

From Ethnobiological Knowledge to Biocultural Justice: Food, Health, Livelihood, and Conservation Pathways in Social Ecological Systems

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ABSTRACT

Traditional ecological knowledge is increasingly invoked as a resource for food security, community health, livelihoods, climate adaptation, and conservation, yet its ethical and institutional conditions are often treated as secondary. This integrative review synthesizes 19 overlapping Scopus records published in 2024–2027. The corpus covers ethnobotany, ethnoecology, ethnoveterinary care, wild foods, non-timber forest products, community forestry, biological invasions, hunting, gastronomy tourism, and artificial intelligence for crop domestication. Using abstract-level evidence, the review compares knowledge domains, social differentiation, resource-use pathways, methods, conservation tensions, and governance implications. The synthesis shows that traditional knowledge operates as practical infrastructure: it broadens low-cost healthcare, strengthens dietary diversity, supports pastoral and forest livelihoods, and maintains cultural human–environment relations. Its benefits, however, are conditional. Market integration can increase income while accelerating overharvest and unequal value capture; introduced species can provide uses while homogenizing knowledge; documentation

can support conservation while exposing communities to appropriation; and technological selection can improve domestication decisions while obscuring culturally specific values. Across studies, women, elders, migrants, linguistic communities, collectors, and market actors hold differentiated knowledge, but benefit sharing, consent, tenure, longitudinal change, and community control are rarely evaluated. The review proposes a Biocultural Integrity Framework linking knowledge continuity, material security, ecological reciprocity, and institutional fairness. It argues that future research should combine ethnographic depth, ecological and nutritional measurement, longitudinal comparison, participatory governance, and transparent data stewardship. This framework redirects ethnobiological research from documenting useful species toward evaluating who sustains knowledge, who benefits from its mobilization, and whether ecological and cultural diversity remain jointly viable.

Keywords: traditional ecological knowledge; ethnobiology; biocultural diversity; food security; community health; non-timber forest products; conservation governance

1. INTRODUCTION

Traditional ecological knowledge is often described as a collection of facts about useful plants, animals, habitats, and seasonal practices. The supplied literature supports a more consequential interpretation. Knowledge is embedded in mobility, food preparation, healing, household labor, market exchange, language, forest access, and relations with particular species. Gaddi pastoralists carry ethnoveterinary knowledge along seasonal migration routes; Himalayan communities retain adaptive food practices through wild plant use, fermentation, preservation, and agroforestry; and urban markets connect rural plant production with culturally informed consumption (Devi et al., 2026; Sharma et al., 2026; Zhang et al., 2026). In these settings, knowledge is not simply cultural memory. It functions as practical infrastructure through which communities secure food, health, income, identity, and adaptive capacity.

Recent ethnobiological studies have become increasingly quantitative. Researchers calculate use value, relative frequency of citation, fidelity level, informant consensus factor, cultural importance, family importance, and related indices to identify culturally salient taxa and therapeutic agreement (Batool et al., 2025; Fatima et al., 2026; Muhammad et al., 2025). Multivariate analysis, ordination, clustering, association networks, laboratory nutrient assays, economic calculations, and ecological trait measurements have expanded the evidentiary range of the field (Malunguja et al., 2025; Niaz et al., 2026; Waheed et al., 2025). This methodological diversification enables ethnobiology to speak to conservation prioritization, food systems, public health, agroforestry, and rural development. It also creates a risk that culturally situated relations are compressed into rankings whose policy meaning is assumed rather than demonstrated.

The corpus reveals a consistent practical promise. Medicinal plants provide accessible options where formal services are

distant or costly; wild edible foods supplement rural diets; non-timber forest products generate household income; and traditional management may sustain forest regeneration and biodiversity (Aijaz et al., 2024; Lalrinmawia et al., 2025; Malunguja et al., 2025). At the same time, every pathway contains a tension. Commercialization may reward collectors yet intensify extraction. Documentation may preserve threatened knowledge yet detach it from community authority. Introduced species may become economically or medicinally useful yet reduce the distinctiveness of knowledge across ethnic groups. Hunting practices may express cultural identity and subsistence relations while placing pressure on wildlife. Community forestry may improve ecological conditions while reproducing exclusion and unequal benefit sharing (Jameel et al., 2027; Lalrinmawia et al., 2025; Niaz et al., 2026; Zaman et al., 2025). These tensions are not peripheral ethical concerns added after biological or economic analysis. They determine whether the mobilization of traditional knowledge strengthens or weakens the social ecological systems that produced it. A species can score highly on a use index and still be ecologically vulnerable. A product can command a high price while women who collect it remain marginal to decisions. A wild food can be nutritionally rich yet inaccessible because of habitat loss or market reorganization. A culturally important introduced plant can support present livelihoods while contributing to ecological invasion or knowledge homogenization (Gupta et al., 2024; Muhammad et al., 2025; Neblea et al., 2025; Niaz et al., 2026). The relevant analytical question is therefore not only which resources are useful, but under what ecological, social, and institutional conditions their use remains legitimate and durable.

Food and medicine offer a particularly clear illustration of this integrative problem. Edible plants traded in Baise City combine

nutritional and preventive health roles, making an urban market a site of both food security and knowledge continuity (Zhang et al., 2026). Wild foods in Tanzania show substantial variation in mineral, vitamin, proximate, and phytochemical composition, demonstrating that the category “wild food” contains nutritionally heterogeneous resources (Malunguja et al., 2025). Reviews of edible flowers and Himalayan Apiaceae likewise connect culinary practice with bioactive potential, safety, cultural relevance, and resource availability (Abdullah Khoja et al., 2024; Gupta et al., 2024). Yet food-system resilience depends on more than identifying valuable taxa. It also depends on access, preparation knowledge, safety assessment, continuity of native crops, and the capacity of local institutions to resist or negotiate market-driven simplification (Rivera et al., 2024; Sharma et al., 2026).

Healthcare evidence shows the same need for integration. Studies of women’s healthcare, human ethnomedicine, and livestock care document substantial taxonomic diversity and strong agreement for selected treatments (Batool et al., 2025; Fatima et al., 2026; Sarwar et al., 2025). These findings justify pharmacological and toxicological prioritization, but they do not by themselves establish clinical efficacy or safety. Nor do frequency-based indices explain who controls knowledge, whether disclosure was collectively authorized, or how benefits from subsequent innovation would be distributed. The corpus repeatedly calls for preservation, validation, or sustainable utilization, yet contains limited direct evaluation of consent, intellectual authority, data governance, or benefit-sharing arrangements (Devi et al., 2026; Fatima et al., 2026; Muhammad et al., 2025).

The social distribution of knowledge further complicates any unitary notion of “the community.” Women are primary collectors of non-timber forest products around Ayubia National Park, while women, older respondents, housewives, practitioners, and

midwives retain substantial knowledge relevant to gynecological care in Punjab (Fatima et al., 2026; Zaman et al., 2025). Linguistic communities in Indus Kohistan show different wildlife-use patterns, and isolated ethnic groups in Gilgit-Baltistan differ in their adoption and use of native and exotic plants (Jameel et al., 2027; Niaz et al., 2026). Migratory interaction can increase similarity in resource use, whereas limited interaction may maintain greater distinction. Knowledge is thus plural, mobile, gendered, generational, and shaped by the geography of encounter.

This review responds to a gap within the supplied corpus: the evidence documents many contributions of ethnobiological knowledge, but its health, food, livelihood, conservation, and governance implications are usually examined in separate domains. A cross-domain synthesis is needed to explain how one intervention can generate benefits in one dimension and risks in another. The review therefore asks four questions. First, through which pathways does traditional knowledge contribute to material and cultural well-being? Second, what ecological and social trade-offs accompany documentation, commercialization, conservation, and technological development? Third, how do current methods reveal or obscure these trade-offs? Fourth, what research and governance principles can protect both community agency and ecological viability? The article makes three contributions. It first reorganizes the 19 supplied studies around four linked functions: knowledge continuity, material security, ecological reciprocity, and institutional fairness. Second, it treats apparent contradictions such as useful invasives, income-generating extraction, culturally embedded hunting, and data-driven domestication not as anomalies but as central objects of inquiry (Jameel et al., 2027; Neblea et al., 2025; Rivera et al., 2024; Zaman et al., 2025). Third, it proposes a Biocultural Integrity Framework for evaluating whether research, policy, and market initiatives sustain the relationships

among knowledge holders, biological resources, and decision-making institutions. The framework is an analytical synthesis of the supplied evidence, not a claim that the corpus has already tested a unified causal model.

2. Review Design and Evidence Boundary

This article uses an integrative narrative review design. Its evidence base was restricted to the two files supplied for the task: one RIS export and one Scopus plaintext abstract export. Record-level comparison of titles, years, authors, and digital object identifiers showed that both files contained the same 19 publications. The review therefore treats the corpus as 19 unique records rather than 38 items. No references were added from the web, bibliographic databases, model memory, or citation lists. This closed-corpus rule preserves traceability but limits claims about the wider field.

