Original Research Article

A Comprehensive review on Indigenous knowledge systems in India and its importance and role in Biodiversity Conservation

ABSTRACT:

Biodiversity is an essential support system consisting of humans, organisms, animals, etc interacting with each other to maintain a balance life on the Earth. It is important for all the living organism, on the Earth to sustain a natural world. It consists of diverse form of animals, plants, fungi, bacteria, etc. Among the aforementioned components of biodiversity plants are the important element that assist 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 act as a keystone in the field of agriculture. It is a unique and traditional character of a group of people residing at a particular place. It is considered as an important country's human capital but often overlooked and unexplored. Various local practices have developed over the time which are innovated, tested and adapted since time immemorial. These practices are non-scientific in nature, developed through various trial and error methods, location specific and dynamic in nature. Various practices that are followed in the states of India are 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 tries to develop practices which are non-harming and conserving in nature. The role of indigenous people and their knowledge have largely been contributing to preserve the biodiversity since very long. They try to interact with their local environment to keep them immaculate. Diversity of various plants and crops are maintained with the efforts of the indigenous people and their knowledge which ultimately assures for improving food security and also helps in adapting the changing climate. According to an estimate 75 per cent of the diversity of the crop was lost between the years of 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

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In writing a scientfic paper the words "should, must, etc" have no place in explaning a subject.

form of indigenous knowledge is disappearing fast hence, measures need to be taken in their favor to sustain the biodiversity and maintain food security.
Keywords: Indigenous knowledge, Indigenous people, Food security, Biodiversity, Climate change, Sustainability.

Indigenous knowledge in farming refers to the traditional knowledge and the 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 (Smith, 2018). 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 the coming future generations (Jones, 2020). Indigenous farming practices often prioritize the conservation of biodiversity as they rely on diverse cropping systems, including intercropping, agroforestry, and crop rotation, which promote genetic diversity and reduces the crop failure risks that arises due to pests, diseases, or adverse weather conditions. By cultivating a wide variety of crops and including trees and shrubs into their agriculture lands, indigenous farmers develop habitats that supports a rich and wide array of plant as well as animal species. Indigenous knowledge systems consider as a local innovation which is based on farmer's experience and the tradition, they follow to suit the agro-ecosystem conditions of the area (Bonny and Vijayaragavan, 2001) and furthermore, indigenous farming techniques often emphasize sustainable land management practices such as conservation of soil, water harvesting, and natural pest control methods, which help to maintain ecosystem health and resilience over time. For example, traditional soil conservation methods like contour bunding and terracing help to reduce and prevent soil erosion, while water harvesting techniques like building small ponds or reservoirs help to recharge groundwater and support biodiversity. 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 change in the attitude of the policy makers due to indigenous knowledge systems and has also led to the

development of the interest in this system of knowledge (Gupta et al., 1996 and Sillitoe, 2009). Recognizing and integrating indigenous knowledge into modern agricultural systems can therefore playa an important role in promoting sustainable food production and preserving biodiversity for future generations.

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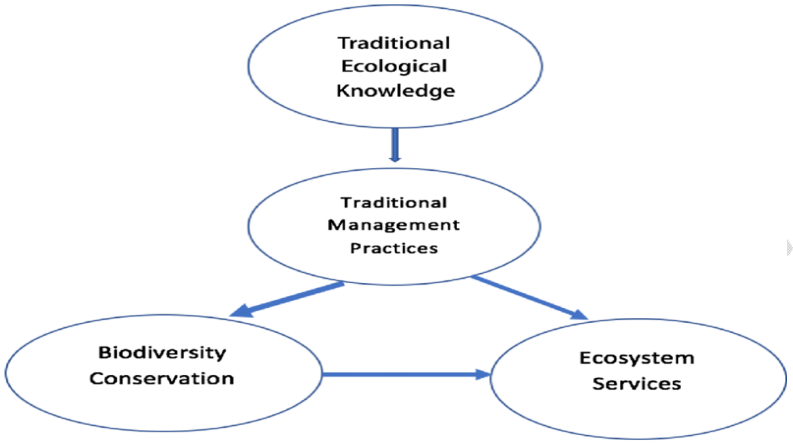

