Kizuna Sabha

A Research Dialogue and Enquiry between India and Japan

An initiative by the Mizuho India Japan Study Centre, IIM Bangalore.

Issue Brief 01
MIJSC–KZ–IB–2025–01
16 September 2025

Cross-National Perspectives on Indigenous Technical Knowledge and Sustainable Agriculture in the Agro-Ecologies of India and Japan

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Abstract

Indigenous Technical Knowledge (ITK) traditions in India and Japan play a crucial role in shaping sustainable agriculture, which is essential in combating climate change, resource scarcity and ensuring food security. India's ITK includes indigenous cropping systems, Panchagavya-based soil management, seed preservation, and community-managed irrigation. At the same time, Japan exhibits Satoyama landscape management, rice-fish co-culture, and bokashi composting techniques. This study examines ITK practices in India and Japan to identify synergies, differences, and transferable lessons for sustainable agriculture and mutual knowledge exchange. Using a systematic, comparative review of peer-reviewed sources, institutional reports, and international datasets (2000–2025), the research identifies key similarities such as biodiversity conservation, organic soil management, and community-based resource governance. Divergences are found in institutionalization, mechanization, and landscape integration. Comparative tables and conceptual diagrams illuminate pathways for mutual knowledge exchange and integration of ITK with modern systems, highlighting the role of institutional frameworks (such as GIAHS) and India-Japan bilateral cooperation in advancing sustainability. The findings suggest new directions for evidence-based policies, emphasizing participatory governance and transnational learning as means to strengthen climate resilience and sustainable agriculture.

Attribution: Anbil Dharmalingam and Navalur Kuttapattu, "Cross-National Perspectives on Indigenous Technical Knowledge and Sustainable Agriculture in the Agro-Ecologies of India and Japan," Kizuna Sabha Issue Brief 2025-01, Mizuho India Japan Study Centre. 16 September 2025

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1. Introduction

Indigenous knowledge (IK) refers to the cumulative and complex bodies of knowledge, practices, and representations that local communities have maintained through long-standing interactions with their environment (UNESCO, 2012). It is a locally grounded, culturally situated knowledge system that informs decision-making in agriculture, health, natural resource management, and other rural activities. Indigenous Technical Knowledge (ITK), a subset of IK, provides a practical and context-specific knowledge base that facilitates communication, problem-solving, and sustainable resource management. It forms a foundational knowledge capital for sustainable development alongside physical and financial resources (World Bank, 1991), contributing to livelihoods, local innovation, and globally relevant practices in medicine, veterinary science, and agriculture.

In Japan, ITK, which is often referred to as traditional ecological knowledge (TEK), is embodied in rural landscapes and agroecological practices. The *Satoyama* system integrates rice paddies, forests, and irrigation networks into a socio-ecological mosaic, while *Satoumi* represents community-managed coastal ecosystems that balance biodiversity with human use (Takeuchi 2010; Yanagi, 2008). Complementary practices such as rice–fish and rice–duck co-culture (Xie et al., 2011), bokashi composting (Subedi, K. (2025), and terraced rice fields (Michinaka et al., 2017) highlight how traditional Japanese knowledge enhances soil fertility, water management, and biodiversity conservation while maintaining cultural heritage.

India, by contrast, exhibits highly diverse ITKs shaped by its vast agro-ecologies. Practices such as Panchagavya-based soil amendments (Natarajan, 2008), community-led seed preservation (Yadav & Devi, 2020), and water management systems like Ahar–Pyne, tank irrigation, and Phad (Agrawal, 1995) demonstrate adaptive strategies for soil fertility, agro-biodiversity, and climate resilience. Indigenous cropping systems, including *utera* and *badi*, further illustrate farmer-led innovations that sustain household nutrition, conserve resources, and minimize external inputs (ICAR, 2022).

Both countries have actively revitalized ITKs in contemporary contexts. In Japan, the Satoyama Initiative (MOEJ & UNU-IAS, 2010) integrates TEK into sustainability policies, while in India, Zero Budget Natural Farming (ZBNF) and grassroots innovation networks mainstream indigenous methods into state and national frameworks (Khadse et al., 2017). Despite differences in mechanization and institutionalization, ITKs in both contexts embody adaptive resilience, biodiversity conservation, and community-based resource management.

