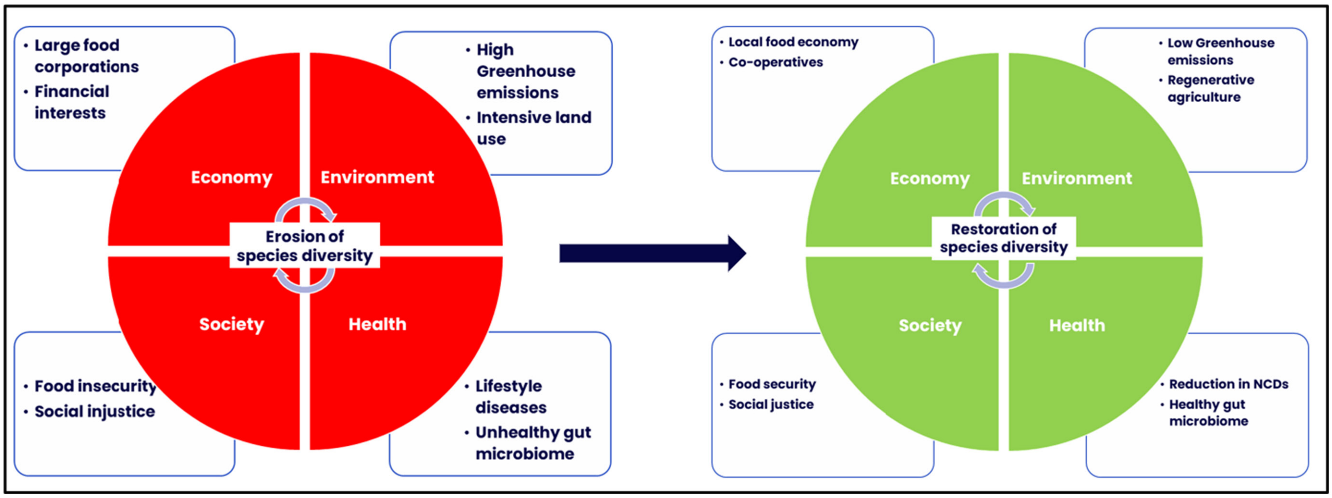

FIGURE 3 (a) [left] and (b) [right]: From red (erosion of diversity, a) to green (restoration of diversity; b): implications for economy, environment, health, and society (CATAPULT Symposium, 2023).

shocks. Studies have shown that species-rich agroecosystems exhibit greater resistance to extreme weather, pest, and diseases, reducing the need for chemical inputs and providing a cushion to farmers (Wang et al., 2023). Within the current framework of food system transformation, the strategic focus on prioritizing and increasing species diversity offers a viable approach for fostering sustainable food production.

Preserving genetic diversity within crop species is also integral to enhancing the climate resilience of communities globally. Locally adapted species possess traits that make them more resilient to specific climate conditions (Maxted & Magos Brehm, 2023). Furthermore, diversity in species-rich systems provides functional redundancy in which different species are able to perform similar roles in the wider ecosystem, increasing resilience to environmental disturbances (Eisenhauer et al., 2023). As such, integrating a diverse range of crop species within food systems becomes paramount as it helps maintain genetic resources crucial for the development of climate-resilient crops for future climates. For instance, during food scarcity periods, communities in urban and rural Nepal, rely heavily on gathering indigenous vegetables from forests for survival such as edible hibiscus, Indian leek (*Allium ampeloprasum var. porrum*), fern asparagus (*Asparagus setaceous*), black jack (*Bidens pilosa*), and caper bush (*Capparis spinosa L*) (Shrestha, 2013).

Moreover, many indigenous tree and plant species such as baobab, *Amaranthus spp*, cat's whiskers (*Orthosiphon aristatus*), Bambara nuts (*Vigna subterranean*) and, Indian jujube (*Ziziphus mauritiana*) have been reported to offer high quality nutrition compared to commonly grown crops like maize and rice (Raneri et al., 2019). King et al. (2021) reported that underutilized crop species like minor millets are highly nutritious for human consumption and adapted to various agroecological niches and marginal areas, which are sometimes not suitable for majority of the common crops in agriculture.

