



INTEGRATING TRADITIONAL ECOLOGICAL KNOWLEDGE IN BIODIVERSITY CONSERVATION: BRIDGING INDIGENOUS WISDOM AND SCIENTIFIC INNOVATION FOR SUSTAINABLE FUTURES

Integrando o conhecimento ecológico tradicional na conservação da biodiversidade: unindo a sabedoria indígena e inovação científica para futuros sustentáveis

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ABSTRACT

Traditional Ecological Knowledge (TEK) represents community-rooted ecological wisdom and insight developed over centuries through repeated, long-term engagement with the surrounding environment. Drawing on publications from 1990–2024, this review assesses the ways how TEK support and reinforce biodiversity conservation and its interface with formal scientific practice and knowledge systems. Through a review of narrative methodology, the research delineates four dominant themes: convergence and divergence between TEK and scientific conservation, actionable integration pathways, structural and epistemic constraints, and the factors and conditions that can strengthen support for successful cross-knowledge collaboration. Findings show that TEK plays a vital role in strengthening environmental assessment, ecosystem restoration, climate-adaptive practices, and sustainable resource governance; however, structural barriers remain such as unequal power dynamics, constrained legal protection, and insufficient acknowledgement of indigenous people's rights. In parallel, evidence from case studies demonstrates that robust TEK integration materialises in contexts and ambience where trust partners cultivate trust, engage in participatory decision-making and adhere to Free, Prior and Informed Consent arrangements. Based on the above, the study concluded that respecting TEK holders' sovereignty and ensuring ethically grounded collaboration are essential for more just, culturally grounded and resilient conservation futures.

Keywords: Biodiversity, Traditional ecological knowledge, Sustainable, Ecosystem, Review

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INTEGRANDO O CONHECIMENTO ECOLÓGICO TRADICIONAL NA CONSERVAÇÃO DA BIODIVERSIDADE: UNINDO A SABEDORIA INDÍGENA E A INOVAÇÃO CIENTÍFICA PARA FUTUROS SUSTENTÁVEIS

*Integrating traditional ecological knowledge in biodiversity conservation: bridging indigenous wisdom
and scientific innovation for sustainable futures*

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RESUMO

O Conhecimento Ecológico Tradicional (TEK) representa a sabedoria e o conhecimento ecológico enraizado na comunidade, desenvolvidos ao longo de séculos por meio de um envolvimento repetido e de longo prazo com o ambiente ao redor. Com base em publicações de 1990–2024, esta revisão avalia as formas como as TEC apoiam e reforçam a conservação da biodiversidade e ela se conectam com a prática científica formal e os sistemas de conhecimento. Por meio de uma revisão da metodologia narrativa, a pesquisa delinea quatro temas dominantes: convergência e divergência entre TEK e conservação científica, vias acionáveis de integração, restrições estruturais e epistêmicas, e os fatores e condições que podem fortalecer o apoio para uma colaboração bem-sucedida entre conhecimentos. Os resultados mostram que a TEK desempenha um papel vital no fortalecimento da avaliação ambiental, restauração de ecossistemas, práticas adaptativas ao clima e governança sustentável de recursos; No entanto, barreiras estruturais permanecem, como dinâmicas de poder desiguais, proteção legal limitada e reconhecimento insuficiente dos direitos dos povos indígenas. Paralelamente, evidências de estudos de caso demonstram que a integração robusta das TEK se materializa em contextos e ambientes onde parceiros de confiança cultivam, participam da tomada de decisões participativa e seguem os arranjos de Consentimento Livre, Prévio e Informado. Com base no exposto, o estudo concluiu que respeitar a soberania dos detentores de EK e garantir uma colaboração eticamente fundamentada são essenciais para futuros de conservação mais justos, culturalmente fundamentados e resilientes. Palavras-chave: Biodiversidade, Conhecimento ecológico tradicional, Sustentável, Ecossistema, Revisão

INTRODUCTION

Biodiversity brings forth the diverseness of species, genes and ecosystems that form the natural world for its perpetual functionality and resilience (OLIVER et al., 2015, AGARWAL, TIWARI 1996). Fundamentally, the impact of biodiversity is fathomable in its ecosystem services like climate regulation, pollination, water purification, and nutrient cycling, which are all discerning to human continuity and well-being (OLIVER et al., SINGH, 2024). Biodiversity also bears profound cultural, spiritual, and psychological significance, particularly for Indigenous peoples and rural communities whose identities and livelihoods are inextricably linked to their ecosystems (GADGIL et al., 1993).

However, global biodiversity is facing unprecedented decline, despite its centrality to human continuity. According to the 2019 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report, nearly one million species may face extinction in the coming decade if transformative changes are not implemented (IPBES, 2019, KADYKALO, YOUNG, 2021). This alarming situation stems from both direct pressures—unsustainable agricultural expansion, deforestation, climate change, pollution, urban sprawl, invasive species, and overharvesting—and indirect drivers such as institutional failures, socio-economic inequalities, and globalization (WUDU et al., 2023).

To counter these trends, many countries have relied heavily on Western scientific conservation models, leading to the creation of national parks, protected areas, and species-specific management plans (KADYKALO, YOUNG, 2021). However, these approaches, though ecologically motivated, have often been socially exclusionary—displacing or criminalizing Indigenous and local communities, and marginalizing their stewardship systems (MARTIN et al. 2020, CAVANAGH, BREHONY, 2024). Scholars argue that these top-down, technocratic interventions have undermined both local legitimacy and long-term sustainability (BAVISKAR, 2013, WEST, HAIDER, 2020). Consequently, there is now a critical need to re-envision conservation frameworks that are inclusive, participatory, and culturally grounded.