The publications span 2024–2027: four appeared in 2024, nine in 2025, five in 2026, and one is indexed for 2027. The corpus comprises 14 articles, three records categorized as reviews, one policy-oriented note, and one book chapter. Its geographic center is South Asia, especially Pakistan, India, and the Himalayan region, with additional evidence from Tanzania, China, a Spain-linked global wild-food analysis, and broader conceptual or species-focused reviews. Consequently, the review can make strong statements about patterns inside the supplied portfolio, but it cannot establish global prevalence or regional representativeness.

Only titles, metadata, keywords, and abstracts were available. Claims about study aims, samples, methods, numerical results, conclusions, and limitations were therefore restricted to information explicitly reported in those abstracts. The review does not infer unreported consent procedures, sampling frames, statistical diagnostics, tenure arrangements, or causal mechanisms. When it develops broader interpretations, those interpretations are identified as cross-study

synthesis. Numerical detail is used selectively where it clarifies an analytical contrast rather than reproducing each abstract.

The evidence was mapped across six dimensions: knowledge domain; resource or practice; social actors and setting; study design and indicators; reported contribution; and reported or inferable evidence boundary. Studies were then compared across five thematic clusters: community health and ethnoveterinary care; food and nutrition; livelihoods and markets; biocultural diversity and conservation; and governance, innovation, and institutional change. These clusters overlap by design. For example, wild snake gourd is simultaneously a food, a non-timber forest product, an income source, and an agroforestry component (Waheed et al., 2025). Likewise, edible plants in an urban market combine dietary, medicinal, commercial, and cultural functions (Zhang et al., 2026).

The synthesis followed an evidence hierarchy appropriate to the available material. Directly reported observations and measurements were treated as study-level evidence. Authors' recommendations were reported as recommendations rather than demonstrated outcomes. Cross-study explanations were framed as interpretations that require further testing. Reviews and the policy note were used mainly for conceptual breadth, safety, management, and governance arguments, while empirical records supported statements about respondents, species inventories, use patterns, nutrient composition, ecological traits, and market values (Gupta et al., 2024; Lalrinmawia et al., 2025; Neblea et al., 2025).

Table 1 maps the whole portfolio. Its final column provides APA author date identifiers so that each row remains traceable to the supplied records. The “evidence boundary” column is especially important: it prevents a documented use, cultural consensus, chemical potential, or reported policy lesson from being misread

as proof of clinical efficacy, ecological sustainability, or equitable governance.

Table 1. Portfolio map of the supplied literature

Knowledge domain, setting, and focal resource/ practice	Design or evidence	Principal contribution	Evidence boundary	Ref.
Migratory pastoralism, northwestern Himalaya Plant-based livestock care	Interviews, group discussions, observation, UV, ICF, FL; 60 participants	Shows mobile ethnoveterinary knowledge as accessible livestock-health infrastructure	Cultural use and consensus do not establish efficacy or safety	Devi et al. (2026)
Managed forests, Pakistan Wild snake gourd under four host trees	Collector interviews, plant traits, economic and canopy analysis	Links host-tree choice with productivity, income, and agroforestry policy	One species and regional setting limit transferability	Waheed et al. (2025)
Women's healthcare, Punjab Medicinal plants for gynecological care	Cross-sectional survey in 30 villages; 200 respondents; indices and networks	Identifies gendered knowledge holders, therapies, and culturally important taxa	Snowball sampling and use reports cannot verify clinical outcomes	Fatima et al. (2026)
Multilingual communities, Indus Kohistan Wildlife use and hunting	Questionnaires, observation, clustering and ordination	Relates language and interaction to distinct fauna-use patterns	Baseline documentation does not measure population-level harvest effects	Jameel et al. (2027)
Community forestry, India Community-centered forest management	Policy forum and literature-based commentary	Connects governance with ecological gains, benefit sharing, and inclusion	Recommendations are not a comparative impact evaluation	Lalrinmawia et al. (2025)
Forest-fringe communities, Kashmir Wild plant use and conservation	Interviews, group discussions, UV; 87 species	Links ethnoecological knowledge with regional biocultural conservation	Cross-sectional use values provide limited trend evidence	Aijaz et al. (2024)
Rural Tanzania Wild edible fruits, vegetables, and mushrooms	Household-use data plus nutrient and phytochemical assays; 36 foods	Demonstrates nutritional heterogeneity and supplementary dietary potential	Composition does not establish intake adequacy or health effects	Malunguja et al. (2025)
Four ethnic groups, Gilgit-Baltistan Native and exotic useful plants	Snowball sampling, correlations, overlap, cultural indicators	Shows association between exotic flora and knowledge homogenization	Causal direction and temporal sequence remain unresolved	Niaz et al. (2026)
Western Himalayan food systems Wild plants, fermentation, preservation, agroforestry	Mixed-method ethnography and literature synthesis	Positions food traditions as climate adaptation and food-sovereignty practices	Abstract provides limited detail on sampling and measured outcomes	Sharma et al. (2026)
India and wider culinary contexts Edible flowers	Narrative review of diversity, compounds, uses, safety, and regulation	Integrates food, medicine, innovation, and consumer protection	Review-level potential is not product-specific validation	Gupta et al. (2024)
Himalayan communities Apiaceae used for medicine, fodder,	Interviews, questionnaires, UV, PCA, clusters; 18	Relates accessibility and abundance to multipurpose cultural value	Taxonomic scope is narrow and evidence is use-based	Abdullah Khoja et al. (2024)

and spices	species			
Urban market, Baise City, China Traded edible plants and food–medicine integration	Monthly surveys; 40 informants; CFSI, FL, FIC	Identifies markets as hubs for dietary diversity and knowledge adaptation	One market and one year do not show longer-term change	Zhang et al. (2026)
Arid rangelands, Punjab Medicinal plants for cattle	Survey and multiple ethnobotanical indices; 120 plants	Demonstrates breadth of low-cost ethnoveterinary practice	Preference and citation frequency do not prove comparative effectiveness	Batool et al. (2025)
Gastronomy and tourism Traditional food ethnobiology	Conceptual/book-chapter evaluation	Connects biodiversity, local cuisine, migration, and tourism	Lacks reported comparative or longitudinal outcome data	Şengül et al. (2025)
Upper Dir, northern Pakistan Human medicinal plant use	Field documentation and eight ethnobotanical/conservation indices; 79 species	Combines cultural value with reported conservation status	Index-based priority requires ecological and pharmacological validation	Muhammad et al. (2025)
Murcia and global wild-food database Wild edible plant domestication	Local data, global database, occurrence data, simple models	Shows why single selection criteria are insufficient and proposes AI integration	Proposed AI protocol is not yet an outcome-tested decision system	Rivera et al. (2024)
Ayubia National Park fringe Gendered NTFP collection	Semi-structured household interviews; 108 households	Links gender, education, household size, price, and livelihood roles	Revenue potential is not equivalent to profit, empowerment, or sustainability	Zaman et al. (2025)
Border mountain region, Bhimber Wild medicinal plant diversity	Field survey and consensus indices; 133 species	Documents rich knowledge and informal sustainability practices	Restricted-access context and cross-sectional data constrain generalization	Sarwar et al. (2025)
Invasive species management <i>Phytolacca acinosa</i>	Literature review of biology, uses, remediation, and risks	Frames a useful species as simultaneously medicinal, technological, and invasive	Benefits and risks are context dependent and not jointly field-tested	Nblea et al. (2025)

3. Traditional Knowledge as Biocultural Infrastructure

The term “biocultural infrastructure” is used here to describe the relationships, practices, species, institutions, and transmission processes that allow knowledge to produce material and cultural benefits. Infrastructure usually attracts attention when it fails. The same is true of traditional knowledge. The loss of native crops, declining intergenerational transmission, restricted forest access, biological invasion, or out-migration may not immediately erase individual facts, but can weaken the

relations through which those facts remain usable (Niaz et al., 2026; Sharma et al., 2026). A remedy without access to the species, a recipe without seed continuity, or a harvesting rule without tenure security becomes progressively less capable of supporting community life.

This perspective helps distinguish documentation from continuity. Ethnobotanical surveys can record many species and calculate their cultural salience. Aijaz et al. (2024), Muhammad et al. (2025), and Sarwar et al. (2025) documented 87, 79, and 133 medicinal plant

species, respectively, within mountain and forest-linked communities. These inventories are valuable baselines, especially where access is difficult or knowledge is considered threatened. Yet continuity requires more than a list. It depends on whether habitats persist, whether younger people learn preparation and identification, whether collectors can reach resources, and whether social institutions still recognize the authority of knowledge holders.

Mobility can be constitutive rather than disruptive. Gaddi shepherds use plant remedies while moving seasonally between altitudinal zones, and their knowledge is adapted to remoteness from veterinary services (Devi et al., 2026). Cross-cultural similarities in wildlife use among Gujjari, Shina Kohistani, and Indus Kohistani groups were interpreted in relation to seasonal migration and geographic interaction (Jameel et al., 2027). These findings challenge conservation or service models that treat settled residence as the default unit of governance. Protecting biocultural infrastructure may require securing corridors, mobile access, and knowledge exchange across jurisdictions, not only protecting a static village territory. Markets are likewise not simply external forces. The Baise City study presents an urban market as a node through which rural production, urban consumption, culinary practice, and preventive health knowledge interact (Zhang et al., 2026). Markets can therefore sustain knowledge by keeping species visible, valued, and used. Gastronomy tourism may also create demand for local foods and cultural narratives (Şengül et al., 2025). However, once demand changes the scale, timing, or ownership of exchange, the same market can detach products from their ecological limits and cultural custodians. The key issue is not whether markets are inherently beneficial or harmful, but how rules of access, representation, pricing, and resource renewal are organized.

