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Revitalizing indigenous people's food systems: Attributes, challenges, and policy directions

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ABSTRACT

Context: Conventional agricultural systems have become major drivers of climate change, biodiversity loss, and environmental degradation, intensifying global food insecurity. In contrast, Indigenous Peoples' Food Systems (IPFS), rooted in traditional ecological knowledge, offer sustainable and resilient alternatives that enhance biodiversity, mitigate climate impacts, and ensure nutritional security.

Objective: This review aims to examine the role of IPFS in promoting sustainability and resilience, identify the key challenges they face, and propose strategies for integrating these systems into global food policies.

Method: - Drawing on literature published, a systemic review was conducted using databases such as PubMed, Scopus, and Web of Science. Peer-reviewed articles, case studies, and policy-focused research published after 2000 were analysed. Boolean operators were used to refine searches related to traditional foods, indigenous agriculture, and policy interventions.

Results: The synthesis shows that IPFS are closely linked to biocultural traditions and local ecosystems, contributing significantly to ecological balance, nutrition, and community wellbeing. However, land dispossession, urbanization, and climate change have disrupted these systems, leading to dietary transitions, processed food dependency, and health disparities among indigenous populations. Emerging evidence points to the need for legal recognition, culturally responsive extension approaches, and participatory governance models that bridge indigenous knowledge with scientific innovation.

Significance: The review argues that by integrating IPFS principles into national and global food strategies along with future research focusing on longitudinal documentation of indigenous food practices, and co-creating frameworks involving communities as knowledge partners rather than beneficiaries would be favourable.

1. Introduction

The global food system is a major driver of environmental degradation, contributing significantly to biodiversity loss, ecosystem damage, and pollution of air, land, and water (IPCC, 2019; Rockström et al., 2020; FAO, 2020). It is also the largest emitter of greenhouse gases (GHGs), accounting for approximately 20% of total emissions, with half originating from agricultural production and the other half from land-use changes such as deforestation (IPCC, 2019; FAO, 2020). When considering production, distribution, and consumption, food systems are responsible for nearly one-third of human-induced greenhouse gas emissions (Crippa et al., 2021). Without urgent intervention, current food production practices will continue to disrupt ecosystems, alter

weather patterns, and threaten global food security, ultimately jeopardizing human well-being and planetary health (FAO, 2020). To address these challenges, there is an urgent need for more sustainable, resilient, and equitable food systems that align with the United Nations Sustainable Development Goals (SDGs). Recognizing this need for systemic transformation, the United Nations Food Systems Summit emphasized the inclusion of diverse stakeholders such as scientists, civil society, indigenous peoples, and private-sector actors to foster healthier and more sustainable food systems (Beamer et al., 2021). Among these stakeholders, indigenous people are considered to hold critical knowledge for sustainable food production. This is due to the fact that their food systems are deeply rooted in traditional ecological knowledge and have sustained the communities for millennia while preserving

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biodiversity, enhancing ecosystem resilience, and ensuring food and nutritional security (Kuhnlein, 2015; Paumgarten & Shackleton, 2011; Rocha et al., 2017, pp. 235–260).

Unlike urban populations, who are dependent on commercial supply chains, many indigenous communities rely on wild food gathering, agroforestry, and traditional farming practices that promote crop diversification, soil fertility, and climate resilience (Ali & Bhattacharjee, 2023; Bose, 2019; Shelef et al., 2017). In context of IPFS, climate resilience encompasses adaptive land-use practices, diversified cropping systems, traditional ecological knowledge, and community-based governance mechanisms that enable socio-ecological systems to respond to environmental variability. Forests and natural ecosystems play a vital role in their food systems and in enhancing their food security (FAO, 2015). For instance, wild and underutilized food plants, offer higher nutritional value than conventional crops and require minimal agricultural inputs, reducing environmental strain (Akinola et al., 2020; Asigbaase et al., 2023; Bello-Bravo & Lutomia, 2022; Chivenge et al., 2015). Moreover, their food systems integrate medicinal plants, climate-adapted crops, and sustainable harvesting techniques, reinforcing both food sovereignty and cultural heritage (Kamwendo & Kamwendo, 2014; Powell et al. 2014; Yaipharembi et al. 2023). This is due to the fact that indigenous communities maintain their control over seeds, land, and resource use, and by preserving cultural heritage through ritualized food practices, intergenerational knowledge transmission, and customary governance structures that regulate harvest and sharing (Akinola et al., 2020). Their food systems represent a living connection between ecology, identity, and social organization, ensuring that food is not only a commodity but a cultural expression (Bello-Bravo & Lutomia, 2022). In addition to long-term environmental pressures, IPFS are increasingly discussed within the context of compounded global crises, where climate change, pandemics, and geopolitical disruptions interact to reshape food security. Recent global analyses highlight how systemic shocks such as COVID-19 supply chain disruptions, regional conflicts, and climate extremes have exposed vulnerabilities in industrialized food systems while reinforcing the resilience of localized and biodiversity-based food practices (Galanakis & Rohm, 2023). Within this context, IPFS offer adaptive strategies that combine ecological knowledge, diversified diets, and community-based governance, positioning them not only as cultural food traditions but also as practical responses to emerging global instability. Despite their sustainability, IPFS face growing threats from deforestation, land dispossession, urbanization, and shifting dietary habits (Sayer et al., 2013; Vira et al., 2015, p. 288). The erosion of these systems has led to increased malnutrition and health disparities among the indigenous communities, as processed foods replace traditional diets (van der Hoeven et al., 2013).

Despite growing recognition of the ecological and nutritional benefits of IPFS, systematic syntheses that link their sustainability attributes, socio-economic challenges, and policy integration pathways remain limited. While these global syntheses have documented the ecological and cultural importance of IPFS, many remain primarily descriptive or policy-oriented. The present review advances this body of work by introducing the Sustainability–Challenge–Integration (SCI) analytical framework, which systematically links ecological attributes, socio-economic pressures, and policy pathways within a single comparative lens. Unlike earlier reports that focus mainly on documentation or advocacy, this synthesis integrates regional comparisons, emerging food-science perspectives such as processing practices and nutritional profiling, and a forward-looking discussion on technological transitions, including innovations. By bridging extension science, food systems research, and policy analysis, this review aims to move beyond descriptive accounts toward a more analytical understanding of how IPFS can inform future sustainable food system transformations.