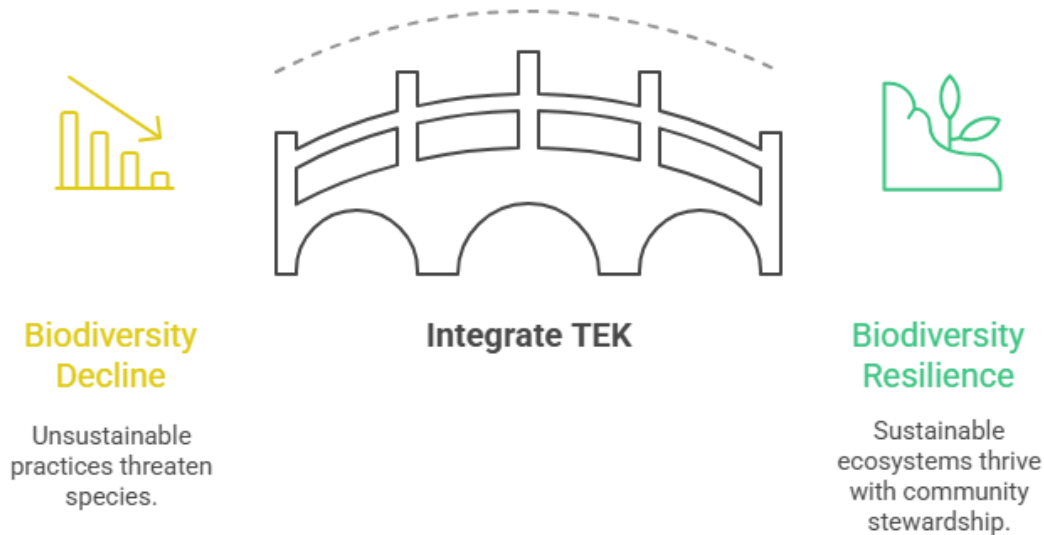
In recent years, there has been a shift toward pluralistic conservation approaches that recognise Traditional Ecological Knowledge (TEK) (GATTO, 2020, LAM et al., 2020). TEK encompasses rich, clustered bodies of knowledge, perspectives, and practices that were construed and sustained over years by the aboriginal and locals by virtue of their immediate human-nature relationships (BELLDINA, 2020). In the same way, it encompasses both spiritual and ethical principles that guide people in the use, promotion, interaction, sustainability, and reciprocation of their environments (TIU, 2016, GUERRERO, SJOSTROM, 2025). TEK offers deep understanding of land-use systems, species behaviour, climate variability, and ecosystem dynamics, while embedding ethical and spiritual principles of reciprocity and stewardship (TIU, 2016, SHARIFIAN et al., 2022).

Unlike the compartmentalized structure of Western science, TEK is holistic, adaptive, and relational, integrating ecological, cultural, and moral dimensions of sustainability. Importantly, it emphasizes co-existence rather than control, and continuous feedback between human and natural systems. Across the world, Indigenous practices such as rotational farming in West Africa (MASON et al., 2015, FÉLIX et al., 2018), seasonal ecological calendars in Australia (MCKEMEY et al., 2020), and Arctic wildlife monitoring among the Inuit (PARLOW, 2022, KULETZ et al., 2024) exemplify TEK's contribution to environmental resilience and adaptive management.

While several review (ALBUQUERQUE et al., 2021, FERNÁNDEZ-LLAMAZARES et al, 2021, LAM et al. 2020) have explored the broad interface between TEK and biodiversity conservation, few have critically examined how TEK is operationalized within modern conservation innovations—such as adaptive co-management, ecosystem-based governance, and participatory monitoring frameworks. This paper therefore seeks to fill this analytical gap by focusing on the mechanisms through which TEK informs, complements, and transforms modern biodiversity conservation strategies. This paper therefore seeks to: (1) to identify and evaluate pathways and barriers for integrating

Traditional Ecological Knowledge (TEK) into contemporary conservation practice; (2) to assess how co-production and “two-eyed seeing” approaches facilitate or constrain alignment between Indigenous and scientific knowledge systems; and (3) to synthesise lessons from global case studies to derive actionable recommendations for policy, governance and community-led practice.

Fig. 1 - Integrating TEK transforms biodiversity conservation for long-term sustainability



1 MATERIALS AND METHODS

1.1 Search Strategy and Data Sources

This study applied a narrative review to synthesise literature on TEK and biodiversity conservation (MADDEN et al., 2018, SIDDAWAY, WOOD, 2019), The search covered works published between 1990 and 2024 and was conducted throughout 2024 across Scopus, Web of Science, JSTOR, Google Scholar and ProQuest, alongside grey literature from IPBES, CBD, UNEP, FAO, UNESCO and national knowledge repositories. Search terms combined TEK, conservation and governance concepts, with database-specific strings provided in Appendix A. After removing duplicates, titles, abstracts and full texts were screened, and only English-language sources directly linking TEK with biodiversity or ecosystem management were retained. The full workflow is shown in the PRISMA diagram in Figure 2.