Fig: 1 Traditional knowledge system (Afentina et al, 2020)

Importance of Indigenous technical knowledge in agriculture

Most of the Indian farmers follows low-input agriculture (approximately 80 per cent of the total) (Mella et al., 2007). It shows the potential for the indigenous technical knowledge for the sustainable agricultural practices. The statisticians have researched that the almost 50 per cent of the population in the world depends on the IK for the food supplies (Hart & Vorster, 2006). The importance is as follows:

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1. **Adaptation to Local Conditions**: Adaptation capacity is the potential success of a particular system in respond to a climate stimulus (Adger et al., 2005). Indigenous technical knowledge is deeply rooted in local ecosystems and the cultural practices. It is developed over the time and tailored to specific and particular environmental conditions, such as type of soil, climate patterns, and water availability. As a result, ITK offers valuable insights into agricultural practices that is well-suited to local contexts, ensuring better adaptation and resilience to the environmental change.

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2. **Sustainable Resource Management**: Indigenous agriculture practice prioritizes sustainability, focusing on techniques that helps to conserve soil fertility, enhance water management, and promote biodiversity. The farmers use the conventional

technology and know-how in the production of crop, water and soil management, pest and diseases control, etc. (Anupam et al., 2020). For example, ITK may include methods such as agroforestry, crop rotation, and traditional irrigation systems, which contributes to the long-term health of agricultural ecosystems and minimize negative environmental impacts.

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3. **Genetic Diversity Conservation**: Indigenous communities are the custodians of rich diversity of crop and livestock verities, and wild plants that are adapted to local conditions over centuries. ITK includes traditional seed selection practices, breeding methods, and crop management practices that helps to preserve and promote genetic diversity, which is essential for crop resilience, food security, and adaptation to the changing environmental conditions. It is also being estimated by the FAO that the 30 per cent of the diversity is at high risk if the neglect is shown in the IK (Muyungi & Tillya, 2003). Therefore, it is necessary to bring the gene pool of domestic and wild crops and livestock under the indigenous knowledge system (Aluma, 2004).

4. **Resilience to Climate Change**: Indigenous agricultural practices and their 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, traditionally 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.

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5. **Cultural Preservation and Social Cohesion**: Indigenous technical knowledge is often deeply intertwined and connected with cultural traditions, beliefs, and social practices. It fosters 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 the valuable knowledge and skills to the future generations.

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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.

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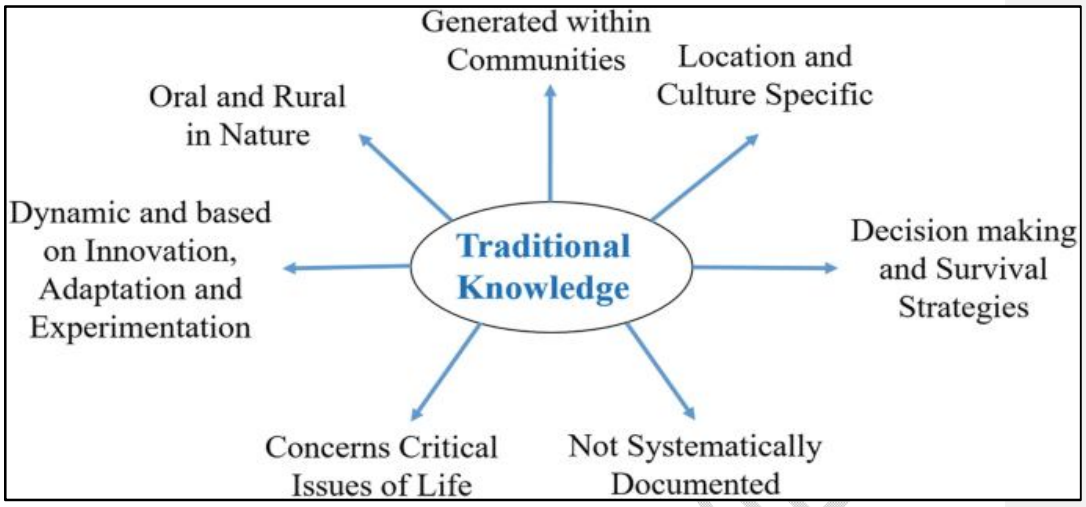

