



A Comprehensive Review of Indigenous Knowledge Systems in India and its Importance and Role in Biodiversity Conservation

Lekha Kalra ^{a+++*}, Srinatha T. N. ^{b++}, Abhishek, G. J. ^{c++},
Popavath Bhargav Naik ^{b++}, Sujatha G. S. ^{d++},
Shreya S Hanji ^{b++}, Shankar M. ^{c++}
and Pavan Kumar Kumawat ^{b++}

^a Department of Agricultural Economics, Banaras Hindu University, Varanasi, Uttar Pradesh, India.

^b Division of Agricultural Economics, ICAR-Indian Agricultural Research Institute, New Delhi, India.

^c Division of Plant Genetic Resources, ICAR-Indian Agricultural Research Institute, New Delhi, India.

^d Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India.

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Biodiversity is an essential support system consisting of humans, organisms, animals, etc., interacting with each other to maintain a balanced life on Earth. It is important for all the living organisms on the Earth to sustain a natural world. It consists of diverse forms of animals, plants,

⁺⁺Research Scholar;

*Corresponding author: E-mail: kalralekha135@gmail.com;

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fungi, bacteria, etc. Among the components of biodiversity, plants are the important element that assists the other life forms. Diversifying the plants through various agricultural practices should be taken as prima facia in the changing environmental conditions. To enhance the productivity and sustainable development in agriculture, Indigenous knowledge of the farmers acts as a keystone in agriculture. It is a unique and traditional character of a group of people residing at a particular place. It is considered an essential human capital but often overlooked and unexplored. Various local practices have developed over time, which have been innovated, tested, and adapted since time immemorial. These practices are non-scientific, developed through various trial and error methods, location-specific, and dynamic. Various practices that are followed in the states of India are the *Panikheti* system, *Apatani*, *Dafla* in Andhra Pradesh, *Boro*, *dimasa* techniques in Assam, *Kanaja* technique in Karnataka, *Bidd* cultivation in Rajasthan, etc. Local people feel a connection with their environment and try to develop practices that are non-harming and conserving in nature. The role of indigenous people and their knowledge have been mainly contributing to preserving biodiversity for a long time. They try to interact with their local environment to keep them immaculate. The diversity of various plants and crops is maintained with the efforts of the indigenous people and their knowledge, which ultimately assures improving food security and helps adapt the changing climate. According to an estimate, 75 percent of the diversity of the crop was lost between the years 1900 and 2000 when the local seed varieties were replaced, and modern varieties were grown. To solve this issue, spending millions of dollars cannot be the solution, but focusing on applying the knowledge of indigenous people in the modern-day world would be of great help as they have developed improved, tested varieties over the years, which can sustain in the changing environment. The invaluable resource of the country in the form of indigenous knowledge is disappearing fast; hence, measures need to be taken in their favor to sustain biodiversity and maintain food security.

Keywords: *Indigenous knowledge; indigenous people; food security; biodiversity; climate change; sustainability.*

1. INTRODUCTION

Indigenous knowledge in farming refers to the traditional knowledge and practices that indigenous communities have developed and refined over generations to manage agricultural systems sustainably within their local environments. This knowledge encompasses a deep understanding of the land, soil, water, climate, and biodiversity of a particular region, as well as the interactions between them. For example, some indigenous communities practice

traditional land management techniques such as rotational grazing, controlled burning, and selective harvesting. These methods help maintain biodiversity by preserving habitats and promoting the growth of diverse plant and animal species [1]. Additionally, indigenous peoples often have intricate knowledge of medicinal plants and their uses, which can contribute to conservation efforts by highlighting the necessity of preserving biodiversity for future generations [2]. Indigenous farming practices often prioritize biodiversity conservation as they rely on diverse

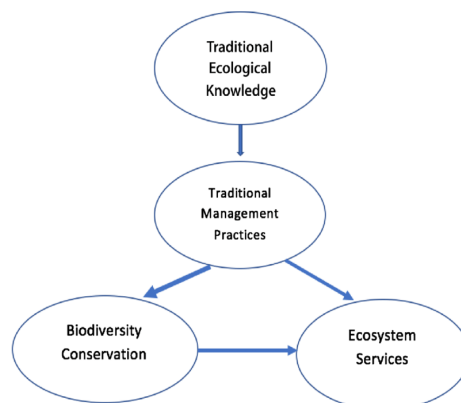


Fig. 1. Traditional knowledge system [5]

cropping systems, including intercropping, agroforestry, and crop rotation. These promote genetic diversity and reduce the crop failure risks due to pests, diseases, or adverse weather conditions. By cultivating a wide variety of crops and including trees and shrubs in their agricultural lands, indigenous farmers develop habitats that support a rich and wide array of plant and animal species. Indigenous knowledge systems are considered a local innovation based on the farmer's experience and the tradition they follow to suit the agroecosystem conditions of the area [3].