1.2 Data Screening and Assessment

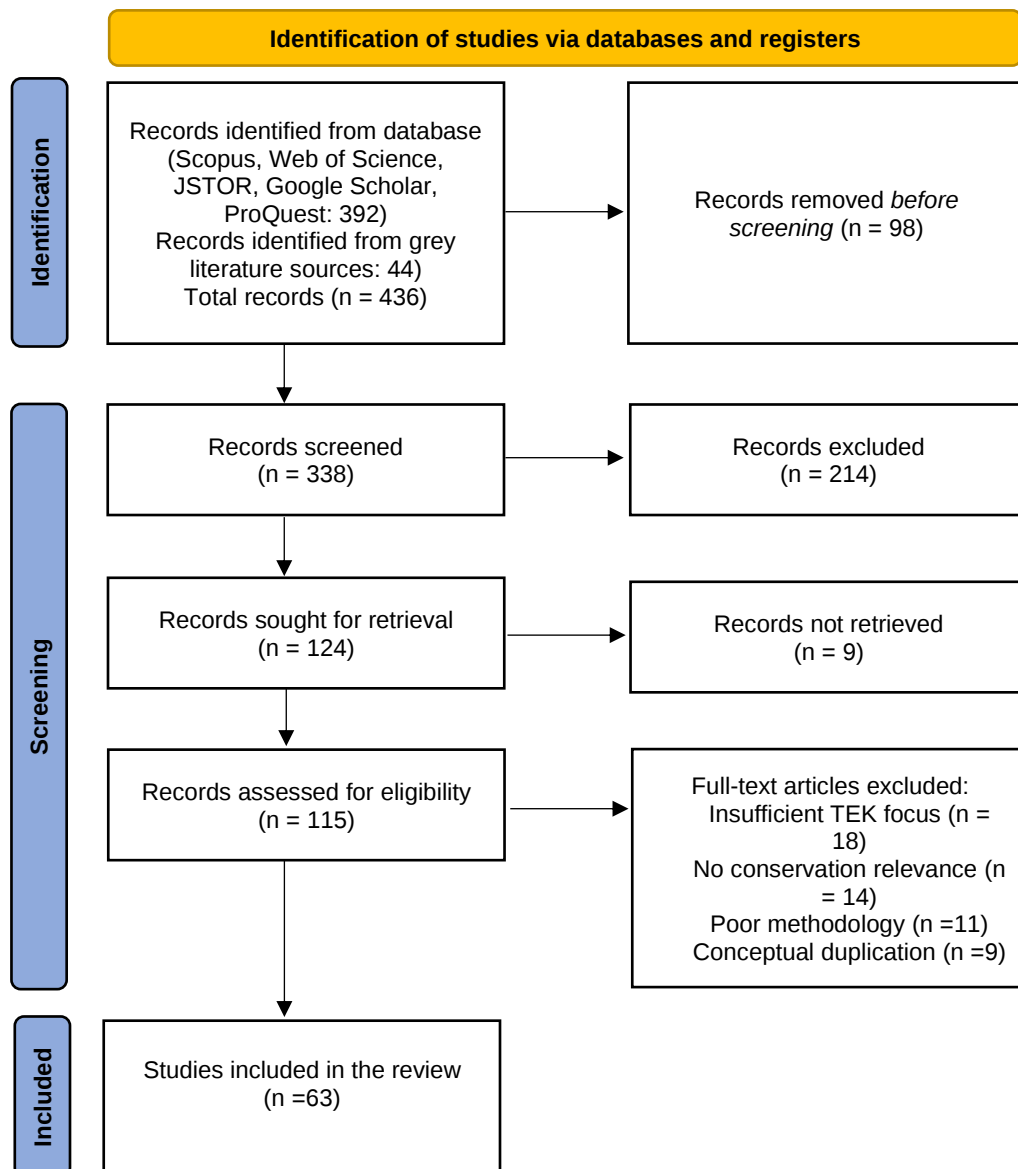
Screening and eligibility checks were independently performed by two reviewers, with disagreements resolved through discussion or by a third reviewer. Extracted information included each source’s context, TEK focus, and conservation relevance, the nature of TEK–science interaction, reported outcomes and governance elements. Empirical studies were appraised using an adapted CASP framework, while grey literature was assessed for credibility and transparency; these assessments informed the interpretive weight assigned to each source. Case studies in Table 1 were

purposely selected to reflect diverse regions and forms of TEK–science collaboration and are illustrative rather than exhaustive.

1.3 Data Analysis and Ethical Considerations

Data were analysed through iterative qualitative coding, leading to four core thematic areas that structure the results: relationships between TEK and scientific conservation, pathways of integration, governance and equity considerations and conditions that enable effective collaboration. Ethical considerations guided the review; only publicly available TEK with documented permission or FPIC was included, and sensitive or restricted materials were omitted. The review acknowledges the limitation of relying on English-language sources and variation in grey-literature quality, both of which were mitigated through appraisal and weighted synthesis.

