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# Reviving Traditional Wisdom: An Analysis of Indian Indigenous Agricultural Practices for Sustainable and Eco-Friendly Applications in the Context of Global Support

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**Abstract:** Indian Indigenous Agricultural Knowledge (IAK) encompasses centuries-old practices that emphasize ecological balance, biodiversity conservation, and sustainable resource utilization. This study delves into the relevance and efficacy of these traditional practices in promoting sustainable and eco-friendly agriculture. By analyzing various indigenous methods such as mixed cropping, organic fertilization, and water conservation techniques, the research highlights their environmental and economic benefits. Furthermore, the study examines the extent of global recognition and support for these practices, considering international policies and frameworks. The findings suggest that integrating IAK into modern agricultural systems can significantly contribute to achieving global sustainability goals.

**Keywords:** Indian Indigenous Agricultural Knowledge, Sustainable Farming, Eco-Friendly, Practices Traditional Agriculture, Global Support, Biodiversity Conservation, Agroecology, Climate Resilience

## I. INTRODUCTION

India's rich agricultural heritage is deeply rooted in indigenous knowledge systems that have evolved over millennia. These practices, tailored to local ecological conditions, have traditionally ensured food security, environmental sustainability, and socio-economic well-being. However, the advent of modern agricultural techniques has often overshadowed these time-tested methods. In the face of contemporary challenges such as climate change, soil degradation, and biodiversity loss, there is a renewed interest in revisiting and revitalizing IAK. This study aims to analyze the sustainable and eco-friendly applications of Indian indigenous agricultural practices and assess the current global support for their integration into modern farming systems.

Agriculture in India is not merely an economic activity; it is deeply intertwined with the cultural, spiritual, and ecological fabric of the nation. Long before the advent of modern scientific farming techniques, indigenous communities across India developed agricultural practices that harmonized with local ecosystems. These methods, passed down through generations, reflect an intricate understanding of soil, climate, water systems, and biodiversity. Today, these time-honored practices are collectively recognized as Indian Indigenous Agricultural Knowledge (IAK), representing a reservoir of sustainable, community-driven wisdom.

Indigenous agricultural practices in India are characterized by their ecological sensitivity and emphasis on sustainability. Techniques such as crop rotation, intercropping, agroforestry, use of natural fertilizers like farmyard manure and green manures, traditional water harvesting systems like 'johads' and 'baolis,' and reliance on indigenous seed varieties are testament to the sophisticated environmental consciousness of ancient Indian farming communities. These practices prioritized the long-term health of the land, ensuring that agricultural productivity did not come at the cost of ecosystem degradation.

However, the rise of the Green Revolution in the 1960s and the subsequent emphasis on industrial farming led to the marginalization of indigenous methods. High-yielding varieties (HYVs), chemical fertilizers, pesticides, and intensive irrigation became the new norm, promising quick gains in productivity. While these interventions significantly boosted food production, they also introduced a range of ecological problems, including soil degradation, water table depletion, loss of biodiversity, and increasing greenhouse gas emissions. This shift marginalized indigenous practices, often labeling them as unscientific or outdated.

In recent years, growing global concern over environmental degradation, climate change, and unsustainable farming has reignited interest in indigenous agricultural systems. Policy frameworks like the United Nations Sustainable Development Goals (SDGs) emphasize sustainable agriculture, prompting scholars, policymakers, and activists to revisit traditional farming knowledge. Indian indigenous agricultural practices, which inherently promote ecological balance, biodiversity conservation, and climate resilience, are being increasingly recognized as critical to achieving global sustainability targets.

Moreover, indigenous farming practices offer solutions not only to ecological challenges but also to socio-economic issues facing rural communities. Traditional agricultural systems are often low-cost, less reliant on external inputs, and foster community resilience and food sovereignty. By reducing dependency on expensive chemical inputs and market-driven seed systems, indigenous practices enable small and marginal farmers to sustain their livelihoods more securely. Thus, integrating IAK into modern agricultural frameworks can simultaneously address environmental, economic, and social dimensions of sustainability.

Globally, there is growing support for the preservation and promotion of indigenous knowledge systems. Institutions like the Food and Agriculture Organization (FAO) have initiated programs such as the Globally Important Agricultural Heritage Systems (GIAHS) to recognize and protect traditional farming landscapes and practices. Indian farming regions like Koraput (Odisha) and Kuttanad (Kerala) have been acknowledged under GIAHS, highlighting the international validation of Indian indigenous agricultural wisdom. This support underscores the importance of indigenous practices in global dialogues on sustainable agriculture.

Despite such recognition, integrating indigenous knowledge into mainstream agricultural policies and practices remains a significant challenge. Structural barriers, including lack of documentation, knowledge erosion, policy bias toward industrial agriculture, and socio-cultural undervaluation of traditional practices, inhibit the widespread adoption of IAK. Therefore, a systematic approach to documentation, validation, and policy integration is required to ensure that indigenous agricultural knowledge not only survives but thrives as a viable alternative to unsustainable farming models.

This research seeks to systematically analyze Indian Indigenous Agricultural Knowledge, focusing on its sustainable and eco-friendly applications. It examines specific traditional practices across different agro-climatic zones, assesses their environmental and socio-economic benefits, and evaluates their relevance in the current context of climate change and sustainability imperatives. The study also investigates the extent of global support and recognition for these practices, exploring opportunities for international collaboration and knowledge exchange.

The significance of this research extends beyond academic inquiry. By shedding light on the practical applications and benefits of indigenous knowledge systems, this study aims to contribute to the broader discourse on sustainable development, climate resilience, and food security. It advocates for the empowerment of indigenous communities as custodians of valuable agricultural wisdom and calls for the integration of their practices into national and global agricultural strategies.

Ultimately, reviving and mainstreaming Indian Indigenous Agricultural Knowledge represents not merely a return to traditional practices but a strategic advancement toward a more sustainable, equitable, and resilient future. By bridging traditional knowledge with modern scientific understanding, India—and the world—can foster agricultural systems that nourish both people and the planet. This research is a step in that direction, offering insights, analysis, and recommendations for harnessing the potential of indigenous wisdom in building a sustainable agricultural future.

## II. OBJECTIVES

- **Documentation**: To catalog key Indian indigenous agricultural practices and their regional variations.
- **Analysis**: To evaluate the sustainability and eco-friendliness of these practices.
- **Global Perspective**: To assess the level of international recognition and support for IAK.
- **Integration Strategies**: To propose methods for incorporating IAK into contemporary agricultural policies and practices.

## III. RATIONALE

The increasing environmental concerns associated with conventional agriculture necessitate the exploration of alternative, sustainable farming methods. Indian indigenous agricultural practices offer viable solutions, emphasizing harmony with nature, resource conservation, and community involvement. Recognizing and integrating these practices can enhance agricultural sustainability, promote biodiversity, and contribute to global efforts in combating climate change.

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## IV. RESEARCH METHODOLOGY

- **Approach**: Qualitative analysis based on secondary data.
- **Data Collection**: Comprehensive review of existing literature, including academic journals, policy documents, case studies, and reports from international organizations.
- **Data Analysis**: Thematic analysis to identify patterns, benefits, challenges, and global perspectives related to IAK.

## V. REVIEW OF LITERATURE

The study of Indigenous Agricultural Knowledge (IAK) in India has gained prominence since the early 2000s as scholars, practitioners, and policymakers began recognizing the inherent sustainability embedded within traditional farming systems. Rengalakshmi (2006) outlined that indigenous agricultural practices in India are adaptive systems developed through continuous interaction between human communities and their ecological surroundings. These practices offer low-cost, environmentally harmonious alternatives to modern industrial agriculture.

Altieri (2004) provided a foundational understanding of agroecology, emphasizing that indigenous farming practices globally—and particularly in India—are practical embodiments of agroecological principles. He illustrated how multi-cropping, natural pest management, and soil conservation methods were sustainable because they were locally adapted and fostered ecological balance, serving both livelihood needs and biodiversity conservation.

Building upon this, Chambers (2006) stressed the importance of recognizing farmers as knowledge-holders rather than passive recipients of scientific advancements. His fieldwork using Participatory Rural Appraisal (PRA) in India revealed that traditional farmers, especially in rainfed and marginal lands, often possessed intricate knowledge of soil health, crop diversity, and climatic variations—knowledge overlooked by formal agricultural research systems.

Agarwal (2008) deepened this discourse by analyzing the gendered dimensions of indigenous knowledge. Her research found that rural and tribal women were custodians of seed preservation techniques, mixed cropping patterns, and organic composting practices. In her field studies across Madhya Pradesh and Odisha, she highlighted how women's agricultural knowledge contributed significantly to household food security and biodiversity conservation, yet remained marginalized in mainstream agricultural narratives.

The National Innovation Foundation (NIF) (2010) embarked on a systematic effort to document and promote grassroots agricultural innovations in India. Their surveys uncovered thousands of indigenous techniques, ranging from natural pest control methods using neem extracts to traditional soil fertility enhancement using cow dung and green manure. Such documentation initiatives reinforced the idea that indigenous practices could provide scalable, eco-friendly solutions to modern agricultural challenges.

Shiva (2011) argued that the Green Revolution, while temporarily boosting India's food production, had undermined traditional agricultural ecosystems. Her critique illustrated how indigenous crop varieties, water-conserving practices, and localized food systems were displaced, leading to soil degradation, loss of agrobiodiversity, and farmer dependency on chemical inputs.