Fig 2: Major attributes of Traditional Knowledge systems (Sharma et al., 2020)

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 the agricultural challenges. First and foremost, ITK contains centuries of accumulated wisdom and practices tailored with local environments, climates, and ecosystem conditions. This knowledge enables indigenous communities to effectively manage the agricultural resources, such as fertility of soil, availability of water, biodiversity conservation, maximizing food production while minimizing the environmental degradation. Additionally, ITK emphasizes crop diversity, traditional seed saving practices, and resilient farming techniques that enhances resilience of food systems to climate variability and extreme weather conditions. By preserving and promoting indigenous agricultural and technical knowledge, communities tries to maintain diverse and nutritious food sources, even in the face of environmentally stressed conditions. Furthermore, ITK fosters community cohesion, cultural identity, self-reliance and empowering communities to assert control over the food production systems and reduce the dependence on external inputs. Ultimately to recognize and integrate 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.

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Types of Indigenous knowledge systems

1. **Traditional Indigenous Knowledge Systems**:

• The practical knowledge and methods that indigenous societies have created and passed down through the years are referred to as 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 that are 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, their primary emphasis is on practical agricultural techniques and resource management strategies. The main objective of the traditional knowledge is to restrict the over exploitation of the natural resources and to bring out a balance in the economy by restoring it (Kareemulla and Ravichandran, 2020)

2. **Cultural Indigenous Knowledge Systems**:

- Cultural indigenous knowledge systems in agriculture has 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 not only agricultural practices but also 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 agriculture system, as well as the cultural identity, worldview, and the 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.

Different Indigenous technical knowledge systems

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Indigenous practices are traditional methods of living and interacting with the environment that has been passed down through the generations within specific cultural groups. These practices often include methods for conserving the 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 the indigenous practices, we can learn valuable lessons about how-to live-in harmony with mother nature and preserve the biodiversity for the future generations. The various practices follow in different parts of the country are mentioned below:

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Table1: 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 (Hussain et al., 2014).
	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 (Bhoi et al., 2005).
	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 (Koul et al., 2012)
	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 (Prasad et al., 2004).
	BAWLIS	Bawlis are stepwells commonly found in North India, including Rajasthan, Gujarat, and Haryana. These structures store rainwater and provide a reliable source of water for

		drinking and irrigation.
	CHAUKA SYSTEM	The Chauka system, practiced in parts of Uttar Pradesh and Bihar, involves the construction of small embankments around fields to capture rainwater and prevent soil erosion (Yadav et al., 2022).
	TANK SYSTEMS	Traditional tank systems, such as Talabs in Rajasthan and Ponds in Uttar Pradesh, are used for rainwater harvesting, irrigation, and livestock watering (Palanisami et al., 1988).
	ZING SYSTEMS	The Zing system, prevalent in Ladakh and parts of Himachal Pradesh, involves diverting glacial meltwater into small channels to irrigate terraced fields (Hill, 1998).
SOUTH INDIA	KULAM	The Kulam system, also known as Eri or Tank systems, involves the construction of traditional rainwater harvesting tanks or ponds. These tanks are prevalent in states like Tamil Nadu and Andhra Pradesh, serving as vital water storage reservoirs for irrigation, domestic use, and livestock watering (Gurukkal, 1986).
	KATTAS	Kattas are traditional water diversion structures found in the Western Ghats region of South India, particularly in Kerala and Karnataka. These structures channel rainwater from streams and rivers into agricultural fields, promoting irrigation and groundwater recharge.
	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 (Crook et al., 2020).
	KAREZ	The Karez system, also known as Qanat, is found in some parts of Karnataka and Telangana. It comprises underground tunnels that transport groundwater from higher elevations to lower-lying areas, providing water for irrigation and drinking purposes (Khan et al., 2015).
	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 (Roy, 2016).
	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 (Elamuhil, 2023).
	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 (Debnath, 2020).
	KURUWA	The Kuruwa system, found in Kerala's Malabar region, involves the construction of traditional stone check dams across streams and rivers to regulate water flow and promote groundwater recharge.
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 (Koul et al., 2012).
	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 (Agossou, 2018).
	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 (Sahu et al., 2022).
	PADDY CUM	Paddy cum fish culture is a traditional farming system