Figure 2 - PRISMA Flow Diagram of Literature Selection Process



2 Results and Discussion

Pathways for integrating traditional ecological knowledge into biodiversity conservation

The narrative synthesis identifies four interconnected pathways for integrating Traditional Ecological Knowledge (TEK) into modern biodiversity conservation. First, it highlights key points of convergence and divergence between TEK and scientific conservation, establishing the basis for meaningful integration. Second, global case studies demonstrate how TEK–science collaborations function and the outcomes they achieve. Third, the analysis underscores persistent barriers that impede effective integration. Finally, it outlines governance mechanisms, legal frameworks, and enabling conditions that support equitable and culturally grounded inclusion of TEK in conservation planning. Together, these themes show how TEK can be embedded in contemporary conservation in ways that respect Indigenous agency, strengthen ecological outcomes, and promote sustainability.

2.1 Convergence and Divergence between TEK and Scientific Conservation

This subsection examines the key areas of convergence and divergence between Traditional Ecological Knowledge (TEK) and Western scientific conservation. While both knowledge systems aim to promote ecological sustainability, they differ in epistemological foundations, modes of transmission, and approaches to environmental management. The following analysis synthesizes these intersections and tensions to establish a conceptual basis for understanding how TEK and scientific conservation can complement—or at times conflict with—one another.

In recent decades, the importance of indigenous perspective and traditional practice in providing a more holistic understanding of environmental issues and solutions is becoming more intense and acknowledged (TURNER et al., 2022). From the standpoint of convergence, the upsurge of Traditional Ecological Knowledge (TEK) hinges on its promotion of cultural sensitivity and because it can as well be integrated with Western scientific approaches to have more effective and sustainable conservation efforts (SILVESTRU, 2023, RANI et al., 2025). The adoption of these interdisciplinary approaches, despite their diverse epistemological traditions, will afford a more comprehensive and savvy understanding of environmental stewardship, species behaviour, ecosystem processes and other environmental issues. Other potential benefits and implications of such an integration of TEK and scientific approaches include fostering more inclusive, adaptive, and culturally attuned responses to biodiversity loss and environmental degradation, which in turn will balance human and environmental needs (RANI et al., 2025, NARUKA, REDDY, 2022).

Scientific knowledge revolves around experimentation, observation and evidence-based research with the focal point and ultimate goal of comprehending ecological processes and systems (NORBERG et al., 2022). By contrast, TEK is generally characterized for its multifaceted, nuanced and integrated approaches in understanding complex systems; it recognizes the interconnectedness of human and natural systems. In contempt of the dissimilarity, both knowledge systems aim to promote a deeper understanding, appreciation and sustainability of the natural world (BAULCH, 2024).

Thus, in areas of clear convergence, the combination and collaboration of both knowledge and systems can inform more effective strategies for environmental conservation and sustainable development and bring about novel and innovative solutions (RANI et al., 2025). Despite these points of synergy, even with these differences, both knowledge systems focus attention and have the common goal of promoting a deeper understanding of the natural world. So, the combination of both approaches in an equitable and respectful manner can bring about hybrid solutions that are scientifically robust and socially meaningful (SILLITOE, 2024). The integration of such will ensure a balance and fair exchange of knowledge without marginalisation or dominance but rather the valuing and acknowledging of the contribution of each knowledge system (SILLITOE, 2024).

One of the identified crystal domains where synergy can bring unique uniformity is the areas of ecosystem management and resource monitoring (Chakraborty, 2024). According to the author, this collaboration will provide information on more effective and sustainable practices for managing natural resources such as fisheries, water, forests and the rest. Surprisingly, the TEK holders often have detailed site-specific knowledge and information of their environment in terms of phenological patterns (such as breeding cycles, flowering times, and migration patterns); species distributions (including knowledge of abundance and geographic range of plant and animal species); and climatic variability (such as precipitation, temperature and weather extremes) that are invaluable for filling gaps in scientific datasets (CHAKRABORTY, 2024, FORD et al, 2016). Take, for instance, Indigenous fire management practices in Australia have informed ecologists and land managers about fire regimes that promote biodiversity and reduce fuel loads (SINGH, SRIVASTAVA, 2025). Much the same, Inuit hunters in the Canadian Arctic have contributed crucial insights into sea-ice dynamics and polar bear behaviour that enhance scientific climate model (PARLOW, 2022).

Furthermore, ecological decisions are more likely to succeed on the assumption that decision-makers are conversant with TEK, which ensures conservation planning and efforts are aligned with local cultural values, context and social institutions. Like in India and West Africa, the sacred groves are community-protected forest patches associated with cultural significance and spiritual beliefs. Littlefair et al. (2024) found that such culturally significant landscapes are rich in biodiversity and have higher conservation value than surrounding managed lands. Therefore, the working of scientists and policymakers with local communities wherein local values and practices are prioritized, can lead to more effective and better conservation outcomes and long-term sustainability (PRAJAPATI, PRIYA, 2025). However, integrating TEK and scientific knowledge is not without tensions (ALBUQUERQUE et al., 2021). Differing worldviews, power imbalances and historical injustices can create uncertainty, misunderstandings and ineffective collaboration. Besides, scientists and institutions may underestimate, exploit or co-opt Indigenous knowledge, giving rise to improper recognition or compensation, whereas TEK holders may harbour fear of exploitation, misrepresentation, loss of traditional practices or the erosion of their cultural autonomy (ALBUQUERQUE et al., 2021, RANI et al., 2025).