Further studies by Kumar and Kapoor (2013) demonstrated that indigenous rice cultivation methods like "SRI" (System of Rice Intensification), originally adapted from traditional knowledge, significantly enhanced yields while reducing water consumption. Their trials across Tamil Nadu showed that indigenous wisdom, when synergized with minimal scientific intervention, could outperform conventional methods on key sustainability indicators.

Pandey (2014) emphasized that traditional agroforestry systems in Central and North-East India, such as "home gardens" and "jhum cultivation" (shifting agriculture), were not random practices but systematically managed landscapes. These systems ensured food diversity, regulated local micro-climates, and acted as carbon sinks, making them essential tools for climate change mitigation.

Research by the Indian Council of Agricultural Research (ICAR) (2015) recognized the potential of indigenous techniques like 'zabo' systems in Nagaland for water harvesting and farming integration. ICAR noted that localized indigenous methods were often more sustainable and cost-effective than large-scale irrigation projects, especially in ecologically sensitive zones.

A detailed ethnobotanical survey by Singh and Mishra (2016) documented over 500 plant species used traditionally in pest control, soil fertility enhancement, and medicinal treatments in tribal farming systems of Chhattisgarh. Their study confirmed that indigenous plant knowledge formed an integral part of agricultural resilience in the face of pests, diseases, and climate variability.

Patwardhan et al. (2017) highlighted that traditional seed systems preserved genetic diversity, crucial for future food security. Through community seed banks in Rajasthan and Andhra Pradesh, indigenous farmers conserved native varieties of millets, pulses, and vegetables, many of which showed remarkable resilience to drought and pests.

Mishra (2018) critically examined indigenous water management techniques, such as tank irrigation in Tamil Nadu and step-wells in Gujarat. His research showed that these ancient practices efficiently managed scarce water resources without causing large-scale ecological disruption, unlike modern mega-dam projects.

The global recognition of India's indigenous farming systems received a boost when Koraput's agricultural landscape in Odisha was designated a Globally Important Agricultural Heritage System (GIAHS) by FAO (2012). Studies by Rao et al. (2019) emphasized that traditional rice cultivation in Koraput involved over 100 native rice varieties, integrated with organic farming techniques, supporting food sovereignty and cultural identity.

The role of indigenous knowledge in enhancing climate resilience has been explored extensively in the last five years. Sahu and Behera (2020) found that indigenous farming communities in Odisha, Jharkhand, and Assam applied risk diversification strategies such as intercropping and early warning systems based on ecological indicators—practices now gaining importance under climate-smart agriculture paradigms.

Sarkar and Basu (2021) analyzed the socio-economic dimensions of IAK. Their studies revealed that indigenous farming not only provided food security but also acted as a cultural repository, preserving rituals, festivals, and communal ties centered around agricultural cycles. This socio-cultural anchoring provided resilience against both market and climatic uncertainties.

During the COVID-19 pandemic, researchers like Dubey et al. (2021) observed a resurgence of interest in indigenous agricultural practices. As global supply chains faltered, many rural communities in India turned back to local seed varieties, traditional storage systems, and natural inputs, highlighting the self-reliant nature of indigenous agriculture.

A comprehensive review by the Centre for Science and Environment (CSE) (2022) noted that indigenous soil fertility practices, such as the application of vermicompost, green manure, and biochar, offered sustainable alternatives to chemical fertilizers. Their field studies in Bundelkhand, Maharashtra, and Rajasthan showed significant improvements in soil organic matter and crop yields.

Most recently, Kumar et al. (2024) have advocated for the incorporation of Indigenous Knowledge Systems (IKS) into formal agricultural curricula and extension services. They argue that participatory research approaches, blending scientific validation with indigenous wisdom, are critical for sustainable food systems transformation.

Moreover, global academic discourses (FAO, 2023; IPCC, 2023) increasingly stress that indigenous and traditional knowledge systems must be recognized as valid forms of science. These reports cite indigenous practices in India as exemplary models of sustainability that should be protected and integrated into global climate adaptation and mitigation strategies.

However, scholars like Verma (2025) caution against the romanticization of indigenous practices. They argue for critical engagement—acknowledging the strengths of indigenous knowledge while adapting it pragmatically to modern challenges like erratic rainfall patterns, emerging pests, and socio-economic pressures.

Collectively, the literature from 2000 to 2025 affirms that Indian Indigenous Agricultural Knowledge represents a robust, diverse, and dynamic knowledge system. It offers profound lessons for sustainable agriculture, biodiversity conservation, climate resilience, and rural development. Yet, integrating this knowledge into mainstream agriculture requires nuanced understanding, ethical engagement, adequate policy support, and most importantly, respect for the communities that have nurtured these traditions for centuries.

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Table (1) State-wise Best Indigenous Agricultural Practices in India

| State | Indigenous Practice | Application | Scientific Reasoning | Citation |
|---|---|---|---|---|
| Rajasthan | **Khadeen system** | Captures runoff water for crop cultivation. | Enhances soil moisture and reduces desertification (ICAR, 2015; Sharma, 2013). | ICAR (2015); Sharma (2013) |
| Odisha | **Koraput Traditional Rice Farming** | Cultivates multiple indigenous rice varieties. | Maintains genetic diversity, improving pest resistance and climate adaptability (FAO, 2012; Rao, Sahu, & Das, 2019). | FAO (2012); Rao et al. (2019) |
| Maharashtra | **Nirgudi (Vitex negundo) pest control** | Natural pesticide from boiled leaves. | Contains insecticidal alkaloids and flavonoids (Singh & Mishra, 2016; Dubey, Sharma, & Patel, 2021). | Singh & Mishra (2016); Dubey et al. (2021) |
| Tamil Nadu | **Eri (Tank) Irrigation** | Harvests rainwater using village tanks. | Boosts groundwater recharge and drought resilience (Mishra, 2018; ICAR, 2015). | Mishra (2018); ICAR (2015) |
| Himachal Pradesh | **Orchard Terracing** | Stone-based terraces for apple farming. | Reduces erosion and enhances soil moisture (Sahu & Dash, 2005; Verma, 2025). | Sahu & Dash (2005); Verma (2025) |
| Assam | **Jhum Cultivation** | Rotational shifting agriculture. | Promotes soil recovery and ecosystem resilience (Pandey, 2014; Sahu & Behera, 2020). | Pandey (2014); Sahu & Behera (2020) |
| Kerala | **Home Gardens** | Multi-layered agroforestry near homes. | Increases biodiversity and carbon sequestration (Altieri, 2004; Kumar, Singh, & Patil, 2024). | Altieri (2004); Kumar et al. (2024) |
| Madhya Pradesh | **Ash and Cow Dung Seed Storage** | Seeds stored in ash-lined dung pots. | Natural antifungal and moisture-regulating properties (National Innovation Foundation, 2010). | National Innovation Foundation (2010) |
| Gujarat | **Vav (Step-wells)** | Groundwater accessed via ancient step-wells. | Reduces evaporation and secures year-round irrigation (Mishra, 2018; Shiva, 2011). | Mishra (2018); Shiva (2011) |
| Nagaland | **Zabo System** | Water harvesting combined with farming. | Maximizes water use and enhances soil health (ICAR, 2015; Sharma, 2013). | ICAR (2015); Sharma (2013) |
| Sikkim | **Traditional Organic Farming** | Entire state practices chemical-free farming. | Maintains soil biota and sustainable productivity (Centre for Science and Environment, 2022). | Centre for Science and Environment (2022) |
| Punjab | **Traditional Intercropping** | Cotton intercropped with sorghum. | Sorghum acts as a natural pest barrier (Kumar & Kapoor, 2013). | Kumar & Kapoor (2013) |
| Chhattisgarh | **Ethnobotanical Pest Control** | Neem and Karanj oil used against pests. | Bioactive compounds prevent pest damage (Singh & Mishra, 2016). | Singh & Mishra (2016) |
| West Bengal | **Pond-Based Integrated Farming** | Rice-fish co-cultivation. | Fish improve soil nutrients; rice provides habitat (Patwardhan, Satheesh, & Sinha, 2017). | Patwardhan et al. (2017) |
| Uttar Pradesh | **Cow Urine Bio-Pesticides** | Sprays from fermented cow urine mixtures. | Natural antibacterial and antifungal agents (Shiva, 2000; Dubey et al., 2021). | Shiva (2000); Dubey et al. (2021) |
| Karnataka | **Guli Raita (Line Planting of Finger Millet)** | Millets planted in rows with uniform spacing. | Enhances aeration, disease resistance (Kumar et al., 2024). | Kumar et al. (2024) |
| Andhra Pradesh | **Community Seed Banks** | Shared indigenous seed storage and revival. | Strengthens food sovereignty and biodiversity (Patwardhan et al., 2017). | Patwardhan et al. (2017) |

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| State | Indigenous Practice | Application | Scientific Reasoning | Citation |
|---|---|---|---|---|
| Meghalaya | **Living Root Bridges** | Bioengineering bridges from rubber fig trees. | Stabilizes soil, water flow; prevents floods (Altieri, 2004; FAO, 2023). | Altieri (2004); FAO (2023) |
| Bihar | **Sathi Rice Cultivation** | Short-duration flood-resistant rice cultivation. | Early harvests avoid flood losses (Sahu & Behera, 2020). | Sahu & Behera (2020) |
| Jammu & Kashmir | **Kerewa Soil Farming** | Cultivation on fertile lacustrine Kerewa soils. | High moisture retention and organic richness benefit crops (Rao et al., 2019). | Rao et al. (2019) |

## VI. ANALYSIS AND INTERPRETATION

*6.1. **Historical Evolution of Indigenous Agricultural Knowledge (IAK): A Scientific and Analytical Discourse:***
India's Indigenous Agricultural Knowledge (IAK) represents a civilizational continuum of ecological intelligence, empirically developed through observation, experimentation, and intergenerational transfer over millennia. This corpus of knowledge integrates agronomy, agroecology, ethno-botany, soil science, meteorology, and hydrology, often aligning with what modern science now conceptualizes as "sustainable agriculture" and "climate-resilient farming."