Establishing seed banks is crucial for preserving the genetic diversity of crop species and their wild relatives in situ (Hazhir et al., 2024; White et al., 2023). Seed banking involves systematically collecting, storing, and preserving seeds from plant species (Hay & Probert, 2013; Walters & Pence, 2021). As such this acts as a repository of genetic material and an insurance policy against threats like climate change. Collaboration with local farmers is essential for ensuring the effectiveness and relevance of seed banking initiatives. Farmers, as stewards of seeds for generations, possess valuable knowledge about the characteristics, adaptability, and resilience of different varieties (Ahnström et al., 2009; Carmichael et al., 2023). Therefore, their understanding of the local ecosystems and agro-climatic conditions makes their contribution to seed banking initiatives invaluable.

Engaging farmers collaboratively acknowledges their role as custodians of agricultural biodiversity and enhances the success of seed banks by incorporating traditional knowledge and practices into the conservation process (Clancy & Vernooy, 2016). It recognizes the connection between cultural practices, agricultural heritage, and sustainable management of plant genetic resources (Brush, 2005; Goswami, 2024). Consequently, seed banking becomes a dynamic and inclusive process, blending scientific expertise with traditional wisdom, contributing to the resilience and sustainability of global food systems (Pullaiah & Galbraith, 2023).

3.3 | Mitigating environmental impact

As we strive for a sustainable food future, a diversity-based food system is a viable and transformative solution. This approach can help reduce greenhouse gas emissions (GHG) but also promotes regenerative forms of agriculture that restore soil health and biodiversity of wild plant and animal species (Figure 3a,b, top right). This aligns with broader conservation goals, acknowledging the interconnectedness of food production, culture and the natural world. Lelamo (2021) complements this viewpoint, demonstrating that agroforestry systems sequester more carbon and enhance overall ecosystem health. These findings emphasize the potential of species diversity in agricultural systems in mitigating the environmental impact of food production.

> Floodplain meadows in the United Kingdom support as many as 40 plant species per metre square, compared to three or four in intermanaged farming systems. Diverse meadows are also valuable for carbon sequestration, improving water quality and for flood mitigation. They are a sustainable, low-input farming system in which the high species diversity determines the broad nutritional quality of the hay harvested in these meadows which, in turn, influences the nutritional quality of produce from animals fed on this hay.
>
> (V. Bowskill)

3.4 | Role of species diversity in nutritional health

Beyond ecological benefits, a species-diverse food system directly impacts public health (Larson et al., 2020). A diverse food system can help address concerns related to malnutrition, obesity, cardiovascular diseases, and cancer by promoting better nutrition, healthy gut microbiome and reducing non-communicable diseases (Figure 3a,b, bottom right). By reducing the prevalence of non-communicable diseases, diverse food systems contribute to the overall well-being of individuals and communities. Research by Verger et al. (2021) explores the nutritional advantages of diverse diets, showcasing that communities with access to a variety of locally grown, diverse crops species experience improved health outcomes. Their work highlights the intricate relationship between species diversity, nutrition, and human well-being.

Nutritional quality in food is often overlooked when we are thinking about food security or the sustainability of our food production. Promoting awareness regarding human health is of the utmost importance, as a healthy lifestyle is facilitated by the consumption of nutritious and high-quality food. An equivalent relationship is also observed in livestock, whereby higher-quality products such as milk and meat result from a diverse supply of forage (Butler et al., 2008).

Indigenous species are crucial in providing local communities with a diverse range of highly nutritious compounds. Notably, many indigenous species exhibit nutritional values comparable to or occasionally surpassing their domesticated counterparts. *Amaranthus* species, commonly consumed in many African countries, surpass cabbages in vitamin A (200-fold) and iron (10-fold) content (McGarry & Shackleton, 2009). Certain indigenous species including Asian *Moringa oleifeira* can provide potassium and calcium minerals, and both vitamin A and C at the recommended dietary levels in a few servings of the vegetable (Asghari et al., 2015).