Overall, indigenous knowledge in farming contributes significantly to biodiversity conservation by promoting agricultural practices that are adapted to local ecosystems, enhance ecosystem resilience, and support the maintenance of diverse plant and animal species. Recent studies have also shown that there is a change in the attitude of the policymakers due to indigenous knowledge systems which has also led to the development of interest in this system of knowledge [4]. Recognizing and integrating indigenous knowledge into modern agricultural systems can play an important role in promoting sustainable food production and preserving biodiversity for future generations.

2. IMPORTANCE OF INDIGENOUS TECHNICAL KNOWLEDGE (ITK) IN AGRICULTURE

Most Indian farmers follow low-input agriculture (approximately 80 percent of the total) [6]. It shows the potential for indigenous technical knowledge for sustainable agricultural practices. The statisticians have researched that almost 50 percent of the population in the world depends on the Indigenous Knowledge for food supplies [7]. The importance is as follows:

1. **Adaptation to Local Conditions:** Adaptation capacity is the potential success of a particular system in response to a climate stimulus [8]. Indigenous technical knowledge is deeply rooted in local ecosystems and cultural practices. It is developed over time and tailored to specific environmental conditions, such as soil type, climate patterns, and water availability. As a result, ITK offers valuable insights into agricultural practices that are well-suited to local contexts, ensuring

better adaptation and resilience to environmental change [1].

2. **Sustainable Resource Management:** Indigenous agriculture practice prioritizes sustainability, focusing on techniques that help to conserve soil fertility, enhance water management, and promote biodiversity. The farmers use conventional technology and know-how in the production of crops, water and soil management, pest and disease control, etc. For example, ITK may include methods such as agroforestry, crop rotation, and traditional irrigation systems, which contribute to the long-term health of agricultural ecosystems and minimize negative environmental impacts [9].
3. **Genetic Diversity Conservation:** Indigenous communities are the custodians of the rich diversity of crop and livestock varieties, and wild plants adapted to local conditions over centuries. ITK includes traditional seed selection practices, breeding methods, and crop management practices that help preserve and promote genetic diversity, essential for crop resilience, food security, and adaptation to changing environmental conditions [10].
4. **Resilience to Climate Change:** Indigenous agricultural practices and knowledge have evolved in response to climatic variability and unpredictability. ITK includes knowledge and techniques that help farmers to cope with extreme weather conditions, such as droughts, floods, heatwaves, etc. For example, traditional water harvesting structures, soil conservation practices, and drought-resistant crop varieties. They help to mitigate the impacts of climate change on agriculture and ensure food security [2,11,12,13].
5. **Cultural Preservation and Social Cohesion:** Indigenous technical knowledge is often deeply intertwined and connected with cultural traditions, beliefs, and social practices. It fosters a sense of identity, pride, and community cohesion among the indigenous peoples, strengthening their resilience to external pressures and promoting cultural continuity. By preserving ITK, communities can maintain their cultural heritage and pass down valuable knowledge and skills to future generations [2,11,12,13].

6. Food Sovereignty and Local Empowerment: ITK empowers the local communities to control their own food production patterns and systems and make decisions based on their unique priorities, needs, and values. By promoting food sovereignty and local food systems, ITK helps reduce the dependence on external inputs, enhances food security, and strengthens local economic conditions [2,11,12,13].

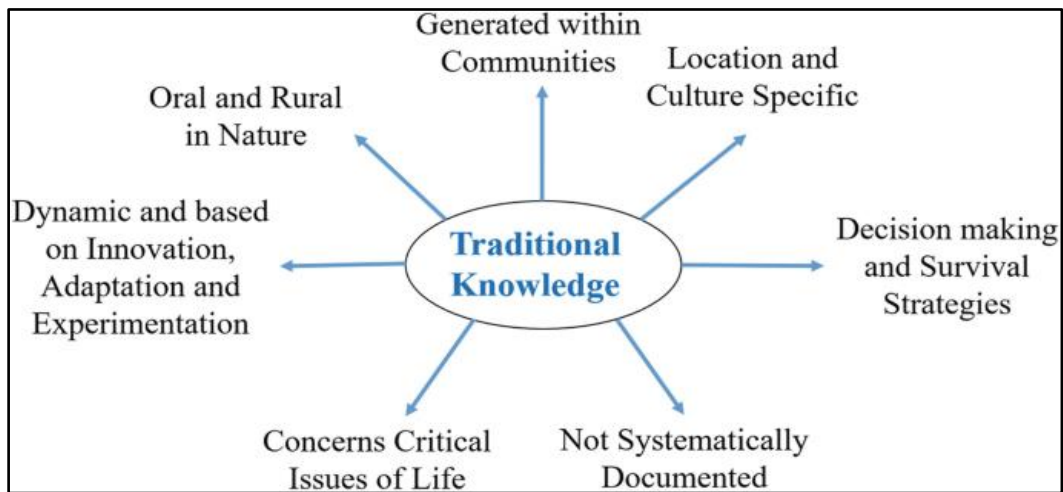


Fig. 2. Major attributes of Traditional Knowledge systems [14]