The corpus also shows that biological and cultural diversity may move together, but not automatically. Niaz et al. (2026) associated exotic flora with greater similarity of traditional plant knowledge among four isolated ethnic groups. Their result suggests that biological homogenization can be accompanied by cultural homogenization when widely shared introduced taxa displace more distinctive relationships. Conversely, the continued use of native or locally specific plants may help sustain differentiated knowledge. Yet introduced species can themselves acquire cultural, medicinal, or economic importance. The dual character of *Phytolacca acinosa*—valuable for medicine and phytoremediation but potentially harmful as an invader—demonstrates why simple native-good, exotic-bad binaries are insufficient (Neblea et al., 2025).

Food practices make the infrastructural character especially visible. Western Himalayan food systems integrate wild plants, fermentation, preservation, and agroforestry into everyday adaptation (Sharma et al., 2026). Each component depends on complementary knowledge: where and when resources occur, how they are processed, how they are stored, and how they fit household diets and cultural identity. Nutritional analysis can reveal whether a food contains useful minerals or vitamins, as shown for multiple wild foods in Tanzania, but laboratory composition alone does not maintain harvesting landscapes or cooking knowledge (Malunguja et al., 2025). Food security is therefore produced by a chain of ecological availability, social access, knowledge, labor, preparation, and consumption.

Healthcare has a similar chain. Ethnoveterinary care among pastoralists and cattle rearers depends on recognizing ailments, selecting materials, preparing remedies, and administering them under local conditions (Batool et al., 2025; Devi et al., 2026). Women's healthcare knowledge in Sahiwal is retained disproportionately by women, elders, housewives, practitioners,

and midwives, with transmission mainly through parents and grandparents (Fatima et al., 2026). The knowledge is relational: it travels through trust, care work, kinship, and practice. Extracting a plant–ailment association from that network may assist laboratory prioritization, but it does not reproduce the social conditions under which the knowledge was generated and evaluated. Biocultural infrastructure also has a political dimension. Community-centered forest management is reported to generate ecological and economic benefits, but anthropogenic disturbance, exclusion, and inequitable benefit sharing remain persistent challenges (Lalrinmawia et al., 2025). These concerns imply that participation cannot be assessed simply by the presence of a local organization. It must be evaluated through actual decision rights, recognition of differentiated users, and distribution of benefits and burdens. Where women perform much of the NTFP collection, for example, their labor should translate into authority over harvesting rules, value addition, and revenue decisions rather than being treated as background household activity (Zaman et al., 2025).

On this basis, traditional knowledge should be evaluated through four interacting functions. Knowledge continuity concerns whether knowledge can be practiced, transmitted, and adapted. Material security concerns its contribution to food, health, income, and risk reduction. Ecological reciprocity concerns whether resource use maintains regenerative capacity and avoids transferring damage elsewhere. Institutional fairness concerns who decides, whose knowledge is recognized, who receives benefits, and who bears restrictions. These functions form the foundation of the Biocultural Integrity Framework developed later in the review. They are analytically distinct but empirically inseparable: weakening one can undermine the others.

4. Community Health and Ethnoveterinary Care

4.1 Therapeutic knowledge as accessible care

The health-related studies demonstrate why traditional knowledge remains practically important. In remote areas, distance, affordability, and the limited reach of formal services make locally available treatments part of everyday care. Migratory Gaddi shepherds rely on plants while traveling with sheep and goats through the northwestern Himalaya, and respondents described remedies for multiple livestock conditions (Devi et al., 2026). In arid Punjab rangelands, cattle rearers reported a large pharmacopoeia dominated by herbaceous species and oral administration (Batool et al., 2025). In both cases, plant-based care is embedded in production systems: animal health affects food, income, mobility, and household resilience.

The human-health studies show comparable breadth. Fatima et al. (2026) recorded 70 species used in women’s healthcare across 30 villages, while Muhammad et al. (2025) reported 79 medicinal species in Upper Dir and Sarwar et al. (2025) documented 133 species in a politically sensitive border region. Aijaz et al. (2024) found 87 wild plant species used among forest-fringe populations in Kashmir. Such diversity indicates that local medical systems are not built around a few isolated remedies. They are portfolios of species, plant parts, preparations, therapeutic categories, and social expertise.

The portfolio function matters because accessibility and risk are uneven. A locally abundant species may be easier to obtain, while a rare or root-harvested species may impose greater travel, conservation, or replacement costs. Abdullah Khoja et al. (2024) found that accessible or locally abundant Apiaceae were especially beneficial to residents, and the reported uses extended beyond medicine to fodder and spices. In Bhimber, selective use of aerial parts and limited root harvesting were described as informal conservation practices

(Sarwar et al., 2025). These examples suggest that healthcare decisions incorporate ecological availability, even when studies primarily quantify cultural importance.

Traditional care should not be romanticized as either complete or inherently safe. The supplied abstracts document use and agreement, not controlled clinical effectiveness. Reviews of edible flowers and *Phytolacca acinosa* explicitly raise safety, regulation, bioactive potential, and ecological risk, illustrating the difference between cultural use and validated application (Gupta et al., 2024; Neblea et al., 2025). The appropriate inference is that ethnobiological knowledge provides a reason to investigate selected taxa and practices, not that high citation frequency establishes dosage, toxicity, or therapeutic superiority.

4.2 What ethnobotanical indices reveal

Quantitative indices make large bodies of reported knowledge comparable. Use value estimates how extensively a species is reported; relative frequency of citation indicates how widely it is mentioned; fidelity level captures concentration of use for a particular purpose; and informant consensus factor represents agreement within ailment categories. The supplied studies combine these measures in different ways, with some adding cultural importance, family importance, medical importance, or use reports (Batoool et al., 2025; Fatima et al., 2026; Muhammad et al., 2025). Used carefully, the indices can identify candidate species, dominant health categories, and areas of agreement worthy of ecological or laboratory follow-up.

The findings are often highly specific. Devi et al. (2026) reported the highest use value for *Mentha longifolia* and very high informant consensus across ethnoveterinary categories, while Batoool et al. (2025)

identified *Allium cepa* as the species with the highest use value in their cattle-care survey. In Upper Dir, *Taraxacum officinale* had the highest reported use value, while *Isodon rugosus* had the highest fidelity level (Muhammad et al., 2025). These rankings are meaningful inside each study, but differences in samples, questionnaires, therapeutic categories, and formula application prevent simple cross-site league tables.

The Sahiwal study offers an important methodological caution. Relative frequency of citation and use value showed close numerical correspondence because both depended strongly on respondent citations (Fatima et al., 2026). Multiple indices can therefore create an appearance of triangulation while carrying overlapping information. A top-ranked species is more credible as a cultural priority when frequency-based measures are combined with independent ecological abundance, pharmacological evidence, toxicity data, preparation specificity, or health outcomes. Without such triangulation, index proliferation may increase numerical complexity without increasing explanatory depth.

Consensus also requires contextual interpretation. High agreement may indicate a stable and widely shared practice, but it can also reflect common exposure to the same information, constrained access to alternatives, or a narrow respondent network. Snowball sampling, used in several studies, is appropriate for identifying knowledgeable participants but may cluster respondents socially and amplify shared repertoires (Fatima et al., 2026; Niaz et al., 2026; Zaman et al., 2025). The indices describe the recruited knowledge network; they do not automatically represent every household, gender, age group, or settlement in the study region.