*Vedic and Early Agrarian Traditions: Roots in Ecology and Sustainability:* The Vedic texts (c. 1500–500 BCE), particularly the *Rigveda* and *Atharvaveda*, contain references to agricultural deities, seasonal cycles (*ritu-chakra*), rain-making rituals, and land preparation. Notably, the *Krishi-Parashara*, attributed to the sage Parashara (~1000 BCE), is among the earliest agricultural manuals, detailing land classification (*urvara*, *ushara*), composting, rainfall forecasting, and crop rotation methods. These reveal a proto-scientific understanding of agro-climatology (Dwivedi, 2001; Nene, 1999).

The treatise *Vrikshayurveda* (c. 1000 BCE), ascribed to Surapala, is a seminal work on plant life, encompassing seed selection, grafting, soil types, disease identification, and organic formulations using cow dung, ash, and botanicals. The methods prescribed in this text correspond with principles of modern plant physiology, organic farming, and integrated pest management (IPM) (Sadhale, 1996).

*Buddhist and Jain Influence: Ethical Land Use and Crop Diversity:* In the Mauryan period (c. 300 BCE), state-sponsored agriculture reached new heights. *Arthashastra* by Kautilya (Chanakya) outlines the management of irrigation canals, cropping patterns based on rainfall and soil texture, and use of natural manures—anticipating state-supported extension services and zoning in modern agriculture. Jain and Buddhist ethics encouraged minimal harm to the soil and biodiversity, promoting low-impact cultivation—a precursor to today's conservation agriculture (Chattopadhyay, 2005).

*Medieval Innovations and Agro-Hydrological Systems:* During the medieval period (8th–16th centuries), agrarian practices evolved through syncretic knowledge exchanges between Hindu, Islamic, and tribal communities. The *Zabti* system of the Mughals under Akbar, documented in *Ain-i-Akbari* by Abul Fazl (1590 CE), records regional cropping calendars, land productivity, and irrigation practices. The *pynes* of Bihar, *phad* irrigation in Maharashtra, and *tanks* in Tamil Nadu emerged as hydrologically engineered community water systems, resembling modern watershed management approaches (Habib, 1999; Mosse, 2003).

These systems were grounded in principles of catchment hydrology, gravity-fed distribution, and aquifer recharge, today validated by hydrogeological studies (Agarwal & Narain, 1997). Their community-managed governance also aligns with *Elinor Ostrom's* framework of collective resource management.

*Colonial Period: Systematic Surveys and Knowledge Marginalization:* The British colonial administration (1757–1947), though exploitative in agricultural policy, inadvertently documented indigenous practices through settlement records, botanical surveys, and ethnographic accounts. Scholars like J.D. Hooker and district gazetteers recorded information on mixed cropping, local irrigation, and famine-resistant millets.

However, the introduction of centralized canal irrigation, cash crops, and Western agronomy led to the systematic marginalization of traditional knowledge systems (Guha, 1989). Indigenous seed systems and bio-cultural landscapes suffered as colonial science prioritized extractive monocultures over ecological resilience.

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*Post-Independence to Green Revolution (1947–1980): State-Led Modernization:* Post-independence India emphasized food self-sufficiency through the Green Revolution, focusing on high-yielding varieties (HYVs), chemical fertilizers, and irrigation expansion (Swaminathan, 1987). While this revolution mitigated famine, it also led to soil degradation**,** biodiversity erosion, and decline in traditional farming systems (Shiva, 2000). Indigenous systems, labeled as "backward," were excluded from formal extension services and agricultural curricula.

Yet, parallel to this techno-centric push, scholars like Dharampal (1971) and organizations like Deccan Development Society began documenting farmer innovations and traditional wisdom, especially among tribal and Dalit communities. This period marks the beginning of epistemic resistance to modernist erasure.

*Late 20th Century Revival: Civil Society and Academic Recognition:* From the 1980s onward, a wave of environmental consciousness—spurred by movements like *Chipko* and *Narmada Bachao*—rekindled interest in traditional farming. Claude Alvares' seminal work *Decolonizing History* (1996) and Vandana Shiva's advocacy brought scholarly attention to indigenous ecological practices as counter-hegemonic knowledge systems.

The establishment of institutions like the National Innovation Foundation (NIF) and People's Science Movements enabled the systematic documentation and scientific validation of traditional agricultural knowledge across India's agro-climatic zones (Gupta, 2003).

*21st Century Convergence: Science Meets Tradition:* In the 2000s, IAK began receiving formal recognition through frameworks like:

- Agroecology: Recognizing traditional polycultures and soil management (Altieri, 2004).
- Climate Resilient Agriculture: Indigenous water-saving and drought-resistant techniques have become part of India's National Adaptation Fund for Climate Change (MoAFW, 2017).
- Natural Farming Movements: Proponents like Subhash Palekar's *Zero Budget Natural Farming* repackage ancient principles of cow-based farming for today's ecological crises.

Furthermore, scientific studies on indigenous seed varieties reveal higher adaptability to changing climate parameters, pests, and soil variability (Rengalakshmi, 2016). The genetic traits preserved in folk rice, millet, and pulses have become resources for plant breeding, agro-biodiversity, and in situ conservation.

*Present Trends and Global Recognition:* In recent years, the FAO, UNEP, and UNESCO have highlighted Indian indigenous systems (e.g., *Koraput's rice diversity*, *Zabo farming of Nagaland*) as models for community-led resilience and agroecological transition. IAK is also featured in India's SDG targets for food security, biodiversity conservation, and climate action.

*Analytical Synthesis: A Scientific Interpretation of India's Indigenous Agricultural Knowledge (IAK):* The historical arc of India's Indigenous Agricultural Knowledge (IAK) presents a complex, multi-dimensional knowledge system that intersects ecology, spirituality, agronomy, hydrology, and social organization. The analytical synthesis of this trajectory reveals five interconnected paradigms that underpin the evolution, validation, marginalization, and revival of IAK. Each phase reflects not only technological or material change but also epistemic shifts in knowledge valuation.

- *Empirical-Ecological Paradigm (Pre-Modern Era):*The pre-modern agrarian ethos in India was guided by deep ecological consciousness and cosmic agricultural philosophies rooted in texts such as the *Vrikshayurveda*, *Krishi-Parashara*, and *Arthashastra*. These sources illustrate a systems-thinking approach where soil health, seasonal timing (*ritu*), lunar phases, and intercropping were integrated for sustainable yields. For instance, intercropping legumes with cereals was practiced to replenish soil nitrogen—an insight corroborated by modern nitrogen-fixation science (Nene, 1999; Sadhale, 1996). This knowledge was location-specific**,** adaptive**,** and community-validated**,** demonstrating early principles of ethno-agronomy and resilience science**.** Techniques such as *jalkunds* (water harvesting pits), mulching with local biomass, and seed preservation with herbal extracts indicate a scientific consciousness rooted in observation and experience**,** rather than laboratory abstraction.

- *Socio-Hydrological Engineering and Institutional Commons:* The medieval period's innovations in decentralized irrigation systems—like tanks in Tamil Nadu, zings in Ladakh, and pynes in Bihar—exemplify indigenous hydrological engineering. These systems were technically advanced, using contour mapping and gravity-flow principles, showing precursors to watershed science and GIS-based modeling today (Agarwal & Narain, 1997). Their management was often community-driven, reflecting Ostrom's design principles for sustainable commons governance. The ability of these systems to persist for centuries underscores the institutional stability and social embeddedness of IAK, linking it to institutional ecology and collective action theory**.**

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- *Knowledge Displacement and Epistemic Disruption (Colonial Modernity):* The colonial era introduced a rupture in the evolution of IAK, primarily through two mechanisms: (a) the introduction of Western agronomic models favoring monocultures and linear yield maximization, and (b) colonial codification of knowledge that filtered traditional practices through orientalist lenses. The epistemic dislocation was evident in the replacement of millets with export-oriented crops like indigo and cotton, which eroded food security and ecological balance. Scientifically, this period marked a shift from integrative, biodiversity-based farming to reductionist agronomy, sidelining indigenous practices as "primitive" or "unscientific" (Guha, 1989; Alvares, 1996). The sidelining of women, tribal, and caste-based knowledge keepers during this era further alienated traditional systems from formal recognition and institutional support.

- *Technocratic Dominance and its Ecological Discontents (Post-Independence to 1980s):* The Green Revolution era, while enhancing food production, institutionalized chemical-intensive, seed-replacing models of agriculture. Although scientifically successful in increasing yield, this approach undermined agro-biodiversity, depleted aquifers, and marginalized traditional cultivars and knowledge systems. This phase introduced a techno-deterministic narrative, where farming was reduced to input-output equations. IAK suffered from the lack of recognition in state policy, agricultural universities, and extension systems. Farmers who retained traditional methods were labeled unscientific—despite empirical evidence of their resilience in fragile and rainfed zones.

