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A Review On Traditional Ecological Knowledge In Biodiversity And Land Conservation.

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Abstract

Through generations of close engagement with their surroundings, Indigenous and local communities have developed cumulative, adaptive, and place-based knowledge known as Traditional Ecological Knowledge (TEK). TEK offers a comprehensive understanding of ecosystems, species behavior, seasonal cycles, and sustainable resource management. It is based on cultural beliefs, practices, and oral traditions. TEK is becoming more widely acknowledged as an essential supplement to scientific approaches in biodiversity and land conservation, especially as society contends with rapid biodiversity loss, land degradation, and climate change (1,2).The importance of TEK in protecting ecological balance and managing natural resources is examined in this review. TEK-based methods demonstrating sustainable land use and biodiversity conservation include community-managed forests, rotational farming, sacred groves, and traditional irrigation systems (3). Through culturally embedded practices, indigenous communities around the world—such as Aboriginal Australians, the Inuit, and in India, the Bishnoi, Apatani, and Khasi-Garo tribes—have successfully conserved ecosystems. Where scientific data is scarce, TEK excels in community-led species identification and habitat restoration initiatives (4,5).Globalization, ecosystem disruption, cultural deterioration, and weak legal protections pose major threats to TEK despite its importance (Aswani et al., 2018). Furthermore, urgent calls for Indigenous data sovereignty and equitable partnerships have emerged in reaction to ethical concerns surrounding TEK exploitation (3). Future conservation efforts must bridge TEK and contemporary science through ethical collaboration, policy support, and participatory models (2,4). This paper advocates for the recognition, preservation, and integration of TEK into national and global conservation strategies. Respecting Indigenous rights and empowering communities will foster biodiversity resilience, cultural continuity, and sustainable development.

Key Words- Traditional Ecological Knowledge (TEK), Biodiversity Conservation,Indigenous Knowledge Systems,Sustainable Land Management, Community-Based Conservation

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1. Introduction

In recent decades, the world has witnessed rapid biodiversity decline and degradation of ecosystems due to industrialization, deforestation, monoculture agriculture, and unsustainable resource use. A systematic review across Web of Science and Scopus highlights the critical role of Indigenous local wisdom in nature conservation—spanning forest management, flora and fauna protection, and water and land stewardship—while warning that modernization threatens both biodiversity and traditional practices (6). Amidst scientific and technological innovations in conservation, Traditional Ecological Knowledge (TEK) emerges as a time-tested, community-based framework for understanding and preserving biodiversity. TEK's cumulative, inter generational insights are increasingly documented: for example, a review of 40 studies across 12 African countries (2001–2022) revealed significant contributions of TEK to biodiversity and resource-management strategies (7).TEK refers to the cumulative body of knowledge, practices, and beliefs developed by Indigenous and local communities over generations, through close interaction with nature. This holistic, adaptive knowledge is rooted in cultural traditions, embodying worldviews and ethical commitments beyond mechanistic analysis (8).Unlike conventional scientific approaches that are often reductionist, TEK is holistic, context-specific, and spiritually grounded. Philosophical analyses emphasize that while TEK can operate through mechanistic understanding, its holistic dimension—integrated with spiritual and ethical worldviews differs significantly from conventional academic ecological knowledge (9).

TEK's potential in enhancing biodiversity conservation and sustainable land management is now widely acknowledged by global institutions such as the United Nations, Convention on Biological Diversity (CBD), and Food and Agriculture Organization (FAO). The CBD framework explicitly recognizes TEK and related Indigenous knowledge systems in global biodiversity governance (7).This paper explores TEK's role, its effectiveness, regional examples, and how integrating it with modern science can foster more resilient and inclusive conservation systems. Case examples such as the participatory development of an ecosystem-based management plan in Brazil's Araçá Bay demonstrate how TEK codified through community practices and social mechanisms—can inform planning and management in disturbed coastal systems (10). Similarly, habitat restoration efforts in India's elephant corridors have effectively integrated TEK into restoration planning and species selection (11).

2.TEK in Biodiversity Conservation

2.1 Sacred Sites as In Situ Conservation: Meghalaya (India) & Ghana

Indigenous communities maintain sacred groves, rivers, forests, and mountains governed by taboos, spiritual beliefs, and social sanctions. These sacred sites effectively function as **in situ conservation areas**, harboring rare, endemic, and often endangered species within local cultural governance systems (12,13). Among the Khasi, Garo, and Jaintia peoples of Meghalaya, small forest patches such as *Law Kyntang* and *Law Lyngdoh* are strictly protected under customary law (14). These groves show significantly higher biodiversity than nearby disturbed areas, with over 500 species across 131 families recorded in baseline surveys (12, 15). Notably, 91 rare or endangered species, many endemic to Northeast India and Meghalaya, are preserved in these sacred groves (16).