Indigenous species also contain phytochemical compounds such as carotenoids, flavonoids, and saponins crucial for human health (Li & Siddique, 2018). These compounds, depending on their type, exhibit various biological effects, including antimicrobial, anticancer, anti-inflammatory, anti-allergenic, cardio-protective, and antioxidant activities (Moyo et al., 2013). The same is true of many wild plants in species-rich meadows that are grazed by livestock, or fed as hay, reducing the need for chemical pharmaceuticals that can damage both ecosystems and may have human health implications in the foodchain (Milliken, 2023). This highlights the critical role of incorporating indigenous species into diets for overall health improvement.

Although there has been an increase in the consumption of indigenous species globally including many parts of Africa, India, Middle-East, and South America, many individuals still prefer their exotic counterparts, especially in urban areas (Dansi et al., 2012; Kaczmarek et al., 2023). The lack of promotion, scientific information, and erosion of indigenous knowledge remain the leading factors contributing to the low consumption of these species (Ashwath et al., 2023; Shelef et al., 2017; Vitousek et al., 1997). The information that is lacking in the public regarding indigenous species includes nutritional composition and their value to our health, appropriate cooking methods for creative innovative culinary delights, and nutrient bioavailability (Chivenge et al., 2015; Tadele, 2019).

3.4.1 | Factors affecting the adoption of indigenous plant species in diets

Despite the evidence of the positive health benefits of indigenous species, there is a lack of global interest in their consistent cultivation and consumption (Weide et al., 2023). A significant factor is the misconception surrounding the definition of "healthy food," which equates healthiness with calorie density rather than essential nutrients (Cardenas & Ochoa, 2023; Lucan & DiNicolantonio, 2015). This has led to misguided priorities in food choices. While meeting daily energy needs is crucial, there is an overemphasis on production and consumption of calorie-dense foods, resulting in individuals potentially suffering from obesity due to over consumption of calories and/or micronutrient deficiencies from insufficient essential vitamin and mineral intake (Drewnowski, 2009; Salvia & Quatromoni, 2023). Consequently, there is a pressing need for a systematic definitional change of the word "healthy foods" to focus on the quality and diversity of nutrient intake.

Negative perceptions towards indigenous species due to Western influence in developing countries also contribute to their low consumption (Ng′endo et al., 2016; Poudyal et al., 2023; Yang & Keding, 2009). This has resulted in farmers preferring to cultivate exotic species especially vegetables and fruits that are widely accepted by consumers and have a ready market (Nemapare et al., 2023). This reduced cultivation is made worse by the fact that the consumption of indigenous species is mainly common among the elderly and women in rural areas, considered by the younger generation and urban dwellers as food used during times of food insecurity (Imathiu, 2021). Weinberger and Msuya (2004) in their study in Asia found that wealthier households are less likely to consume indigenous vegetables, possibly due to the preference for exotic vegetables.

The erosion of indigenous knowledge about local wild species has led to the misconception that commercialized produce is healthier than indigenous species (Moyo et al., 2024; Nikolić et al., 2023). For example, Keding et al. (2022) found that some indigenous Turkana fruits have higher nutritional content than apples, yet local communities in the region perceive exotic fruits like apples as more nutritious. This emphasizes the need for increased nutrient analysis and community awareness programs highlighting the nutritional significance of indigenous species.

It is also noted that individuals, to some degree may prefer packaged foods, driven by the perception of sanitation standards than foraged products sold along roadsides rather than in super markets (Peters-Texeira & Badrie, 2005). This pattern suggests that there is a tendency to overlook nutritional needs in the pursuit of cleanliness and convenience. This perpetuates a misinformed understanding of a healthy diet, with repercussions extending beyond personal wellbeing, impacting culture and the environment (Chen et al., 2023; Ogba & Johnson, 2010). Consequently, there arises a compelling need to advocate for value addition and marketing strategies for indigenous species, recognizing that their acceptance hinges on effective promotion and education.