- *Scientific Resurgence and Plural Epistemology (1990s Onward):* The environmental crises of the 1980s and 1990s—soil degradation, pest resistance, and water scarcity—prompted scientific re-engagement with traditional knowledge. Agroecology, permaculture, and participatory breeding began drawing from IAK. The rise of transdisciplinary science blurred the binary between traditional and modern, privileging plural epistemologies (Visvanathan, 2003).Studies began validating indigenous drought-resistant varieties, seed sovereignty models, and microbial-rich organic inputs. For instance, indigenous paddy varieties in Odisha were shown to outperform hybrids under climate stress (Rengalakshmi, 2016). This empirical convergence marks a return to holistic agricultural paradigms.

- *Climate Resilience and Policy Mainstreaming (2010s–Present):* Currently, IAK is increasingly positioned within climate resilience frameworks—both nationally and internationally. The National Mission on Sustainable Agriculture (NMSA) and Paramparagat Krishi Vikas Yojana (PKVY) promote traditional practices like mixed cropping, organic manuring, and indigenous seeds. International institutions (FAO, UNFCCC) recognize IAK's role in achieving Sustainable Development Goals (SDGs). Scientific validation through carbon sequestration studies, life cycle analysis, and soil biota profiling have established IAK's potential to combat the climate crisis, soil infertility, and food insecurity. These results reflect the integration of traditional practices with modern metrics of impact assessment, creating new knowledge hybrids.

*Meta-Synthesis: Integrating IAK into a Future-Facing Scientific Framework:* In synthesizing this historical and scientific evolution, we identify three foundational truths:

- IAK is a dynamic, adaptive system, grounded in local ecologies but capable of scaling through scientific validation and technological integration.
- Scientific frameworks must evolve to embrace complexity, plurality, and experiential learning—moving beyond input-centric models to systems-based, resilience-driven paradigms.
- Policy and academic institutions must decolonize their knowledge hierarchies, allowing IAK not just a supportive role but a co-equal epistemic status in shaping sustainable futures.

Therefore, the analytical synthesis of IAK is not merely retrospective. It provides a template for post-carbon, climate-resilient agriculture and challenges us to rebuild science in dialogue with lived wisdom.

**6.2. *Geo-Regional Diversity and Practice Distribution of Indigenous Agricultural Knowledge (IAK) in India:***
India's diverse topography, climatic variability, and socio-cultural heterogeneity have given rise to regionally distinct Indigenous Agricultural Knowledge systems. Based on secondary data from the Indian Council of Agricultural Research (ICAR), the National Innovation Foundation (NIF), Food and Agriculture Organization (FAO) reports, and ethnographic field studies (Singh et al., 2003; Nair, 2015), IAK is revealed as ecologically embedded, community-managed, and innovation-rich. The following regional overview captures the geo-specific adaptive strategies rooted in traditional wisdom and validated by emerging scientific inquiry.

*North India: Mountain Agroecology and Soil Stabilization Practices:*
- *Practice*: *Terraced orchards and rainfed cultivation* in Himachal Pradesh and Uttarakhand.
- *Scientific Basis*: These terracing systems are engineered to reduce runoff velocity, increase soil-water retention, and prevent topsoil erosion. Crops such as amaranth, rajma (kidney bean), and pome fruits like apricot and apple are cultivated.

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- *Validation*: Terracing aligns with contour plowing principles and hydrological engineering. Studies by ICAR-Central Soil and Water Conservation Research Institute validate the reduction of erosion by up to 50% (ICAR-CSWCRTI, 2019).
- *Citations:* Negi (2001); Thakur & Singh (2013).

*East India: In-situ Biodiversity Conservation in Paddy Agroecosystems:*
- Practice: *Koraput Rice Diversity* in Odisha, maintained by tribal communities such as the Paraja and Kondh.
- Scientific Basis: Over 100 indigenous paddy landraces are cultivated in diverse altitudes and water availability zones. These landraces exhibit tolerance to drought, flooding, and pests.
- Validation: FAO recognized the Koraput region under its Globally Important Agricultural Heritage Systems (GIAHS) initiative in 2012. These varieties are studied for genetic resilience and climate adaptability.
- Citations: Rengalakshmi (2016); FAO (2012); Deb (2001).

*West India: Arid-Zone Water Harvesting and Moisture Retention Technologies:*
- Practice: *Khadeen* (Jaisalmer) and *Johad* (Alwar) in Rajasthan.
- Scientific Basis: Khadeen farming captures rainwater from adjoining rocky surfaces into plots, enabling post-monsoon cropping without irrigation. Johads are community-built check dams that recharge groundwater.
- Validation: Water table improvements of 6–10 meters and yield increases of 30–70% in arid zones have been reported (Agarwal & Narain, 1997). These systems are now studied under arid-zone hydrological models.
- Citations: Sharma et al. (2006); CSE (1999); Narain (2005).

*South India: Moisture Management and Millets-Based Farming:*
- Practice: *Eri systems* in Tamil Nadu and *Guli Raita* millet-based polycultures in Karnataka.
- Scientific Basis: Eri (tank) irrigation systems are community-managed reservoirs dating back to the Chola period. Guli Raita involves growing minor millets like ragi, foxtail millet, and legumes, enhancing soil fertility and food security.
- Validation: ICRISAT research affirms these systems as sustainable under erratic rainfall and marginal soils. Millets' low glycemic index and resilience are being revived under India’s National Millet Mission.
- Citations: ICRISAT (2018); Palanisami et al. (2009); Nayak & Dinesh (2017).

*Northeast India: Shifting Cultivation and Watershed Integration:*
- Practice: *Zabo* system in Nagaland and *Jhum* cultivation across Assam, Meghalaya, and Mizoram.
- Scientific Basis: Zabo integrates forest catchments, water harvesting, and livestock, functioning as an indigenous integrated watershed management system. Jhum cultivation, with rotational fallow periods of 7–15 years, conserves biodiversity and replenishes soil nutrients.
- Validation: NIF and NEPED studies report higher biodiversity indices and sustainable yields. Research suggests that fallow-based shifting systems outperform settled monocultures in soil organic carbon (Tripathi & Barik, 2003).
- Citations: NEPED (2004); Ramakrishnan (1992); Goswami et al. (2015).

Table (2) Synthesis: Regional Practices and Scientific Convergence

| Region | Key Practice | Scientific Benefit | Institutional Validation | Citation |
|---|---|---|---|---|
| North India | Terraced orchards | Soil erosion control, moisture conservation | ICAR-CSWCRTI | Negi (2001), Thakur (2013) |
| East India | Koraput rice landraces | Genetic diversity, flood/drought resistance | FAO-GIAHS, MSSRF | Deb (2001), Rengalakshmi (2016) |
| West India | Khadeen, Johad | Groundwater recharge, water efficiency | CSE, Tarun Bharat Sangh | Agarwal (1997), Narain (2005) |
| South India | Eri system, Guli Raita | Tank irrigation, millet nutrition & agroecology | ICRISAT, NABARD | Palanisami (2009), Nayak (2017) |
| Northeast India | Zabo, Jhum | Watershed integrity, biodiversity preservation | NEPED, NIF | Ramakrishnan (1992), Tripathi (2003) |

International Multidisciplinary Research Journal Reviews (IMRJR)
A Peer-reviewed journal
Volume 2, Issue 5, May 2025
DOI 10.17148/IMRJR.2025.020501

The diversity of Indigenous Agricultural Knowledge across Indian states is not only a repository of ancestral wisdom but also a repository of site-specific ecological solutions. These systems demonstrate adaptive intelligence and ecological rationality—offering vital frameworks for climate-resilient, low-input agriculture. Contemporary scientific research increasingly affirms that traditional does not mean unscientific, but rather, contextually optimized and evolutionarily tested.

***6.3. Scientific Validation of Traditional Practices in Agriculture:***

The scientific validation of traditional agricultural practices underscores the convergence of ancient wisdom and modern agronomy. While many indigenous practices were initially regarded as outdated or inefficient by early modern agricultural science, recent advancements in agroecology, organic farming, and sustainable agriculture have demonstrated their ecological and economic benefits. These practices, often dismissed in the past, are now recognized for their contributions to enhancing agricultural resilience, soil health, biodiversity, and pest control. Below is an elaboration on key practices and their validation by modern science:

*Crop Diversification and Mixed Cropping***:**Crop diversification and mixed cropping are traditional agricultural practices that have been utilized for centuries across diverse regions. Early modern agronomists considered these techniques inefficient, arguing that monoculture farming was more productive and economically viable. However, agroecologists now recognize the importance of mixed cropping for improving pest control, enhancing soil fertility, and building resilience against climate change. According to Altieri (1995), mixed cropping systems contribute to biodiversity, which stabilizes ecosystems, increases pest resistance, and improves yield resilience. This ecological balance significantly reduces dependency on synthetic pesticides and fertilizers.

Research has shown that crop diversification offers several benefits, such as increasing the abundance of beneficial organisms that naturally regulate pest populations and promoting nutrient cycling in the soil. The inclusion of nitrogen-fixing legumes in crop rotations is a prime example, as they enhance soil fertility by converting atmospheric nitrogen into a form accessible to other plants (Altieri, 1995; Giller, 2001). Additionally, mixed cropping systems help buffer against unpredictable weather patterns by distributing the risk across different crop species with varying growth requirements and susceptibilities (McIntyre et al., 2009).

*Neem-Based Pest Control***:** Neem (Azadirachta indica) has long been used in traditional agricultural practices for pest management. Indigenous farmers have employed neem-based pest control techniques for centuries, using neem leaves, seeds, and oil to protect crops from pests and diseases. Scientific studies have validated these practices, particularly the use of azadirachtin, a compound found in neem that disrupts the feeding, growth, and reproduction of pests. Neem has been shown to be effective against a wide range of insect pests, including aphids, whiteflies, and caterpillars (Patwardhan et al., 2017; Isman, 2006).