Meanwhile, divergence becomes more pronounced in methodological traditions. Western knowledge is, to a large extent, preferred for quantitative data and written documentation, while TEK, which is deeply rooted in cultural and community heritage, is qualitative and embedded, transmitted via storytelling, songs, and oral narratives (RANI et al., 2025). These divergences are not merely technical but reflect deeper epistemic worldviews. Accordingly, to manoeuvre these tensions, practitioners and scholars such as Albuquerque et al. (2021), Rani et al. (2025) and Tumbali (2025) have therefore advocated and reiterated the need for intercultural dialogue and knowledge co-production. Intercultural dialogue represents the open and respectful exchange of communication between individuals and groups from different cultural backgrounds.

2.2 Global Evidence Studies: Applications of TEK-Science Integration

Building on the conceptual analysis, the second theme draws on global case studies to illustrate how TEK and scientific conservation have been combined in practice. These cases demonstrate the diverse ways Indigenous knowledge enhances ecological monitoring, resource management, and adaptive decision-making across cultural and ecological contexts (refer Table 1). Together, they provide empirical evidence for the potential and effectiveness of TEK–science partnerships.

Australia: Aboriginal Fire Management

In Australia, one of the well-documented examples of TEK employed by the Aboriginal communities, particularly for fire management, is what is known as “fire-stick farming” (NEALE, 2023, SINGH, SRIVASTAVA, 2025). This fire ecology technology, which has been in existence for thousands of years, is practically executed by adopting controlled burns, low intensity, to prevent large-scale wildfires, to promote ecological renewal and to manage landscapes (LIEBLICH, 2023). Neale (2023) and Liebllich (2023) further asserted that these schemes and methods enhance ecosystem health, resilience and biodiversity. This technology has therefore been incorporated into contemporary fire management programs. This is particularly evident in a project named “Savanna Burning”, where it was seen that incorporating these traditional methods resulted in reducing carbon emissions, revitalising ecosystems, and increasing Indigenous employment

Nigeria: Sacred Forests and Indigenous Agroforestry

There is another critical form of TEK-driven conservation found among Indigenous Yoruba communities in Nigeria for preserved sacred forests (JIMOH et al., 2012, SINTHUMULE, 2023). The Indigenous people actually emplace and spell out religious and cultural taboos to protect these forest patches which they esteem as decent and copious havens for endangered animal and plant species. Studies have shown that there are massed intact forest structures and bounteous biodiversity in sacred groves placed in juxtaposition with neighbouring non-protected regions (OGAR, 2023, ADENIYI, 2021). In the same vein, Okomanyi (2022) state that in northern Nigeria, the engagement in traditional agroforestry practices where species like locust bean (*Parkia biglobosa*) and shea (*Vitellaria paradoxa*) are cultivated contributes immensely not only to food security and soil fertility but also to biodiversity conservation.

Canada: Inuit Knowledge and Arctic Wildlife Monitoring

In the Canadian Arctic, reputable and germane collaborations have been well established between the Inuit communities and scientists towards monitoring climate change impacts and, more importantly, wildlife populations. According to Rode et al (2021), Inuit hunters have, for instance, been instrumental in providing meticulous, longitudinal observations of sea ice conditions, animal behaviour and environmental changes that have greatly complemented and built up the accuracy of ecological assessments. While Buschman (2021) corroborates the assertion, they state that TEK played a contributory role in co-management of polar bear populations and effectively and culturally contributed to any framework pertinent to wildlife governance.

Brazil: Kayapo Indigenous Forest Stewardship

In the Brazilian Amazon, the Kayapo people possess far-reaching experience and knowledge of managing and maintaining resource management and forest ecology (TALLMAN ET AL., 2024). The land stewardship systems including selective harvesting, rotational farming, and ethnoecological classification developed by the indigenous people are quite impactful and have gone a long way in preserving vast tracts of tropical rainforest. In the meantime, by virtue of partnerships and collaborations with relevant conservation organisations, the Kayapo have fortuitously harnessed their Traditional Ecological Knowledge (TEK) to curb deforestation, rack up territorial rights, and also bring about biodiversity conservation (GARCIA et al., 2024). Obviously, in this relation, the contribution of TEK and Indigenous governance to sustainable livelihoods and large-scale forest preservation were succinctly manifested.

Malaysia: Orang Asli and Community-Based Forest Management

In Peninsular Malaysia, for generations the Indigenous Orang Asli people maintained a well-documented, nuanced, and complicated traditional knowledge system for forest resource management⁵³. As part and parcel of their cultural heritage and identities, historically, the Orang Asli people engaged in participatory resource assessments and

community mapping projects towards achieving advocacy for their land rights, participated in co-management initiatives, and mapped out their traditional territories (DIANSYAH, SAKAWI, 2022). Forests are better preserved and protected given the TEK role contribution that avail immense and opened opportunities for such a collaborative model arrangements. Be that as it may, the taken of Orang Asli's rights and self-reliance into cognizance to attain environmental stewardship and actualize sustainable end results clearly demonstrated community-led-based forest management.

Tanzania: Maasai Pastoralism and Rangeland Conservation

Lankester & Davis (2016) made known that Maasai people in East Africa, have long sustained the ecological balance of their communities' savannah landscapes by employing traditional rotational grazing approaches. The authors reiterated that the group's pastoral management technique which involves alternating livestock through different grazing fields, practically allows and supports plant vegetation recovery, development and reduce grazing pressure natural habitat, stimulates plants growth, enables animal movements, and enhances overall ecosystem wholeness. This perhaps may have been the rationale prompting various stakeholders to enter into collaborations with the community. A study by Tubey et al. (2019) reported that in recent years, conservation NGOs have partnered with Maasai communities to foster community conservancies and development goals that support the sustainable coequality both livestock and wildlife. This model also demonstrates the compatibility of traditional pastoralism with modern conservation goals.