3.5 | Role of species diversity in enhancing food security and social justice

Presently, the global food system is influenced by capitalist metrics which promote quantity (high yields) regardless of the suitability of the species to community dietary needs and the local environment (Nicholson et al., 2019). Transformation requires a massive mindset change to provide enhanced food security and evoke social justice in addressing systemic inequalities. An effective food system should encompass improved production, distribution, and consumption practices, and reorientation by promoting diversity. This fosters resilience, ensuring that communities have access to a variety of nutritious foods, thereby creating a more just and equitable food landscape (Figure 3a,b, bottom left).

3.6 | Role of species diversity on soil health and the environment

Crop species diversity can significantly contribute to soil health and, consequently, address various environmental issues such as water quality, water management, and carbon storage. Diversified cropping systems, can enhance soil health by optimizing nutrient cycling, improving soil structure, increasing soil organic matter, and promoting microbial diversity (Dybzinski et al., 2019; Venter et al., 2016). Healthy soils are the foundation of sustainable food production, as they require fewer external inputs, are more resilient to climate stressors, and can help mitigate climate change through carbon sequestration (Lal, 2020). Therefore, by promoting crop diversity, we can address multiple challenges facing our current food systems, such as soil degradation, water pollution, climate change, and biodiversity loss (Foley et al., 2011).

Crop diversity can also contribute to sustainable food system transformation by reducing the environmental impact of agriculture. Diversified systems can minimize the need for synthetic fertilizers and pesticides, which can lead to water pollution and biodiversity loss (Letourneau et al., 2011). By providing ecosystem services such as erosion control and water purification, diverse cropping systems can help maintain and restore the natural resource base upon which agriculture depends (Schulte et al., 2017).

4 | LINKING SPECIES DIVERSITY WITH INDIGENOUS SPECIES

The relationship between species diversity and indigenous species is a crucial factor for the transformation of our food system. Adaptive traits of indigenous species, developed through centuries of coevolution with local environments and cultures, provide vital benefits in building resilience against a wide range of challenges. The preservation and utilization of indigenous species, within the broader context of species diversity, hold significant potential for addressing the complex dimensions of global food security.

4.1 | Indigenous species and the changing environment

There is compelling evidence that food systems are negatively affected by land degradation and climate change. Projections indicate that climate change will exacerbate existing non-climatic drivers, further stressing and undermining the resilience of agricultural and food systems (Aura et al., 2016). Concurrently, shifts in temperature, precipitation patterns, and the occurrence of extreme events are already decreasing the suitability and productivity of crops leading to food insecurity globally (Loeben et al., 2023).

Despite these challenges, studies highlight a contrasting trend, revealing that indigenous species demonstrate a remarkable ability to adapt to climate variations and extreme events (Chanza, 2023). This accentuates the crucial role of indigenous species can play in sustainable food system transformations. Their resilience to climate change, coupled with high nutritional value, renders them integral to the health and cultural practices of numerous local communities (Trogrlić et al., 2019).

Indigenous plant species, deeply rooted in their local ecosystems, possess a distinct advantage in facing the challenges posed by land degradation and climate change (Jäger & Kowarik, 2010; Talucder et al., 2024). In contrast, conventionally bred crop species often struggle to adapt to changing environmental conditions (e.g., Robles-Zazueta et al., 2024). Historical instances, such as those in the 1830s, illustrate the skepticism of local Indian farmers towards foreign cotton seeds, contending that these seeds took longer to mature and were more sensitive to adverse weather conditions (Hazareesingh, 2016). This arose due to the foreign cotton originating from America, where traits had been genetically selected to fit the commercial needs of the specific region. While these traits were profitable to American farmers, this breed of cotton fundamentally lacked ecological relationships necessary to achieve the same profitability in new environments in India. Consequently, this highlights the importance of indigenous knowledge in decision-making for species promotion, introduction, and breeding.