In Ghana, sacred forests managed by local communities show higher biodiversity than state reserves, with studies documenting greater species richness and density for trees and mammals in sacred groves compared to state-managed areas (17,18)These community-managed ecosystems are maintained through spiritual and cultural norms, including taboos and rituals, which discourage overuse and support conservation (19,20). Despite external pressures, such sites remain vital refuges amid widespread ecological degradation (21).

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2.2 Traditional Wildlife Stewardship: The Bishnoi and Inuit Communities

Indigenous communities such as the Bishnoi in Rajasthan and Inuit in the Arctic embody deeply rooted ecological wisdom honed over centuries. Their traditional stewardship practices, grounded in spiritual values and environmental observation, support both biodiversity conservation and climate-resilient livelihoods.

Bishnoi Community of Rajasthan Established by Guru Jambheshwar in the 15th century, the Bishnoi community's environmental ethic forbids harming trees or wildlife and mandates compassion for all living beings (22). Their religious rules emphasize "do not cut green trees" and "be compassionate toward all living beings" as core principles (23).

In 1730, Amrita Devi and 363 others sacrificed their lives to prevent the felling of Khejri trees—an event now legendary in environmental activism (24). Contemporary Bishnoi practices include building and maintaining water tanks ("nadi" and "talao") to provide water during summer, permitting wild animals to drink freely, storing grains ("sandh-ghera") in fields for wildlife, and even feeding injured animals, sometimes nursing fawns with human milk (23). A recent documentary underscores how these stewardship practices support strong biodiversity—herds of blackbuck and chinkara thrive even along the Indo-Pak border zones (25)

To honor such values, the Government of India established the Amrita Devi Bishnoi National Award for Wildlife Conservation, awarded annually since 2001, commemorating her sacrifice and promoting wildlife guardianship (26)

2.3 Indigenous Agricultural Biodiversity

Traditional agroecological systems maintain high levels of genetic diversity through techniques such as mixed cropping, seed saving, and rotational farming. These time-tested practices contribute not only to food and livelihood security but also to ecological sustainability (27, 28). In India's Ziro Valley, the Apatani tribe practices an integrated paddy-cum-fish cultivation system where rice and fish (Cyprinus carpio) are raised together, enhancing productivity and resource efficiency. Millet is often cultivated on field bunds, adding to crop diversity and soil stability (29,30).

Similarly, in Central America, the Milpa system—a traditional polyculture of maize, beans, squash, and other crops—mimics natural ecosystems and supports agro-biodiversity. This triad of crops offers ecological complementarities: beans fix nitrogen, maize provides structural support, and squash suppresses weeds with its ground cover (27). Additionally, the Milpa system integrates fallowing and agroforestry, contributing to long-term soil regeneration and pest control without chemical inputs (27, 28) These Indigenous systems exemplify how cultural traditions and ecological knowledge are interwoven to maintain biodiversity and ecosystem services over time.

3.TEK in Land Conservation and Sustainable Land Use

3.1 Traditional Soil and Water Management

Traditional ecological knowledge (TEK) in India offers powerful models for water conservation aligned with natural hydrological cycles, especially in drought-prone and semi-arid landscapes. Three celebrated examples—Ahar-Pyne in Bihar, the Zabo (or Ruza) system in Nagaland, and the johad system in Rajasthan—demonstrate how TEK fosters regenerative agriculture, groundwater recharge, and community resilience.

In *South Bihar*, the **Ahar-Pyne** system comprises interlinked catchment ponds (*ahars*) and diversion channels (*pynes*) that capture both monsoon runoff and river overflows. These structures drain

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floodwater during high rainfall, while retaining enough water in ahars to support irrigation and recharge aquifers during drought years (29)

In **Nagaland**, the **Zabo system**—recently clarified by researchers as properly termed *Ruza*—is a 100-year-old integrated regenerative farming method practiced by the Chakhesang Naga in Phek District (30,31) It layers natural catchment forest at hilltops, silt-retention tanks and lined ponds mid-slope, cattle yards, and paddy fields downslope. Rainfall runoff is channelled through forested catchments and sediment traps into ponds; the same water passes through livestock enclosures and picks up manure before irrigating rice fields—thus delivering both water and fertility in one flow (32,33,34.). Research shows that this system yields around 1.9 t/ha of paddy—almost double the output of shifting cultivation (jhum)—and fosters soil organic carbon and nutrient buildup without chemical fertilizers (32, 34). As of 2023, over 200 harvesting ponds across roughly 26 hectares support over 950 households in Kikrüma village, under communal governance structures like village development boards (31).