Patwardhan et al. (2017) describe neem's insecticidal properties and its potential as a bio-pesticide in integrated pest management (IPM) programs. Unlike synthetic pesticides, neem products degrade quickly in the environment and have minimal residual toxicity, making them safer for non-target species, including beneficial insects like pollinators and natural pest predators. As such, neem-based pest control methods align with the global movement toward organic farming and sustainable agriculture (Isman, 2006; Ayyanar & Subash-Babu, 2012).

Neem's popularity in modern organic farming is also attributed to its low environmental impact and its role in enhancing ecological sustainability. The integration of neem-based products in crop protection is an example of how traditional ecological knowledge can inform and enhance contemporary farming practices.

*Use of Cow Dung, Ash, and Herbal Mixtures for Seed Preservation and Soil Enrichment***:** The use of cow dung, ash, and various herbal mixtures for seed preservation and soil enrichment has deep roots in traditional farming systems, particularly in India and other parts of Asia. These practices have now gained recognition in the field of organic agriculture for their role in maintaining soil health, improving nutrient cycling, and reducing dependency on chemical fertilizers. Cow dung is a rich source of organic matter and microbial life, which promotes soil fertility and structure by enhancing microbial activity (Alvares, 1996; Sharma et al., 2009).

Ash, often combined with cow dung, provides essential minerals such as potassium, calcium, and magnesium, which are vital for plant growth (Alvares, 1996). The use of herbal mixtures for seed treatment is another ancient practice that prevents fungal, bacterial, and insect infestations. These mixtures typically contain plant extracts with antifungal, antibacterial, and insecticidal properties, which help preserve seeds during storage and reduce the risk of seed-borne diseases (Shiva, 2011; Ghosh et al., 2013).

International Multidisciplinary Research Journal Reviews (IMRJR)
A Peer-reviewed journal
Volume 2, Issue 5, May 2025
DOI 10.17148/IMRJR.2025.020501

Modern research into organic farming supports these practices by highlighting the importance of organic matter recycling and microbial management. The use of cow dung in soil management aligns with the principles of agroecology, which emphasize the conservation of natural resources and the promotion of biodiversity. Additionally, herbal seed treatments align with the principles of integrated pest management (IPM) and sustainable agriculture, which aim to minimize the use of synthetic chemicals (Shiva, 2011; Altieri, 1995).

*Integration with Modern Organic Farming and Climate-Resilient Agriculture**:*** The integration of traditional agricultural practices into modern organic farming systems is increasingly recognized for its potential to address the challenges of climate change, biodiversity loss, and food insecurity. Subhash Palekar's model of natural farming, for instance, draws heavily on indigenous practices and emphasizes soil health, biodiversity, and minimal intervention. Palekar's methods, which include the use of cow dung, herbal concoctions, and organic mulching, are based on principles of self-sufficiency and sustainability (Palekar, 2004).

Contemporary research on climate-resilient agriculture also supports the importance of these traditional practices in mitigating the impacts of climate change. Crop diversification, organic matter recycling, and the use of natural pest control methods contribute to farming systems that are better equipped to withstand the effects of unpredictable weather patterns, such as droughts and heavy rainfall (Giller, 2001; Altieri, 2004). By drawing on traditional knowledge, modern farming systems can enhance soil fertility, promote water conservation, and reduce reliance on external chemical inputs, thus fostering resilience in the face of climate change (Altieri, 2004; McIntyre et al., 2009).

The scientific validation of traditional agricultural practices highlights the relevance and importance of indigenous knowledge in modern agriculture. Practices such as crop diversification, neem-based pest control, and the use of organic inputs like cow dung and herbal mixtures are now recognized for their contributions to sustainability, soil health, and climate resilience. As the world shifts toward more sustainable and eco-friendly farming practices, these traditional methods are being integrated into contemporary organic farming systems, providing an important bridge between the past and the future of agriculture. This convergence of old and new underscores the value of traditional wisdom in building a more sustainable agricultural future.

***6.4. Sustainability Parameters in Indigenous Agricultural Knowledge (IAK) Systems vs. Conventional Farming:***

Recent studies from organizations like the FAO (2023), CSE (2022), and ICAR (2015) demonstrate that Indigenous Agricultural Knowledge (IAK) systems consistently outperform conventional chemical-based farming practices in several critical sustainability parameters. These metrics, encompassing water use, soil health, biodiversity, pest control, economic viability, and climate adaptation, underline the superior environmental and economic benefits offered by IAK systems.

*Water Use:*

*Indigenous Practices*: Traditional systems such as Zabo (in Nagaland) and Eri (in Assam) have been observed to use water more efficiently. These practices focus on water harvesting, storage, and conservation, making optimal use of available resources, which is crucial in water-scarce regions (FAO, 2023). IAK systems employ localized and small-scale irrigation techniques that focus on minimizing water wastage, integrating water management with agricultural practices to maintain consistent crop yields even in drought-prone areas (CSE, 2022).

*Conventional Practices**:*** In contrast, conventional chemical-based farming often involves large-scale irrigation systems that are not always efficient, leading to excessive water usage. The reliance on monoculture crops and extensive irrigation systems can lead to the depletion of local water resources and contribute to water wastage, especially when these practices are poorly managed (ICAR, 2015).

*Soil Health:*

*Indigenous Practices**:*** Indigenous practices emphasize organic inputs such as compost, cow dung, and mulch, which enhance soil fertility through natural processes. These practices support the maintenance of healthy soils, improve soil organic matter, and promote microbial activity, ensuring long-term soil health and productivity (FAO, 2023). Techniques like crop rotation and agroforestry further enrich the soil by preventing soil erosion and enhancing nutrient cycling (CSE, 2022).

*Conventional Practices**:*** Chemical-based farming, on the other hand, often degrades soil health over time due to the excessive use of synthetic fertilizers and pesticides. These chemicals can alter the natural microbial balance in the soil, decrease organic matter, and lead to soil compaction. Over time, this results in reduced soil fertility and greater dependence on external inputs (ICAR, 2015).

International Multidisciplinary Research Journal Reviews (IMRJR)
A Peer-reviewed journal
Volume 2, Issue 5, May 2025
DOI 10.17148/IMRJR.2025.020501

*Biodiversity:*
*Indigenous Practices:* Indigenous farming systems typically feature high genetic diversity, with a wide variety of crops, plants, and animals integrated into the system. This diversity helps maintain a resilient agricultural ecosystem, as it reduces the risk of pests and diseases affecting large portions of crops. In systems like agroforestry and mixed cropping, biodiversity is encouraged, which also contributes to ecological stability and resilience (CSE, 2022; FAO, 2023).
*Conventional Practices*: In contrast, conventional farming often relies on monoculture, where a single crop species is grown extensively over large areas. Monoculture practices lead to a loss of genetic diversity, making crops more vulnerable to pests, diseases, and climate-related stresses. Furthermore, monocultures deplete the soil of specific nutrients, requiring the continued use of synthetic fertilizers (ICAR, 2015).

*Pest Control:*
*Indigenous Practices:* Indigenous methods of pest control typically involve the use of botanical and herbal solutions, as well as integrated pest management (IPM) strategies. These methods are environmentally friendly, with minimal impact on non-target species and ecosystems. For example, the use of neem or garlic-based extracts to control pests is common in many indigenous systems (FAO, 2023). These practices promote natural pest predators and reduce the need for chemical pesticides.

*Conventional Practices:* Conventional farming, conversely, relies heavily on synthetic chemicals for pest control. Pesticides and herbicides are applied in large quantities to ensure crop protection. However, this can lead to harmful environmental effects, including pesticide resistance, harm to beneficial insects like bees, and contamination of soil and water systems (ICAR, 2015). Overuse of chemical pest control is also associated with increased input costs and potential health risks.

*Economic Viability:*
*Indigenous Practices:* IAK systems are often more economically viable for smallholder farmers due to their low input costs. Farmers rely on locally available resources, such as organic fertilizers, and natural pest control methods. The relatively low financial investment required makes indigenous systems more accessible to rural populations with limited resources. Additionally, these systems encourage self-sufficiency and reduce dependency on external inputs (FAO, 2023).

*Conventional Practices:* On the other hand, conventional farming practices often require high input costs, including chemical fertilizers, pesticides, and specialized machinery. These high costs can be a barrier to entry for smallholder farmers and lead to greater economic vulnerability, especially in times of market fluctuations or climate-related disruptions (CSE, 2022). The dependence on expensive chemical inputs also reduces the profitability of conventional farming over time.

*Climate Adaptation:*
*Indigenous Practices*: Indigenous farming systems are typically more resilient to climate change. Practices like intercropping, soil conservation, and the use of drought-resistant crops enhance the system's ability to withstand environmental stresses such as drought, floods, or extreme temperatures (CSE, 2022). These systems are flexible and adaptive, able to adjust to changing climate conditions through knowledge passed down across generations (FAO, 2023).

*Conventional Practices:* While conventional farming systems may adapt to climate change through technological interventions, they generally exhibit lower resilience. Heavy reliance on chemical inputs and monoculture farming reduces the adaptability of these systems to changing weather patterns and extreme climatic events. Additionally, the depletion of soil health and biodiversity associated with conventional practices further weakens the capacity of these systems to recover from climate shocks (ICAR, 2015).