Yet, comparative cross-national research remains limited. Much of the existing literature is either descriptive or localized, with insufficient focus on systematic comparisons or integration into modern policy frameworks (Pretty, 2007). This study therefore, addresses a crucial gap by juxtaposing Indian and Japanese ITKs, exploring their convergences, divergences, and potential for bilateral cooperation in sustainable agriculture.

2. Objectives of the Study

This study aims,

- To document and analyse key ITK practices in India and Japan.
- To identify convergences and divergences in approaches to sustainable agriculture.
- To evaluate potential synergies for climate-resilient and sustainable agriculture.
- To assess the impact of ITK on rural livelihoods and community participation.
- To explore pathways for integrating ITK with modern agricultural frameworks and bilateral initiatives.

3. Materials and Methods

3.1 Research Design

This research uses a conceptual, comparative design that focusses on secondary data synthesis from peer-reviewed articles, institutional reports, and global datasets. Practices were documented and categorized according to ecological domain and observed outcomes.

3.2 Data Sources

India: Publications on ZBNF, Panchagavya soil management, Seed preservation, and Irrigation; ICAR, State agriculture departments and NGO reports.

Japan: Satoyama landscape management, Rice–fish co-culture, Organic soil management; JIRCAS, MAFF, Satoyama Initiative.

International: FAO, World Bank, IPCC reports.

3.3.Data Collection

Systematic literature review (1991–2025) employed keywords: "Indigenous Technical Knowledge", "ITK India", "TEK Japan", "sustainable agriculture", "Satoyama", "ZBNF", "agroecology", "community-based agriculture". Inclusion is focused on field-validated practices with ecological or livelihood outcomes.

3.4.Data Analysis and Synthesis

Collected data were analyzed thematically:

- Soil fertility
- Water management
- Cropping systems
- Pest control
- Seed preservation

Comparative analysis mapped convergences (e.g., biodiversity, community management) and divergences (e.g., mechanization, governance). Results were synthesized using narrative, tables, and diagrams.

3.5.Reliability and Validity

Triangulation across multiple sources and standardized thematic categories (FAO agroecology) ensured reliability/validity.

3.6.Ethical Considerations

All sources used are publicly available; no direct human or animal subjects were involved; appropriate citation was maintaine

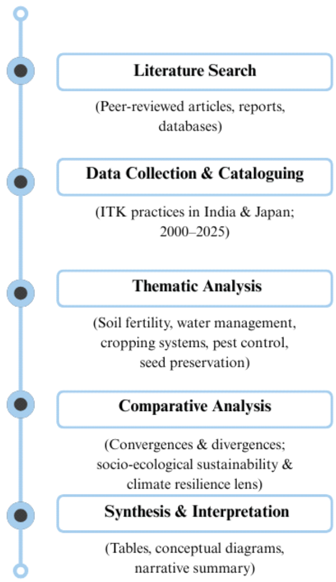

Figure 1. Literature Search & Thematic Flow

4. Results

4.1.Documentation of ITKs in India and Japan

Indigenous Technical Knowledge (ITK) systems in India are diverse and region-specific, shaped by centuries of farmer experimentation and cultural embeddedness. Major examples include tank irrigation systems in South India that ensure water security in semi-arid conditions (Agrawal, 1995), seed preservation through community-managed seed banks that maintain agrobiodiversity (Singh et al., 2008), and Panchagavya-based soil amendments that enhance fertility while reducing chemical dependency (Rao & Ramana, 2010). Similarly, Zero Budget Natural Farming (ZBNF) has gained prominence in recent decades as a holistic approach minimizing external inputs and strengthening farmers' autonomy (Khadse et al., 2017).

In Japan, ITKs are manifested through integrated socio-ecological systems such as Satoyama landscapes, which integrate paddy fields, forests, and irrigation channels in a balanced mosaic supporting both biodiversity and rural livelihoods (Takeuchi, 2010). Traditional rice–fish co-culture systems enhance nutrient cycling and pest regulation while diversifying farmer income (JIRCAS, 2018). Organic soil fertility management using bokashi composting also demonstrates a sustainable method that reduces chemical input dependency (MAFF, 2020). These practices reflect Japan's orientation toward small-scale ecological intensification embedded within rural landscapes.