Finally, in **Rajasthan**, the **johad** is a traditional crescent-shaped earthen check dam built across drainage lines so that monsoon runoff is captured and allowed to percolate into the soil, recharging groundwater and curbing erosion (35, 36) . From 1985 onward, Tarun Bharat Sangh (TBS), led by Rajendra Singh—the “Waterman of India”—mobilized communities to revive over 8,600 johads across 1,086 villages, particularly in Alwar district 36) The results have been dramatic: shallow aquifer water tables rose from depths of 100–120 m to 3–13 m, crop intensity increased, drinking water security improved, and local rivers such as Arvari were rejuvenated (35, 36).

Across all three systems, TEK aligns with natural hydrological cycles: forested catchments feed ponds and paddy fields; water flows follow gravity-run channels; excess percolates into the ground. Simultaneously, nutrient cycles are closed via livestock manure and organic litter, reducing dependency on external chemical inputs. These systems foster land regeneration—improving soil moisture, rebuilding aquifers, expanding vegetation cover, and stabilizing local climates.

In summary, Ahar-Pyne, Zabo (Ruza), and johads exemplify how traditional ecological knowledge integrates hydrology, agroecology, and community governance. They not only conserve water and regenerate land but also enhance resilience to floods, droughts, and climate variability. Reviving and adapting these models offers compelling pathways for sustainable water management across India’s semi-arid and monsoon-mediated landscapes.

3.2 Forest Conservation and Shifting Cultivation

Shifting cultivation—or *jhum*—when practiced with long fallow periods and cyclic rotations, can enhance soil fertility and support biodiversity in tropical forest ecosystems. Research reviewing tropical forest soils under shifting cultivation systems indicates that fallow phases lead to increased soil organic matter, higher activity and diversity of soil fauna, and rehabilitation of seedbanks and soil structure (37) (SciELO). Shifting cultivators in the Indian Northeast also employ controlled burning as part of community-based fire management traditions, particularly in Mizoram among Mizo villagers. The system is regulated by village councils with clear roles, fire line preparation, burning schedules, and penalties for uncontrolled spread. Long fallow cycles and careful burning help rejuvenate grasslands and favor certain bird and herb species that thrive in post-burn and successional habitats (38.) In the Amazon, the Kayapo people maintain forest mosaics and shifting cultivation systems that generate a patchwork of regenerating and cultivated areas. Their agro-ecological practice of slash-and-burn cultivation followed by extended fallows supports a wide diversity of food crops (up to 250) and medicinal plants (up to 650), and preserves forest mosaics that enhance ecosystem productivity over time (39). These mosaic landscapes allow rapid crop yields in new plots (e.g. sweet potatoes, manioc), while older fields concentrate useful wild species and soil-enhancing vegetation. Such systems reflect the Kayapo's deep ecological knowledge and intentional management to sustain long-term forest and soil health. (39). Across the Amazon and other regions, Indigenous cultural burning practices—involving small, low-intensity burns timed seasonally—have been shown to benefit biodiversity and reduce the risk of catastrophic wildfires. These burns rejuvenate fire-adapted plants, stimulate flowering and fruiting, and support habitat heterogeneity (40, 41)

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4.Case Studies on TEK: India

4.1 Community Forest Management under CFR Rights in Odisha, Madhya Pradesh, and Maharashtra

Community Forest Resource (CFR) rights under Section 3(1)(i) of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, empower Gram Sabhas to govern, conserve, and sustainably manage customary forest lands and resources (42,43). These rights are central to tribal self-governance, livelihood security, and ecological stewardship (42).