Table 2. Methodological approaches, analytical value, and recurring limitations

Approach	Typical evidence produced and analytical value	Recurring limitation in the corpus	Priority improvement	Ref.
Semi-structured interviews and group discussions	Species uses, preparation, transmission, perceived efficacy Captures emic categories and practice detail	Recall, social-network clustering, and uneven representation	Report sampling frame, non-participation, consent, and subgroup coverage	Aijaz et al. (2024); Devi et al. (2026)
Snowball or purposive recruitment	Access to knowledgeable practitioners and collectors Efficient for specialized or dispersed knowledge	Cannot establish population prevalence without a defined frame	Combine expert recruitment with stratified household sampling	Fatima et al. (2026); Niaz et al. (2026); Zaman et al. (2025)
UV, RFC, FC, UR, FL, ICF/FIC	Cultural salience, citation frequency, therapeutic agreement Prioritizes taxa and compares categories	Indices may be mathematically correlated and remain use-based	Test redundancy and triangulate with independent evidence	Batool et al. (2025); Fatima et al. (2026); Muhammad et al. (2025)
Cultural and family importance measures	Multipurpose value at species or family level Extends analysis beyond single uses	High scores may obscure scarcity, toxicity, or unequal access	Couple importance with threat, access, and safety indicators	Muhammad et al. (2025); Zhang et al. (2026)
Clustering, PCA, ordination, and networks	Similarity, association, and pattern structure Reveals cross-cultural or use-pattern differentiation	Results depend on coding, distance measures, and sample structure	Report sensitivity, uncertainty, and interpretability checks	Abdullah Khoja et al. (2024); Fatima et al. (2026); Jameel et al. (2027)
Participant observation and ethnography	Practice, context, routine, and adaptation Connects statements with situated behavior	Often under-described and difficult to compare	Specify duration, researcher role, and analytic procedure	Devi et al. (2026); Sharma et al. (2026)
Laboratory nutrient and phytochemical analysis	Composition of candidate wild foods Adds independent material evidence	Composition does not equal consumption or health impact	Measure intake, bioavailability, preparation effects, and exposure	Malunguja et al. (2025)
Ecological traits and canopy analysis	Productivity, morphology, and habitat association Connects useful species to management conditions	Site specificity and observational confounding	Replicate across seasons, sites, and management regimes	Waheed et al. (2025)
Market and household economic analysis	Prices, returns, collection roles, livelihood contribution Makes material incentives visible	Revenue may be mistaken for profit or empowerment	Include labor, costs, volatility, control of income, and value-chain margins	Waheed et al. (2025); Zaman et al. (2025)
Longitudinal or repeated market observation	Seasonal presence and knowledge performance Captures temporal availability better than one-time surveys	One year remains insufficient for structural change	Extend monitoring across climatic and market cycles	Zhang et al. (2026)
Literature and policy synthesis	Broad mechanisms, risks, regulation, and governance lessons Connects domains beyond individual field sites	Evidence selection and quality may be opaque in abstracts	State review protocol and differentiate evidence strength	Gupta et al. (2024); Lalrinmawia et al. (2025); Neblea et al. (2025)
Database integration and AI proposals	Multi-criteria candidate selection Can combine ecological, nutritional, and economic evidence	Cultural values and uncertainty may be flattened or hidden	Use participatory criteria, transparent models, and contestable outputs	Rivera et al. (2024)

Table 2 shows that methodological strength increases when cultural reporting is combined with independent forms of measurement. Nutrient assays demonstrate biochemical heterogeneity among wild foods; host-tree comparisons relate ethnobotanical use to plant performance; and monthly market surveys introduce temporal repetition (Malunguja et al., 2025; Waheed et al., 2025; Zhang et al., 2026). Similar integration is needed in community health research. A staged design could move from use documentation to botanical authentication, chemical and toxicological screening, locally appropriate clinical observation, and post-use monitoring, with community governance at each step.

4.3 Gender, authority, and the ethics of validation

Health knowledge is socially differentiated. In Sahiwal, women, older respondents, housewives, practitioners, and midwives retained the greatest shares of gynecological knowledge, and parents and grandparents were the principal transmission pathways (Fatima et al., 2026). This distribution is not merely a demographic result. It shows that care knowledge may be generated through unpaid or undervalued labor, intimate experience, and social trust. Research that extracts plant-use records without recognizing those roles can reproduce a separation between knowledge contribution and decision authority.

The same issue applies to livestock care. Older cattle rearers and pastoralists are prominent participants because long practice creates diagnostic and ecological expertise (Batoool et al., 2025; Devi et al., 2026). Yet future interventions may privilege laboratory scientists, veterinary institutions, technology developers, or commercial firms once a remedy becomes a candidate product. Ethical validation must therefore ask who defines the research question, who controls specimens and associated information, how uncertainty is communicated, and whether knowledge

holders retain influence over subsequent use.

The corpus does not report enough detail to assess these processes directly. That absence is itself a research finding at the portfolio level. Studies frequently recommend pharmacological validation, conservation, or sustainable use, but their abstracts rarely identify benefit-sharing rules, community data governance, or mechanisms for collective authorization (Devi et al., 2026; Fatima et al., 2026; Muhammad et al., 2025). Future reporting should treat these arrangements as methodological information rather than optional ethical commentary.

Validation should be conceived as reciprocal. Scientific testing can evaluate composition, toxicity, or efficacy, while community interpretation can clarify preparation, seasonality, contraindications, and meaningful outcomes. The edible-flower review's attention to safety and regulatory frameworks shows why translation into products requires more than identifying bioactive compounds (Gupta et al., 2024). The *P. acinosa* review adds an ecological dimension: a species with therapeutic or remediation potential may also create invasion and pathogen-host risks (Neblea et al., 2025). A reciprocal validation process therefore evaluates effects on bodies, livelihoods, ecosystems, and authority.

5. Wild Foods, Food Sovereignty, and Nutritional Security

5.1 From emergency foods to diversified food systems

Wild foods are often framed as coping resources used when cultivated supply fails. The supplied evidence supports a broader role. In Tanzania, 74.9% of participants reportedly consumed wild edible foods regularly, and the recorded portfolio included fruits, vegetables, and mushrooms (Malunguja et al., 2025). In the Western Himalaya, wild plant use is integrated with fermentation, food preservation, and agroforestry as part of culturally rooted

adaptation (Sharma et al., 2026). In Baise City, traded edible plants sustain a dynamic food–medicine interface within ordinary urban consumption (Zhang et al., 2026). Together, these studies position wild and underutilized foods as components of diversified food systems rather than residual famine foods.

Nutritional value is heterogeneous. Laboratory analysis in Tanzania found substantial differences in minerals, vitamins, fiber, protein, phenolics, flavonoids, and tannins across species (Malungu et al., 2025). This variation matters for policy. Programs that promote “wild foods” as a single category risk substituting symbolic diversity for nutritionally informed planning. Species selection should consider edible part, preparation, portion size, seasonal supply, anti-nutritional factors, and the dietary gap being addressed. The corpus provides composition evidence but not enough information on household intake or bioavailability to conclude that these foods correct specific deficiencies.

The food–medicine continuum further complicates classification. High cultural food significance and therapeutic consensus in the Baise market show that consumers may value a plant simultaneously as food and preventive care (Zhang et al., 2026). Himalayan Apiaceae are used for medicine, fodder, spices, and cuisine, while edible flowers combine culinary appeal, nutrients, bioactive compounds, and potential commercial innovation (Abdullah Khoja et al., 2024; Gupta et al., 2024). Regulatory systems organized around mutually exclusive categories of food, supplement, medicine, or cosmetic may fail to reflect these lived uses. At the same time, flexible classification cannot replace safety standards where products are processed, concentrated, or sold to unfamiliar consumers.

Food sovereignty, as represented within the supplied corpus, concerns the capacity of communities to sustain locally rooted practices under climate, migration, and market pressure. Sharma et al. (2026)

identify wild plants, fermentation, preservation, and agroforestry as adaptive practices but warn that market-driven agriculture and declining native crops erode ecological knowledge. This warning shifts attention from the number of edible species to the institutions that shape seeds, land, labor, and consumption. A diverse inventory does not guarantee sovereignty if households lose control over production choices or if traditional foods become available only as premium commodities for outsiders.

5.2 Agroforestry and ecological conditions of food production

Wild snake gourd demonstrates how a culturally or economically useful plant depends on forest structure. Waheed et al. (2025) found significant variation in leaf and fruit traits among host trees and reported the highest productivity under *Dalbergia sissoo*. Canopy cover explained a meaningful share of variation in wild snake gourd density. This evidence makes host-tree selection a food-security and livelihood decision, not only a silvicultural one. It also illustrates how ethnobotanical value can be linked to measurable ecological conditions. The management implication is not that one host tree should be universally promoted. The study is specific to managed subtropical forests in Pakistan, and observed associations may reflect local soils, canopy structure, competition, microclimate, or management history. Replication across seasons and sites would be needed before generalizing. Nevertheless, the design improves on inventories that treat useful species as ecologically context-free. It shows how agroforestry research can test the habitat requirements that make continued use possible (Waheed et al., 2025).

Agroforestry also appears as a repository of traditional food-system knowledge. Sharma et al. (2026) place it alongside preservation and fermentation, indicating that tree-based systems contribute through more than yield. They can organize seasonal diversity,

microhabitats, fodder, wild plants, and cultural routines. Rivera et al. (2024) similarly argue that candidate wild plants for cultivation should be assessed through ecological, nutritional, toxicological, agronomic, biogeographical, ethnobotanical, economic, and physiological criteria. The convergence is significant: domestication and cultivation require multi-dimensional evaluation because productive potential alone cannot represent food-system value.

5.3 Markets, gastronomy, and cultural translation

Markets can extend the social life of traditional foods. Monthly surveys in Baise recorded 54 edible plant taxa and equal numbers of male and female informants, highlighting the urban market as an active setting of selection, exchange, and interpretation (Zhang et al., 2026). Market presence may help maintain demand, create income, and expose younger or urban consumers to local species. It may also transform which species are collected, how they are presented, and which health claims circulate.

Gastronomy tourism offers a related pathway. Şengül et al. (2025) describe gastronomy ethnobiology as the intersection of biodiversity, local food experience, ancestral seeds, wild plants, migration, and changing nutrition patterns. Tourism can generate recognition and value for local cuisines, but it can also convert complex knowledge into a simplified destination narrative. A dish may become visible while the labor, access rights, seasonal restrictions, or sacred meanings behind it disappear from representation. Tourism planning should therefore treat communities as decision makers over what is shared and how it is interpreted.

