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Original Research Paper

Ethnobotanical Plant Species a Systematic Assessment of Therapeutic Potential, Biodiversity Conservation, and Sustainable Utilization

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Abstract

Ethnobotanical plant species are an important connection between human cultural heritage, traditional health care systems and global biodiversity conservation. Medicinal plants are being used for the treatment of different illnesses worldwide. Over 50,000 species of plants are used as medicine. The traditional uses of medicinal plants offer primary healthcare to about 80% of the populations in the developing world and also provide important lead compounds for modern pharmacotherapy. However, due to severe anthropogenic pressures like destructive harvesting practices, habitat fragmentation, expansion of agriculture and climate change, more than 20% of the wild medicinal flora are threatened with extinction. This systematic review provides collective global evidence on the therapeutic potential, phytochemical diversity, and conservation dynamics of ethnobotanical flora. We assessed quantitative ethnobotanical indicators such as Use Value (UV), Informant Consensus Factor (ICF), and Fidelity Level (FL) in the main ecological biomes, in accordance with Best Practice in Ethnopharmacology (BPEP) guidelines. Our results show a strong association between high informant consensus (ICF = 0.75 - 0.92) and validated pharmacological activities, especially in the gastrointestinal, dermatology and respiratory treatment categories. The decline of wild populations is mainly attributed to harvesting and unmonitored commercial bioprospecting which destroy roots. To address these threats, we offer an integrative governance framework which includes in-situ protected areas, ex-situ germplasm cryopreservation, Good Agricultural and Collection Practices (GACP) for commercial cultivation, and community-based resource management. The ethical obligation for bioprospecting is emphasised to respect international Access and Benefit-Sharing (ABS) legislation in Nagoya Protocol. In the end, the most viable way to secure botanical healthcare resources, protect ecosystem integrity and support local livelihoods is to integrate indigenous traditional ecological knowledge with modern biotechnological propagation.

Keywords: Ethnobotany; Therapeutic potential; Biodiversity conservation; Sustainable utilization; Traditional ecological knowledge

1. Introduction

Civilisation has developed in a long, complex, co-evolutionary relationship with the plant kingdom. Ethnobotany is an interdisciplinary science that investigates complex relations of local flora with human society. It contains important knowledge on classification, use and management of botanical resources by indigenous cultures (Bala, 2020; Cox & Balick, 1994). TEK has been used by many cultures around the world to develop primary health care systems. In developing countries, over 80% of the population relies on traditional plant medicines for their basic health care needs (World Health Organization [WHO], 2013). In the industrialised countries natural products are still important lead structures for the development of drugs. About 25 % of the current prescription drugs are derived, directly or indirectly, from higher plants (Fabricant & Farnsworth, 2001).

Ethnobotanical bioprospecting has resulted in breakthrough pharmacotherapeutics in the past. Prominent examples include the antimalarial compound artemisinin from Artemisia annua, the antihypertensive alkaloid reserpine from Rauvolfia serpentina, the analgesic morphine from Papaver somniferum and the anticancer paclitaxel from Taxus brevifolia (Cox & Balick, 1994; Fabricant & Farnsworth, 2001). The use of TEK as a particular filter can greatly increase the efficiency of discovery

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compared to random, high-throughput screening of synthetic chemical libraries (Fabricant & Farnsworth, 2001).

However, these ethnobotanical plant species are confronted with unprecedented ecological and socio-cultural threats (Chen et al. 2016). Globally it is estimated that some 15,000-20,000 species of medicinal plants are under threat of population decline or local extinction due to unregulated wild harvesting, agricultural expansion, deforestation and climate change (Hamilton, 2004). Meanwhile, the rapid pace of urbanisation and cultural homogenisation has accelerated the loss of oral traditional knowledge. An imminent danger of losing valuable botanical knowledge before it can be recorded or scientifically validated (Bala, 2020).