	FISH CULTURE	practiced in states like Assam and West Bengal, where paddy fields are integrated with fishponds. This integrated approach enhances agricultural productivity, conserves water, and provides additional protein sources through fish cultivation (Pakhmode et al., 2023).
	BAULI SYSTEM	The Bauli system is prevalent in parts of Bihar and West Bengal. It involves constructing traditional stepwells or underground tanks to capture and store rainwater for domestic use, livestock watering, and irrigation (Siddique, 1986).
	TANKAS AND KHADINS	Tankas and Khadins are traditional rainwater harvesting systems found in states like Odisha, Jharkhand, and West Bengal. These systems involve the construction of underground storage tanks or embankments to capture and store rainwater for domestic and agricultural purposes.
	JOHAD	Johad systems, similar to 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 (Hussian et al., 2014).
	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 (Debnath et al., 2020).
WEST INDIA	VAV (STEPWELL)	Stepwells, known as Vavs, are traditional water storage and management structures found in states like Gujarat and Rajasthan. These elaborate underground structures collect rainwater during the monsoon season, providing a year-round water supply for drinking, irrigation, and domestic use (Selvaraj., 2022).
	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 (Bisen et al., 2022).
	KHADIN	The Khadin system is practiced in the arid regions of Rajasthan and Gujarat. It involves the construction of earthen embankments to capture and store rainwater, creating small reservoirs for irrigation and groundwater recharge.
	TANKA	Tankas are traditional underground storage tanks prevalent in Rajasthan and parts of Gujarat. These structures collect rainwater from rooftops and store it underground, providing a good source of water supply for drinking and domestic purpose.
	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 (Agossou, 2018).
	DONG SYSTEM	The Dong system is prevalent in tribal areas of Gujarat and Maharashtra. It involves constructing small earthen embankments across streams and rivers to capture rainwater and prevent soil erosion, promoting groundwater recharge and supporting agriculture.
	GAVAKSHI SYSTEM	The Gavakshi system, found in Maharashtra, involves the construction of small check dams and contour trenches to capture rainwater and recharge groundwater, promoting agricultural sustainability in semi-arid regions.
	PAT SYSTEM	The Pat system, practiced in parts of Gujarat, involves constructing traditional earthen embankments and ponds to capture rainwater and provide water for irrigation and domestic use.

Indigenous knowledge and biodiversity conservation

Indigenous knowledge plays an important role in biodiversity conservation by offering unique insights and practices that have been 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. Indigenous communities actively engage in practices such as rotational farming, selective harvesting, and habitat restoration, which help maintain biodiversity while ensuring the resilience of ecosystems. Furthermore, indigenous stewardship often fosters a sense of connection and reverence for the land, motivating conservation efforts that extend beyond immediate economic interests. Recognizing and integrating indigenous knowledge systems into biodiversity conservation strategies not only enhances the effectiveness of conservation efforts but also promotes cultural diversity and respects the rights and wisdom of indigenous peoples.

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Various Biodiversity conservation areas:

Protected Areas

Protected areas, such as national parks, wildlife reserves, and marine sanctuaries, are designated regions set aside for the 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 (CBD, 2000).