These findings align with previous studies that highlight the ecological wisdom embedded in Satoyama and Satoumi systems in Japan (Takeuchi, 2010; Yanagi, 2008) and traditional irrigation and soil management practices in India (Agrawal, 1995; Singh et al., 2008). By synthesizing secondary data into a comparative framework, this study extends prior fragmented documentation into a cross-national perspective.

Table 1. Comparative Summary of Major Indigenous Technical Knowledge (ITK) Systems in Indian Agriculture: Practices, Benefits, and Modern Relevance.

ITK Concept	Definition / Core Practices	Ecological Benefits	Socio-Economic Benefits	Modern Relevance / Policy
Panchagavya-based Soil Management	Use of fermented cow products (dung, urine, milk, curd, ghee) for soil conditioning and plant growth	Improves soil fertility, enhances microbial activity, and increases resistance	Reduces chemical fertilizer dependence, improves yield	Validated in scientific studies, integrated into organic/natural farming initiatives
Seed Preservation Practices	Indigenous storage via ash, cow dung, slurry, neem, turmeric, and traditional containers	Maintains seed viability, conserves agro-biodiversity	Ensures local seed security, preserves traditional landraces	Recognized under seed sovereignty, biodiversity conservation efforts
Utera Cropping System	Sowing the next crop before the paddy harvest to use residual moisture and increase diversity	Efficient moisture use promotes cropping diversity	Additional yield without irrigation supports food security	Demonstrated via ICAR–NAIP projects, recommended for dryland farming
Badi Cropping System	Diversified home/kitchen gardens with indigenous, drought-tolerant crops, using wastewater	Enhances biodiversity and improves soil/water conservation	Ensures food variety and supports resilience to drought	Maintains rural livelihoods and sustains crop genetic diversity
Community Irrigation Systems	Indigenous management (Ahar-Pyne, tanks, Phad, Khadin, etc.) tailored to local ecologies	Efficient water use, groundwater recharge, and ecosystem support	Equitable water distribution, social cohesion, and opportunity for double cropping	Revived through watershed and governance projects for climate resilience

Note. Sources: Natarajan (2008); Upadhyay et al. (2018); Rao & Ramana (2007); Yadav & Devi (2020); Singh & Sureja (2008); ICAR (2022); Agrawal (1995); Koul et al. (2012); Bhattacharya (2015).

Table 2. Comparative Summary of Major Indigenous Technical Knowledge (ITK) Systems in Japanese Agriculture: Practices, Benefits, and Modern Relevance

ITK / TEK Concept	Core Practices / Methods	Ecological Benefits	Economic / Livelihood Benefits	Modern Relevance / Policy
Satoyama Landscape	Mosaic of rice paddies, forests, irrigation canals, and communal resource management	Maintains biodiversity and ecosystem services and supports soil & water management	Supports rural livelihoods through food, fodder, and crop production	Framework for socio-ecological production landscapes—SEPLs; Satoyama Initiative for biodiversity and well-being
Satoumi (Coastal ITK)	Community-managed coastal and tidal flats; seaweed/sea grass restoration; regulated fishing	Enhances coastal biodiversity, habitat restoration, and ecosystem resilience	Supports fisheries/ seaweed harvests; sustains coastal livelihoods	Incorporated in environmental policy; model for coastal sustainability
Rice-Fish Co-culture	Integrated rice paddies with fish for pest/nutrient management, protein/fish sale	Improves soil & water quality, boosts biodiversity, and nutrient cycling	Additional income from fish enhances rice yield and food security benefits	Modern studies optimize species integration and productivity
Aigamo (Rice-Duck Farming)	Ducks are introduced into rice fields for weeding/pest control and natural fertiliser	Reduces pests/ disease; lowers chemical inputs; enhances soil health	Income from duck meat/eggs; labour savings	Used in sustainable rice production models; recognized for ecological/ economic gains
Bokashi (Fermented Organic Fertiliser)	Fermentation of crop residues and manure using microbes applied to fields	Enhances soil fertility, water retention, and microbial activity	Reduces chemical fertilizer use, improves productivity	Applied in modern agriculture; eco-friendly soil management practice
Terraced Paddy Fields (Tanada/Senmaida)	Hillside/terrace paddies with irrigation channels, stone retaining walls, and community labour	Prevents soil erosion, stabilises slopes, and supports biodiversity	Sustains rice in hilly regions; supports rural livelihoods	Recognized for landscape conservation and sustainable rice production