Key Research Gaps and Study Rationale

While the local uses of Ethnobotanicals have been extensively documented, there are still important gaps in the research:

1. **Methodological gap:** lack of systematic integration between quantitative ethnobotanical metrics (e.g. Use Value, Informant Consensus Factor) and bioactivity-driven pharmacological validation.
2. **Conservation Gaps:** Ethnobotanical studies at the local level do not lead to practical in-situ and ex-situ conservation protocols for endangered wild flora.
3. **Governance and ethical gaps:** Weak implementation of Access and Benefit-Sharing (ABS) frameworks to safeguard indigenous intellectual property rights in commercial bioprospecting.

This study aims to fill these major knowledge gaps by assessing the global therapeutic potential of important ethnobotanical species, analysing the main ecological and anthropogenic threats to plant diversity and proposing an integrated governance framework for the sustainable use of resources.

Region / Domain	**Estimated Medicinal Flora Species**	**Primary Healthcare Reliance (%)**	**Iconic Ethnobotanical Plant Discovery**	**Key Phytochemical & Mechanism**	**Primary Threat Driver**
Asia & Subcontinent	~11,500 – 15,000	75% – 85%	*Rauvolfia serpentina* (L.) Benth.	Reserpine (VMAT inhibitor / Antihypertensive)	Destructive root collection & market demand (Fabricant & Farnsworth, 2001)
Africa & Sub-Sahara	~5,400 – 7,500	80% – 90%	*Prunus africana* (Hook. f.) Kalkman	□ -Sitosterol (5α-reductase inhibitor / Prostate care)	Commercial debarking & habitat loss (Hamilton, 2004)
Americas & Amazonia	~8,000 – 10,000	60% – 70%	*Cinchona officinalis* L.	Quinine (Heme polymerase inhibitor / Antimalarial)	Deforestation & land-use change (Cox & Balick, 1994)
Global Ecosystems	> 50,000	~80 % (Developing regions)	*Artemisia annua* L.	Artemisinin (Endoperoxide antimalarial clearance)	Wild over-harvesting & climate variability (Chen et al., 2016)

Table 1: Global Overview of Ethnobotanical Plant Diversity, Healthcare Reliance, and Major Bio-Discovery Milestones

2. Materials and Methods

2.1 Systematic Search Protocol

A comprehensive literature search was carried out to perform a meticulous systematic evaluation of ethnobotanical plant species, therapeutic efficacy and conservation strategies consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009). Structured search included peer-reviewed publications from 2000 to 2026 in the major scientific databases such as PubMed/MEDLINE, Web of Science, Scopus, Google Scholar, and ScienceDirect. The key search domains were combined with Boolean operators: (“ethnobotany” OR “ethnomedicine”) AND (“medicinal plants” OR “therapeutic potential”) AND (“biodiversity conservation” OR “sustainable utilization”). The methodology followed BPEP (Best Practice in Ethnopharmacology) guidelines strictly, so as to ensure reproducibility, taxonomic accuracy and transparency of the reported data (Heinrich et al., 2020).

2.2 Inclusion and Exclusion Criteria

We applied strict screening criteria to the initial body of literature. The inclusion criteria included: (1) original research articles and systematic reviews published in English or Farsi by peer-reviewed journals; (2) field studies that presented primary empirical quantitative ethnobotanical data; (3) phytochemical studies that reported specific secondary metabolites, in-vitro/in-vivo bioactivity assays, or clinical validation; and (4) ecological studies that evaluated conservation statuses, harvesting impacts, or community-based resource management protocols. Anecdotal reports not supported by scientific botanical verification, studies that did not explicitly define sampling frameworks, unpublished grey literature and commercial promotional materials were systematically excluded.

2.3 Data Extraction and Taxonomy Validation

The data collected from the last selection of literature were systematically grouped into taxonomic identities, geographic distribution, traditional therapeutic indications, active phytochemical constituents, modes of preparation and conservation statuses according to the International Union for Conservation of Nature (IUCN) Red List. All taxonomic nomenclature was standardised and cross-referenced with global authoritative databases (World Flora Online (WFO) and Plants of the World Online (POWO) (Tardío & Pardo-de-Santayana, 2008) to solve synonymy problems and ensure botanical precision.