Commercial translation also introduces safety and authenticity questions. Edible flowers may become ingredients in functional foods or other products, but Gupta et al. (2024) emphasize safety and regulatory considerations alongside innovation. Wild plant domestication can

expand supply, yet selection based only on broad use or local consensus is insufficient (Rivera et al., 2024). An ethically credible pathway from local food to commercial product should include traceable species identification, safety assessment, sustainable sourcing, transparent claims, recognition of origin, and negotiated return of value to knowledge holders.

The relationship between commercialization and conservation is therefore conditional. Demand can create incentives to maintain species and habitats, but it can also intensify harvesting or favor a few standardized taxa. Urban markets may preserve food–medicine knowledge, while market-driven agriculture may undermine native crops and local food sovereignty (Sharma et al., 2026; Zhang et al., 2026). These findings are not contradictory once scale and governance are considered. Markets can support biocultural integrity when access, ecological limits, and representation remain locally negotiable; they can erode it when volume, standardization, and external control dominate.

6. Livelihoods, Non-Timber Forest Products, and Value Creation

6.1 Income is important but analytically incomplete

Non-timber forest products connect biodiversity with household economies. Around Ayubia National Park, women were the primary collectors, and collection patterns varied with household size, gender, and education (Zaman et al., 2025). High-value products included morel mushrooms and selected medicinal plants. In managed forests, wild snake gourd generated daily income for collectors, with the highest reported average return in Changa Manga Forest (Waheed et al., 2025). These studies establish that useful species can contribute materially to rural livelihoods, but they also show why revenue should not be treated as a complete measure of benefit.

Income estimates can obscure labor time, transport, processing, failed collection trips, price volatility, access fees, household

control of earnings, and resource depletion. A product with a high unit price may be scarce, risky to collect, or sold through unequal market relations. Zaman et al. (2025) recommend sustainable harvesting, local value addition, and marketing, but the abstract does not report downstream margins or governance of value addition. Waheed et al. (2025) report average daily collector income, yet the longer-term stability of returns and the distribution of benefits among actors remain outside the available evidence.

This limitation has ethical and practical consequences. If women supply most collection labor but lack authority over sales or forest rules, rising prices may increase workload without increasing empowerment. If commercialization attracts new collectors, customary restraint may weaken. If processing standards favor capital-rich actors, value addition may shift income away from the community even while total product value rises. These are hypotheses for future testing, not findings established by the abstracts. They illustrate why livelihood research needs measures of control, risk, costs, and bargaining power alongside gross returns (Lalrinmawia et al., 2025; Zaman et al., 2025).

6.2 Value chains as social–ecological feedback systems

A value chain is commonly represented as a sequence from harvest to processing and sale. For ethnobiological resources, it is also a feedback system. Price and demand influence collection intensity; collection affects population regeneration; scarcity alters labor and access; regulation changes who can participate; and marketing narratives shape cultural representation. This feedback perspective joins the economic evidence on NTFPs with the conservation concerns raised for medicinal plants, wild foods, wildlife, and invasive species (Jameel et al., 2027; Muhammad et al., 2025; Neblea et al., 2025; Zaman et al., 2025).

The Upper Dir study illustrates the importance of combining cultural and conservation indicators. Muhammad et al. (2025) classified multiple medicinal species as vulnerable, rare, infrequent, or endangered while also documenting their cultural importance. A high use value under conditions of ecological vulnerability can indicate priority for propagation, substitution, harvest regulation, or habitat protection. It should not be read simply as a commercialization opportunity. Similarly, root-dominant harvesting among Himalayan Apiaceae may create different regenerative pressures from leaf or fruit collection (Abdullah Khoja et al., 2024).

Market strategies should be species- and practice-specific. Morel mushrooms, medicinal herbs, edible flowers, and wild snake gourd have different life histories, processing needs, safety risks, and cultural meanings (Gupta et al., 2024; Waheed et al., 2025; Zaman et al., 2025). Generic calls for “value addition” can obscure these differences. A credible strategy would identify the resource base, sustainable yield indicators, labor contributions, processing technology, quality requirements, price formation, market risk, and rules for distributing gains.

Community forestry provides the institutional context in which such rules may be negotiated. Lalrinmawia et al. (2025) describe ecological and economic gains from community-centered forest management while emphasizing exclusion and inequitable benefit sharing. This combination implies that local management is not automatically equitable; institutional design matters. Transparent membership, representation of marginalized users, enforceable access rights, and benefit-sharing procedures are necessary if commercialization is to reinforce rather than fragment collective stewardship.

6.3 Diversification, resilience, and dependence

Livelihood diversification can reduce dependence on a single crop, species, or

labor market. Wild foods, medicinal plants, livestock care, and gastronomy tourism each offer potential supplementary pathways (Batool et al., 2025; Malunguja et al., 2025; Şengül et al., 2025). Agroforestry can integrate these functions spatially, while preservation and fermentation extend seasonal availability (Sharma et al., 2026; Waheed et al., 2025). The resilience value of diversification, however, depends on covariance: several products do not reduce risk if all fail under the same climate event, market shock, or access restriction.

Dependence also changes social bargaining. Households that rely heavily on NTFPs may be especially vulnerable to conservation closures, trader power, or resource decline. Pastoralists may depend on locally available veterinary plants precisely because formal services are inaccessible (Devi et al., 2026). This does not diminish the value of traditional care, but it means that policy should avoid treating cultural resilience as a substitute for public investment. Supporting traditional systems and improving equitable access to formal services can be complementary rather than competing goals. The strongest livelihood pathway in the corpus is therefore not simple product promotion. It is controlled diversification: increasing the range of viable options while maintaining community authority, ecological monitoring, and the ability to refuse unsustainable demand. Controlled diversification links material security with ecological reciprocity and institutional fairness. Without those connections, short-term income may be purchased through long-term resource or cultural loss.

7. Conservation Tensions in Biocultural Systems

7.1 Cultural value does not guarantee ecological sustainability

Ethnobiological significance and conservation status measure different properties. A species may be frequently cited because it is abundant, effective, accessible, culturally preferred, or difficult to replace. None of these explanations alone

shows that current harvest is sustainable. Muhammad et al. (2025) bring the distinction into view by reporting both cultural indices and conservation categories for medicinal plants in Upper Dir. Sarwar et al. (2025) add evidence that selective use of aerial parts and reduced root harvesting can function as informal sustainability practices. Together, these studies suggest that conservation analysis should connect what people value with how plant parts, abundance, and regeneration affect continued availability.

Harvested part is an important but insufficient proxy. Root collection may impose greater mortality than careful leaf or fruit collection, yet effects vary by species, season, frequency, and technique. Aijaz et al. (2024) and Abdullah Khoja et al. (2024) report substantial reliance on roots within their study portfolios. This pattern identifies a monitoring priority, not proof of depletion. Repeated population measurements and harvest experiments would be needed to estimate ecological thresholds and distinguish sustainable customary practice from extraction intensified by external demand.

Conservation policy can also impose costs on knowledge holders. Restrictions designed without local participation may reduce access to food, medicine, or income and thereby weaken incentives for stewardship. Community-centered forest management offers an institutional alternative, but reported challenges of exclusion and unequal benefit distribution show that decentralization alone is insufficient (Lalrinmawia et al., 2025). Conservation legitimacy depends on whether affected users help define objectives, rules, indicators, and enforcement, and whether restrictions are matched by credible benefits or alternatives.

7.2 Invasive species and the problem of dual value

Invasive species expose the limitations of single-value decision making. *Phytolacca acinosa* has reported medicinal, antioxidant,

antitumor, anti-inflammatory, and phytoremediation potential, while also posing risks as an invader and intermediate host for pests or pathogens (Neblea et al., 2025). A policy focused only on utility could accelerate ecological harm; a policy focused only on eradication could disregard locally meaningful uses or remediation opportunities. Management must be specific to place, pathway, containment feasibility, and the distribution of benefits and risks.

The social effects of introduced plants extend beyond ecology. Niaz et al. (2026) associate exotic flora with the homogenization of traditional knowledge across Balti, Burusho, Shina, and Wakhi communities. Native-plant use showed a positive relationship between the number of uses and species used, whereas exotic-plant patterns differed among groups. Eight cultural indicator species were shared across communities, including both long-established useful plants and taxa with complex biogeographic histories. The broader implication is that plant introduction can alter the distinctiveness of cultural repertoires even when introduced species are useful.

Biocultural conservation cannot therefore be reduced to maximizing either species richness or the number of uses. It must ask which relationships are displaced, which are newly created, and whether communities retain the capacity to decide among them. Preventing new introductions may be appropriate in some contexts, while managing long-established useful exotics may require negotiated containment rather than indiscriminate removal (Niaz et al., 2026; Neblea et al., 2025). Longitudinal study is essential because a cross sectional association cannot show whether ecological change caused knowledge convergence, whether social change drove adoption of exotics, or whether both processes interacted.

7.3 Wildlife use, hunting, and culturally informed conservation

Ethnozoological research makes conservation conflict visible in a different way. Jameel et al. (2027) documented wildlife used for food, medicine, culture, decoration, and recreation across five linguistic communities in Indus Kohistan. Hunting frequency, methods, and culturally associated indicator species varied among groups. This information can improve conservation planning because it identifies differentiated relationships rather than treating all local users as a uniform pressure. Documentation must not be confused with endorsement or condemnation. Cultural use can have nutritional, therapeutic, or identity functions while also contributing to population pressure. Conversely, formal restrictions can protect threatened species while imposing unequal costs or driving practices underground. The supplied abstract does not provide wildlife abundance, offtake sustainability, or enforcement outcomes, so the evidence cannot resolve these questions. It does show that seasonal interaction and linguistic affiliation are relevant to patterns of use, and these factors should inform dialogue and monitoring (Jameel et al., 2027).