Similarly, the limited diversity and subsequent growing challenges of commercially bred crops have resulted in an increased pursuit of alternatives. The case of wild rice cultivation provides a compelling example of how native plant species can be more resistant to climate change than non-native species (Fuller et al., 2007). Historically, indigenous communities in North America have long cultivated wild rice in shallow lakes and rivers, using traditional techniques to manage water levels and promote growth. These techniques have allowed wild rice to thrive in a range of environmental conditions, including periods of drought and flooding (Qiu et al., 2020; Sweeney & McCouch, 2007). Eventually, this plant was documented as a viable crop that was low-cost and labour-free, particularly suited for colder regions (Khush, 1997). Now, wild rice is considered a luxury grain and is marketed as a health alternative to other staple grains.

Furthermore, from a dietary standpoint, the consumption of native indigenous plant species tends to be adapted to the local community's gut biome (Xu & Knight, 2015). Humans globally vary in the digestibility of different foods. Just as some are lactose-intolerant, others are more compatible with the consumption of certain foods. Over generations, populations have developed gastrointestinal compatibility with their native edible species, which tends to result in improved digestibility and nutrient absorption (David et al., 2014).

Accordingly, in Japanese culture, seaweed is a highly valued marine vegetable that is paired with many dishes. Referred to as 'nori', seaweed contains large amounts of sulphate polysaccharides that are absent in terrestrial plants. Interestingly, carbohydrate-active enzymes, called porphyranases, that are involved in the degradation of porphyrin, a polysaccharide originating in red algae were found in the natural gut microbiota of Japanese individuals. Frequent contact with marine microbes likely promoted the transfer of carbohydrate-active enzymes from marine bacteria to Japanese gut microbiota.

In the face of ongoing challenges posed by climate change to agriculture and food security, cultivating native species underscores the critical role of preserving and promoting indigenous knowledge. This approach emerges as a key strategy for building resilience in the agricultural sector and adapting to environmental changes.

4.2 | Cultural barriers to the cultivation of indigenous species

The uncertainty in consumer acceptance of certain foods mirrors the unpredictability surrounding the cultural acceptance of indigenous species. While indigenous species have deep historical roots in the diets of indigenous communities, locals often resort to foraging for these plants specifically during periods of food scarcity or hunger (Moore et al., 2022). The inclination to forage during times of need is somewhat anticipated, and it prompts the question: Why do these foods not gain similar appeal during the other times of the year when staples are plenty?

The answer to this question is likely complex. Firstly, cultural perceptions and preferences heavily influence dietary choices. Certain indigenous species may be associated with periods of hardship or scarcity, contributing to a perception of them as survival foods rather than everyday staples. Additionally, the unfamiliarity with preparation methods and flavours of indigenous species could be a deterrent during regular conditions when more conventional food options are readily available. Furthermore, the modernization of diets and the increased accessibility to commercialized produce may contribute to a diminished interest in foraging for indigenous species during times of abundance.

Despite the nutritional superiority of indigenous species, factors such as taste preferences and associated activities, like identification and travel to collection sites, can lead to their cultural abandonment, as observed in rural island communities in Spain. Conversely, staple grains, particularly cereals are prioritized as a foundational element of a proper meal; cereals were the most globally produced crop (32%) compared to vegetables (12%) and fruits (10%). For instance, rice is deeply embedded in Asian cultures, with the average person on the Asian continent consuming 128 g/day (Balaji et al., 2020). Unfortunately, this cultural preference has led to rice and other cereals taking up a high proportion of a single meal as opposed to a more balanced one with a wide range of fruits, legumes, nuts and vegetables. The same narrative holds true for majority of African countries, where maize is considered as the staple crop.

Additionally, increasing per capita income and food purchasing power, coupled with changes in the food system, contributes to shifts in dietary preferences. Currently, there is a noticeable shift in consumer behavior as people allocate more financial resources to staple foods, moving away from coarse whole grains and tubers towards increased consumption of highly refined carbohydrates and sugars (Kearney, 2010). However, this cultural shift was identified as a driving factor in obesity and diabetes in Tanzania. The key factor behind this trend in Tanzania was the perception that unrefined grains and brown rice have lesser taste appeal and are associated with poverty, while the consumption of refined carbohydrates is viewed positively. This underscores the critical need for effective communication strategies if indigenous species are to become a dietary priority in the broader context of food consumption and for food system transformation.