Restoration of Habitat

Habitat restoration process involves rehabilitation of 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 (Clewell and Aronson, 2006).

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 (FAO, 2006).

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 (WWF, 2022). Species conservation maintains ecosystem balance, prevents loss of genetic diversity, and ensures the survival of iconic species.

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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 (WWF, 2021). Community participation fosters a sense of ownership and responsibility, promotes traditional ecological knowledge, and enhances conservation outcomes.

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Table 2: List of biodiversity conservation methods

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	The Philippines' Rice Terraces Heritage Seed Bank conserves heirloom rice	Ensures food security, safeguards against crop failures, supports crop breeding	Collect and store seeds, monitor viability, promote community participation.

	future use.	varieties.	efforts.	

Role of Indigenous knowledge and biodiversity conservation methods in food security

Indigenous communities around the world have developed unique ways to manage their environments sustainably while ensuring food security for themselves. These practices include methods like 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.

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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 (Smith et al., 2019). By integrating trees into farming landscapes, agroforestry diversifies agricultural production, promotes resilience to climate change, and ensures a steady supply of various food products throughout the year. This approach contributes significantly to food security and sustainable land use practices.

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2. **Traditional Seed Saving**

Traditional seed saving, a practice deeply rooted in indigenous communities, plays a crucial role 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 (Jones, 2020). By safeguarding food security through the maintenance of a diverse gene pool, traditional seed saving enables crops to adapt to changing environmental conditions while also preserving culturally significant foods.

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3. **Community-Based Fisheries Management**

Indigenous communities leverage traditional knowledge to sustainably manage local fisheries, employing methods like regulating fishing seasons, areas, and techniques (Berkes et al., 2000). Community-based fisheries management not only conserves fish stocks but also supports food security by ensuring a steady supply of protein-rich food and preserving

cultural fishing traditions. This approach exemplifies a harmonious coexistence between human activities and the environment, benefiting both present and future generations.

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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 (Jahiruddin et al., 2013). These practices not only improves the fertility of soil but also lead to increased crop yields, contributing significantly to food security. Furthermore, by mitigating the effects of climate variability on agricultural production, terracing and water harvesting serve as sustainable solutions for bolstering resilience in farming communities.

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5. **Indigenous Agroecological Knowledge Systems**

Indigenous agroecological knowledge systems encompass a holistic understanding of local ecosystems and sustainable agricultural practices. This includes practices such as crop rotation, companion planting, and natural pest control methods (Altieri, 2018). These systems plays an important role in promoting food security by enhancing soil health, reducing dependence on external inputs, and fostering resilience to environmental changes.

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How Indigenous knowledge is different from scientific knowledge

Despite differences in methods, views, and sources, indigenous and scientific knowledge are 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 how to create more environmentally friendly and culturally aware solutions. We will examine each significant distinction in this, offering a comprehensive grasp of the ways in which scientific and indigenous knowledge contribute to the larger framework of food security. (Kumbar et al.,2023).

A. Source and Origin:

Indigenous knowledge has its origins in the customs, knowledge, and experiences that have been 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. It is upheld by lived experiences and oral traditions and

reflects a comprehensive awareness of the environment that frequently incorporates social, cultural, and spiritual components (Mistry et al., 2016).

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 (Kamwendo, 2014).

Essentially, these two systems of knowledge—indigenous and scientific—offer different but complimentary 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 that is 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 (Ajayi, et al., 2017).

B. Nature of Knowledge:

Indigenous knowledge is deeply ingrained in a larger cultural and spiritual framework, and it is distinguished by its holistic approach. 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 (Vicziany, 2017). On the other hand, scientific knowledge frequently demonstrates a narrower concentration, focusing on particular elements and perhaps separating itself from more general cultural or spiritual considerations. In science, the focus is on attaining impartiality, following standard operating procedures, and making sure 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, despite the fact that it often offers insightful explanations for specific phenomena (Kamwendo, 2014).