Table (3) Summary of Key Sustainability Metrics

| **Metric** | **Indigenous Practices** | **Conventional Practices** |
|---|---|---|
| **Water Use** | Efficient (Zabo, Eri systems) | Often wasteful, with high water use |
| **Soil Health** | Enhanced with organic inputs | Degrading with heavy use of chemicals |
| **Biodiversity** | High genetic diversity | Monoculture farming |
| **Pest Control** | Botanical/herbal methods | Synthetic chemicals |
| **Economic Viability** | Low input costs | High input dependency |
| **Climate Adaptation** | High resilience | Low to moderate resilience |

International Multidisciplinary Research Journal Reviews (IMRJR)
A Peer-reviewed journal
Volume 2, Issue 5, May 2025
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The studies from FAO (2023), CSE (2022), and ICAR (2015) strongly support the idea that Indigenous Agricultural Knowledge systems are inherently more sustainable and economically inclusive compared to chemical-based conventional farming practices. The metrics on water use, soil health, biodiversity, pest control, economic viability, and climate adaptation all indicate that traditional systems provide a more balanced approach to agriculture, promoting environmental sustainability while fostering economic resilience among farming communities. These findings highlight the importance of integrating indigenous knowledge into contemporary agricultural practices to achieve sustainable, climate-resilient, and economically viable farming systems.

***6.5. Policy Attention and Institutional Support for Indigenous Agricultural Knowledge (IAK):***

The preservation, promotion, and integration of Indigenous Agricultural Knowledge (IAK) into mainstream agricultural development have increasingly become focal points for both national and international policy frameworks. Recognizing the socio-cultural, environmental, and economic benefits of traditional knowledge systems, a growing number of government schemes and institutional programs now aim to provide structured support and visibility to IAK.

*Indian Government Initiatives: Paramparagat Krishi Vikas Yojana (PKVY):* Launched in 2015 under the National Mission on Sustainable Agriculture (NMSA), PKVY aims to promote organic farming through cluster-based approaches and certification under the Participatory Guarantee System (PGS). It encourages farmers to adopt traditional and sustainable agricultural practices by offering training, certification, and financial incentives. PKVY explicitly integrates practices such as the use of indigenous seeds, natural pest control (e.g., neem extracts), and composting techniques rooted in age-old wisdom (Ministry of Agriculture & Farmers Welfare, 2023).

*National Innovation Foundation (NIF):* An autonomous body under the Department of Science and Technology, Government of India, NIF plays a pivotal role in identifying, documenting, and scaling grassroots innovations, many of which stem from indigenous knowledge systems. It supports farmer innovators who use traditional practices to address local agricultural problems and provides technical validation and support for patenting where appropriate (NIF India, 2022).

*Tribal Development Programs:* Through institutions like the Tribal Cooperative Marketing Development Federation (TRIFED) and Integrated Tribal Development Agencies (ITDAs), several government programs have incorporated local ecological and farming knowledge into tribal livelihood promotion schemes. These programs emphasize agroforestry, medicinal plant cultivation, and traditional cropping systems, reinforcing the ecological and cultural sustainability of indigenous practices (Ministry of Tribal Affairs, 2021).

*International Recognition and Support:* FAO's Recognition of IAK Systems: The Food and Agriculture Organization (FAO) has recognized India's indigenous farming models—including the Zabo system in Nagaland and the Apatani system in Arunachal Pradesh—as globally important agricultural heritage systems (GIAHS). These systems are celebrated for their integrated water management, biodiversity conservation, and community-driven governance (FAO, 2023). FAO has also featured India's traditional farming practices in its documentation of successful South-South cooperation frameworks for sustainable agriculture.

UNEP's Agroecology Transition Frameworks: The United Nations Environment Programme (UNEP) has identified India as a key player in agroecological transitions. In its reports, UNEP has acknowledged that indigenous practices such as multi-cropping, traditional seed use, and ecological pest management are instrumental in building climate-resilient food systems. These elements are viewed as foundational to agroecology—a model that UNEP promotes for global adoption to meet the UN Sustainable Development Goals (UNEP, 2022).

The convergence of national policy initiatives and global institutional recognition highlights a pivotal shift toward valuing Indigenous Agricultural Knowledge not just as cultural heritage but as a critical component of sustainable development. Government schemes like PKVY, the National Innovation Foundation, and Tribal Development Programs ensure that traditional practices receive scientific validation, market access, and policy-level support. Simultaneously, endorsements by FAO and UNEP underline India's role as a leader in agroecological transition, showcasing how indigenous practices can shape resilient and sustainable agricultural futures.

***6.6. Gender and Community Dimensions of Indigenous Agricultural Knowledge (IAK):***

The social fabric of Indigenous Agricultural Knowledge (IAK) systems is deeply woven with the contributions of women, tribal elders, and marginalized communities. Ethnographic and participatory research in rural India highlights how these social actors are not only custodians of traditional knowledge but also active agents in its transmission, adaptation, and ecological significance. However, their contributions have historically been undervalued in mainstream agricultural research and policy discourse.

International Multidisciplinary Research Journal Reviews (IMRJR)

**International Multidisciplinary Research Journal Reviews (IMRJR)**
A Peer-reviewed journal
Volume 2, Issue 5, May 2025
DOI 10.17148/IMRJR.2025.020501

*Women as Custodians of Agroecological Wisdom:* Ethnographic studies (Shiva, 2000; Patel, 2007) consistently document women's central role in the maintenance and dissemination of IAK. In many tribal and rural societies, women are the primary seed selectors and savers, ensuring genetic diversity through careful observation and selection across generations. Their knowledge of plant-based pest repellents—such as chili-garlic sprays, neem solutions, or ash treatments—has formed the basis for many organic pest control practices now recognized in agroecology (Singh, 2016).

Women also manage kitchen gardens, mixed cropping patterns, and seasonal crop rotation schedules based on intimate ecological knowledge. Their understanding of microclimates, soil types, and biodiversity is shaped through everyday interaction with nature and passed orally through community traditions. Yet, despite this central role, women's voices are often excluded from agricultural extension services, formal research platforms, and decision-making processes (Agarwal, 2018).

*Tribal Elders and Intergenerational Knowledge Transmission:* Tribal elders, particularly in regions like the Northeast, Odisha, and Central India, serve as oral repositories of generational knowledge. They preserve ecological practices related to agroforestry, water harvesting, lunar planting cycles, and climate indicators. Practices such as the Zabo system (Nagaland), Dongar cultivation (Odisha), and bamboo drip irrigation (Meghalaya) have been maintained and adapted over centuries by these communities (Bora & Das, 2019).

This intergenerational transmission of knowledge is critical for the resilience and continuity of traditional systems. However, modernization, youth migration, and the marginalization of tribal languages threaten this knowledge base. Encouraging community-based documentation, and ensuring that tribal elders are included in formal knowledge-sharing mechanisms, are essential for ecological sustainability and cultural preservation (ICSSR, 2021).

*Marginalized Communities and the Ethics of Recognition:* Dalits, indigenous groups (Adivasis), and other socially excluded communities have historically been sidelined in formal agricultural narratives. Yet, they have innovated and maintained ecologically sound farming practices such as dryland farming techniques, contour bunding, and mixed cropping suited to low-input environments (Shiva, 2000; Baviskar, 2004). Their exclusion not only perpetuates social inequity but also deprives the agricultural sector of rich agroecological alternatives rooted in lived experience and land stewardship.

Recognizing their role is essential not just for social justice, but for ecological resilience. As agroecology becomes central to sustainable agriculture dialogues, inclusion of these voices in research, policy-making, and extension systems becomes imperative (FAO, 2023).

Empowering women, tribal elders, and marginalized communities is not merely an issue of social equity—it is a strategic necessity for sustainable agriculture and biodiversity preservation. These groups serve as frontline stewards of traditional knowledge systems that align closely with global sustainability goals. Strengthening their agency, protecting their intellectual property rights, and integrating their knowledge into institutional frameworks are critical steps toward a more inclusive, resilient, and ecologically sound food system.

*6.7. Challenges in Documentation and Transmission of Indigenous Agricultural Knowledge (IAK):*
Indigenous Agricultural Knowledge (IAK), though ecologically robust and socially inclusive, faces significant threats in the contemporary agricultural landscape. While its practices have proven sustainable over generations, the mechanisms for their transmission are increasingly vulnerable due to socio-economic, institutional, and cultural shifts. Scholars such as Alvares (1996) and institutions like the Indian Council of Social Science Research (ICSSR, 2023) warn that without timely intervention, much of this invaluable knowledge may disappear.

*Oral Transmission and Intergenerational Loss:* IAK is predominantly oral, passed down through storytelling, demonstration, and observation within families and communities. This mode of transmission, while intimate and culturally embedded, makes the knowledge highly susceptible to loss—especially as elder custodians pass away without formal documentation or successors interested in preserving the traditions (Alvares, 1996; ICSSR, 2023). The absence of written records or digitized repositories leads to irretrievable knowledge erosion, particularly in remote tribal areas.

*Youth Disinterest and Cultural Disconnect:* Rapid modernization, migration, and exposure to dominant market-driven agricultural models have alienated younger generations from traditional practices. Ethnographic studies suggest that many youths associate IAK with "backwardness" or inefficiency (Sharma & Reddy, 2020). The glamorization of chemical-intensive, high-yield agriculture in media and policy discourse further marginalizes indigenous methods, reducing their intergenerational transmission and practice.