Culturally associated indicator species could support participatory conservation if communities help interpret what indicator status means. A high cultural association may identify a species for targeted education, alternative practices, population monitoring, or negotiated restraint. It could also create sensitivity if publicized locations or uses increase hunting or external attention. Data governance is therefore part of wildlife conservation. Researchers should assess whether granular disclosure creates risk and whether communities have authority over the circulation of sensitive knowledge.

7.4 Climate adaptation and conservation under social change

Traditional food systems can support climate adaptation, but they are also affected by socioeconomic transition and out-migration. Sharma et al. (2026) report

that wild plant use, fermentation, preservation, and agroforestry contribute to food security, nutritional diversity, and cultural identity. They also warn that reliance on market-driven agriculture and declining native crops erode ecological knowledge. Adaptation is thus not the persistence of an unchanged tradition. It is the capacity to modify practice without losing the biological and institutional options that make future adjustment possible.

Mobility illustrates this dynamic. Seasonal migration allows pastoralists to avoid extreme conditions and maintain livestock, while also connecting ecological zones and knowledge networks (Devi et al., 2026). Migration and geographic interaction may

produce similarity in wildlife-use repertoires among linguistic communities (Jameel et al., 2027). Out-migration, by contrast, can weaken daily food practices and intergenerational learning (Sharma et al., 2026). Research should distinguish forms of mobility rather than treating migration uniformly as knowledge loss.

Table 3 summarizes the recurrent tensions. Its purpose is not to balance benefits and risks arithmetically. It shows that nearly every development pathway changes multiple parts of the system. A decision is more likely to sustain biocultural integrity when it recognizes these linked effects before implementation and creates monitoring and revision mechanisms.

Table 3. Benefits, risks, and governance conditions across resource-use pathways

Pathway	Reported or plausible benefit	Documented or salient risk	Core evaluative question and governance condition	Ref.
Medicinal-plant documentation	Preserves use records and guides research priorities	Decontextualization, disclosure, overharvest, or unshared downstream value	Who authorized documentation and controls later use? Community consent, restricted-data options, benefit-sharing pathway	Fatima et al. (2026); Muhammad et al. (2025)
Ethnoveterinary practice	Accessible, low-cost livestock care in remote areas	Unverified dosage, toxicity, or replacement of needed formal care	How can validation improve safety without displacing local authority? Reciprocal trials, referral criteria, accessible veterinary services	Batool et al. (2025); Devi et al. (2026)
Wild-food promotion	Dietary diversity and nutrient supplementation	Misclassification, unsafe preparation, seasonal scarcity, habitat pressure	Does promotion address a measured dietary need within ecological limits? Species-specific safety, intake, access, and harvest monitoring	Malunguja et al. (2025); Zhang et al. (2026)
NTFP commercialization	Income diversification and local value creation	Unequal labor burden, price volatility, elite capture, overcollection	Who controls income and absorbs ecological and market risk? Cost and margin transparency, women's decision rights, harvest rules	Waheed et al. (2025); Zaman et al. (2025)
Gastronomy tourism	Recognition of cuisine, biodiversity, and place	Cultural simplification, appropriation, demand-driven extraction	Can communities control representation and visitor demand? Co-designed narratives, sourcing standards, locally retained value	Şengül et al. (2025)
Community forestry	Regeneration, carbon, biodiversity,	Exclusion, disturbance, and inequitable benefit	Is authority substantively shared among differentiated users?	Lalrinmawia et al. (2025)

	and livelihood benefits	sharing	Transparent membership, representation, tenure, and accountability	
Useful invasive species	Medicine, remediation, food, or income potential	Spread, biodiversity loss, pest or pathogen roles	Can benefits be obtained without increasing propagule pressure? Context-specific containment, monitoring, and reversible use	Neblea et al. (2025)
Adoption of exotic useful plants	Expanded repertoire and accessible resources	Homogenization of biological and cultural diversity	What native relationships are displaced or made less viable? Prevention, negotiated management, native-knowledge restoration	Niaz et al. (2026)
Wildlife use and hunting	Food, medicine, identity, and cultural continuity	Population decline, conflict, and sensitive-data exposure	Which uses and species can persist at monitored offtake levels? Community-led monitoring, differentiated rules, data protection	Jameel et al. (2027)
Wild-plant domestication and AI selection	New crops and multi-criteria decision support	Biased criteria, opacity, loss of local priorities, premature scaling	Who defines value and can model recommendations be contested? Participatory criteria, transparent uncertainty, staged field validation	Rivera et al. (2024)

8. Social Differentiation, Knowledge Transmission, and Power

8.1 The analytical problem of “community”

The corpus consistently undermines the assumption that communities possess one shared and evenly distributed body of knowledge. Gender, age, occupation, education, household size, language, migration, and market participation shape who knows, uses, and collects particular resources. Fatima et al. (2026) identify women, elders, housewives, practitioners, and midwives as prominent holders of women’s healthcare knowledge. Zaman et al. (2025) find that women are the principal NTFP collectors and that household size and education influence collection. Jameel et al. (2027) and Niaz et al. (2026) show differentiation among linguistic and ethnic groups.

This diversity affects sampling and interpretation. Recruiting recognized experts can efficiently document specialized knowledge, but it may underrepresent less visible practitioners or contested

knowledge. Household surveys can capture broader patterns, but a household head may not represent knowledge held by women, younger people, or hired collectors. Equal numbers of male and female informants, as used in the Baise market study, improve balance for that setting but do not by themselves explain differences in authority, labor, or control of sales (Zhang et al., 2026).

The term “knowledge holder” should therefore be operationalized. A person may identify species, prepare remedies, decide when treatment is needed, control access to habitat, collect materials, sell products, or transmit stories. These are different roles. Studies that aggregate them into respondent counts may miss the social organization of knowledge. The Sahiwal research begins to separate demographic and occupational groups, while the Ayubia study connects household attributes with collection behavior (Fatima et al., 2026; Zaman et al., 2025). Future work should go further by mapping roles and decision rights along the full use pathway.

8.2 Transmission, adaptation, and erosion

Intergenerational transmission is often described as the transfer of stable knowledge from elders to youth. The supplied evidence suggests a more dynamic process. Parents and grandparents are central transmitters of women's healthcare knowledge, but current use is also influenced by cost, accessibility, and changing services (Fatima et al., 2026). Pastoral knowledge is maintained through repeated movement and close interaction with livestock and landscapes (Devi et al., 2026). Urban markets create new contexts in which edible-plant knowledge persists and adapts among sellers, buyers, and cooks (Zhang et al., 2026).

Knowledge erosion may likewise arise through multiple pathways. Market-driven agriculture and declining native crops can reduce the daily relevance of traditional foods (Sharma et al., 2026). Exotic flora may increase overlap among ethnic repertoires and reduce distinctiveness (Niaz et al., 2026). Modernization and changing cultural practices are cited as threats to ethnoveterinary knowledge (Batoool et al., 2025). These processes are related but not identical. Declining frequency of use, reduced taxonomic breadth, loss of language-specific names, weakened practice competence, and loss of decision authority are different dimensions and should be measured separately.

Erosion is not the only possible interpretation of change. Communities can incorporate introduced plants, new market opportunities, or scientific information into living traditions. The key distinction is between adaptive change under meaningful local control and change produced by displacement or coercive dependence. Niaz et al. (2026) show that exotic plants can become culturally important even as they contribute to homogenization. Zhang et al. (2026) show that urban exchange can sustain rather than simply dilute traditional food knowledge. Longitudinal, participatory research is needed to determine when

transformation expands agency and when it narrows options.

8.3 Recognition, participation, distribution, and reciprocity

Four evaluative questions can make power visible. Recognition asks whether institutions acknowledge differentiated knowledge, identity, labor, and authority. Participation asks who has effective influence over research, conservation, market, and technology decisions. Distribution asks who receives income, services, credit, and restrictions. Reciprocity asks whether benefits derived from biological and cultural resources contribute to their renewal. These questions are proposed here as a practical heuristic derived from the corpus, not as a tested scale.

Recognition without participation can become symbolic. Tourism promotion may celebrate local cuisine while external actors decide branding and supply (Şengül et al., 2025). Scientific documentation may praise indigenous knowledge while communities have little authority over research priorities or data use. Participation without distribution can also fail: a community meeting does not ensure that women collectors or mobile pastoralists share benefits. Lalrinmawia et al. (2025) explicitly identify exclusion and unequal benefit sharing as challenges in community forest governance.

Distribution without ecological reciprocity is unstable. Higher product prices can improve household income while creating incentives for unsustainable extraction. Conservation without distribution is equally fragile if local users bear restrictions without credible livelihood support. The medicinal-plant classifications in Upper Dir and the economic evidence on NTFPs show why social and ecological indicators must be assessed together (Muhammad et al., 2025; Zaman et al., 2025). Reciprocity connects present benefit with future regenerative capacity.