Despite their differences, these two knowledge systems provide complimentary 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 call for knowledge of both particulars and larger cultural contexts (Jarvis, 2007).

C. Methods of Transmission:

Indigenous knowledge is mainly passed down orally through customs or through 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 (Mistry et al., 2016). 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. In order to assure clarity, precision, and the capacity for others to critically examine and expand upon previous research, written records are prioritized in the transfer of scientific knowledge (Vicziany, 2017).

Despite their differences, these two approaches of exchanging knowledge add significantly to our collective understanding of the world. While scientific knowledge offers a codified, internationally accessible platform for information sharing and expanding upon collective understanding, indigenous knowledge is firmly anchored in the lived experiences of communities, promoting a feeling of cultural continuity. The effectiveness and richness of knowledge systems in tackling different difficulties can be improved by integrating these distinct techniques.

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D. 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 deep grasp of the relationship between culture and environment. This understanding foster behavior that are not only ecologically sustainable but also customized to meet the unique requirements of the community (Mistry et al., 2016). On the other hand, whereas scientific information may be broadly applied and generalized, it frequently lacks the precise precision needed in particular locales. The complexities of a given community's behaviors may not be entirely considered by scientific methods, which might result in treatments that are 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 (Vicziany, 2017).

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 take use of the wider perspectives offered by scientific research while recognizing and valuing local populations' adaptive skills. This cooperative strategy may be able to handle difficult problems more successfully and sustainably (Mistry et al.,2016).

E. 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 (Ajayi et al., 2017).

However, in academic and policymaking circles, scientific knowledge has always possessed a strong and authoritative position. A major factor in the legitimacy of scientific research is the rigorous peer-review process it goes through. This procedure guarantees that scientific results adhere to strict criteria for dependability, precision, and methodology. Scientific knowledge is institutionalized and distributed through institutional and scholarly channels, making it a fundamental source of information for formulating policies and making decisions (Warren et al., 1988). In order to promote more inclusive and comprehensive ways to tackling global

concerns, it is imperative to strike a balance in the acknowledgment and integration of 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 (Vicziany, 2017).

F. Integration and Collaboration:

Indigenous Knowledge promotes cooperative strategies that respect and embrace indigenous knowledge in addition to outside initiatives. It emphasizes the need of local empowerment and engagement heavily, recognizing that communities themselves have priceless insights into their own settings and difficulties. Indigenous knowledge is collaborative in character, acknowledging that active participation and respect for the knowledge maintained within the community are key factors in the emergence of sustainable solutions (Ajayi et al., 2017). Alternatively, scientific knowledge usually aims to improve or augment traditional methods, usually with an emphasis on increasing output or efficiency. In scientific circles, there is a growing realization that stronger and longer-lasting treatments can result from combining scientific knowledge with indigenous wisdom. This recognition represents a change in viewpoint toward recognizing the complimentary qualities of both systems and realizing that each offers special insights and techniques (Warren et al., 1988).

For comprehensive and long-lasting solutions to be developed in the area of 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 is in line with a more all-encompassing and inclusive vision for handling the intricate problems associated with food security (Jarvis, 2007).

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

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)

Source: Vicziany, M., & Plahe, J. (2017)

Various threats to Indigenous knowledge system

Indigenous knowledge systems are under attack from a number of 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:

***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 the destruction of traditional traditions (Mistry et al., 2016).

Concurrently, urbanization poses an additional obstacle to the conservation of traditional knowledge concerning food security among indigenous people. Indigenous groups may become profoundly disconnected from their ancestral lands and customs of agriculture as a result of their relocation to metropolitan regions. Younger generations may not be directly exposed to or involved in the agricultural traditions of their communities as a result 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. In order to solve these issues and promote food security and cultural preservation, efforts must strike a balance between valuing the good features of urbanization and globalization and preserving and reviving indigenous knowledge (Warren et al., 1988).