3. INDIGENOUS KNOWLEDGE AND FOOD SECURITY

Indigenous technical knowledge (ITK) plays an important role in ensuring food security by providing sustainable and context-specific solutions to agricultural challenges. First and foremost, ITK contains centuries of accumulated wisdom and practices tailored to local environments, climates, and ecosystem conditions. This knowledge enables indigenous communities to effectively manage agricultural resources, such as fertility of the soil, availability of water, biodiversity conservation, and maximizing food production while minimizing environmental degradation. Additionally, ITK emphasizes crop diversity, traditional seed-saving practices, and resilient farming techniques that enhance the resilience of food systems to climate variability and extreme weather conditions. By preserving and promoting indigenous agricultural and technical knowledge, communities maintain diverse and nutritious food sources, even under environmentally stressed conditions. Furthermore, ITK fosters community cohesion, cultural identity, and self-reliance and empowers communities to assert control over the food production systems and reduce their dependence on external inputs. Ultimately, recognizing and integrating the ITK into food security strategies helps to contribute to more resilient, equitable, and sustainable food

production systems that meet the needs of present as well as future generations.

3.1 Types of Indigenous Knowledge Systems

1. **Traditional Indigenous Knowledge Systems:** The practical knowledge and methods indigenous societies have created and passed down through the years are called traditional indigenous knowledge systems in agriculture. These knowledge systems primarily focus on agricultural practices, such as crop cultivation, seed banks, management of soil, and water harvesting, adapted to local environments and cultural conditions. Traditionally, indigenous knowledge systems are often grounded with empirical observations, trial-and-error experiments, and practical experience accumulated over time of interaction with the land and natural resources. While traditional indigenous knowledge systems incorporate cultural elements, such as languages, rituals, and community practices, they primarily emphasize practical agricultural techniques and resource management strategies. The main objective of traditional knowledge is to restrict the over-exploitation of natural resources and to bring out a balance in the economy by restoring it [15].

Table 1. List of Indigenous practices with respect to water-saving and irrigation techniques

NORTH INDIA	JOHAD	Traditional rainwater harvesting structures known as Johads are prevalent in the arid and semi-arid regions of North India, particularly in Rajasthan and Haryana. These structures capture and store rainwater, replenishing groundwater levels and providing water for irrigation during dry periods [16]
	BHAL	The Bhal irrigation system, found in parts of Uttar Pradesh and Rajasthan, involves diverting river water into small earthen embankments to create temporary water storage reservoirs for irrigation [17]
	AHAR-PYNE	The Ahar-Pyne system, practiced in Bihar and parts of Uttar Pradesh, is a community-managed irrigation system comprising interconnected reservoirs (ahars) and channels (pynes) that distribute water to agricultural fields [18]
	KHADINS	Khadins are traditional earthen embankments used for rainwater harvesting and groundwater recharge in the desert regions of North India, particularly in Rajasthan and Gujarat [19]
SOUTH INDIA	SURANGA	Suranga is a traditional tunnel irrigation system practiced in parts of Karnataka and Kerala. It involves excavating horizontal tunnels to tap into groundwater sources and provide water for irrigation, particularly in hilly and rocky terrain [20]
	NADAPPU	Nadappu is a traditional water distribution system practiced in Kerala, particularly in the Kuttanad region. It involves regulating water flow through canals and sluices to ensure equitable distribution among agricultural fields [21]
	VAYALAGAM	The Vayalagam system, prevalent in Kerala's Kuttanad region, involves the cultivation of paddy fields below sea level. Traditional embankments and water management techniques are used to prevent flooding and control water levels in the fields [22]
	TANKA	The Tanka system, practiced in parts of Karnataka and Kerala, involves the construction of underground storage tanks or reservoirs to capture and store rainwater for domestic use and irrigation [23]
EAST INDIA	AHAR PYNE	The Ahar-Pyne system is prevalent in the eastern states of Bihar and West Bengal. It involves interconnected reservoirs (ahars) and channels (pynes) that distribute water to agricultural fields, facilitating irrigation and water management [18].
	BAMBOO DRIP IRRIGATION	Bamboo drip irrigation is practiced in parts of northeastern India, including Assam and Manipur. This traditional technique involves using bamboo pipes to deliver water slowly and efficiently to crops, conserving water and enhancing agricultural productivity [24]
	JHIRI SYSTEM	The Jhiri system is a traditional method of water harvesting and management practiced in the hilly terrains of states like Jharkhand, Odisha, and Chhattisgarh. It involves constructing small check dams and contour trenches to capture rainwater and prevent soil erosion [25]
	PADDY CUM FISH CULTURE	Paddy cum fish culture is a traditional farming system practiced in states like Assam and West Bengal, where paddy fields are integrated with fishponds. This integrated approach enhances agricultural