*Lack of Institutionalization in Academia and Extension:* Despite the growing academic recognition of IAK's value, mainstream agricultural education and research institutions in India have historically excluded it from curricula. Agricultural universities and Krishi Vigyan Kendras (KVKs) have focused on the Green Revolution model—promoting hybrid seeds, chemical fertilizers, and mechanization—at the expense of documenting or validating traditional practices (Sundar, 2006; ICAR, 2015). This exclusion results in a gap between grassroots innovation and formal agricultural systems, limiting research funding, policy integration, and scalability of IAK.

*Market Pressures and Commercial Disincentives:* Globalized input markets have undermined the economic viability of traditional methods. The dominance of proprietary seeds, agrochemicals, and large-scale mechanization leaves little room for seed-saving, local seed banks, or low-input farming systems. Corporatization of agriculture often pressures farmers to abandon community-based knowledge in favor of uniform, input-intensive practices that promise short-term yield gains but often erode long-term sustainability (Patel, 2007; Shiva, 2011).

*Urgency for Conservation and Revitalization:* Reports by Alvares (1996) and the ICSSR (2023) emphasize the urgent need to:

- Document traditional knowledge through ethnographic research, digital archives, and participatory rural appraisals.
- Integrate IAK into agricultural education and extension programs, offering scientific validation where possible.
- Incentivize its use through government schemes, market support, and intellectual property protections for community knowledge holders.
- Sensitize youth through awareness campaigns, community-based training, and recognition of IAK’s scientific and ecological relevance.

### *6.8. Temporal Trends in the Recognition of Indigenous Agricultural Knowledge (1950–2025):*

A chronological analysis of academic discourse, policy shifts, and grassroots movements from 1950 to 2025 shows a dynamic evolution in how Indigenous Agricultural Knowledge (IAK) has been perceived—ranging from marginalization during the Green Revolution to its recent revalorization amid climate and sustainability discourses. This transformation highlights the growing acknowledgment of IAK as a critical resource for sustainable and resilient agriculture.

*1950–1980: Dominance of Green Revolution and Marginalization of IAK:* This era marked the onset of the Green Revolution in India, driven by the adoption of High-Yielding Varieties (HYVs), chemical fertilizers, pesticides, and irrigation-based cropping. While this strategy aimed at addressing food security, it significantly displaced traditional farming methods.

- IAK was sidelined as “unscientific” and inefficient.
- Institutional focus shifted to monoculture, chemical inputs, and yield maximization.
- Indigenous practices like mixed cropping, seed saving, and organic fertilization were dismissed in policy and academic arenas (Frankel, 1971; Shiva, 1991).

*1980–2000: Rise of Environmental Movements and Grassroots Revival:* This period witnessed the emergence of environmental and anti-dam movements such as the Chipko Movement (Uttarakhand) and the Narmada Bachao Andolan.

These movements emphasized the link between indigenous communities, ecological stewardship, and sustainable livelihoods.

- Scholars like Vandana Shiva and Claude Alvares began advocating for the scientific validity of IAK.
- Agroecology and environmental sociology started recognizing the ecological intelligence of traditional farming systems (Alvares, 1996; Shiva, 2000).
- Community seed banks and revival of indigenous varieties gained attention in local initiatives.

*2000–2015: Academic Recognition and Institutional Documentation:* With the UN’s emphasis on biodiversity (CBD, 1992) and the FAO’s interest in smallholder sustainability, this phase saw increasing academic validation of IAK.

- Indian institutions like ICAR, NIF, and CSE initiated efforts to document grassroots innovations and validate them scientifically.
- Universities introduced pilot courses in agroecology, ethno-botany, and sustainable farming.
- Studies began highlighting the comparative sustainability of indigenous over chemical-based systems (Pretty, 2008; Altieri & Toledo, 2011).

*2015–2025: Climate Crisis and the Global Mainstreaming of IAK:* The acceleration of climate change, the launch of the Sustainable Development Goals (SDGs) in 2015, and increased global discourse on food sovereignty have driven renewed attention to IAK.

- IAK is now seen as a strategic tool for climate-resilient agriculture, especially under SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption), and SDG 13 (Climate Action).

- FAO, UNEP, and IPBES cite indigenous practices as critical to agroecological transition and planetary health.
- Models like Zero Budget Natural Farming (ZBNF) and Paramparagat Krishi Vikas Yojana (PKVY) in India incorporate traditional knowledge into national programs (NITI Aayog, 2020).

*From Neglect to Revalorization: A Paradigm Shift:* This 75-year trajectory reflects a broader transformation:

- From disregard in the era of industrial agriculture,
- Through rediscovery during ecological activism,
- To revalorization and policy integration in the era of sustainability and climate resilience.

The transition underscores how knowledge once considered obsolete has now become central to the future of agriculture, biodiversity, and inclusive development.

### *6.9. Interpretative Summary: Indigenous Agricultural Knowledge as a Science of Sustainability:*

An extensive review of secondary literature, historical trends, institutional reports, and ethnographic studies confirms that India's Indigenous Agricultural Knowledge (IAK) constitutes a sophisticated, contextually adapted science of sustainability. Far from being anecdotal or obsolete, IAK reflects systematic ecological intelligence rooted in centuries of localized experimentation, social resilience, and cultural continuity.

*Key Interpretations and Insights:* Low Ecological Footprint:
IAK minimizes environmental degradation by avoiding synthetic inputs, encouraging biodiversity, and relying on natural cycles. Practices like mixed cropping, composting, botanical pest control (e.g., neem, ash, cow dung), and local seed usage contribute to ecological regeneration and soil health (Altieri, 1995; Shiva, 2000; FAO, 2023).
*Cost-Effectiveness:* IAK systems are characterized by low input dependency, which reduces the financial burden on farmers, especially smallholders and tribal communities. With minimal external inputs and a reliance on available natural resources, these systems offer a sustainable alternative to debt-inducing, high-cost modern farming models (ICAR, 2015; NITI Aayog, 2020).

*Community-Centricity:* IAK is deeply embedded in communal practices—knowledge is collectively developed, shared, and preserved across generations. This fosters collective food security, cooperative labor, and social cohesion, contrasting with the individualist and profit-oriented models of industrial agriculture (Alvares, 1996; Singh, 2016; Shiva, 2011).
*Adaptability to Climate Change:* Traditional practices exhibit remarkable resilience to climatic variability due to their diversity, flexibility, and low water dependency. Techniques like Zabo farming, rain-fed cropping, and seasonal calendars based on local ecological indicators allow communities to navigate erratic weather and resource scarcity (CSE, 2022; UNEP, 2021).

*Strategic Recommendations:*

- Mainstreaming IAK through Policy: Government schemes like PKVY and ZBNF must go beyond promotion to deep integration—by empowering local practitioners, funding community knowledge banks, and recognizing IAK in agrarian governance (NITI Aayog, 2020; ICSSR, 2023).
- Educational Integration: Curricula in agricultural universities and rural schools should institutionalize IAK through participatory learning, field-based modules, and intergenerational knowledge-sharing platforms.
- Research-Policy Convergence: IAK must be validated not just through laboratory science but through farmer-led trials, community science initiatives, and pluralistic research methodologies (Altieri & Toledo, 2011).

IAK is not merely a remnant of the past—it is a viable pathway for the future of sustainable agriculture. By embracing IAK's core attributes—ecological harmony, socio-economic inclusivity, and cultural rootedness—India and other agrarian societies can reimagine food systems that are equitable, resilient, and sovereign. The revival and respectful integration of IAK can serve as a foundational pillar in the global agroecological transition toward planetary health and rural justice.

## VII. DISCUSSION

The resurgence of Indigenous Agricultural Knowledge (IAK) in academic, policy, and environmental domains is a result of its scientific alignment with multidimensional sustainability imperatives, including climate resilience, agroecological balance, socio-economic inclusivity, and food sovereignty. Once dismissed as archaic or unscientific, IAK is now increasingly recognized as a dynamic knowledge system grounded in empirical observation, ecological symbiosis, and intergenerational experimentation (Altieri & Toledo, 2011; Berkes et al., 2000; Pretty, 2008).

*Convergence of IAK with Contemporary Scientific Objectives:* Modern agroecology and sustainability sciences validate IAK through robust empirical and comparative studies. Practices such as multi-tiered cropping, in-situ biodiversity conservation, organic pest management, and soil nutrient cycling using bio-resources have been shown to outperform industrial agriculture across various ecological and economic indicators (FAO, 2023; ICAR, 2015; Gliessman, 2016).

- Climate Resilience: Traditional cropping systems—like millets, pulses, and intercropping—demonstrate superior adaptability to abiotic stresses such as drought, heat, and erratic rainfall due to their genetic variability, root depth, and water efficiency (Altieri et al., 2015; IPCC, 2019).
- Soil Health and Carbon Sequestration: IAK emphasizes the use of compost, green manure, cow dung, and biochar, promoting microbial activity and organic carbon build-up in soils, thus mitigating greenhouse gas emissions and enhancing soil fertility (Lal, 2020; Shiva, 2011).
- Low External Input Systems (LEIS): Indigenous systems reduce dependency on fossil fuel-based inputs, thereby lowering the carbon footprint and making farming more accessible and economically viable for marginal farmers (Pretty et al., 2006; CSE, 2022).

*Addressing Global Challenges: Food Security and Environmental Degradation:* IAK provides a multifunctional agricultural model capable of addressing overlapping global crises. In regions like sub-Saharan Africa and South Asia, where smallholder farming dominates, IAK has proven essential for sustaining nutritional diversity, seasonality, and localized value chains (FAO, 2020; UNEP, 2021).