Note. Sources: Takeuchi (2010); Natori & Hino (2021); MOEJ & UNU-IAS (2010); Yanagi (2008); Saito & Shibata (2013); Ministry of the Environment, Japan (n.d.); Xie et al. (2011); Inayat et al. (2023); JIRCAS (2018); Furuno (2001); Wakui (2009); Subedi (2025); Ministry of Agriculture, Forestry and Fisheries (2020); Michinaka et al. (2017).

4.2.Comparative Analysis: Convergences and Divergences

Earlier scholarship has emphasized the adaptive sustainability of ITKs but often lacked systematic juxtaposition between regions (Pretty, 2007). The present results contribute by mapping convergences in ecological stewardship and divergences in governance, providing a novel comparative dimension to ITK research.

A comparative reading reveals convergences in biodiversity-orientated practices, community-based resource management, and reliance on low external inputs. Both Indian and Japanese ITKs emphasize a balance between production and ecology. For instance, tank irrigation and satoyama landscapes illustrate how local communities co-manage water and ecological resources (Agrawal, 1995; Takeuchi, 2010). Similarly, natural fertilizers such as Panchagavya and bokashi compost highlight reliance on organic matter for soil fertility (Rao & Ramana, 2010; JIRCAS, 2018).

However, divergences also exist. Japan's ITKs are often institutionalized within landscape-level governance frameworks, such as satoyama conservation programmes supported by local governments (Takeuchi, 2010). In contrast, Indian ITKs remain more localized and diverse, often lacking formal state integration. Moreover, mechanization levels differ: while India's ITKs rely on labour-intensive practices, Japan integrates ITKs with moderate mechanization and advanced resource-use monitor

Table 3. Comparative Features of Indigenous Technical Knowledge Systems in India and Japan.

Feature	India (ITK)	Japan (ITK)
Knowledge Focus	Diversity/locality	Landscape integration
Soil Management	Panchagavya, ZBNF	Bokashi composting
Biodiversity	Seed banks/diversity	Rice–fish/duck systems
Institutionalization	Fragmented/local	Integrated/government
Mechanization	Low/labor-intensive	Moderate/tech-enabled
Community Role	Farmer-led/local	State/community