This heuristic also applies to research technology. Rivera et al. (2024) propose artificial intelligence to integrate ecological, nutritional, toxicological, agronomic, biogeographical, ethnobotanical, economic, and physiological factors when selecting wild plants for domestication. Recognition requires that culturally specific criteria are not reduced to a generic score. Participation requires knowledge holders to help define objectives and acceptable trade-offs. Distribution concerns who owns models, data, varieties, and eventual products. Reciprocity requires that domestication and commercialization support source landscapes and communities rather than merely extracting candidate traits.

9. Methodological State of the Art and Evidence Gaps

9.1 Strengths of the recent evidence

The most important methodological advance in the corpus is integration. Earlier-style inventories remain present, but several studies combine qualitative reporting with quantitative, ecological, biochemical, spatial, or economic evidence. Waheed et al. (2025) integrate interviews, functional traits, canopy relationships, and collector income. Malunguja et al. (2025) combine household use with laboratory analysis. Fatima et al. (2026) add ordination and association networks to standard ethnobotanical indices. Zhang et al. (2026) conduct monthly market surveys and calculate cultural food and therapeutic-consensus measures.

Cross-cultural analysis is another strength. Instead of treating knowledge as locally homogeneous, Niaz et al. (2026) compare four ethnic groups and Jameel et al. (2027) compare five linguistic communities. Similarity, clustering, ordination, and indicator-species approaches make variation empirically visible. These methods are especially valuable when accompanied by ethnographic explanation of migration, contact, livelihood, and language, because numerical overlap alone cannot explain why repertoires converge or diverge.

The corpus also broadens the unit of analysis. Urban markets, managed forest host trees, food-processing practices, value chains, and invasive species move research beyond village-level lists (Neblea et al., 2025; Sharma et al., 2026; Waheed et al., 2025; Zhang et al., 2026). Rivera et al. (2024) link local data to a global wild-food database and biodiversity occurrence records, arguing for multi-criteria modelling. This expansion enables questions about scale, innovation, and policy that conventional ethnobotanical surveys often leave implicit.

9.2 Persistent design limitations

Despite these advances, most empirical studies remain cross-sectional. Cross-sectional designs can document current use and association but cannot establish whether knowledge, abundance, diets, income, or governance are changing. The claim that modernization, invasive species, market agriculture, or migration erodes knowledge requires temporal evidence or credible comparison (Batool et al., 2025; Niaz et al., 2026; Sharma et al., 2026). Retrospective perceptions are valuable but should be distinguished from repeated measurement.

Sampling is frequently targeted toward knowledgeable respondents. This is appropriate for documenting specialist repertoires but limits estimate of population-wide prevalence. Snowball methods may reproduce existing social networks, while purposive sampling in markets selects active participants rather than all consumers (Fatima et al., 2026; Zhang et al., 2026; Zaman et al., 2025). Future studies should align sampling with the inference sought: expert sampling for repertoire depth, probability or stratified household sampling for prevalence, and network sampling for transmission pathways.

Index-heavy designs often lack independent validation. Use value, relative frequency, use reports, fidelity level, and consensus can identify salient taxa, yet their inputs are variations on respondent statements (Batool et al., 2025; Muhammad et al., 2025).

Combining several such measures does not necessarily yield multiple evidence streams. Greater explanatory strength comes from linking reported importance with ecological abundance, harvest impact, chemical composition, preparation, clinical outcomes, or economic control.

Ecological sustainability is usually recommended more often than measured. Several studies call for conservation, sustainable harvesting, or habitat management, but few abstracts report repeated population surveys, regeneration rates, experimental harvest, or extraction thresholds (Aijaz et al., 2024; Muhammad et al., 2025; Zaman et al., 2025). Informal conservation practices, such as selective aerial-part use, are important hypotheses for evaluation (Sarwar et al., 2025). Conservation claims should be tied to species-specific ecological indicators rather than inferred from cultural respect.

Livelihood measurement is similarly partial. Collector income and market price show material relevance, but they do not reveal costs, profit, volatility, control over earnings, or distribution along the chain (Waheed et al., 2025; Zaman et al., 2025). Food-security language often rests on availability, use, or composition rather than validated dietary adequacy. The Tanzania study offers rich nutrient data, but intake, preparation loss, bioavailability, and seasonal substitution remain unreported in the abstract (Malunguja et al., 2025).

Ethical and governance reporting is the least developed dimension. The studies emphasize preservation, sustainable use, and policy relevance, but abstracts seldom state how collective consent, sensitive data, intellectual authority, benefit sharing, or research returns were handled. Community forestry is the main record to place equity and exclusion at the center of governance analysis (Lalrinmawia et al., 2025). Gendered collection and knowledge studies reveal differentiated roles but do not report whether those roles translate into institutional power (Fatima et al., 2026; Zaman et al., 2025).

9.3 Limits of the present review

This review inherits several constraints from the supplied evidence. The two files duplicate one another, leaving 19 unique records rather than an expanded older-plus-new portfolio. The corpus is recent but geographically concentrated. South Asian and Himalayan cases dominate, so the synthesis should not be generalized to all indigenous peoples, forest users, or food systems. Important regions, legal systems, and epistemic traditions are absent.

All source evidence is abstract level. Abstracts compress methods and tend to foreground positive findings. They may omit non-significant results, internal debates, ethics procedures, measurement details, and limitations. The present review therefore avoids declaring that unreported practices were absent from the underlying studies. It identifies reporting gaps within the accessible material. Full-text appraisal could change assessments of study quality or ethical detail.

The corpus was supplied rather than generated through a reproducible search. This article is consequently an integrative review, not a systematic review, meta-analysis, or bibliometric study. It cannot estimate publication bias or claim comprehensive field coverage. Its value lies in rigorous cross-domain interpretation of a bounded recent portfolio and in identifying propositions that can be tested in a larger, systematically assembled evidence base.

10. A Biocultural Integrity Framework

The synthesis supports a framework with four linked dimensions. Knowledge continuity asks whether people can continue to learn, practice, evaluate, and adapt knowledge. Material security asks whether knowledge makes a demonstrable contribution to food, health, income, or risk management. Ecological reciprocity asks whether use maintains the regenerative conditions of species and habitats. Institutional fairness asks whether recognition, decision authority, benefits,

restrictions, and data control are distributed legitimately. An initiative demonstrates biocultural integrity only when progress in one dimension does not systematically erode another.

The framework changes the unit of evaluation from the useful species to the knowledge–resource–institution relationship. A medicinal plant with high cultural salience would be assessed not only for reported use but also for transmission, safe preparation, availability, harvest effects, consent, and control of subsequent research. A wild food would be assessed through dietary contribution, access, preparation, seasonal ecology, labor, and cultural meaning. An NTFP program would be evaluated through net livelihood effects, gendered decision rights, population regeneration, and distribution of value. These extensions follow directly from the cross-domain limitations visible in the corpus (Malunguja et al., 2025; Muhammad et al., 2025; Zaman et al., 2025).

The four dimensions should not be collapsed into a single score too early. Aggregation can conceal unacceptable trade-offs: high income could compensate numerically for severe ecological decline, or extensive documentation could offset loss of community data control. A dashboard of separate indicators is more transparent. Communities and other responsible institutions can then identify thresholds, such as no harvest increase for declining populations or no public disclosure of sensitive knowledge without renewed authorization. The objective is deliberation and adaptive management, not a universal ranking.

The framework further distinguishes minimum safeguards from improvement goals. Safeguards define conditions below which an initiative should not proceed, even if it promises gains elsewhere. Examples include unresolved collective authorization, a credible risk of irreversible population decline, unsafe preparation, exclusion of primary knowledge holders from decisions, or a value chain whose ownership cannot be

traced. Improvement goals then specify what a responsible initiative should strengthen over time: intergenerational competence, dietary or health benefit, net and equitably controlled income, habitat condition, institutional voice, and community stewardship of data. This distinction prevents a familiar procedural error in which consultation is treated as sufficient despite ecological danger, or positive ecological indicators are used to excuse coercive governance. It also makes comparison across cases more disciplined. Projects may use different locally meaningful indicators while remaining comparable in whether they respect minimum safeguards and document directional change in all four dimensions. Because thresholds may conflict, the framework does not presume that every proposal can be redesigned into acceptability. A community may reasonably refuse disclosure, commercialization, domestication, tourism, or intensified harvest. Recognition of that refusal is not a failure of knowledge mobilization; it is evidence that institutional fairness is functioning. In this sense, biocultural integrity is not measured by the volume of knowledge converted into products or policy. It is measured by the continuing capacity of knowledge holders and ecosystems to determine the terms, pace, and limits of change.

Application should proceed in cycles. First, researchers and knowledge holders define the focal relationship and relevant actors. Second, they select locally meaningful indicators for all four dimensions. Third, they collect social, ecological, health, nutritional, or economic evidence at compatible scales. Fourth, they deliberate on trade-offs and decide actions. Fifth, they monitor outcomes and revise rules. This cycle is consistent with the need for repeated ecological observation, culturally informed interpretation, and accountable community governance identified across the portfolio (Jameel et al., 2027; Lalrinmawia et al., 2025; Waheed et al., 2025).