In Maharashtra—particularly in Gadchiroli district—Gram Sabhas have successfully claimed CFR rights and set up Community Forest Resource Management Committees (CFRMCs) that manage forest use, monitor fire lines, and limit commercial timber extraction. Bamboo productivity in such Gram Sabha-managed areas reportedly doubled, and local ecological indicators improved compared to state-managed forests (44,45). In Odisha, several villages like Kamtana, Pipri, and Bidapaju have used CFR rights to restore degraded forest ecosystems, prevent illegal tree felling, and auction minor forest produce—earning lakhs of rupees in revenue and strengthening local economies (45).CFR rights hold immense potential to reconcile forest conservation with tribal livelihoods. Maharashtra offers scalable governance models, while Odisha demonstrates socio-economic transformation through CFR-based local enterprises. Strengthening financial, technical, and administrative support to CFRMCs, aligning conservation policies with FRA-mandated rights, and enforcing gram sabha consent mechanisms remain critical to realising the Act's promise for millions of forest dwellers across India.

4.2 Integration of Traditional Ecological Knowledge and Scientific Knowledge: A Synergistic Approach

Traditional Ecological Knowledge (TEK)—the place-based, culturally transmitted understanding of ecosystems—offers deep historical and localized insight that can complement scientific ecological understanding (42). Scientific knowledge, with its emphasis on standardized methodologies and predictive modeling, fills in gaps in TEK's qualitative depth, forging a more robust environmental stewardship approach.For instance, Albuquerque et al. (2021) explore how TEK and academic ecological knowledge (AEK) can be related across scales—population, community, and ecosystem—highlighting the complementarity of these systems (42). Similarly, Souther et al. (2023) review two decades of TEK literature, noting TEK's contributions to ecological assessment, conservation, and restoration within U.S. public land management, while pointing to persistent gaps in policy integration (43).One applied example comes from Kenya's mountain bongo conservation. Sheppard, Muturi, and Munene (2024) demonstrate that when scientific data are limited—such as demographic parameters from camera trapping—TEK collected through expert interviews can fill critical knowledge gaps, aiding reintroduction planning (44).On the global integration front, (45) propose the "multiple evidence base" approach, where TEK and scientific knowledge are treated as parallel, valid strands feeding into ecosystem governance, rather than one subordinating the other. Mistry and Berardi (46) also emphasize that bridging knowledge systems is essential for resilient science.Despite these opportunities, integration remains challenging. Henn, Ostergren, and Nielsen (47) uncover obstacles in integrating TEK into U.S. natural resource management, including differing epistemological perspectives and institutional resistance to collaboration with Indigenous knowledge systems.Addressing these challenges requires **co-production**: meaningful collaboration where TEK holders and scientists jointly design research, interpret findings, and delineate actions. This ensures both knowledge traditions maintain integrity and influence outcomes equally.In summary, TEK enriches scientific understanding with context-specific, long-term perspectives, while science adds analytical rigor and scalability. When integrated equitably—through frameworks like multiple evidence bases—these knowledge systems can together enhance biodiversity conservation, resource management, and climate resilience. Embedding ethical, participatory, and institutional support mechanisms is essential to unlocking the full potential of this synergy.

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4.3 Policy Frameworks Supporting Integration of TEK and Scientific Knowledge

Policy instruments at international and national levels are increasingly designed to integrate Traditional Ecological Knowledge (TEK) with scientific knowledge, fostering equitable environmental governance. Article 8(j) of the Convention on Biological Diversity (CBD) mandates that contracting Parties "respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities and promote their wider application and encourage the equitable sharing of benefits arising from their utilization" (48). At COP16 (49), Parties adopted a new Programme of Work on Article 8(j) and established a permanent Subsidiary Body to ensure Indigenous peoples' meaningful participation in convention processes (50). The Kunming–Montreal Global Biodiversity Framework (KMGBF) further reinforces this commitment, with goals and targets explicitly recognizing TEK. Notably, Target 3 commits to the fair and equitable sharing of benefits from traditional knowledge associated with genetic resources (51), while SBSTTA-26 (May 2024) recommended the addition of a headline indicator for land-use change and land tenure in traditional territories, crucial for operationalizing the Programme of Work on Article 8(j) (52). Complementing these developments, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) promotes a "multiple evidence base" (MEB) approach that treats TEK and scientific knowledge as separate but equally valid, enabling them to collaboratively inform assessments without one dominating the other (53). The 2010 Nagoya Protocol strengthens these protections by applying to genetic resources and associated traditional knowledge, ensuring fair benefit-sharing, and including measures for prior informed consent (PIC) and mutually agreed terms (54). More recently, in May 2024, the World Intellectual Property Organization (WIPO) adopted a landmark treaty requiring patent applicants to disclose the source of genetic resources and associated traditional knowledge, directly addressing intellectual property protection and biopiracy (55, 56). COP16 also delivered new funding mechanisms, such as the "Cali Fund," which mandates that corporations using genetic-resource-derived data share a portion of their revenues, with at least 50% directed to Indigenous peoples and local communities (57). Furthermore, the agreement formally recognizes Indigenous peoples and people of African descent as key biodiversity stewards, affirming their central role in conservation governance (58).