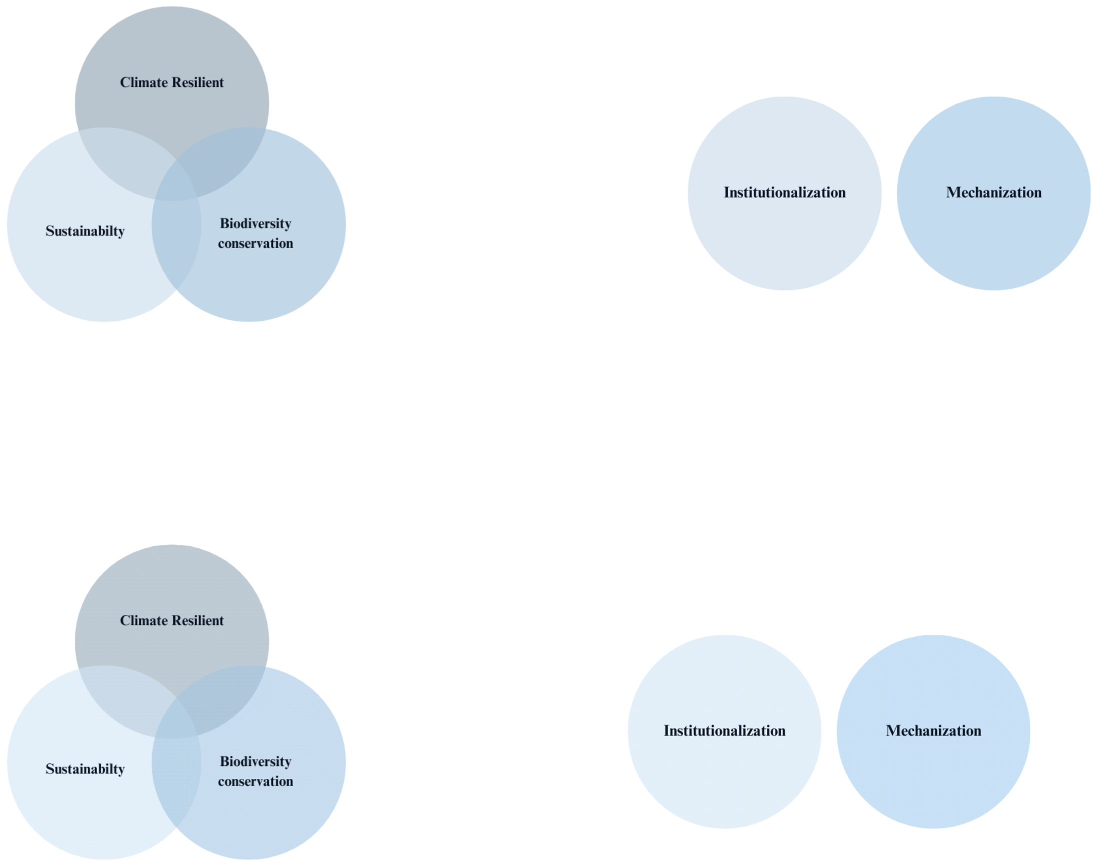

Figure 2. Key Convergent and Divergent Features in Indigenous Technical Knowledge Systems: India vs. Japan. (Modified & adapted from: Singh et al., (2008), Takeuchi (2010), FAO (2020), ICAR (2022), JIRCAS (2018), Khadse et al. (2017)).

5. Discussion

5.1.ITKs as Drivers of Socio-Ecological Sustainability

ITKs embody socio-ecological sustainability by linking agricultural productivity with cultural practices and ecological stewardship. In Japan, satoyama practices reflect the co-evolution of human and natural systems, aligning with Berkes' (1993) framework of socio-ecological systems. In India, ITKs like tank irrigation and community seed banks ensure both ecological security and rural social cohesion (Agrawal, 1995). These traditions affirm that agriculture is not merely a production system but also a sociocultural practice.

Such ITKs also reinforce the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land) (FAO, 2018). By conserving biodiversity, reducing chemical dependency, and strengthening community institutions, ITKs operationalize sustainability at grassroots levels.

5.2.ITKs and Climate Resilience

One of the most significant contributions of ITKs lies in enhancing climate resilience. In India, mixed cropping, drought-tolerant landraces, and indigenous pest management reduce vulnerability to erratic rainfall and pest outbreaks (Singh et al., 2008 ; FAO, 2018). Similarly, in Japan, rice–fish co-culture and organic soil practices buffer against climate shocks while maintaining food diversity (JIRCAS, 2018).

Comparatively, Indian ITKs provide resilience through diversity and adaptability, whereas Japanese ITKs focus on ecosystem-level balance and nutrient cycling. Both approaches offer transferable lessons: India can learn from Japan's governance-based integration, while Japan may benefit from India's wide genetic resource base and farmer-led innovations.

5.3. Institutional Recognition – GIAHS Framework

The FAO's *Globally Important Agricultural Heritage Systems (GIAHS)* programme provides international recognition to traditional agricultural systems that embody unique biodiversity conservation, cultural heritage, and sustainable land-use practices (FAO, 2020). GIAHS sites are characterized by the integration of Indigenous Technical Knowledge (ITK) with ecological management, thereby offering resilience against environmental and socio-economic challenges.