Environmental Degradation:

The growing effects of climate change provide significant obstacles to the sustainability of native knowledge systems, especially when it comes to food security. Climate change and an increase in the frequency of extreme weather events have a profound impact on 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 this predictability is being challenged more and more, making it harder to adjust traditional agricultural techniques to the fast-changing environment (Ajayi, et al.,2017).

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 that are central to many indigenous knowledge systems. According to (Ajayi et al. 2017), the loss of these natural underpinnings makes traditional farming techniques less successful, which exacerbates the difficulties indigenous communities already face in maintaining food security.

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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 that both play in ensuring food security amidst the complexities of a changing climate (Kumbar et al.,2023).

Economic Pressures:

The prevalence of international markets presents a serious danger to customary farming methods and native knowledge bases for food security. The adoption of 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 in an effort to become more profitable and competitive in the market. 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 have a propensity to rely more on outside resources, such artificial fertilizers or genetically engineered crops, when they struggle financially or try to boost output to satisfy market demands. This move 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 (Ponge, 2011).

A balanced strategy that navigates the demands of the global market while acknowledging the importance of traditional, sustainable farming techniques is needed to address these issues. Encouraging agroecological techniques can provide a long-term solution since they combine traditional knowledge with contemporary farming practices. A more resilient and culturally aware approach to food security may also be achieved by promoting policies that prioritize environmental sustainability, strengthening market access for traditional goods, and assisting local economies. For the long-term survival of both people and the ecosystems they rely on for food production, it is imperative to acknowledge the significance of maintaining indigenous knowledge in the face of market pressures (Warren et al., 1988)

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 (Ponge, 2011).

Reevaluating policies to guarantee the participation of indigenous viewpoints in decision-making processes is necessary to address these difficulties. Policies that assist the preservation of indigenous knowledge must acknowledge its importance in agricultural practices and food security. Furthermore, putting in place measures to defend indigenous people' intellectual property rights can help preserve their cultural legacy and the viability of their traditional agricultural expertise. To provide resilient and culturally sensitive solutions to food security concerns, it is imperative to promote a more egalitarian and inclusive approach that recognizes and values indigenous knowledge (Ponge, 2011).

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 (Mistry et al., 2016).

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 a big 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 (Mistry et al., 2016).

It will need work to identify and appreciate traditional knowledge bearers within communities in order 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, it is imperative that indigenous knowledge be included into formal education institutions in order to close the knowledge gap between traditional wisdom and modern perspectives, thereby guaranteeing the ongoing dissemination of important perspectives on food security. In order to support sustainable behaviors that benefit both the current and future generations, this cooperative approach strengthens the robustness of indigenous knowledge systems (Kamwendo, 2014).

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, which may result in community dislocation and the degradation of sustainable land management principles ingrained in their traditional knowledge systems (Kumbar et al.,2023).

Similarly, indigenous agricultural techniques are at danger from modernization programs that are adopted without proper respect for traditional knowledge. Government programs that place a high priority on 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 a given 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 striking a balance between modernization initiatives and the incorporation of indigenous knowledge (Mistry et al., 2016).

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 the creation of 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 (Kumbhar et al.,2023).

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.

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Policy recommendations and Conclusion

To enhance 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 the agricultural research, development, and the 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 made and prioritize the protection of the indigenous intellectual property rights, ensuring that the traditional knowledge is not exploited without consent or the compensation. Education programs should also be implemented regularly to raise the awareness among farmers, researchers, and policymakers about the value of the indigenous knowledge in sustainable agriculture. Furthermore, investments should be made in infrastructure and technology and should be directed towards empowering the indigenous communities and local people, enabling them to leverage their own knowledge effectively while also addressing any existing barriers that they face. By embracing and supporting the indigenous knowledge systems, policymakers can also foster agriculture practices that are not only environmentally sustainable but also culturally relevant and socially inclusive.

Fig 3: Policy recommendations for indigenous technological systems (Vijayan et al., 2022)

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