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Table 1 - Global Case Studies Demonstrating Applications of TEK–Science Integration in Biodiversity Conservation					
Country / Region	Indigenous Group / Community	TEK Practice or Knowledge System	Scientific / Conservation Integration	Key Lessons	Ref.
Australia	Aboriginal communities	“Fire-stick farming”: controlled low-intensity cultural burning for landscape management	Integrated into national and regional fire management programs (e.g., Savanna Burning initiative)	Reduced fuel loads; decreased catastrophic wildfire risk; enhanced biodiversity; increased Indigenous employment and carbon credit benefits	43-44,39
Nigeria	Yoruba communities; Northern rural communities	Sacred grove protection; Indigenous agroforestry involving species such as <i>Parkia biglobosa</i> and <i>Vitellaria paradoxa</i>	Scientific validation of biodiversity richness in sacred groves; agroforestry incorporated into sustainable landscape approaches	High species richness and intact forests in sacred sites; improved soil fertility; food security; sustainable livelihoods	45-48
Canada (Arctic)	Inuit communities	Longitudinal observations of sea-ice conditions, wildlife behaviour (e.g., polar bears, seals)	TEK incorporated into wildlife co-management plans, climate models, and Arctic monitoring frameworks	More accurate ecological assessments; strengthened climate models; effective polar bear co-management	49-50
Brazil (Amazon)	Kayapo people	Ethnoecological classification; selective harvesting; rotational farming; territorial surveillance	Partnerships with NGOs and scientists to support Indigenous-led forest management and monitoring	Effective forest preservation; reduced deforestation; strengthened Indigenous territorial rights	51-52
Malaysia	Orang Asli communities	Participatory mapping; customary forest use; ecological knowledge of species and habitats	Incorporated into co-management models, community forest monitoring, and land rights advocacy	Improved forest protection; enhanced recognition of Indigenous land tenure; strengthened community governance	53-54
Tanzania / Kenya (East Africa)	Maasai pastoralists	Rotational grazing; pasture management; water and rangeland stewardship	Integrated into community conservancies and wildlife–livestock coexistence frameworks	Improved rangeland health; sustained wildlife migration routes; reduced overgrazing; enhanced community income	55-56

2.3 Structural and Epistemic Constraints to Integration

Despite their complementarity, integrating TEK into conservation frameworks remains constrained by longstanding systemic barriers. These impediments cut across epistemological differences, political, cultural, linguistic, and institutional dynamics, and dimensions. This subsection, therefore, synthesizes how these constraints have hindered the integration efforts and made them often fall short. It went further to underscore the need for more just and inclusive governance approaches and in the interest of guaranteeing worthwhile, purposeful, ethical, and effective collaboration between the knowledge systems.

Epistemological Differences and Knowledge Hierarchies

Prominent among the key challenges facing the integration of TEK into Western conservation models has to do with epistemological differences (SINTHUMULE, 2023). Generally, TEK is qualitative, comprehensive, and practical, often transmitted by way of lived experience, oral traditions, and ritual (LUDWIG, POLISELI, 2028). On the contrary, scientific knowledge gives precedence to replicability, abstraction, and empirical quantification^{58,59}. These disparities, according to Albuquerque et al. (2021), could lead to fallacious assumptions and weakening of TEK when scientific standards are single-handedly and absolutely used as the only valid lens without scrutiny. To further worsen the situation, the institutionalised knowledge hierarchies tend to sideline TEK, conceiving it as inferior, anecdotal, or secondary to scientific data, which in turn debilitates its credibility and its application in conservation planning and frameworks.

Intellectual Property and Biopiracy

A further major blockade stems from insufficient legal and ethical frameworks safeguarding Indigenous intellectual property. In most cases, according to Gaitenidis (2025), the extraction or appropriation of TEK is being carried out without the consent, recognition, permission or consultation of the local communities, with the aftermath of cultural exploitation and biopiracy. This will then culminate in the withholding of vital information or sharing knowledge by the Indigenous communities on account of dismay and abhorrence of misappropriation or commercialisation by corporations, NGOs, or external researchers. It also said that the absence of legal frameworks to safeguard cultural integrity and collective ownership further attenuates people's participation and trust at both national and international levels (SCHULER, 2013, SINTHUMULE, 2023).

Power Imbalances and Political Marginalization

The socio-political space in which the TEK holders (including Indigenous and local communities) operate is often marked by systemic inequities, land dispossession, and historical marginalisation (PANNELL, 1997, MOSURSKA et al., 2023). It could rightly be said that these power imbalances to a greater extent delimit the ability of TEK holders to access decision-making forums, influence conservation policies, or secure tenure rights. Therefore, the challenge is that the conservation interventions spearheaded by international organisations in particular can inadvertently perpetuate colonial imperialism by imposing external agendas that undermine local communities' autonomy and agency. There is no mincing words: without proper fundamental shifts that empower Indigenous governance and policymaking, integration efforts will continue to suffer extractivism or tokenism.