In Japan, eleven systems were designated as GIAHS as of March 2020, including *Noto's Satoyama and Satoumi*, *Sado's Satoyama in Harmony with the Japanese Crested Ibis*, and *Traditional Wasabi Cultivation in Shizuoka* (Takeuchi, 2010; MOEJ & UNU-IAS, 2010; FAO, 2020). These examples illustrate how Japan's ITK practices have been embedded within agro-ecological landscapes and subsequently elevated to global conservation status.

India currently has three designated GIAHS sites—Koraput Traditional Agriculture (Odisha), Kuttanad Below Sea Level Farming System (Kerala), and the Saffron Heritage of Kashmir—each reflecting distinctive agro-ecological practices rooted in ITK. The program supports community seed banks, organic farming, and biodiversity conservation embedded within these landscapes. Government of India schemes, including Rashtriya Krishi Vikas Yojana (RKVY) and Mission for Integrated Development of Horticulture (MIDH), channel resources toward maintaining and enhancing these heritage systems (Ministry of Agriculture & Farmers Welfare, 2024). Recent initiatives in states like Odisha and Kerala further emphasize infrastructural development and ecological restoration, highlighting how institutional frameworks increasingly anchor ITK conservation within national agricultural policies.

A comparative overview of Japan and India's GIAHS sites demonstrates how institutional recognition signifies a vital pathway for safeguarding traditional knowledge, promoting sustainable agriculture, and fostering rural livelihoods.

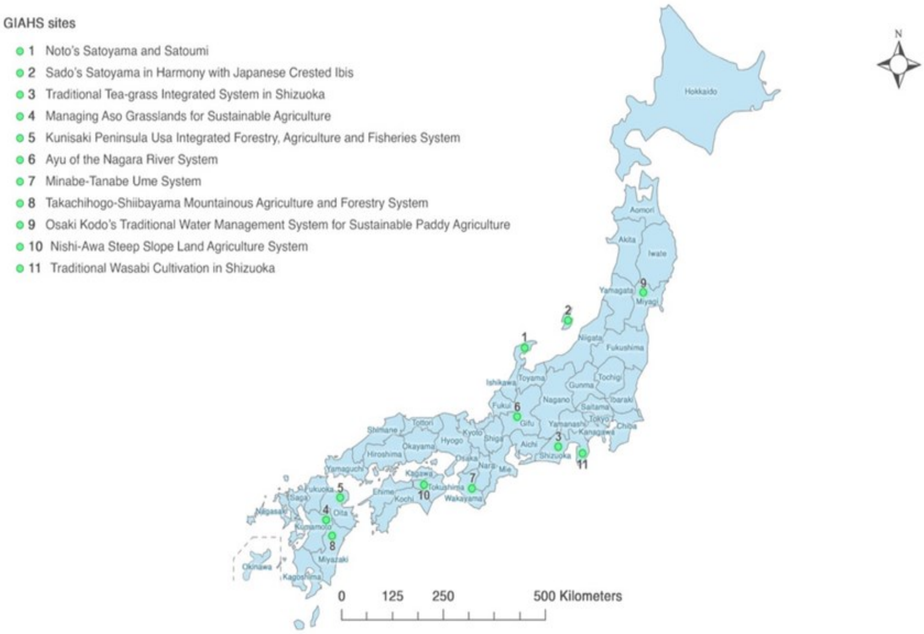

Figure 3. Map of GIAHS Sites in Japan (Maharjan et al.,)