Addressing this research gap is essential to identify actionable strategies for revitalizing Indigenous food systems and aligning them with global sustainability goals. Therefore, this review adopts a global scope,

drawing upon studies from diverse ecological and cultural contexts across Asia, Africa, Latin America, and Oceania to capture the multifaceted nature of IPFS. While the synthesis remains global, selected examples from India are included to illustrate region-specific dynamics and policy implications, given the country's rich diversity of indigenous communities and food traditions. This approach balances broad generalization with contextual understanding, allowing for globally relevant yet locally grounded insights. Specifically, the review aims to: (i) Examine the structure and key elements of IPFS, including their agro-ecological practices and socio-cultural foundations, (ii) Highlight their contributions to biodiversity conservation, climate resilience, and nutrition security, (iii) Identify challenges such as land rights conflicts, market pressures, and cultural erosion, (iv) Assess impacts of environmental and socio-economic changes on IPFS, (v) Explore strategies for revitalizing IPFS, including policy interventions and community-led initiatives and (vi) Outline future research directions to strengthen documentation, advocacy, and integration of IPFS into global food policies. By compiling case studies and evidence-based insights, this review underscores the urgent need to protect and elevate IPFS as viable models for sustainability. Their integration into broader food policies could offer transformative solutions to contemporary crises in agriculture, nutrition, and climate change.

2. Materials and methods

This study employs a systematic literature review approach to comprehensively analyse the sustainability, value, and threats to IPFS, following a structured, multi-step process to ensure rigor, transparency, and reproducibility while adhering to established guidelines for systematic reviews by PRISMA framework (Brocke et al., 2009; Rethlefsen et al., 2021). This was completed in three phases: identification, screening and reporting.

Identification phase: The topics to be covered in the review are considered in the identification phase. In the present case, the review synthesized evidence from peer-reviewed articles, book chapters, government and non-governmental organization (NGO) reports, and case studies to provide a holistic understanding of IPFS, utilizing a comprehensive search across four major academic databases: PubMed (for health and nutrition-related studies), Scopus (for interdisciplinary coverage), Web of Science (for high-impact environmental and social science research), and Google Scholar (to capture grey literature and regional studies). The search strategy incorporated keywords and combinations using Boolean operators (AND, OR), including core concepts ('Indigenous food systems', 'tribal food systems'), sustainability focus ('sustainable livelihoods', 'climate resilience'), challenges ('land dispossession', 'policy gaps'), and geographical terms ('tribal communities in India'), with an example search string: ("Indigenous food systems" OR "tribal food systems") AND ("sustainability" OR "climate resilience") AND ("challenges" OR "policy interventions"). The review primarily targets publications post to the year 2000 and the prior were excluded because interdisciplinary research integrating sustainability, nutrition, and IPFS expanded considerably after 2000, coinciding with the global discourse on sustainable development and the institutional recognition of indigenous knowledge within international policy frameworks. Earlier literature, while insightful, often addressed indigenous food practices in isolation from the broader food systems perspective adopted in this review. The articles are selected based on their relevance to the topic. A total of 193 articles have been identified through database searching in the identification phase. Inclusion criteria encompassed peer-reviewed articles, case studies, and reports on indigenous populations globally addressing food systems, agroecology, and socio-cultural dimensions, while excluding studies on non-indigenous populations, non-English publications, articles lacking primary and meaningful IPFS data, and pre-2000 publications.

Screening phase: In the screening phase, the suitable and required information was collected and mined from the selected papers. In this

comprehensive review, the screening is done manually for each paper to cull out the relevant information. The screening process began with initial identification of 193 records, duplicate removal (yielding 169 unique records), title/abstract screening by two independent reviewers (155 articles advanced), and full-text assessment resulting 98 included studies after evaluating methodological rigor and resolving discrepancies through consensus discussions. Data extraction utilized a structured template documenting bibliographic details, study characteristics, key findings (ecological sustainability, socio-cultural dimensions, policy challenges), and recommendations, with thematic analysis organizing data into 10 categories: IPFS structure, biodiversity linkages, climate resilience, nutrition/health, threats, policy gaps, gender roles, youth engagement, case studies, and global comparisons. Rather than assigning numerical scores, a narrative appraisal approach was used to retain diverse knowledge sources while ensuring analytical rigor. Two reviewers independently screened titles, abstracts, and full texts, and any differences in interpretation were resolved through discussion and consensus to improve reliability. The inclusion of grey literature, such as NGO reports and policy documents, was considered essential for capturing Indigenous perspectives often absent from peer-reviewed sources; however, these materials were critically evaluated for source credibility and contextual relevance. The papers that are not directly related to the review topic and the papers that don't contain information

related to our subject area were excluded. To enhance the completeness of the search process, additional structured search techniques were applied. Backward searching was conducted by screening the reference lists of key articles to identify relevant studies not captured during the database search. Forward citation tracking was also performed to identify more recent publications that cited the selected papers. Clear inclusion and exclusion criteria were applied during the screening process, focusing on studies directly addressing IPFS, sustainability attributes, or policy and socio-ecological dimensions. Studies were grouped according to recurring themes relating to sustainability attributes, systemic challenges, and integration pathways discussed in the literature.

Reporting phase: In the final phase, the findings from the selected literature were synthesized and discussed. The analysis was organized into three main categories: Context of IPFS and its importance, challenges faced by IPFS, and various IPFS promoting interventions and its goals. The review concludes with a discussion of results, and key insights drawn from the reviewed studies. In the final reporting stage, a total of 98 articles were included in this review. The identification, screening and reporting phase of this review is summarized in the PRISMA flow diagram shown in Fig. 1.

Ethical considerations were also taken into account in the study emphasizing that the included studies gave due importance to the cultural sensitivity in attributing indigenous knowledge, representation