Institutional Rigidity and Policy Gaps

Another bottleneck militating against the integration of traditional ecological knowledge into scientific conservation is the institutional rigidity and policy gaps. It is a common phenomenon to see conservation frames of reference and governance systems not patterned or constructed to give room for plural knowledge systems. Those

frameworks, such as technocratic procedures, bureaucratic structures, and rigid mandates, most likely have a tendency to favour standardised, quantifiable approaches over participatory, place-based ones (RANY ET AL., 2025). Furthermore, many national biodiversity action plans and policies are devoid of a substantial practical framework that can adequately accommodate TEK or support the Indigenous-led initiatives.

Linguistic and Cultural Barriers

Considering the frame-up of TEK being engrossed in Indigenous worldviews, languages, and cosmologies, it will be somehow arduously difficult to translate into policy or scientific language. This is further imperilled by the loss of Indigenous languages due to cultural assimilation and by extension thwarting the transmission of TEK across generations (BOLDT, LONG, 1984). The consequential effects of those scenarios are oversimplification or misinterpretation of knowledge shared during the exchange processes which outrightly lead to decontextualization or cultural insensitivity of TEK, thus reducing its authenticity and efficacy in conservation planning.

Ethical Concerns and Consent

From all indications, ethical engagement with TEK encompasses not only data collection but also requires building on informed consent (FPIC), benefit-sharing, free prior and mutual respect so as to sustain the relationship (RANI et al, 2025, CHAKRABORTY, 2024). It is, however, awesome and disturbing to note that many previous conservation projects and research have failed to recognise and hold to these fundamental principles, giving rise to resistance, distrust and disengagement from Indigenous communities. That is to say, past failures have caused widespread scepticism and triggered community pushback. It is therefore distinctly obvious that in the absence of culturally appropriate ethical protocols and safeguards that respect indigenous cultures, TEK integration can be good-for-nothing.

2.4 Governance Conditions and Policy Mechanisms Enabling Integration

The final theme identifies the policy environments, governance structures, and enabling conditions necessary for effective and ethical incorporation of TEK into conservation planning. It examines international legal frameworks, national innovations, and rights-based approaches that support co-production, Indigenous leadership, and knowledge pluralism. These policy mechanisms outline the pathways through which TEK can be fully embedded in biodiversity conservation strategies.

International Legal and Policy Instruments

In recent times, considerable conventions and policy frameworks are given due recognition, upholding the role of Indigenous Peoples and TEK in biodiversity conservation. In particular, Article 8(j) of the Convention on Biological Diversity (CBD) emphasises the need to respect, preserve, and maintain Indigenous knowledge significant to biodiversity conservation^{65,66}. The CBD also gives priority to getting approval for its promotion and the involvement of knowledge holders in its wider application. Ditto, the call for inclusive governance and equitable benefits-sharing among stakeholders, particularly Indigenous Peoples and local communities in respect to their genetic resources and traditional knowledge, was further augmented by the Post-2020 Global Biodiversity Framework and the Aichi Biodiversity Targets (CARIÑO, ZALTZMAN, 2025).

The same way the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) formulated a framework which precisely encourages and empowers Indigenous communities' participation in decision-making and further promotes and protects their rich cultural diversity. According to Articles 25–32, the Indigenous Peoples are given the right to self-determination, which enables them to not only take control over traditional lands, territories and

resources but also make decisions about them (BARRIE, 2013, KNOWLES, LOVERN, 2015, CAMBOU, 2020). These global legal instruments are not just established references for national policy development handling indigenous people but, in the same vein, promote consistency and accountability.

National and Regional Policy Innovations

At the national level, several countries are sequentially allowing their institutions, policies, and laws to incorporate, recognise, and value TEK in environmental conservation and management. In New Zealand, for instance, the Treaty of Waitangi acknowledged and supported joint governance and supervision with traditional concepts of Māori (indigenous people) in areas like kaitiakitanga (guardianship) of natural resources and the rest (WEBSTER, 2017). In the Philippines, the recognition of Indigenous land tenure and knowledge systems under the Indigenous Peoples' Rights Act (IPRA) of 1997 legally enables the communities to set up Ancestral Domain Sustainable Development and Protection Plans (ADSDPPs) that integrate TEK into conservation strategies^{71,72}. These examples bring to light the significance of legal recognition and organisational support in integrating and implementing TEK-galvanised conservation efforts. In a similar manner, Canada's Constitution Act, under Section 35, recognises Indigenous rights, upholding incorporation of Inuit Qaujimajatuqangit (traditional knowledge) and the co-management arrangements in environmental assessments⁷³.

Participatory and Rights-Based Approaches

Hither, emphasis is laid on creating an enabling environment that will accommodate robust participatory, rights-based approaches, as these will be a prime foundation for conservation strategies to be articulated. The centre of attention of this framework takes into account collaborative planning, power-sharing in governance structures and Free, Prior and Informed Consent (FPIC). Studies like Corson et al. (2020) and Rani et al. (2025) made known that participatory bounding, indigenous-led supervising, and intermutual management of protected areas are practical tools that can foster mutual learning and trust. Added to the above, affirming and respecting Aboriginal sovereignty also plays a fundamental role in preserving cultural richness and sustainable biological diversity (DAVIS, 1999).