	JOHAD	productivity, conserves water, and provides additional protein sources through fish cultivation [26]. Johad systems, like those found in other parts of India, are also prevalent in eastern states like Bihar and Jharkhand. These traditional rainwater harvesting structures help recharge groundwater levels, provide water for irrigation, and mitigate the impacts of droughts [16].
	CHANDELA	The Chandela system is a traditional method of water management practiced in parts of Odisha. It involves constructing small earthen embankments and channels to divert and distribute water for irrigation and domestic use [23].
WEST INDIA	BHANDARA SYSTEM	The Bhandara system is prevalent in Maharashtra and involves the construction of traditional water storage tanks or reservoirs called Bhandaras. These structures capture and store rainwater, providing water for irrigation and domestic use during dry periods [27]
	BAMBOO DRIP IRRIGATION	Bamboo drip irrigation is practiced in parts of Gujarat and Maharashtra. This traditional technique involves using bamboo pipes to deliver water slowly and efficiently to crops, conserving water and enhancing agricultural productivity [24]

2. **Cultural Indigenous Knowledge Systems:** Cultural indigenous knowledge systems in agriculture have a broader range of cultural beliefs, values, and practices that shape people's relations with the land, nature, and each other. This knowledge system includes agricultural practices and culture rituals, ceremonies, spiritual beliefs, and social customs related to farming, land use, and environmental stewardship. Cultural indigenous knowledge reflects the spiritual, symbolic, and symbolic dimensions of the agriculture system, as well as the cultural identity, worldview, and social organization of indigenous communities. While cultural indigenous knowledge systems may incorporate practical agricultural techniques, their primary emphasis is to preserve cultural heritage, maintain social cohesion, and express cultural identity through farming practices.

3.2 Different Indigenous Technical Knowledge Systems

Indigenous practices are traditional methods of living and interacting with the environment passed down through the generations within specific cultural groups. These practices often include methods for conserving biodiversity, which is the variety of life on the Earth. This method ranges from sustainable agriculture techniques to rituals that honor and protect natural resources. By recognizing and understanding indigenous practices, we can learn valuable lessons about how to live in harmony with Mother Nature and preserve biodiversity for future generations. The various practices followed in different parts of the country are discussed in Table 1.

4. INDIGENOUS KNOWLEDGE AND BIODIVERSITY CONSERVATION

Indigenous knowledge plays an important role in biodiversity conservation by offering unique insights and practices developed and refined over generations within specific ecosystems. Indigenous peoples possess a deep understanding of their environments, including the behavior of plant and animal species, ecological interdependencies, and sustainable resource management techniques. This knowledge is often embedded in cultural practices, traditional stories, and customary laws

that promote harmony between humans and nature.

4.1 Various Biodiversity Conservation Areas

Protected Areas: Protected areas, such as national parks, wildlife reserves, and marine sanctuaries, are designated regions for biodiversity conservation. These areas aim to safeguard habitats, species, and ecosystems from human activities such as deforestation, habitat destruction, and overexploitation. Protected areas play a crucial role in preserving biodiversity by providing safe havens for vulnerable species and allowing ecosystems to thrive without human interference [28].

Restoration of Habitat: The habitat restoration process involves rehabilitating degraded ecosystems to improve their ecological health and functionality. This process may include removing invasive species, planting native vegetation, and restoring natural waterways. By restoring habitats to their original state, biodiversity can be enhanced, and ecosystems can become more resilient to environmental changes. Habitat restoration projects are essential for reversing habitat loss and supporting the recovery of threatened species [29].

Sustainable Land Management: Sustainable land management practices aim to maintain or improve land productivity while enhancing biodiversity and ecosystem services. This approach involves implementing techniques such as agroforestry, rotational grazing, and soil conservation to ensure that land use activities do not degrade natural habitats or deplete biodiversity. Sustainable land management practices promote the coexistence of human activities and biodiversity conservation, resulting in long-term environmental sustainability [30].

Species Conservation: Species conservation focuses on protecting endangered species from extinction. This involves breeding programs, habitat protection, and legal measures to prevent poaching and trade of endangered species. An example is the conservation efforts for the Bengal tiger in India, which include strict anti-poaching measures and habitat restoration projects [31].