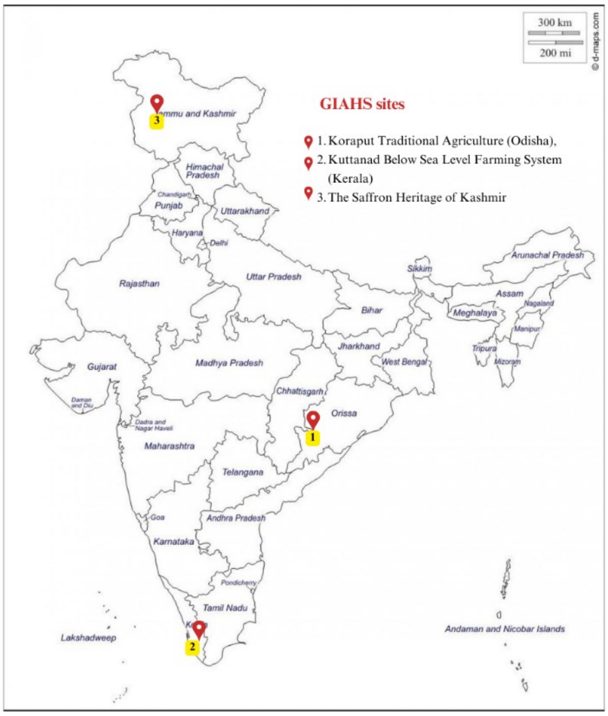

Figure 4. Map of GIAHS Sites in India

5.4.Synergies for Bilateral Cooperation

India–Japan agricultural cooperation is increasingly recognizing ITKs as complementary assets. Projects under the Japan International Research Centre for Agricultural Sciences (JIRCAS) and the Indian Council of Agricultural Research (ICAR) focus on knowledge sharing for sustainable intensification (JIRCAS, 2018). Incorporating ITKs into these frameworks can enrich policy and practice. For example, India's community-based irrigation models could complement Japan's Satoyama revitalization, while Japanese composting and low-input mechanized models could be adapted to Indian smallholder contexts.

Participatory seed conservation networks, as demonstrated by the IPSI SITR8-7 programme, exemplify dynamic farmer-led efforts to enhance agrobiodiversity and adaptive capacity through active seed exchange and community knowledge sharing. Furthermore, the IPSI SDM project highlights how integrative stakeholder collaborations can foster sustainable harvesting practices linked to market mechanisms, thereby promoting rural income diversification and resilience.

Such synergies can facilitate cross-learning, like the 2017 Memorandum of Cooperation on Agriculture and Food (MOFA Japan, 2021), strengthen sustainable value chains, and build joint climate resilience strategies, making ITK a bridge for deepening India–Japan agricultural relations.

5.5. Research Gaps and Policy Implications

Despite growing recognition, research on Indigenous Technical Knowledge (ITK) continues to face several limitations. Documentation remains fragmented, often descriptive and under-theorized, with limited quantitative assessments of resilience outcomes (Pretty, 2007; Altieri, 1996; FAO, 2018). Comparative frameworks are particularly scarce, despite India's agro-biodiversity and Japan's governance-based integration complementing each other. In India, scaling ITKs is constrained by socio-economic heterogeneity, while in Japan, rural depopulation and urbanization threaten the continuity of traditional practices (Takeuchi, 2010). Furthermore, insufficient integration into policy frameworks has restricted the translation of ITK into broader sustainability agendas. By contrasting Indian and Japanese systems, this study highlights both gaps and opportunities for cross-national collaboration, paving the way for evidence-based policies incorporating indigenous wisdom into modern agricultural frameworks.

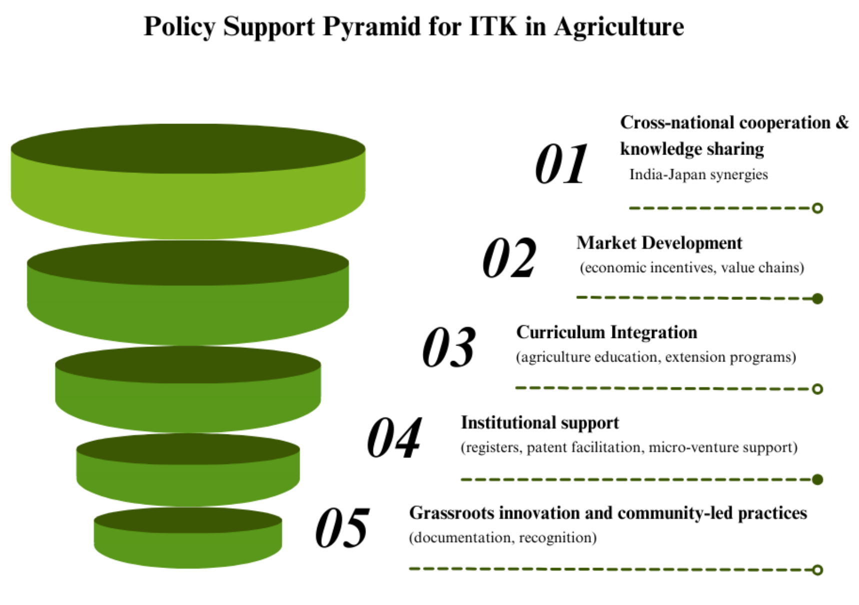

Figure 5. Policy Support Pyramid: Levels of Support to Sustain and Scale Indigenous Technical Knowledge in Agriculture. (Modified & adapted from: Khadse et al. (2017), FAO (2018 & 2020), Takeuchi (2010)).