5 | POTENTIAL RISKS ON INDIGENOUS SPECIES

5.1 | Overexploitation

The proliferation of knowledge and consumption of indigenous species brings significant risks in the exploitation of indigenous knowledge systems and the environment. The perceived value associated with these species can lead to over-exploration practices, as exemplified by the case of açaí palm in the amazon (Weinstein & Moegenburg, 2004). The global demand for açaí has led to large-scale cultivation, competing with local farmers, contributing to deforestation, and exacerbating social inequalities (Yamaguchi et al., 2022). The continued growth of the açaí market, projected at a Compound Annual Growth Rate of 10.6% from 2021 to 2028, suggests that these challenges are likely to persist.

Over-exploitation of indigenous species like medicinal plants, can also deplete populations, disrupt ecosystem functions, and can trigger a cascade effect, resulting in biodiversity loss (Dulloo et al., 2014; Joppa et al., 2016). To mitigate these risks, sustainable management practices must be developed through collaboration between indigenous communities, researchers, and policymakers to ensure responsible harvesting, cultivation, and trade of these valuable resources.

5.2 | Habitat degradation

Increased harvesting of indigenous species threatens natural habitats, particularly forests, potentially leading to degradation. Unsustainable harvesting practices including clear-cutting can have severe, lasting consequences on the environment (Semenya & Maroyi, 2019). Furthermore, as species are removed in large quantities, the ecological functions they perform within their habitats may be compromised, affecting other dependent species and disrupting the overall ecosystem equilibrium (Haq et al., 2023; Lindenmayer & Fischer, 2006). To mitigate the risks associated with habitat degradation, sustainable harvesting strategies, such as selective harvesting, rotational harvesting, and community-based conservation, are needed to balance human needs and preserving the integrity of natural habitats.

5.3 | Loss of nutritional qualities

Overcultivation of indigenous species poses risks compromising their nutritional value. Their nutritional richness is partly attributed to a broader gene pool from evolutionary adaptations (Fernandez et al., 2021). Domestication favors yield-enhancing traits, potentially removing the nutritious factors. For example, cultivated legumes have less levels of carotenoids compared to their wild relatives, a consequence of selection for improved storability and taste. Whether intentional or not, it can be challenging to manage biases when attempting to rely on regular cultivation of these indigenous species. Developing sustainable food production systems should mimic nature's production systems.

5.4 | Erosion of cultural values

The cultural significance of Indigenous species is deeply intertwined with the identity, spirituality, and heritage of Indigenous communities (Maffi, 2005). The commercialization of these species can disrupt the intrinsic cultural values attached to them, potentially diluting the spiritual, symbolic, and communal meanings that have been passed down through generations (Sujarwo et al., 2014). Additionally, the erosion of cultural values can have significant impacts, leading to the loss of unique cultural practices tied to the use and conservation of indigenous species (Athayde et al., 2017; Pearson et al., 2023). It is therefore crucial to establish systems that regulate the responsible use of indigenous species when contemplating commercialization.

5.5 | Inequitable benefit sharing

As indigenous species become valuable commodities, there is a potential for uneven distribution of economic benefits. This uneven distribution can result in social tensions and conflicts, as community members grapple with perceived injustices and imbalances in resource access and wealth (Narloch et al., 2017). For example, certain community members especially women and the elderly, who have less access to resources and limited decision-making power, may be marginalized in the wake of inequitable benefit sharing (Martin et al., 2014). This may lead to the marginalization of these susceptible populations, further exacerbating existing social inequalities. In conjunction with community-based management strategies, the implementation of transparent and inclusive benefit distribution systems can aid in the reduction of the predicted social tensions and conflicts that result from unequal economic gains.