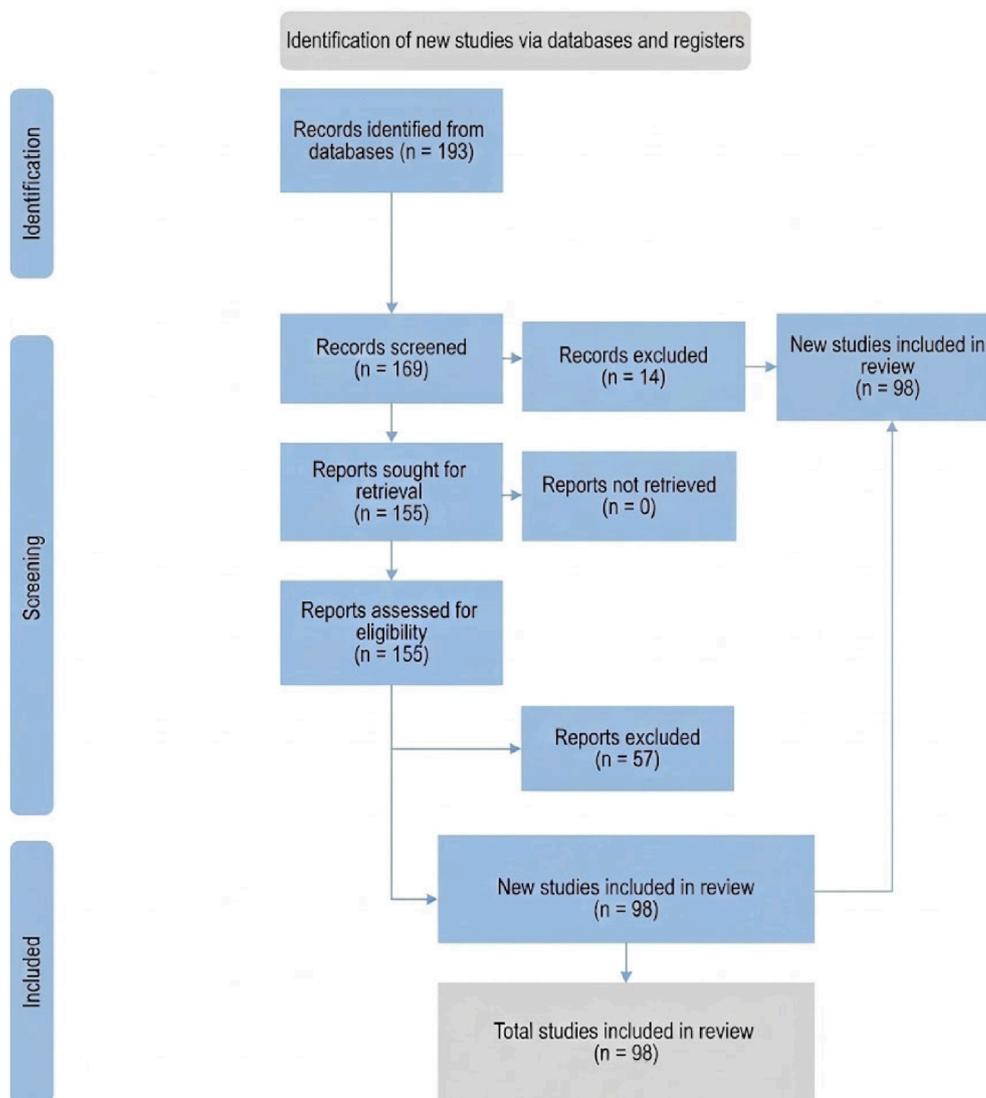


Fig. 1. PRISMA flow diagram illustrating the study selection process used in this review.

across different countries, and transparency in declaring conflicts of interest, while acknowledging limitations including potential language bias, and variable quality of grey literature. This systematic review synthesizes 98 studies to provide a global, evidence-based perspective on IPFS sustainability, integrating ecological, socio-cultural, and policy dimensions to highlight the need for indigenous-led governance and intersectional policy frameworks, with recommendations for future research prioritizing longitudinal studies and participatory methodologies to amplify indigenous voices and their food systems.

3. Results & discussions

To maintain conceptual clarity and organize the review findings, this paper adopted the Sustainability–Challenge–Integration (SCI) Analytical Framework (Fig. 2). The framework positions IPFS within three interconnected domains.

- (i) Sustainability: highlighting ecological, nutritional, and socio-cultural attributes that contribute to resilience;
- (ii) Challenges: encompassing ecological degradation, policy neglect, market transitions, and socio-economic pressures that undermine IPFS; and
- (iii) Integration: outlining pathways through which IPFS principles can inform and complement mainstream sustainable food policies and practices.

This framework not only structures the synthesis of results but also demonstrates how strengthening IPFS can contribute simultaneously to food security, biodiversity conservation, and climate adaptation.

3.1. IPFS and its importance

Food systems are those that encompass the complex network of activities and stakeholders involved in food production, processing, distribution, and consumption (Zimmerman et al., 2023), operating within interconnected feedback mechanisms that amplify contemporary challenges. Food systems are said to be sustainable when they strive to achieve food and nutrition security while minimizing environmental impacts and promoting socio-economic equity, particularly for marginalized groups (Fanzo, 2019). These systems prioritize accessibility, affordability, safety, and health while maintaining environmental

stability through sustainable cultural and ecosystem practices (Jerath et al., 2021). In this backdrop of sustainable food systems, IPFS are represented as exemplary models for the same, having evolved through deep ecological and socio-cultural relationships with local environments (Gao & Erokhin, 2020). Rooted in traditional ecological knowledge, these systems integrate cultivated and wild food sources including plants, animals, and fungi through practices adapted to local conditions. Their resilience to climatic extremes, low resource intensity, and minimal greenhouse gas emissions demonstrate their environmental compatibility (FAO, 2020). Nutritionally superior to many commercial alternatives, IPFS offer solutions to food insecurity and malnutrition (IUCN Director General's Statement on International Day of the World's Indigenous Peoples 2019, 2019; World Bank, 2019), while their socio-historical and spiritual foundations promote responsible resource stewardship, contributing significantly to sustainable diets and SDG achievements (Jerath et al., 2021).

As defined by María Eugenia Choque Quispe of United Nations Permanent Forum on Indigenous Issues (UNPFII), IPFS embody harmonious relationships with nature, integrating cultural identity, agricultural cycles, and spirituality to sustain both physical and spiritual wellbeing. These sophisticated systems reflect indigenous cosmologies and land management approaches, preserving complex traditional knowledge through intergenerational transmission in native languages. Governed by ancestral institutions with biocentric worldviews, they reverse all ecosystem components and maintain ecological balance through holistic approaches. Moreover, characterized by mobile livelihoods and collective resource rights, these systems encompass diverse activities including farming, fishing, hunting, and gathering, often involving hundreds of species utilized in multiple ways. Fundamental to these systems are community principles of reciprocity, circularity, and solidarity that reinforce social cohesion (FAO, 2021a). This intricate integration of ecological wisdom, cultural values, and sustainable practices positions IPFS as vital models for addressing contemporary food system challenges while preserving biodiversity and cultural heritage.

According to the FAO (Fig. 3), IPFS have five main aspects to consider. Importantly, (i) They have an intense understanding of nature and natural cycles where the diet changes according to seasons; (ii) It is a combination of food generation with food production which includes growing multiple crops in a field and harvesting as needed; (iii) Includes going distances to gather food, then preparing and consuming it in the

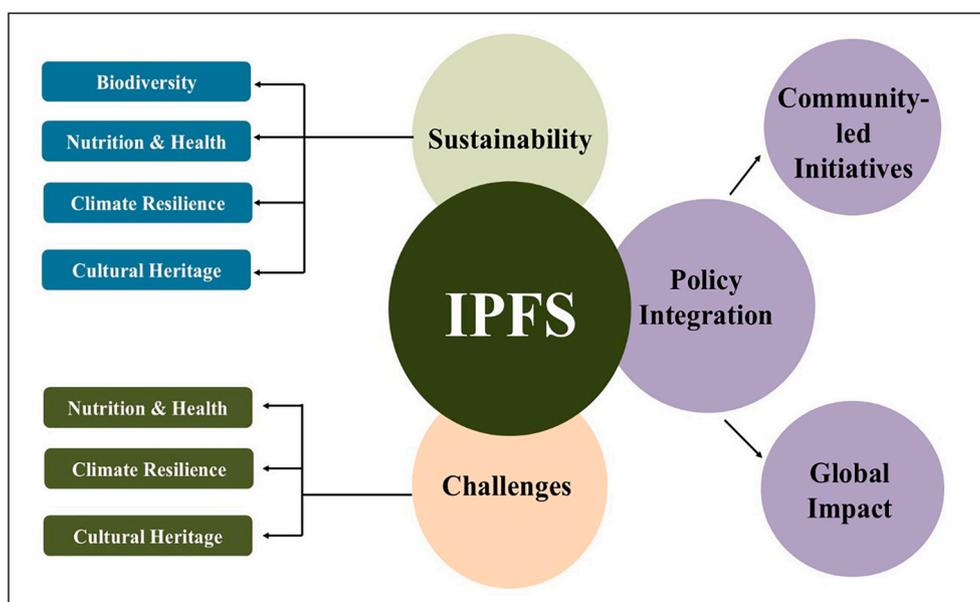


Fig. 2. The Sustainability–Challenge–Integration (SCI) Analytical Framework used to structure the review and discussion.