Table 2. List of biodiversity conservation methods [31]

Conservation Method	Description	Example	Benefits	How to Perform
Sacred Groves	Designated forest areas protected by communities due to religious or cultural beliefs.	In India, many villages maintain sacred groves dedicated to local deities.	Preserves biodiversity, protects water sources, and maintains soil fertility.	Establish community agreements; restrict human activities in designated areas.
Traditional Farming	Agricultural practices that integrate diverse crops and livestock, promoting ecosystem resilience.	In Nepal, terrace farming combines crops like rice and vegetables, enhancing soil fertility.	Enhances soil health, conserves native plant varieties, reduces reliance on chemicals.	Rotate crops, use organic fertilizers, adopt agroforestry techniques.
Community Reserves	Areas set aside and managed by local communities for conservation purposes.	In Kenya, Maasai communities establish wildlife conservancies to protect biodiversity.	Protects habitat for endangered species, fosters community stewardship.	Develop management plans, enforce regulations, and promote eco-tourism.
Traditional Knowledge	Indigenous knowledge systems passed down through generations, guiding sustainable resource use.	In Australia, Aboriginal fire management practices maintain biodiversity and prevent wildfires.	Preserves cultural heritage, enhances resilience to environmental changes.	Learn from elders; integrate traditional practices with modern conservation methods.
Seed Banks	Facilities storing seeds of diverse plant species, preserving genetic diversity for future use.	The Philippines' Rice Terraces Heritage Seed Bank conserves heirloom rice varieties.	Ensures food security, safeguards against crop failures, supports crop breeding efforts.	Collect and store seeds, monitor viability, promote community participation.

Community Participation: Community participation involves involving local communities in biodiversity conservation efforts. This can include education programs, community-managed reserves, and sustainable livelihood initiatives. For example, in some areas of India, local communities are involved in turtle conservation efforts, protecting nesting sites and monitoring hatchlings [31].

5. ROLE OF INDIGENOUS KNOWLEDGE AND BIODIVERSITY CONSERVATION METHODS IN FOOD SECURITY

Indigenous communities worldwide have developed unique ways to manage their environments sustainably while ensuring food security for themselves. These practices include planting trees alongside crops (agroforestry), saving traditional seeds, managing fisheries collectively, conserving soil and water through terracing, and utilizing indigenous knowledge for sustainable agriculture. These methods not only provide diverse food sources but also protect the environment and help communities adapt to challenges like climate change and resource scarcity.

1. **Agroforestry:** Agroforestry, a method of land management, combines trees and shrubs within agricultural settings. This practice, often employed by indigenous communities, offers numerous benefits, such as enhanced soil fertility, water conservation, and a broader range of food sources [1]
2. **Traditional Seed Saving:** Traditional seed saving, a practice deeply rooted in indigenous communities, is crucial in preserving and exchanging seeds adapted to local conditions. This age-old tradition not only conserves traditional crop varieties but also ensures genetic diversity and resilience to pests and diseases [32]
3. **Community-Based Fisheries Management:** Indigenous communities leverage traditional knowledge to sustainably manage local fisheries, employing methods like regulating fishing seasons, areas, and techniques [33]
4. **Terracing and Water Harvesting:** Indigenous communities utilize traditional methods such as terracing and water harvesting to conserve soil moisture and combat erosion, ultimately enhancing agricultural productivity, particularly in drought-prone regions [34]

6. INDIGENOUS AGROECOLOGICAL KNOWLEDGE SYSTEMS

Indigenous agroecological knowledge systems encompass a holistic understanding of local ecosystems and sustainable agricultural practices. This includes crop rotation, companion planting, and natural pest control methods [12]

6.1 How Indigenous Knowledge is Different from Scientific Knowledge

Despite differences in methods, views, and sources, indigenous and scientific knowledge is vital in tackling issues related to food security. A more thorough examination of these variations and the possibility of integration can yield important information about creating more environmentally friendly and culturally aware solutions. We will examine each significant distinction, offering a comprehensive grasp of how scientific and indigenous knowledge contribute to the larger food security framework [35].

6.1.1 Source and origin

Indigenous knowledge originates in the customs, knowledge, and experiences passed down through the generations within the communities where it is found. Each community's unique ecological background, culture, and customs are deeply entwined with this vast repository of information. Lived experiences and oral traditions uphold it and reflect a comprehensive awareness of the environment that frequently incorporates social, cultural, and spiritual components [11,36].

Conversely, scientific knowledge is obtained through an empirical and methodical methodology. The cornerstones of scientific investigation are rigorous experimentation, observation, and analysis, motivated by a dedication to objectivity and the search for truth. To ensure a high level of reliability, this information is institutionalized, documented, and put through a rigorous inspection and peer review process. Standardized techniques used in scientific methodologies enable study replication and the gradual accumulation of evidence [37].

Essentially, these two knowledge systems—indigenous and scientific—offer different but complementary viewpoints. While scientific knowledge depends on methodical research and analysis to produce a more comprehensive and broadly applicable understanding, indigenous

knowledge is derived from the wisdom of local communities firmly anchored in their historical and ecological surroundings. When tackling complicated issues like food security, integrating these various forms of information can produce thorough insights and solutions [38].