6 | POLICY MEASURES TO ENCOURAGE

Securing a sustainable food future hinges on a fundamental shift towards promoting species diversity and embracing the cultivation of indigenous plant varieties. By implementing a comprehensive set of targeted policies and strategic incentives, we can transform our current food system into one that values biodiversity, empowers local communities, and ensures long-term food security. Below are some of our recommendations:

First, government and civil society organizations should work together to increase awareness, importance, and understanding of species diversity and indigenous species through existing programs such as in schools, health systems, markets, youth groups, food councils, restaurant associations, chambers of commerce, cultural networks, religious programs, agricultural and environmental groups. These can include:

- Mobile/teaching kitchens – nutrition education with food preparation and tasting.
- Integration of food samples (in schools, hospitals, markets, restaurants, etc.) so people can taste indigenous species.
- Posters, booklets, videos, media, TV and radio shows.
- Inclusion of indigenous species with educational information in public green spaces, museums, etc.

Second, policymakers and institutions involved in the agriculture sector must design financial rewards that incentivize farmers to integrate multiple crop species, including indigenous ones. These incentives should offer tiered rewards based on the level of diversity, mandate minimum thresholds to encourage polycultures and require long-term commitments to prevent short-term exploitation (European Commission, 2021; Kleijn et al., 2019). Additionally, payment rates must be attractive enough to outweigh the potential benefits of monocultures, considering factors like opportunity costs and the inherent value of diverse agricultural systems. Initiatives like the EU's Common Agricultural Policy (CAP) and the UK's Environmental Land Management Schemes offer practical examples of such policies (DEFRA, 2022; European Commission, 2021).

Third, policymakers must also actively promote agroecological practices like regenerative agriculture, intercropping, conservation agriculture, and agroforestry. This requires expanding agricultural extension services, establishing demonstration farms as learning hubs, and investing in research that explores the potential of these practices to enhance diversity, improve soil health, and increase farm resilience.

Fourth, research has long established that community seed banks play a crucial role in the preservation of indigenous species. These banks act as repositories of genetic material, safeguarding against threats like climate change, pests, and diseases. Moreover, they maintain and conserve genetic resources that have evolved naturally or through generations of traditional farming practices (Pullaiah & Galbraith, 2023). To strengthen their role, policymakers should allocate dedicated funding, provide training programs for local communities, and establish supportive legal frameworks that protect community seed banks from restrictive intellectual property rights. Fostering collaboration between these banks, research institutions, and gene banks further facilitates the exchange of knowledge and genetic resources.

Finally, there must be a prioritisation of research and development focused on improving the productivity, resilience, and nutritional quality of all plant species, with a particular focus on indigenous varieties. This includes engaging farmers in participatory breeding programs, conducting nutritional analyses to identify species with superior profiles, and exploring the climate resilience of indigenous crops.

We believe that by implementing these policy recommendations, we can effectively promote species diversity and the utilization of indigenous edible plants. This will pave the way for a more sustainable and equitable food system, one that values ecological wealth and empowers local communities to become stewards of their own food security.

7 | CONCLUSION

Our current agricultural and industrialized food system pushes us to consume ever more industrially produced and ultra-processed food, posing substantial threats to both individual health and environmental sustainability. This trajectory calls for a critical re-evaluation, where embracing a diverse array of species including indigenous species in our diets emerges as a pivotal strategy for reshaping our food system and building resilience in the face of global challenges. Choosing to diversify our diets with 'real food,' represents more than a mere dietary preference; it becomes a deliberate act of contribution to the preservation of indigenous species, safeguarding a robust and resilient food supply. When amplified through support for local farmers cultivating diverse crops, this choice not only bolsters regional food systems but also mitigates the risks associated with overreliance on a few staple crops, thereby enhancing overall food security.

Beyond its immediate implications, the transformative power of species diversity extends to societal structures. Embracing diversity in our diets encourages a departure from a centralized, mass-production model, empowering local communities and fostering meaningful connections between consumers and producers. This shift not only supports the preservation of indigenous agricultural knowledge but also promotes sustainable, culturally diverse food systems. Ultimately, this multifaceted approach contributes significantly to the broader goal of building a resilient, equitable, and sustainable global food landscape.

In essence, the choices we make for our meals and snacks extend far beyond personal preferences. They wield the power to shape our food system, impact local economies, and influence global sustainability. Opting for species diversity in our diets emerges as a transformative force, steering us towards a future where food security, environmental health, and societal well-being are harmoniously intertwined.

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DATA AVAILABILITY STATEMENT

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