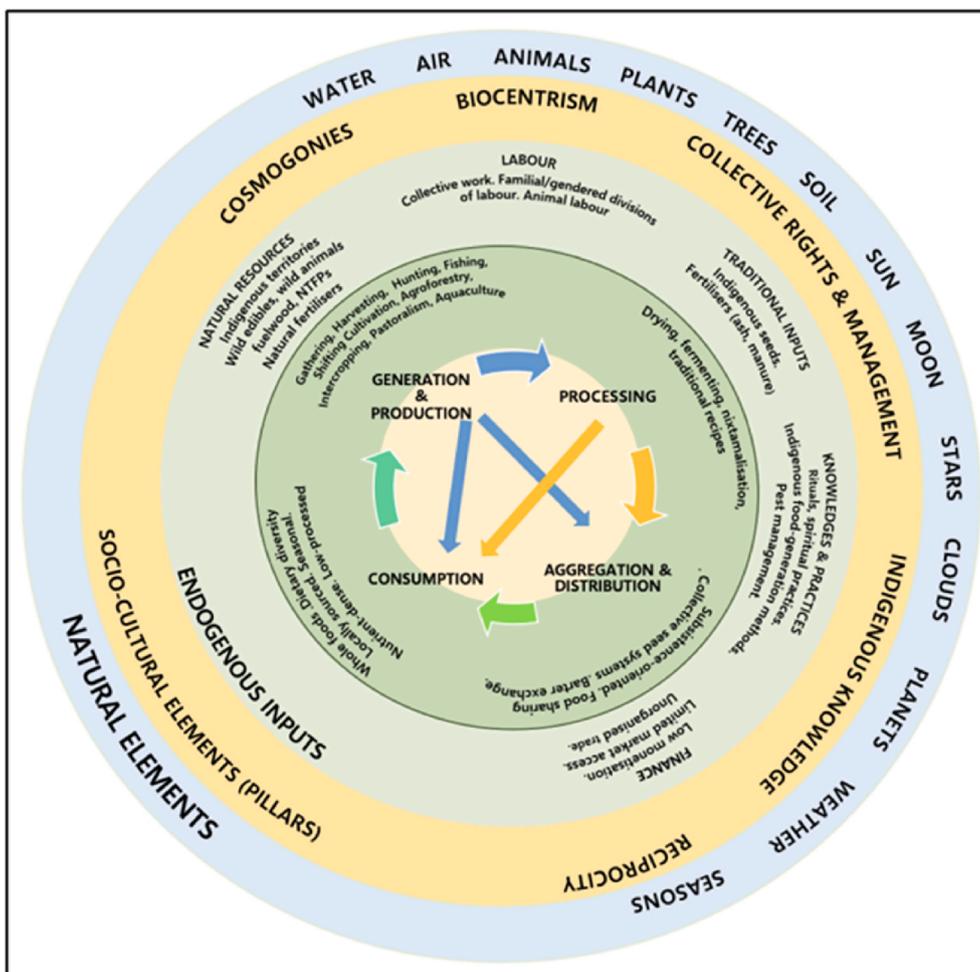


Fig. 3. Food systems wheel illustrating key dimensions of Indigenous Peoples' food systems (FAO, 2021a).

same place. Here food production spans large areas; (iv) Involves generation of food through territorial management, where local trades and services are managed in the same system; and (v) Belief that spirituality is important and the basis for every part of the food system and that humans are stewards of their environment (FAO, 2021a; World Economic Forum, 2023).

Recognized in a 2020 International Institute for Environment and Development (IIED) workshop, these systems were seen to offer viable solutions to the global food crisis, contrasting sharply with unsustainable industrial systems that drive greenhouse gas emissions, biodiversity loss, and resource depletion (IIED, 2020). While corporate-dominated systems perpetuate inequity, indigenous models demonstrate productivity, sustainability, and equity, safeguarding biodiversity, delivering nutritious food, and ensuring climate resilience with minimal carbon footprints (FAO, 2021a). Far from being “backward,” these systems present a forward-looking paradigm for food security amid environmental challenges. The major features of IPFS include: (a) *Better management practices*: in IPFS, land, territories, and resources are often governed collectively by families, clans, or entire communities. These customary governance systems, grounded in traditional knowledge, aim to uphold the collective well-being by regulating rights, responsibilities, and access to land, territories, natural resources, livelihoods, and food systems (Marrero & Mattei, 2022; Acharya et al., 2023). Traditional land management and collective governance of IPFS are designed to generate food whilst preserving biodiversity (Gowthami et al., 2021; IFAD, 2022). (b) *Composite knowledge and innovation*: IPFS differ from conventional scientific approaches by encompassing not only empirical observations of flora, fauna, and ecosystems, but also cultural and

spiritual principles that shape human-environment relationships (Borelli, 2020; Gras et al., 2021). This place-based knowledge, deeply tied to specific cultural contexts, evolves from centuries of interaction with local environments. Its preservation relies on intergenerational transmission through elders and community members, ensuring continuity. However, Indigenous knowledge is also dynamic and adaptive, incorporating innovation and experimentation to respond to changing socio-ecological conditions (Jernigan et al., 2021; Kodzwa et al., 2023). (c) *Enhanced sustainability and resilience*: the resilience of IPFS stems from their diverse food sources, territories, and sustainable management practices, as well as sociocultural values such as reciprocity, sharing, and collective care. For example, the exchange of food and seeds are rooted in principles of mutual aid and solidarity that enhances community resilience (Kumar et al., 2021). Historically, indigenous practices have prioritized ecological balance, guided by an understanding of ecosystem carrying capacity to ensure biodiversity conservation. Furthermore, indigenous lands serve as vital spaces for crop diversification and adaptation to climate change (Fanzo, 2021). (d) *Holistic culture and spirituality*: IPFS are deeply embedded within cultural frameworks encompassing language, taxonomic systems, resource management practices, social organization, spiritual beliefs, and cosmologies. Ritual practices and spiritual traditions reflect how IPFS are fundamentally tied to Indigenous sociopolitical and cultural institutions. Moreover, sacred ecological relationships play a vital role in sustaining local ecosystems (IFAD, 2022). The 2021 Rome Manifesto explicitly recognizes indigenous agro-biodiversity as critical for achieving the 2030 SDGs, emphasizing the protection of biocultural diversity through four key commitments: (1) integrating food cultures and traditional