- Food Security: Seed sovereignty, local crop adaptation, and traditional grain systems (e.g., millets, sorghum, amaranth) enhance both food quantity and nutritional quality, especially in marginal agroecologies (Padulosi et al., 2013).
- Biodiversity Conservation: IAK promotes in-situ conservation of genetic resources, including rare landraces and medicinal plants, contributing to global biodiversity and resilience of ecosystems under stress (Thrupp, 2000; ICSSR, 2023).
- Water Stewardship: Indigenous irrigation techniques like Zabo, Ahar-Pyne, and Eri systems exemplify sustainable watershed management with minimal ecological disruption (Kumar & Singh, 2008; FAO, 2023).

*Barriers to Integration: Epistemological and Institutional Disconnects:* Despite its benefits, IAK remains underutilized in mainstream agronomy and policy due to several systemic challenges:

- Lack of Documentation and Codification: A significant portion of IAK is transmitted orally, often embedded in rituals, idioms, and seasonal folk wisdom. The absence of written records and standardized methodologies makes academic validation and institutional adoption difficult (Alvares, 1996; ICSSR, 2023).
- Generational Discontinuity: Youth in rural areas increasingly migrate to urban centers, often viewing IAK as backward. This leads to a loss of custodianship and a rupture in intergenerational knowledge transmission (Shiva, 2000; Singh, 2016).
- Policy Marginalization: Agricultural education and national research priorities have historically privileged industrial monoculture models and export-oriented crops, thereby neglecting IAK in pedagogy, extension services, and funding (NITI Aayog, 2020; ICAR, 2015).
- Global Market Pressures: WTO regimes, seed patents, and agro-corporate influence often undermine traditional seed systems and agroecological autonomy, making local practices economically non-viable (Patnaik, 2007; ETC Group, 2019).

*Pathways for Integration and Institutional Synergy:* Realizing the full potential of IAK requires cross-sectoral, participatory, and decolonial approaches. The way forward lies in co-production of knowledge through collaboration between farmers, researchers, policy-makers, and civil society.

- Participatory Research Models: Farmer-led trials, ethnographic documentation, and citizen science initiatives should be scaled up to legitimize IAK as evidence-based, adaptive knowledge (Chambers et al., 1989; Altieri, 1995).
- Policy Realignment: Programs like Paramparagat Krishi Vikas Yojana (PKVY) and National Mission on Sustainable Agriculture (NMSA) should allocate more funds for the revival, dissemination, and institutional recognition of IAK (MoAFW, 2022).
- Curriculum Reform: Agricultural universities must integrate IAK into syllabi, field studies, and extension modules, emphasizing agroecological literacy and transdisciplinary research (ICAR, 2015; NITI Aayog, 2020).
- International Collaboration: Global bodies like FAO, UNEP, and IFAD should support IAK under the umbrella of South-South cooperation, indigenous rights, and agroecological transition frameworks (FAO, 2023; UNEP, 2021).

Indigenous Agricultural Knowledge represents a scientifically valid, ecologically sound, and socially just framework for future-ready agriculture. Its integration into mainstream systems is not merely about heritage preservation but about redefining scientific paradigms in light of planetary boundaries and equitable development. As climate change intensifies and conventional systems show diminishing returns, IAK offers an epistemic and practical alternative—anchored in resilience, community, and ecological reciprocity.

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A Peer-reviewed journal
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## VIII. LIMITATIONS: STRUCTURAL AND ANALYTICAL BOUNDARIES

- Data Constraints: The present analysis relies predominantly on secondary sources, limiting granular insights into hyperlocal agro-ecological variations and the lived experiences of indigenous practitioners. Primary field-level ethnographies and participatory observations remain underrepresented, affecting empirical robustness.
- Agro-Climatic Disparities: India's vast agro-ecological heterogeneity—ranging from arid deserts to high-altitude Himalayas and tropical coastlines—renders IAK practices non-transferable without contextual adaptation. This restricts the formation of a standardized IAK framework.
- Knowledge Attrition: The rapid mechanization and commercialization of agriculture have precipitated cultural amnesia—a significant erosion of unwritten, orally transmitted agrarian knowledge, particularly in peri-urban and migratory regions.

## IX. CRITICAL CHALLENGES: STRUCTURAL, EPISTEMIC, AND POLITICAL

Despite its profound potential, Indian Indigenous Agricultural Knowledge (IAK) is under systemic threat from structural neglect and epistemic marginalization. The following interlocking challenges impede its full-scale revival and institutionalization:

1. Intergenerational Discontinuity: With youth migration and declining rural attachment, IAK suffers from severe transmission breakdown, often perceived as antiquated in the face of techno-centric agriculture (Altieri & Nicholls, 2017).
2. Absence of Scientific Codification: The lack of formalized, peer-reviewed documentation relegates IAK to anecdotal status, undermining its legitimacy in academic and policy-making spheres (Berkes et al., 2000).
3. Policy Marginalization: Post-Green Revolution paradigms institutionalized input-intensive, yield-maximization models, systematically excluding IAK from curricula, R&D priorities, and state extension services (ICAR, 2015; Shiva, 2011).
4. Market and Trade Pressures: Global agribusiness structures incentivize monoculture-based, input-dependent farming, economically disincentivizing traditional polycultures and landrace cultivation critical to IAK systems (ETC Group, 2019).
5. Perceived Yield Inferiority: Though ecologically sound, IAK is often dismissed as economically inefficient due to slower yield curves, particularly in the absence of holistic metrics that value biodiversity, nutrition, and long-term soil health (Pretty et al., 2006).
6. Unprecedented Climate Extremes: While inherently resilient, IAK systems may lack scalability under extreme, rapid-onset climate shocks (e.g., glacial melts, salinity intrusion), necessitating hybrid resilience frameworks (IPCC, 2019).
7. Fragmented Scientific Validation: Current research efforts are sporadic and disciplinarily siloed, lacking the transdisciplinary rigor required for comprehensive evaluation under contemporary agronomic stressors (FAO, 2023).
8. Intellectual Property and Biopiracy: Inadequate legal protections expose traditional seed systems and practices to unauthorized appropriation and patenting, discouraging open-source community knowledge-sharing (RAFI, 2000).
9. Socio-Cultural Devaluation: Prevailing narratives that equate "progress" with industrial modernity stigmatize traditional knowledge holders, eroding cultural legitimacy and intergenerational pride in indigenous farming (Singh, 2016).

## X. STRATEGIC RECOMMENDATIONS: PATHWAYS FOR REVITALIZATION AND INTEGRATION

To harness the full transformative potential of IAK within sustainable agriculture, the following actionable pathways are proposed:

1. Policy Reorientation: Embed IAK within national agricultural frameworks such as the PM-Kisan scheme, NMSA, and MSP policies, ensuring budgetary allocation, incentive structures, and institutional legitimacy (NITI Aayog, 2020).
2. Curricular Mainstreaming: Integrate IAK into agricultural education syllabi, rural development programs, and farmer field schools, promoting epistemic equity between indigenous and formal scientific knowledge (ICAR, 2015).
3. Decentralized Knowledge Platforms: Facilitate community-led documentation, digital archiving, and oral history projects to preserve and revitalize localized agro-ecological wisdom (CSE, 2022; ICSSR, 2023).
4. Interdisciplinary Research Ecosystems: Promote longitudinal, site-specific studies using both qualitative ethnographic tools and quantitative yield/soil data to validate IAK efficacy under evolving climate scenarios (Altieri et al., 2015).
5. International Framework Synergy: Align IAK promotion with SDGs (2, 13, 15), UNDRIP (United Nations Declaration on the Rights of Indigenous Peoples), and FAO's Agroecology Hub to access global funding and collaborative platforms (FAO, 2023).

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## XI. CONCLUSION

Indian Indigenous Agricultural Knowledge (IAK) represents a dynamic, context-specific system of agricultural practices deeply embedded in ecological wisdom, cultural continuity, and sustainable resource management. In an era marked by climate volatility, biodiversity loss, and unsustainable input-intensive farming, IAK emerges not merely as an alternative but as a *scientifically grounded, culturally resilient, and ecologically integrative model* of agriculture. Its core principles—such as polyculture, organic soil amendments, traditional seed systems, and community-managed agro-ecosystems—align closely with the global objectives of agroecology, climate adaptation, and food sovereignty.

Contemporary scientific validation has increasingly corroborated the effectiveness of indigenous techniques in improving soil health, reducing dependency on chemical inputs, enhancing crop resilience, and sustaining biodiversity (Altieri & Nicholls, 2017; FAO, 2023). However, this traditional corpus of knowledge faces existential threats from socio-economic modernization, generational disconnection, lack of policy integration, and market-driven homogenization of agricultural practices.

To fully harness the transformative potential of IAK, multi-scalar collaboration is imperative. This includes integrating IAK into national research agendas, educational curricula, climate-resilient development programs, and international frameworks such as the UN Sustainable Development Goals (SDGs). Local communities, particularly women, tribal groups, and smallholder farmers—who are the primary custodians of this knowledge—must be empowered and involved in co-creating future agricultural paradigms.

Therefore, preserving, documenting, and institutionalizing IAK is not only a matter of cultural restitution but also a strategic imperative for sustainable development, ecological balance, and equitable food systems. The revalorization of IAK, grounded in both traditional wisdom and scientific inquiry, offers a promising path toward agroecological transition and planetary health.

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**International Multidisciplinary Research Journal Reviews (IMRJR)**
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