5.Challenges in Preserving Traditional Ecological Knowledge (TEK)

Preserving Traditional Ecological Knowledge (TEK) faces multifaceted challenges—social, cultural, institutional, and technological—that threaten its transmission and continued relevance. Urbanization, global market integration, and modern education often disrupt traditional lifestyles, weakening intergenerational TEK transfer. As communities become wealthier and more urban, dependence on traditional ecological practices declines, eroding the cultural and environmental bonds TEK depends upon (59). Formal education that excludes TEK further limits its uptake among youth; in New Zealand, for example, formal schooling tends to displace *mātauranga* (60), diminishing cultural identity and pride (61).

Power imbalances also shape how TEK is documented and applied. TEK research is often framed and controlled by Western institutions, leading to the extraction of knowledge without meaningful participation by Indigenous peoples. This process risks transferring authority over TEK from knowledge holders to external researchers, undermining community control and decision-making (62). Moreover, historical and ongoing colonial attitudes contribute to the dismissal of TEK as inferior or incompatible with "scientific" knowledge (63). Documentation of TEK presents further concerns. Being dynamic, orally transmitted, and culturally contextual, TEK can lose its meaning, vitality, and relational context when converted into static formats such as documents, maps, or digital archives (*Sustainability Directory*, "What Are the Challenges in Documenting and Preserving TEK?"). Archival efforts led by outside institutions may perpetuate harm, limiting access or refusing repatriation of culturally significant materials. The risk is illustrated by the wildfire that destroyed the Dene community's YKS building, along with its TEK archives, with no formal catalog or backup (64). Institutional and technical barriers also impede TEK preservation. Conservation practitioners and institutions often lack the cultural competence to respectfully engage TEK holders, including understanding cultural protocols, building trust, and appreciating the dynamic nature of TEK. Misinterpretations or misapplications can occur if researchers impose Western paradigms without adequate sensitivity (65). Finally, linguistic and digital divides complicate preservation efforts. TEK is deeply embedded in Indigenous languages, and translating it into dominant languages can lead to loss of nuance

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(65). Digital preservation poses further challenges, as many Indigenous communities lack infrastructure, resources, or digital literacy for effective archiving. When repositories are controlled by external actors, TEK risks commodification, depriving communities of control or benefit—a concern intensified by AI and data platforms that may misinterpret TEK or prioritize commercial over cultural interests (66).

6. The way forward

Strengthening the role of Traditional Ecological Knowledge (TEK) in biodiversity conservation requires multi-pronged strategies. Documentation and digitization through oral histories, local biodiversity registers, and digital archives—preferably in native languages—are vital for safeguarding intergenerational knowledge transfer (67). Education and awareness initiatives should embed TEK into school curricula, environmental education, and citizen science, fostering respect for Indigenous knowledge systems (68). Legal frameworks must be reinforced to ensure Indigenous territorial rights and equitable access–benefit sharing (69). Capacity building should train Indigenous youth in ecological monitoring while promoting participatory, interdisciplinary research combining ecology, anthropology, and ethnobotany (70). Finally, ethical collaboration demands adherence to Free Prior and Informed Consent (FPIC) protocols, with explicit recognition of community intellectual property rights (71). These measures can integrate TEK and science into resilient, culturally grounded conservation models.

7.Conclusion

Traditional Ecological Knowledge represents a rich, often untapped reservoir of wisdom in biodiversity and land conservation. It reflects a deep, reciprocal relationship between people and nature, emphasizing stewardship rather than exploitation. Amid mounting ecological crises, TEK offers resilient, adaptive, and culturally respectful pathways to sustainability. However, recognizing its value is not enough. Efforts must focus on protecting its carriers—Indigenous communities and local custodians—through legal, educational, and ethical frameworks.Integrating TEK with modern science is not merely a conservation strategy; it is a paradigm shift toward inclusive, pluralistic, and equitable environmental governance. There is a long way forward for TEK to creep into the people for a true enforcement.

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