6.1.2 Nature of knowledge

Indigenous knowledge is deeply ingrained in a larger cultural and spiritual framework, and its holistic approach distinguishes it. It encompasses a thorough understanding of social dynamics, spiritual beliefs, and environmental relationships in addition to practical abilities related to agriculture. This knowledge system, which has its roots in local customs, acknowledges the connections between different aspects of the community's way of life [39].

On the other hand, scientific knowledge frequently demonstrates a narrower concentration, focusing on elements and perhaps separating itself from more general cultural or spiritual considerations. Science focuses on attaining impartiality, following standard operating procedures, and ensuring that tests can be repeated. The holistic essence ingrained in the larger cultural and spiritual components that constitute indigenous knowledge may not always be captured by scientific knowledge, even though it often offers insightful explanations for specific phenomena [37].

Despite their differences, these two knowledge systems provide complementary viewpoints. While scientific knowledge offers specialized insights with an emphasis on accuracy and reproducibility, indigenous knowledge delivers a holistic perspective that is deeply ingrained in cultural and spiritual contexts. Acknowledging the advantages of each system and encouraging cooperation across them might result in more thorough solutions, particularly when dealing with complicated problems that require knowledge of both particulars and larger cultural contexts [40].

6.1.3 Methods of transmission

Indigenous knowledge is mainly passed down orally through customs or hands-on demonstrations within the community. It is ingrained in the customs and ceremonies of the surrounding areas. This type of collective knowledge-sharing emphasizes experiential learning that takes place in the everyday routine of the community. Indigenous knowledge is typically transferred through face-to-face

interaction between people, which promotes a sense of intergenerational continuity and collective understanding [11]. On the other hand, the distribution of scientific knowledge adheres to a more structured and documented procedure. It is frequently disseminated through conferences, academic journals, and educational establishments. Scientific discoveries are meticulously recorded in written documents, offering an organized and consistent communication channel. The global exchange of knowledge is facilitated by this broadcast approach, which makes information widely accessible. To assure clarity, precision, and the capacity for others to examine and expand upon previous research critically, written records are prioritized in transferring scientific knowledge [39].

6.1.4 Adaptation to local context

Indigenous knowledge, being highly sensitive to the local environment, exhibits exceptional flexibility by considering elements such as soil, climate, and long-standing customs. This type of knowledge is context-specific by nature, providing long-term solutions that have been refined over many generations to balance the particularities of a certain group. Indigenous knowledge systems are rich in wisdom that represents a profound grasp of the relationship between culture and environment. This understanding fosters behaviors that are not only ecologically sustainable but also customized to meet the unique requirements of the community [11]. On the other hand, whereas scientific information may be broadly applied and generalized, it frequently lacks the precise precision needed locales. The complexities of a given community's behaviors may not be entirely considered by scientific methods, which might result in treatments not perfectly tailored to the local context. The depth of context-specific wisdom embedded in indigenous traditions can occasionally be overlooked by the more standardized and universal character of scientific knowledge [39].

Identifying the advantages of both knowledge systems is essential to developing complete solutions. Combining scientific methods with indigenous knowledge can result in more complex and culturally aware plans that use the broader perspectives offered by scientific research while recognizing and valuing local populations' adaptive skills. This cooperative strategy may handle difficult problems more successfully and sustainably [11].

Table 3. Different principles behind scientific and indigenous agriculture systems in India [39]

Contemporary Agriculture/Modern	Indigenous/Traditional Farming
Cultivation of single crops (monocultures)	Embrace of diverse crops and biodiversity
Use of external, science-based, commercial inputs	Preference for local, reusable, and organic inputs
Lower yield per hectare	Higher yield per hectare
Dependent on capital-intensive methods	Reliance on labor-intensive practices
Increasing dominance of large-scale producers (60% of agricultural land)	Dominated by small-scale farmers (40% of agricultural land)

6.1.5 Recognition and validation

Indigenous wisdom has not always been acknowledged to the same extent as scientific knowledge throughout history. It could have been disregarded or sidelined in favor of scientific methods that are more codified and standardized. Nonetheless, people are becoming more conscious of the intrinsic worth of indigenous knowledge and its distinct perspectives and all-encompassing methods. Indigenous knowledge is becoming more and more important in tackling complex challenges, especially when it comes to environmental sustainability and community well-being. As a result, there is a growing acknowledgment of the need to incorporate this knowledge into larger plans for sustainable development [38].

To promote more inclusive and comprehensive ways of tackling global concerns, it is imperative to strike a balance in acknowledging and integrating indigenous and scientific knowledge. A more comprehensive understanding that integrates conventional knowledge with cutting-edge scientific insights for sustainable and equitable development might result from recognizing the capabilities of each system while encouraging collaboration [39].