knowledge into nutrition strategies, (2) creating biodiverse market incentives, (3) expanding consumer awareness of traditional foods' nutritional value, and (4) diversifying production systems through Indigenous-scientific knowledge integration (Rome, 2021; Ahmed et al., 2022). IPFS inherently embody sustainability across three vital dimensions: (i) *Environmentally*, they employ low-input practices like agroforestry and seed saving that enhance biodiversity and climate resilience (Swiderska et al., 2022; Tianyu et al., 2021), with adaptive strategies offering crucial climate adaptation blueprints (Santini & Miquelajauregui, 2022); (ii) *Socio-culturally*, they preserve identity through food rituals and intergenerational knowledge (Smith et al., 2019); and (iii) *Nutritionally*, they provide diverse, nutrient-dense diets that combat modern malnutrition (Sarkar et al., 2020).

IPFS occupy a central position in global discussions on climate change mitigation, biodiversity conservation, and sustainable food production. However, the significance of these systems extends far beyond traditional subsistence; they offer actionable models for achieving global sustainability targets. The FAO (FAO, 2021b) emphasizes how IPFS provide critical insights into ecosystem relationships that can inform sustainable food policies. This importance was further highlighted at the 2nd International Agro-biodiversity Congress, which identified IPFS being rooted in ancestral knowledge, sustain some of the world's most resilient and nutritionally rich food production models that simultaneously support human health and environmental balance (CGIAR, 2021; CGIAR, 2024; Milbank et al., 2021). For instance, the profound connection between indigenous cultures and their food systems is exemplified by the maize diversity in Mexico, where ethnicity, culinary traditions, spiritual beliefs, and seed systems converge to sustain agricultural biodiversity. The Yucatec Maya food system integrates beekeeping, home gardens, forest management, and traditional milpa agriculture, creating ecologically complementary networks of species that support both environmental and social well-being (IFPRI, 2014). Similarly, in northeastern India, the Naga people practice jhum (shifting cultivation) alongside community forest management, relying on wild foods such as forest fruits, leafy greens, mushrooms, and edible insects to enhance dietary micronutrients. This approach results in not only superior health outcomes, but also demonstrates lower rates of malnutrition and metabolic disorders compared to non-Indigenous regional populations (Ali & Bhattacharjee, 2023).

Additionally, IPFS significantly advances multiple SDGs, as demonstrated during a virtual workshop co-hosted by the International Institute for Environment and Development (IIED). Participants from indigenous communities across Asia, Africa, Latin America, and the Arctic, along with academic and UN representatives, underscored how these systems, steeped in millennia of ecological knowledge, are vital for cultural identity, food sovereignty, and biodiversity conservation. Indigenous peoples safeguard an estimated 80 percent of global biodiversity alongside immense cultural diversity (Das et al., 2023; Mirza-baev et al., 2023). For instance, in Kenya, the Tharaka tribe's revival of traditional seed systems strengthened community cohesion and mitigated pandemic impacts. Similarly, Quechua communities in Peru's Potato Park distributed tons of native potatoes to vulnerable populations, leveraging their biocultural heritage of reciprocity and ecological balance. These systems, enriched by scientific collaboration, maintain extraordinary crop diversity and food security despite climate pressures (IIED, 2020). Further illustrating this resilience, Mijikenda communities in coastal Kenya employ Indigenous Local Knowledge (ILK), including crop rotation, drought-resistant varieties, and wild species domestication, to combat climate-induced food insecurity (Ndalilo et al., 2020). Though some practices have declined, their cultural governance frameworks keep these methods relevant. Likewise, in India's Wayanad district of Kerala, a climate-vulnerable region, the Paniya, Kuruma, and Kattunayakan tribes adapt their farming and foraging strategies based on ecological changes. While Paniya and Kattunayakan communities rely on wild plants and small game, the Kuruma specialize in medicinal plants and paddy farming, showcasing adaptive

knowledge critical for broader climate resilience (Swaran et al., 2023).

These case studies affirm that IPFS are not relics of the past but dynamic solutions for contemporary challenges. By integrating traditional wisdom with scientific innovation, they offer scalable models for sustainable agriculture, equitable food access, and climate adaptation which are urgently needed in the face of global environmental crises. But, despite their immense ecological, nutritional, and cultural significance IPFS today are under increasing strain from multiple and overlapping pressures. The very systems that once ensured community resilience, biodiversity conservation, and sustainable livelihoods are being challenged by processes of land alienation, climate change, and market-driven agricultural transitions. Modern development paradigms often undervalue indigenous knowledge, leading to policy marginalization and loss of traditional governance structures. These pressures have accelerated dietary shifts, eroded local seed systems, and weakened intergenerational transmission of food-related knowledge. Understanding these emerging challenges is therefore critical not only to safeguard Indigenous heritage but also to harness IPFS as vital models for building resilient and regenerative food futures.

3.2. Challenges posed to IPFS

IPFS face mounting pressures that jeopardize their sustainability and cultural continuity. Globalization and modernization have eroded traditional ecological knowledge, disrupting intergenerational transmission of vital practices (FAO, 2021a). Climate change exacerbates these challenges by altering weather patterns and ecosystems critical for traditional agriculture and foraging (NESFAS, 2019). Land dispossession through mining, industrial agriculture, and infrastructure projects further disrupts Indigenous territories and food sovereignty (Powell et al., 2015), while systemic marginalization excludes indigenous voices from resource governance. The influx of processed foods compounds these threats, driving malnutrition and health crises (GOI, 2021). Additionally, legal and policy frameworks often actively undermine these systems. As a case in point, in Northeast India, restrictive forest policies displaced Lepcha communities from biodiverse ancestral lands, forcing transitions to cash crops. Likewise, Thailand criminalized Karen rotational farming (a proven sustainable practice) despite its biodiversity and food security benefits (IIED, 2020). Similarly, Russia's Arctic industrialization has decimated traditional hunting/fishing cultures, while land auctions in Chad dismantled resilient pastoralist systems (IIED, 2020).