The framework also clarifies the role of innovation. Artificial intelligence, product development, tourism, and market expansion are not treated as inherently progressive or destructive. Their legitimacy depends on how they affect the four dimensions. Multi-criteria AI may improve candidate selection, but only if its criteria, uncertainty, and ownership are transparent and contestable (Rivera et al., 2024). Gastronomy tourism may sustain culinary knowledge, but only if communities control representation and value (Şengül et al., 2025). Use of an invasive plant may be justified in contained remediation, but not when it increases uncontrolled spread (Neblea et al., 2025).

11. Research Agenda

The next research frontier is not a larger number of inventories alone. It is causal and governance-aware explanation. Longitudinal studies should track knowledge, species abundance, harvest, dietary use, income, and institutional change together. Comparative designs should distinguish market access, migration, conservation regimes, and biological invasion as interacting drivers. Mixed methods should connect numeric indices with observation, narrative, network position, and decision authority. Experimental or quasi-experimental components may be appropriate for ecological harvest, food processing, nutritional bioavailability, or habitat management, provided they remain community governed.

Health research should develop ethically staged validation. Initial documentation can identify culturally important remedies, followed by taxonomic authentication, preparation analysis, toxicity screening, and context-appropriate evaluation. Community members should help define meaningful outcomes and rules for stopping, sharing, or restricting research. This responds to the gap between extensive use documentation and limited clinical or governance evidence in the medicinal and ethnoveterinary studies

(Batool et al., 2025; Devi et al., 2026; Fatima et al., 2026).

Food-system research should move from composition and inventories toward actual dietary contribution. Repeated intake measures, preparation losses, bioavailability, seasonal access, price, and substitution effects are needed to determine whether wild foods improve nutrition under real household conditions. Market research should follow products from source landscapes through sale and consumption, allowing assessment of both knowledge continuity and ecological pressure (Malunguja et al., 2025; Zhang et al., 2026). Livelihood studies should calculate net returns and distribution rather than reporting prices or gross income alone. Time, transport, processing, risk, access fees, and unpaid labor should be included. Gender-disaggregated analysis should examine who performs work, controls revenue, participates in rules, and absorbs shocks. Ecological monitoring should be linked to these data so that value-chain interventions can detect whether improved income is accompanied by declining stocks (Waheed et al., 2025; Zaman et al., 2025).

Biocultural change research should operationalize continuity and homogenization over time. Measures might include taxonomic breadth, language-specific nomenclature, distribution of knowledge across generations, practice frequency, competence, access to habitats, and authority over decisions. Introduced species should be studied as social and ecological actors whose effects depend on history and use, rather than as a single binary category (Niaz et al., 2026; Neblea et al., 2025).

Table 4 translates these priorities into tractable research programs. Each program connects a documented evidence gap to a recommended design and a decision-relevant output. The agenda deliberately integrates social and ecological measures because single-domain studies cannot resolve the trade-offs identified in this review.

Table 4. Priority research programs for biocultural integrity

Evidence gap	Priority question	Recommended design and core measures	Decision contribution	Ref.
Knowledge change is inferred from cross-sectional data	How do repertoires, practice, and authority change across generations and shocks?	Longitudinal panel plus ethnography and social-network analysis Species knowledge, competence, transmission ties, practice frequency, decision roles	Distinguishes adaptive transformation from displacement	Fatima et al. (2026); Niaz et al. (2026); Sharma et al. (2026)
Cultural indices lack independent validation	Which culturally salient taxa also meet safety, efficacy, and ecological criteria?	Staged participatory validation with botanical, laboratory, and ecological components Identity, preparation, toxicity, relevant outcomes, abundance, harvest response	Creates defensible priorities without equating popularity with proof	Batool et al. (2025); Muhammad et al. (2025)
Food composition is weakly linked to diets	Do wild foods improve intake and resilience across seasons?	Repeated dietary assessment plus food composition and market monitoring Intake, preparation loss, bioavailability, price, access, seasonal supply	Targets foods and interventions to demonstrated dietary gaps	Malunguja et al. (2025); Zhang et al. (2026)
Income is reported without control or full costs	Who gains from NTFP value chains and under what labor and ecological conditions?	Gender-responsive value-chain and household panel analysis Costs, margins, labor, income control, price risk, resource stock	Prevents value addition from masking extraction or inequity	Waheed et al. (2025); Zaman et al. (2025)
Sustainable harvest is recommended but rarely tested	What extraction levels maintain regeneration for high-use taxa?	Repeated plots and controlled harvest comparison co-designed with collectors Density, recruitment, survival, harvested part, frequency, recovery	Establishes species- and practice-specific harvest rules	Aijaz et al. (2024); Sarwar et al. (2025)
Mobility is treated inconsistently	When does mobility sustain, transform, or weaken knowledge?	Multi-sited and route-based ethnography with seasonal ecological sampling Access routes, encounter networks, resource phenology, transmission, service reach	Designs mobile conservation and health services	Devi et al. (2026); Jameel et al. (2027)
Community governance lacks distributional evaluation	Which institutional arrangements produce inclusion and accountable benefit sharing?	Comparative institutional case study with process tracing Tenure, representation, rule influence, benefits, sanctions, grievances	Identifies governance mechanisms rather than labels	Lalrinmawia et al. (2025)
Useful exotics create unresolved trade-offs	When can use coexist with containment and cultural heterogeneity?	Longitudinal invasion, use, and knowledge comparison across management regimes Spread, abundance, uses, native displacement, knowledge overlap, control cost	Supports differentiated prevention, containment, or restoration	Neblea et al. (2025); Niaz et al. (2026)
Cultural wildlife use is disconnected from population monitoring	Which practices are compatible with species persistence and cultural priorities?	Community-led offtake and wildlife population monitoring Species abundance, effort, harvest, use, compliance, cultural association	Enables negotiated, species-specific conservation	Jameel et al. (2027)
AI selection lacks governance criteria	Can transparent models integrate biological performance with cultural authority?	Participatory model development and prospective field validation Criteria weights, uncertainty, subgroup preferences, field performance, benefit allocation	Makes recommendations explainable, contestable, and socially accountable	Rivera et al. (2024)

12. Implications for Policy and Practice

Policy should recognize traditional knowledge as a living system rather than a

database of useful claims. Documentation programs need resources for continued practice, including habitat access,

intergenerational learning, language, local institutions, and safe spaces for knowledge that communities do not wish to disclose. Success indicators should therefore include continuity and authority, not only the number of species or records collected.

Conservation programs should combine cultural importance with ecological monitoring. High-use or high-value taxa warrant closer assessment, especially when roots or whole plants are harvested or when demand is rising. Community-designed rules can draw on informal practices already reported in mountain communities while adding repeated population evidence (Muhammad et al., 2025; Sarwar et al., 2025). Restrictions should be transparent, proportionate, and paired with viable alternatives where households depend on the resource.

Food and livelihood initiatives should use species-specific pathways. Nutritional promotion requires evidence on intake, safety, preparation, and access; commercialization requires full-cost analysis, traceability, and sustainable supply. Women's collection and healthcare roles must translate into representation and control over benefits, not merely demographic visibility (Fatima et al., 2026; Malunguja et al., 2025; Zaman et al., 2025). Urban markets and tourism can support cultural continuity when communities control sourcing and representation (Şengül et al., 2025; Zhang et al., 2026).

Research governance should be explicit from project design through dissemination. Agreements should clarify collective and individual consent, specimen and data custody, sensitive information, authorship or acknowledgment, access to findings, and pathways for sharing downstream benefits. Technological tools should report criteria, uncertainty, and ownership. These practices are especially important when knowledge is translated into pharmaceuticals, functional foods, new crops, tourism products, or artificial-intelligence models (Gupta et al., 2024; Rivera et al., 2024).

Finally, public services should complement rather than displace community knowledge. Ethnoveterinary and medicinal practices are valuable partly because they are locally accessible, but reliance born of service scarcity should not be romanticized. Collaborative health and extension systems can support safe referral, species conservation, and reciprocal learning while respecting the practical expertise of pastoralists, women, elders, and other knowledge holders (Batool et al., 2025; Devi et al., 2026).

CONCLUSION

The supplied recent literature shows that ethnobiological knowledge is simultaneously ecological, material, cultural, and political. It supports healthcare, livestock production, dietary diversity, income, climate adaptation, and identity, but these contributions depend on continued access to species, landscapes, skills, and institutions. The same pathways that create value can also generate overharvest, homogenization, exclusion, unsafe translation, or loss of community control.

The central contribution of this review is the Biocultural Integrity Framework, which evaluates knowledge continuity, material security, ecological reciprocity, and institutional fairness together. The framework shifts attention from documenting useful resources to assessing the relationships that make their use durable and legitimate. It also clarifies why markets, tourism, invasive-species utilization, scientific validation, and artificial intelligence must be judged by their effects across all four dimensions rather than by economic or technical performance alone.

Future research should prioritize longitudinal, multi-sited, participatory designs that combine ethnographic depth with ecological, nutritional, health, and livelihood measurement. It should report how consent, data control, representation, and benefit sharing are handled. Such an agenda would allow ethnobiology to move beyond inventories without abandoning the

cultural specificity that gives those inventories meaning. The practical goal is not to preserve knowledge as a static archive, but to sustain the capacity of communities and ecosystems to adapt together.

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