Capacity Building and Knowledge Co-Production

It is noteworthy to note that building community and institutional capacity has also been identified as an integral fundamental integration framework. This ranges from training programmes and multicultural education to co-research initiatives that can help traverse knowledge systems while adhering to their distinct epistemologies. As such, a frame-up like this must be entrenched in order to foster integration effortlessly. Recent studies, such as Rani et al. (2025), provide invaluable insight on the need to build community and institutional capacity. Tengö et al. (2020) emphasis biocultural protocols, intercultural forums, and knowledge exchanges, particularly to support knowledge co-production and improve the legitimacy and effectiveness of conservation decisions. Still, their findings underscore the importance of creating avenues to ensure and establish equitable integration where TEK and scientific knowledge can inform each other—without assimilation or dominance. This will depend on, according to authors, the flexibility, humility, and willingness to challenge dominant paradigms within science and policy in a bid to have good policy frameworks and enabling conditions for integrating TEK into conservation.

CONCLUSION

This review shows that Traditional Ecological Knowledge (TEK) is a vital, living system that enriches biodiversity conservation when engaged respectfully and on equal terms with science. Evidence from diverse contexts demonstrates that TEK strengthens ecological understanding, supports sustainable management and enhances

community-led stewardship. However, tensions arise when TEK is marginalised, extracted without consent or detached from the rights of its holders. Effective conservation therefore requires genuine partnerships grounded in trust, FPIC, shared decision-making and legal protection. Safeguarding TEK is not only an ethical obligation but a practical pathway toward more just, resilient and culturally grounded conservation futures.

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Conflict of interest

The authors declare that there is no conflict of interest concerning this paper.

Author Contributions

Ahmed Ahmed Olaitan conceived the study, designed the research framework, conducted the literature review, and led the manuscript writing. Asmawi Ibrahim, Hezzrin Binti Mohd Pauz and Ahmad Aizuddin Md Rami provided supervision, critical revisions, and strategic oversight. Azeez Fatai Abiola, Mohd Syaiful Nizam Abu Hassana, Umunna and Mathias Ofonedu contributed to theoretical framing, methodology, and literature validation. Bolaji Kofoworola Adedigba and Tokede Abiodun Morenike assisted with case study analysis and policy discussions. Adebayo Dorcas Olukemi and Nosiru Mojisola Olubukola supported data synthesis, citation management, and manuscript review. All authors reviewed and approved the final version.

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APPENDIX A: SEARCH STRING

Scopus	(TITLE-ABS-KEY("Traditional Ecological Knowledge" OR "Indigenous Knowledge" OR "Local Ecological Knowledge" OR "Indigenous Environmental Knowledge" OR "Traditional Knowledge") AND TITLE-ABS-KEY("biodiversity conservation" OR "ecosystem management" OR "environmental stewardship" OR "protected areas" OR "conservation practice" OR "climate adaptation") AND TITLE-ABS-KEY("co-production" OR "knowledge integration" OR "two-eyed seeing" OR "co-management" OR governance OR "environmental policy")) AND PUBYEAR > 1989 AND PUBYEAR < 2025
Web of Science	TS=("Traditional Ecological Knowledge" OR "Indigenous Knowledge" OR "Local Ecological Knowledge" OR "Traditional Knowledge") AND TS=("biodiversity conservation" OR "ecosystem management" OR "environmental governance" OR "protected areas" OR "conservation strategy") AND TS=("co-production" OR "knowledge co-production" OR "two-eyed seeing" OR "knowledge integration" OR co-management OR governance) Timespan: 1990–2024 Indexes: SCI-EXPANDED, SSCI, AHCI, ESCI
JSTOR	("Traditional Ecological Knowledge" OR "Indigenous Knowledge" OR "Local Ecological Knowledge") AND ("biodiversity conservation" OR "ecosystem management" OR "environmental governance") AND ("co-management" OR "knowledge integration" OR "co-production" OR "two-eyed seeing")
Google Scholar	(Google Scholar supports broad strings; results were filtered manually.) "Traditional Ecological Knowledge" OR "Indigenous Knowledge" OR "Local Ecological Knowledge" "biodiversity conservation" OR "ecosystem management" OR "environmental governance" "co-production" OR "knowledge integration" OR "two-eyed seeing" OR "co-management" 1990..2024
ProQuest	AB("Traditional Ecological Knowledge" OR "Indigenous Knowledge" OR "Local Ecological Knowledge") AND AB("biodiversity conservation"

INTEGRATING TRADITIONAL ECOLOGICAL KNOWLEDGE IN BIODIVERSITY CONSERVATION: BRIDGING INDIGENOUS WISDOM AND SCIENTIFIC INNOVATION FOR SUSTAINABLE FUTURES

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BOLAJI KOFOWOROLA ADEDIGBA, TOKEDE ABIODUN MORENIKE, ADEBAYO DORCAS OLUKEMI,
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	OR "ecosystem management" OR "environmental governance") AND AB("co-production" OR "knowledge integration" OR "two-eyed seeing" OR "co-management") Publication dates: 1990–2024 Language: English Document type: Theses, dissertations, reports
Grey Literature Sources	Grey literature sources required manual search, using combinations of the keywords: • Traditional Ecological Knowledge • Indigenous Knowledge • biodiversity • conservation governance • co-management • FPIC • knowledge co-production Platforms searched included: • IPBES • CBD Clearing-House Mechanism • FAO Indigenous Peoples Platform • UNEP Publications Repository • UNESCO LINKS Programme



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