Globalization and cultural assimilation have altered food preferences, leading to dietary transitions away from traditional and nutrient-rich foods toward processed alternatives. These transformations, compounded by inadequate policy recognition and weak land rights, have collectively diminished the economic viability, ecological balance, and cultural vitality of IPFS. Consequently, understanding the various negative impacts working on IPFS is critical not only for safeguarding indigenous livelihoods but also for informing global strategies aimed at achieving sustainable, equitable, and culturally inclusive food systems (Joseph & Turner, 2020). The key detrimental effects undermining IPFS include: (a) *Systemic racism*: access to healthcare, education, basic necessities, increased vulnerability to violence, increased likelihood of incarceration, and extreme poverty, are all impacted by systemic racism. One aspect of the racist views that have governed society is the failure to acknowledge the role that indigenous communities play in maintaining and improving their food resources, or the significance of Indigenous food for people's health and welfare (Turner & Mathews, 2020). (b) *Dispossession of land*: Indian agents were established to keep an eye on when and if indigenous individuals were permitted to go to harvest because the colonial government's reserve system separated Indigenous Peoples from many of their foods and food harvesting sites (Joseph, 2020; Turner, 2020a). In addition, there was constant pressure on people to adopt "civilized" farming and ranching methods, and many parts of indigenous lands that were declared parks were restricted or

outright prohibited. (c) *Residential schools*: these schools forcibly separated indigenous children from their families, systematically suppressing their traditional foodways. School authorities not only denied access to ancestral foods but actively disparaged them as primitive and inferior, further severing cultural ties and eroding indigenous identities. The children's opportunities to learn about the collecting and preparation of indigenous foods were similarly limited, while they were discouraged from consuming their native food and frequently made to consume inferior meals (Warm Springs Museum, 2019; Joseph, 2020). (d) *Predominance of wage economy*: indigenous communities often shifted away from using traditional foods as a result of the increased opportunities brought forth by the wage economy. People had less time and opportunity to produce food on the lands and seas as they moved into paying jobs. In any event, as was already mentioned, the newcomers occupied significant areas of people's territory, and indigenous people were frequently excluded by force (Turner, 2020b).

Additionally, the indigenous and traditional knowledge systems are frequently marginalized as lacking scientific validity, dismissed as anecdotal, and perceived as inadequate for confronting contemporary global crises (Milbank et al., 2021; FAO 2021b). Indigenous knowledge systems are declining at an alarming rate due to the widespread adoption of external practices, urban expansion, and the globalization of food markets. This ultimately accelerates biodiversity decline, land dispossession, forced community displacement, and the disappearance of native languages (Ferguson, 2017; Joseph & Turner, 2020; Neitzel et al., 2019). IPFS are increasingly undermined by rapid socio-economic and environmental transitions that disrupt their cultural and ecological foundations. A declining reliance on wild and traditional foods, coupled with a growing preference for processed and convenience products, reflects the broader global and national dietary shift that threatens local biodiversity and nutritional well-being (FAO, 2021b; Ghosh et al., 2021). This transition erodes food sovereignty and contributes to rising malnutrition among the indigenous populations (Jernigan et al., 2021; Tallman et al., 2022). In Bangladesh's Chittagong Hill Tracts, for instance, land seizures and violent conflicts have led to severe human rights abuses, including multiple fatalities, underscoring the intersection between food insecurity and territorial dispossession (Jernigan et al., 2021). Not only that, but the persistent failure to acknowledge indigenous rights continues to compromise their economic security, socio-cultural cohesion, and human dignity (Li et al., 2020). Furthermore, the ongoing dispossession of ancestral lands and natural resources has disrupted traditional livelihoods and weakened the intergenerational transmission of indigenous knowledge on IPFS, resulting in the gradual erosion of social structures, customary governance, and cultural-spiritual traditions (Chandra et al., 2020). These systemic breakdowns perpetuate poverty, hunger, and the loss of identity and self-determination. The absence of robust legal safeguards further exacerbates vulnerability, leaving these indigenous territories exposed to exploitation and forced displacement. A recent example from Kenya illustrates this reality, where over 700 Ogiek people were forcibly evicted from their ancestral forestlands without consultation or compensation, reflecting the urgent need for legal protection and recognition of indigenous tenure rights (IWGIA, 2024). Collectively, these interlinked challenges threaten not only the continuity of IPFS but also the cultural integrity and resilience of Indigenous communities worldwide.

In addition, the erosion of traditional agricultural practices among India's tribal communities also reveals the complex pressures facing IPFS. Chatterjee and Chakraborty's (2019) study of West Bengal's Jangalmahal tribes adds to this, where, the study documented a 3.65 percent occupational shift from farming to non-agrarian livelihoods, driven by monsoon variability, soil degradation, urbanization, and education reforms. Paradoxically, while education undermines agricultural engagement for some, the tribal youth do not envision integrating modern science with traditional systems, highlighting tensions between preservation and adaptation. Similar transitions emerge in Assam's Boro Kachari tribe, where Gogoi (2019) identified multiple threats to their

diverse agro-food systems such as, environmental degradation, generational knowledge loss, commercial food penetration, and population growth. Historically the Boro tribe use to cultivate varied crops, fruits, and wild edibles, but, now the same tribe faces declining dietary diversity due to urbanization, altered cropping patterns, and cultural assimilation. This shows a microcosm of how modernization homogenizes IPFS. Adding to this, Jerath et al. (2021), further illuminated these dynamics through the Munda community's experience in Vilakpur-Vichihiri. While traditional ecological knowledge persisted regarding wild and cultivated foods, nutritional transitions toward hybrid rice and market dependence jeopardized the Munda community's millet-based food systems. Such shifts precipitate genetic erosion, traditional knowledge loss, and reduce climate resilience, because energy-dense processed foods replace nutrient-rich traditional diets. The above examined cases collectively demonstrate three critical threats to the IPFS. Ecologically, land degradation and climate variability compromise traditional agriculture's viability. Culturally, urbanization and education shifts disrupt intergenerational knowledge transfer. And, nutritionally, hybrid crop adoption and market dependence diminish dietary diversity and resilience.

3.3. Interventions taken for elevating IPFS

Despite the discussion highlighting the complex challenges constraining IPFS, addressing them requires examining the broader landscape of interventions related to food that have already been implemented to enhance sustainability and dietary diversity. Although this review draws on global literature to understand the attributes and constraints of IPFS, the discussion of interventions focuses primarily on India, where government-led initiatives in food and nutrition security provide valuable contextual insights. Moreover, India has implemented several pioneering programmes and policy frameworks aimed at encouraging sustainability agendas. Studying such interventions offers practical lessons on how large-scale policies can be adapted or re-oriented to align with the principles of IPFS. Moreover, this national perspective helps illustrate how future policy frameworks, whether in India or globally, can integrate indigenous knowledge systems into mainstream food and nutrition strategies, ensuring inclusivity, sustainability, and cultural relevance in the pursuit of food system transformation. India has implemented numerous policies and programs to address its severe food and nutrition security crisis, particularly vulnerable sections including indigenous communities. These interventions (NESFAS, 2019; GOI, 2021) demonstrate initial efforts, but must be scaled to meet the specific biocultural needs of IPFS.