The above pyramid depicts the strategic requirements in a layered policy support pyramid. The base emphasizes grassroot innovation and community-led documentation to address fragmented knowledge. Above this, institutional supports such as registers and patent facilitation formalize indigenous practices, vital for overcoming socio-economic and governance challenges. Next, integration into educational curricula and extension programmes helps mainstream ITK knowledge. Market development creates economic incentives through organic product value chains, empowering practitioners. At the top, cross-national cooperation illustrates India-Japan synergies essential for bridging policy gaps and scaling sustainable indigenous agricultural practices. This pyramid encapsulates the multifaceted, multi-level efforts required to sustain and amplify ITK impact effectively.

5.6 Pathways Forward: Integrating ITK with Modern Systems

Indigenous Technical Knowledge (ITK) systems represent practices that are not only socially desirable and economically viable but also sustainable and risk-minimizing in agricultural contexts. A central challenge, however, lies in harmonizing traditional skills with modern scientific tools, thereby ensuring that indigenous practices remain relevant in the face of emerging climatic and socio-economic uncertainties (Agrawal, 1995; Berkes, 1993).

Policy interventions are critical to sustain and scale ITKs. Key strategies include the creation of national registers of grassroot innovations, provision of patent facilitation and micro-venture support, and the establishment of formal recognition programs for ITK innovators. Moreover, the integration of ITKs into agricultural curricula and the development of markets for indigenous and organic products are essential to strengthen their long-term viability (FAO, 2018).

Examples of successful ITK-led approaches illustrate this potential. Zero Budget Natural Farming (ZBNF), promoted by Subhash Palekar in the late 1990s, draws from cow-based and Vedic agricultural traditions, offering a low-input, ecologically grounded production model that has since influenced state policies in India (Khadse et al., 2017). Similarly, the rice–fish co-culture system in Japan exemplifies a convergence of indigenous wisdom and scientific validation. While community-based traditions emphasize heritage and ecological stewardship, contemporary scientific trials refine planting densities and species integration, reinforcing the ecological and economic viability of such systems under changing climatic conditions (Takeuchi, 2010; FAO, 2018).

At a global level, the erosion of indigenous knowledge parallels biodiversity loss, highlighting the urgency of preservation (IPCC, 2023). Beyond conservation, however, ITKs must be recognized as dynamic systems capable of enhancing rural livelihoods. Participatory research on natural resource management, led by interdisciplinary teams, can expand knowledge of agro-biodiversity and promote the rational use of local resources for sustainability. Furthermore, micro-level management of land and biodiversity, combined with active community involvement in planning, implementation, and evaluation, can sustain agro-ecosystems more effectively.

Participatory governance, community-led documentation, and stakeholder collaboration form the backbone of these integrative efforts. Additionally, increasing awareness among policymakers about ITK's contributions to agroecological resilience can catalyze mainstreaming indigenous practices within national and international sustainability agendas. Ultimately, blending ITK with contemporary systems ensures these knowledge bases evolve as dynamic, living traditions, essential for advancing climate-resilient and sustainable agriculture globally.

6. Conclusion

This comparative study reveals that Indigenous Technical Knowledge in India and Japan offers crucial, complementary solutions for sustainable and climate-resilient agriculture. By systematically analysing convergences and divergences, supported by visual and tabular synthesis, it is clear that bilateral cooperation, participatory governance, and institutional integration are essential for realising ITK's full potential. Addressing research gaps and policy barriers will enable ITK systems to not only persist as cultural heritage but also actively drive environmental adaptation and rural prosperity.

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