6.1.6 Integration and collaboration

Indigenous Knowledge promotes cooperative strategies that respect and embrace indigenous knowledge in addition to outside initiatives. It emphasizes the need for local empowerment and engagement, recognizing that communities have priceless insights into their settings and difficulties. Indigenous knowledge is collaborative, acknowledging that active participation and respect for the knowledge maintained within the community are key factors in emerging sustainable solutions [38]. Alternatively, scientific knowledge usually aims to improve or augment traditional methods, usually emphasizing increasing output or efficiency.

For comprehensive and long-lasting solutions to be developed in food security, indigenous and scientific knowledge must be acknowledged and integrated. More successful tactics may be achieved by identifying the advantages of each system and encouraging cooperation between local communities, academics, and government. When ecological, cultural, and social factors are considered, solutions that are not only based on strong science but also consider cultural norms and community needs are produced. This cooperative endeavor aligns with a more all-encompassing and inclusive vision for handling the intricate problems associated with food security [40].

7. VARIOUS THREATS TO THE INDIGENOUS KNOWLEDGE SYSTEM

Indigenous knowledge systems are under attack from several directions that might compromise their effectiveness and ability to provide sustainable and context-specific solutions for food security. A few of the main dangers are as follows:

7.1 Cultural Erosion

Indigenous cultures and their traditional knowledge systems are seriously threatened by the process of globalization, especially when it comes to food security. The increasing interconnectedness of the world puts additional pressure on indigenous populations from outside sources. Globalization has the potential to bring in foreign food systems, agricultural techniques, and technology that are incompatible with indigenous knowledge's emphasis on context-specificity and sustainability. As communities may be persuaded or forced to adopt more economically driven and standardized techniques, the growing availability and impact of mass media and global markets might contribute to destroying traditional traditions [11].

Concurrently, urbanization poses an additional obstacle to conserving traditional knowledge

concerning food security among indigenous people. Indigenous groups may become profoundly disconnected from their ancestral lands and customs of agriculture because of their relocation to metropolitan regions. Younger generations may not be directly exposed to or involved in the agricultural traditions of their communities because of the change from rural to urban living. Because urban contexts value alternative skills and livelihoods, this disturbance in the intergenerational transmission of information may cause a steady reduction in the relevance and practice of indigenous agricultural systems. As a result, the combined effects of urbanization and globalization degrade indigenous knowledge systems, endangering the complex web of sustainable farming techniques that have been honed over many generations.

7.2 Environmental Degradation

The growing effects of climate change provide significant obstacles to the sustainability of native knowledge systems, especially regarding food security. Climate change and an increase in the frequency of extreme weather events profoundly impact traditional agricultural techniques and change the validity of indigenous knowledge about important topics like crop management and planting seasons. Indigenous people have historically relied on predictability, but it is being challenged increasingly, making it harder to adjust traditional agricultural techniques to the fast-changing environment [38].

At the same time, the ecosystems that indigenous populations depend on for their traditional agricultural expertise are being threatened by land degradation. Unsustainable land use practices, such as soil erosion and deforestation, weaken the resilience of these ecosystems and the resilience of traditional farming techniques. Land degradation upsets the complex relationships among biodiversity, soil health, and sustainable resource management central to many indigenous knowledge systems.

In navigating the intersection of climate change and land degradation, preserving and adapting indigenous knowledge becomes imperative. Strategies aimed at mitigating these threats should integrate the resilience inherent in indigenous wisdom with contemporary climate adaptation and sustainable land management practices. This collaborative approach recognizes the interconnectedness between environmental sustainability and the preservation

of indigenous knowledge, acknowledging the vital role in ensuring food security amidst the complexities of a changing climate [35].

7.3 Economic Pressures

The prevalence of international markets presents a danger to customary farming methods and native knowledge bases for food security. Adopting commercial agricultural practices may be encouraged by the powerful impact of global market forces, possibly pushing aside more traditional and sustainable farming techniques. Communities may be encouraged to adopt more industrialized and standardized methods to become more profitable and competitive. However, this might ignore the holistic and context-specific nature of indigenous agricultural techniques. In addition, economic strains have the potential to cause a reliance on outside resources, upending the customary, self-sufficient farming methods that have long been essential to indigenous populations. Communities may rely more on outside resources, such as artificial fertilizers or genetically engineered crops, when they struggle financially or try to boost output to satisfy market demands. This moves away from customary, regionally appropriate methods may jeopardize the sustainability ingrained in indigenous knowledge by causing soil erosion, biodiversity loss, and other adverse environmental effects [36].