- a) *National Food Security Act (NFSA)* of 2013 represents a landmark legislation aiming to ensure food and nutrition security for approximately two-thirds of India's population through the Targeted Public Distribution System (TPDS). While this program provides subsidized food grains and nutritional support for children and mothers, implementation challenges persist, including food quality issues, high subsidy costs, beneficiary identification problems, and inadequate supply chain infrastructure (GOK, 2020).
- b) *PM Poshan Shakti Nirman* (PM-POSHAN) scheme demonstrated measurable success in improving child nutrition through its school meal program. By providing free, nutritious cooked meals in government schools, the initiative has boosted enrolment, attendance, and retention rates, particularly benefiting girls' education. However, similar to other nutrition interventions, the scheme faces operational challenges in maintaining consistent quality and coverage across India's diverse regions (Thomas et al., 2021).
- c) *National Iron Plus Initiative & National Iodine Deficiency Disorders Control Program* have made progress in reducing anaemia prevalence, though significant challenges remain. Indigenous populations continue to suffer disproportionately from conditions like sickle cell anaemia, which impacts physical growth, cognitive development,

and economic productivity (Smallwood et al., 2021). Persistent issues include inadequate dietary diversity, high disease burdens, and uneven supplement distribution (Sabu, 2019).

- d) The *Poshan Abhiyaan* (National Nutrition Mission) represents an ambitious convergence strategy, integrating various nutrition schemes through technological and community-based approaches. Its four pillars - Convergence Action Plan (CAP), Jan Andolan awareness campaign, Incremental Learning Approach (ILA), and ICDS-CAS mobile application, create a multidimensional framework for nutrition improvement. However, implementation hurdles mirror those of other programs, including uneven regional execution and variable community engagement (Ghosh et al., 2020).
- e) The *Integrated Child Development Services* (ICDS) scheme has provided essential health, nutrition, and education services since 1975. Targeting children under six and pregnant/lactating women, ICDS operates at remarkable scale but faces quality consistency challenges across India's vast geography (Madore et al., 2018). Complementary initiatives like the *India Newborn Action Plan* (INAP) and *Reproductive and Child Health* (RCH) Programme address specific life-stage needs, working toward ambitious targets like single-digit neonatal mortality by 2030 while tackling geographic and social inequities in healthcare access (George et al., 2020).
- f) The *Public Distribution System* (PDS), while theoretically comprehensive, suffers from leakages, corruption, and quality control issues that disproportionately affect marginalized groups (Haseena, 2016). These implementation gaps underscore the need for strengthened monitoring and grievance redressal mechanisms (Thomas et al., 2021).

Howsoever, these interventions face policy implementation gaps persist despite comprehensive frameworks, compounded vulnerabilities faced by indigenous communities, and traditional knowledge systems being an underutilized assets in combating malnutrition. Moreover, rapid urbanization and dietary shifts toward processed foods (Abson et al., 2017) are eroding both nutritional quality and cultural knowledge, contributing to a dangerous rise in diet-related diseases (GOI, 2021). This complex scenario demands integrated solutions that combine nutrition education respecting cultural preferences (George et al., 2020) with carefully governed public-private partnerships (NEFAS, 2019). This can help to scale effective interventions without compromising health equity (UNU-IAS & IGES, 2015) and aid in integrating IPFS in order to address India's dual nutrition challenges. Therefore, priorities must not only ensure food sovereignty and sustainability but also guide the inclusion of clear goals that must be multidimensional, grounded in cultural integrity, ecological sustainability, and social equity for IPFS initiatives, such as:

Cultural preservation, emphasizing the revitalization of traditional foods, agricultural practices, and intergenerational knowledge transfer through community-based programs that link seasonal rituals and elder-youth learning exchanges (Robert Wood Johnson Foundation, 2018). *Health promotion* should also be adopted as a holistic perspective that integrates physical, emotional, and cultural wellbeing, as illustrated by initiatives such as Hawaii's MA'O Organic Farms, where youth engagement in traditional horticulture fostered healthier dietary habits and stronger cultural connection (Mauli Ola Study, 2024). Ensuring *cultural food security* is equally critical, combining improved food access with the preservation of dietary diversity through innovative models like Community Supported Agriculture (CSA) and mobile produce markets that maintain cultural relevance while enhancing nutritional outcomes (Carlson, 2015). Including *environmental stewardship*, further provides a sustainable alternative to industrial agriculture by promoting biodiversity conservation and reciprocity with nature, as seen in programs like the Cochiti Youth initiative in New Mexico (FAO, 2021a; Miltenburg et al., 2022). Parallel to this, *economic development* should also be a focus as it reinforces cultural continuity rather than undermining it, as demonstrated by Montana's Federally Recognized Tribes

Extension Program (Rowe et al., 2024). Similarly, the Center for Excellence in Sustainable Tribal Development (IBRAD, 2024) integrate climate adaptation, biodiversity conservation, and participatory skill development, advancing multiple Sustainable Development Goals (SDGs 1, 2, 5, and 13) while safeguarding indigenous knowledge systems. Finally, *knowledge democratization* also forms an essential frontier in planning IPFS interventions, demanding cognitive justice, intercultural co-creation, and equitable knowledge exchange through mechanisms such as data sovereignty agreements (Vijayan et al., 2022).

Across the included studies (Ghosh et al., 2021; Louvain Corporation, 2024; Lovell et al., 2021; Sowerwine et al., 2019) a large proportion focused on ecological sustainability and biodiversity conservation, while comparatively fewer investigations examined food processing practices, nutritional profiling, or food safety aspects. This imbalance indicates that although IPFS are widely recognized for cultural and environmental value, their potential contributions to food science innovation remain underexplored. Regional comparisons further illustrate differences in research emphasis. Studies from Latin America frequently documented agro-biodiversity and seed sovereignty initiatives, whereas African research highlighted wild food utilization and climate resilience strategies. In South and Southeast Asia, including India, the literature often emphasized policy implementation challenges and nutrition transitions linked to market integration. These regional contrasts suggest that IPFS research is shaped by local development priorities, yet a more integrated comparative framework is still needed to bridge ecological, nutritional, and technological perspectives. From a policy standpoint, many interventions continue to prioritize food security through standardized grain-based programs, with limited incorporation of traditional food diversity or community-led governance. This review indicates that implementation gaps often arise when policies overlook indigenous knowledge systems, resulting in reduced dietary diversity and weak local engagement. Importantly, the reviewed literature also highlights several food-science dimensions that deserve greater attention. Moreover, recent advances in sustainable food processing also provide opportunities to connect Indigenous practices with emerging green extraction technologies. Many traditional IPFS methods, such as slow cooking, fermentation, aqueous extraction of plant compounds, and minimal-input preservation, reflect principles similar to contemporary low-impact processing approaches. For instance, pressurized hot water extraction (PHWE) and related green extraction techniques use water-based solvents and reduced chemical inputs to recover bioactive compounds while minimizing environmental impact (Kovačević et al., 2018). Integrating traditional ecological knowledge with modern green extraction technologies could support the development of nutrient-dense foods, functional ingredients, and climate-resilient processing pathways, thereby strengthening the relevance of IPFS within future sustainable food innovation systems.

Looking ahead, IPFS can also be positioned within broader future food transitions rather than as parallel alternatives to technological innovation. Concepts such as the circular bioeconomy emphasize resource efficiency, waste reduction, and nutrient recycling, principles that closely align with Indigenous stewardship practices and localized food cycles. Similarly, digitalization and smart food system monitoring offer opportunities to document biodiversity, support community-based decision making, and strengthen transparent value chains (Galanakis, 2024). Many traditional crops, wild edibles, and minimally processed foods contain diverse phytochemicals, antioxidants, and micronutrients that support immune function, metabolic health, and dietary resilience. Advances in bio functional profiling and fortified food system design highlight opportunities to integrate Indigenous ingredients into functional foods, nutraceutical products, and culturally adapted fortification strategies (Kafantari et al., 2025). Linking traditional ecological knowledge with modern analytical approaches, such as metabolomic screening and nutrient bioavailability assessments, can help validate the health benefits of Indigenous foods while ensuring that innovation remains aligned with cultural values and community ownership. Emerging

discussions around alternative proteins and diversified food sources further highlight complementarities between traditional plant-based diets, wild foods, and modern sustainable protein innovations. Framing IPFS within these evolving transitions helps move beyond binary narratives and instead highlights how traditional ecological knowledge and contemporary food science can co-evolve to support resilient and inclusive food futures. In some cases, commercialization of traditional foods can generate new livelihood opportunities, yet it may also introduce trade-offs, including pressure on biodiversity, cultural commodification, or shifts toward monocropping for market preferences. Recent scholarship also highlights how Indigenous knowledge systems align with emerging sustainability paradigms such as the circular economy. For example, [Beamer et al. \(2021\)](#) describe the Hawaiian concept of *Aloha ʻĀina*, which reflects a relational worldview emphasizing reciprocity, stewardship, and kinship between people and the environment. The study also illustrates how Indigenous Island systems demonstrate practical forms of circularity, where food production, resource management, and waste cycles are interconnected within community-based ecological practices. These perspectives resonate strongly with the principles underlying Indigenous Peoples' Food Systems, which traditionally operate through localized production, minimal waste, biodiversity conservation, and collective stewardship of natural resources. Integrating such perspectives into contemporary sustainability debates provides opportunities for cross-cultural learning and highlights how Indigenous knowledge can inform broader transitions toward circular and regenerative food systems.

4. Recommendations and conclusion

The preceding discussion on the attributes, challenges, and policy dimensions of IPFS highlights both their transformative potential and the systemic barriers that constrain their growth and resilience. While the sustainability attributes of IPFS demonstrate their value as models for biodiversity conservation, nutrition security, and climate adaptation, the identified challenges underscore the urgent need for enabling policy environments. The review of existing policies further revealed that most current frameworks acknowledge indigenous knowledge symbolically but lack operational mechanisms for its integration into mainstream food systems. Together, these insights guided the formulation of a set of strategic recommendations and policy interventions aimed at protecting, revitalizing, and scaling IPFS through participatory, rights-based, and context-specific approaches. These recommendations seek to bridge traditional knowledge with contemporary innovation, ensuring that IPFS contribute meaningfully to national and global sustainability goals.

A key priority is to enhance domestic production of native crops, reintegrating traditional foods into indigenous diets to restore both cultural identity and dietary diversity. Since many communities now depend on hybrid seeds, collecting, conserving, and promoting indigenous seed varieties is essential to preserve agricultural biodiversity and climate resilience. Equally important are education and awareness initiatives that highlight the ecological and nutritional value of traditional and wild foods, supported by the transfer of ancestral knowledge from elders to younger generations. Fostering food pride, stewardship, and valorisation by recognizing the social, environmental, and knowledge capital embedded in IPFS, will also support their long-term sustainability. Encouraging behaviour change toward nutrient-rich, organic, and local diets is also critical to sustain the momentum of indigenous food revival. Globally, countries are increasingly organizing multi-stakeholder dialogues that bring together UN agencies, academia, civil society, and private sectors to strengthen sustainable food systems. These platforms could adopt a multifaceted approach that amplifies the voices of marginalized groups, especially women, and youth. Rather than expanding uniform industrial models, future food security should depend on a mosaic approach where IPFS-inspired practices coexist with scientific and Industry 4.0 innovations. Recent work highlights how

digital technologies such as artificial intelligence, smart sensors, blockchain, robotics, and Internet of Things (IoT) platforms can strengthen food system resilience by improving traceability, reducing waste, and supporting climate-responsive decision making. Integrating these technologies with indigenous ecological knowledge does not imply replacing traditional practices, but rather enhancing community-led monitoring, digital documentation of food biodiversity, and participatory food governance. Such hybrid models can allow IPFS to remain culturally grounded while benefiting from data-driven tools that improve sustainability and transparency across food systems. Meeting global food demand amid climate and resource constraints requires plural pathways. Integrating IPFS principles into mainstream food policies offers a complementary route, enhancing biodiversity, resilience and forming a balanced strategy for feeding a growing population within planetary limits.

However, they do confront difficulties like the loss of traditional knowledge, problems with land rights, and the effects of climate change and modern agriculture. While this review synthesizes a broad range of literature on IPFS, several limitations should be acknowledged. First, the analysis is based primarily on published literature and selected grey literature sources, which may not fully capture the diversity of localized Indigenous knowledge systems or undocumented community practices. Second, regional representation in the available studies remains uneven, with certain geographical areas receiving greater scholarly attention than others. Third, the review adopts a qualitative synthesis rather than a quantitative meta-analysis, which limits the ability to establish causal relationships between IPFS attributes and measurable outcomes. Therefore, future research should focus on the documentation of traditional knowledge, assessment of climate change impacts, analysis of policy effectiveness, ensuring community participation, and examining the economic viability of IPFS. It should also emphasize the adoption of interdisciplinary approaches, recognition of Indigenous women's roles, detailed study of the core elements and interactions within IPFS, evaluation of natural, socio-cultural, and endogenous factors influencing sustainability, and the integration of modern technology with traditional practices to enhance their resilience and relevance. Additionally, future research must prioritize the protection of indigenous land and resource rights, conservation of agrobiodiversity, and recognition of women's vital roles in food production (natural resource management through training, access to technology, and participation in decision-making), cuisine, and community health. Together, these measures chart a pathway for inclusive, resilient, and sustainable Indigenous food systems that contribute meaningfully to global food security and climate goals.

Authorship contribution statement - CRediT

Holy Mercy Divina Matla: Conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, validation, visualization, roles/writing-original draft.

Saravanan Raj: Project administration, supervision, writing review and funding acquisition.

Raahalya S: Writing - review and editing.

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