7.4 Lack of Recognition and Respect

The preservation of indigenous knowledge and its ability to support other facets of community well-being, such as food security, are seriously threatened by its marginalization. Indigenous knowledge is often marginalized or undervalued in policy and decision-making processes, which ignores its significance and applicability. The marginalization of indigenous knowledge systems pertaining to agriculture and food security may lead to a dearth of resources, recognition, and support for their maintenance and advancement. Concerns about intellectual property further exacerbate the difficulties experienced by indigenous people. The cultural integrity of these communities is directly threatened by the exploitation of indigenous knowledge without due acknowledgment or recompense. Indigenous knowledge is the result of a community's collective learning and experiences, and it is frequently passed down through the generations. The cultural legacy of

indigenous communities is weakened when this knowledge is used without proper recognition or recompense, and it also deters people from continuing to use and pass down traditional farming techniques [36].

7.5 Educational Gaps

The survival of indigenous wisdom is seriously threatened by the potential loss of traditional knowledge bearers, especially when it comes to food security. The direct transfer of traditional agricultural knowledge and techniques is in real danger of ceasing as younger generations relocate to metropolitan regions or seek different forms of employment. There may be fewer heirs for the elders and community members who have historically preserved this wisdom, which could result in the loss of priceless insights into ecological management, sustainable farming methods, and other vital indigenous knowledge pertaining to food security [11].

Concurrently, the risk of losing this treasure of understanding is increased by the absence of traditional knowledge's incorporation into official educational institutions. There is an extensive comprehension and appreciation gap among younger people when traditional information is not included in traditional schooling. Indigenous viewpoints are excluded from formal schooling, which furthers the generational divide by educating younger people less about the sustainable farming methods that have traditionally been essential to their communities [11].

It will need work to identify and appreciate traditional knowledge bearers within communities to address these issues. The main objectives of strategies should be to support mentoring programs, preserve oral traditions, and provide chances for knowledge transmission across generations. Furthermore, indigenous knowledge must be included in formal education institutions to close the knowledge gap between traditional wisdom and modern perspectives, guaranteeing the ongoing dissemination of important perspectives on food security. To support sustainable behaviors that benefit both the current and future generations, this cooperative approach strengthens the robustness of indigenous knowledge systems [37].

7.6 Government Policies

Indigenous knowledge that is the basis of sustainable land management and the

continuation of traditional farming methods are seriously threatened by policies that violate their right to ancestral lands. Indigenous populations depend on traditional farming methods that are intricately entwined with their cultural and ecological settings, and they frequently have complex connections with their ancestral lands. These long-standing traditions may be disrupted by policies that neglect or weaken indigenous land rights, resulting in community dislocation and the degradation of sustainable land management principles ingrained in their traditional knowledge system [35].

Similarly, indigenous agricultural techniques are in danger from modernization programs adopted without proper respect for traditional knowledge. Government programs that prioritize quick modernization may unintentionally ignore or downplay the extensive agricultural knowledge that indigenous groups have amassed over many centuries. Neglect can lead to the abandoning of agricultural practices that have been proven effective in each context, which could result in biodiversity loss, environmental deterioration, and a reduction in the ability to adapt to changing conditions. Developing sustainable and culturally aware agricultural policy requires balancing modernization initiatives and incorporating indigenous knowledge [11].

An all-encompassing strategy that respects and protects indigenous groups' land rights is needed to address these issues. Indigenous stakeholders should be actively included in creating policies, considering their traditional knowledge and methods for sustainable land management. Resilience, sustainability, and the ongoing well-being of indigenous communities depend on promoting a balanced integration of modernization initiatives with the preservation of traditional agricultural expertise [35].

A multifaceted strategy is needed to counter these dangers, including attempts to close the gap between traditional and formal education systems, sustainable environmental practices, policymaking that acknowledges indigenous knowledge, and cultural preservation. Preserving indigenous knowledge presents a chance to improve food security by incorporating tried-and-true, regionally appropriate methods.

8. CONCLUSION

To enhance the indigenous technical knowledge system in agriculture, a multifaceted policy

approach is recommended. Firstly, it is important to recognize and respect the prevailing traditional practices and wisdom of the indigenous communities, integrating them into agricultural research, development, and extension services. This can be successfully achieved by establishing partnerships with the indigenous groups, facilitating the knowledge exchange, and providing them financial support for the community-led initiatives. Additionally, policies should be made and prioritize the protection of indigenous intellectual property rights, ensuring that traditional knowledge is not exploited without consent or compensation. Education programs should also be implemented regularly to raise awareness among farmers, researchers, and policymakers about the value of indigenous knowledge in sustainable agriculture.

Furthermore, investments should be made in infrastructure and technology. They should be directed towards empowering the indigenous communities and local people, enabling them to leverage their knowledge effectively while also addressing any existing barriers that they face. By embracing and supporting indigenous knowledge systems, policymakers can also foster agriculture practices that are not only environmentally sustainable but also culturally relevant and socially inclusive.

CONFERENCE DISCLAIMER

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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