2.4 Quantitative Ethnobotanical Indices

To objectively evaluate the cultural significance and pharmacological consensus of the documented medicinal flora, the extracted data were subjected to established quantitative ethnobotanical indices (Hoffman & Gallaher, 2007). The Use Value (UV) was calculated to quantify the relative cultural importance of individual species based on the total number of distinct use-reports, expressed as $UV = \sum U_i / N$. The Informant Consensus Factor (ICF) was applied, using the formula $ICF = (N_{ur} - N_t)/(N_{ur} - 1)$, to identify specific disease categories exhibiting the highest cultural agreement regarding plant efficacy, thereby prioritizing therapeutic targets for downstream pharmacological bioassays. Finally, the Fidelity Level (FL) was assessed, calculated as $FL(\%) = (I_p / I_u) \times 100$, to determine the community preference for a specific plant species in treating a primary ailment compared to alternative botanical remedies.

3. Results

3.1 Therapeutic Profiling and Phytochemical Diversity

The therapeutic efficacy of the ethnobotanical species is mainly mediated by a large variety of specialised secondary metabolites as shown by systematic synthesis of the extracted literature. The most frequently cited plant families used for medicinal purposes in the world ecosystems surveyed are Fabaceae, Asteraceae, Lamiaceae, Euphorbiaceae, Ranunculaceae and Solanaceae (Heinrich, 2000). Phytochemical profiling of these families revealed high prevalence of alkaloids, flavonoids, terpenoids, phenolic compounds and saponins. These secondary metabolites are mainly synthesised by plants as ecological defence mechanisms, but they show significant pleiotropic pharmacological effects on human biological systems such as antimicrobial, anti-inflammatory, antidiabetic and neuroprotective effects (Atanasov et al., 2021).

The bioactivity-guided fractionations reported in the reviewed studies are in agreement with the traditional uses of these plants. For instance, indigenous systems used for the treatment of fever and malaria have led to the discovery of endoperoxide sesquiterpene lactones (artemisinin) with high antimalarial clearance properties (Atanasov et al., 2021). Similarly, plants traditionally used for neurological and stress-related diseases such as Withania somnifera (Solanaceae) and Nardostachys jatamansi (Caprifoliaceae) have been shown to contain withanolides and sesquiterpenes that serve as adaptogens modulating the hypothalamic-pituitary-adrenal (HPA) axis and exerting significant neuroprotective effects (Bala, 2020; Kala, 2005).

3.2 Quantitative Ethnobotanical Evaluation and Disease Categories

Quantitative ethnobotanical indices applied in the different biomes of the world reveal clear and reliable trends of traditional health care priorities. The highest consensus values were calculated for the disease categories associated with gastrointestinal disorders, dermatological conditions and respiratory infections based on the analysis of the Informant Consensus Factor (ICF) across the globe (Gonfa et al., 2020). This is especially relevant considering the ICFs for gastrointestinal disorders have been reported between 0.78 and 0.92, indicating a high degree of cultural consensus regarding the efficacy of some plant-based remedies for common health problems (Ridwan et al., 2022).

UV calculations also show highest scores for polyvalent species (species with a number of therapeutic uses). However, species with high Fidelity Level (FL) scores, often >85%, are used for highly specific serious conditions such as parasitic infestations or localised venomous bites. In the view of pharmacologists, high FL values are important indicators of plant species with highly targeted biological activities and thus the best candidates for the isolation of active compounds (Gonfa et al., 2020; Heinrich, 2000).

Ecolo gical	Domi nant	M ea	Top Disease	Prim ary	Key Cons

Biome / Region	**Plant Families**	**n Use Value (UV) Range**	**Category (ICF)**	**Harvesting Threat**	**ervation Challenge**
Himalayan Alpine & Sub-alpine	Ranunculaceae, Asteraceae, Gentianaceae	0.65 – 1.45	Gastrointestinal (0.89); Respiratory (0.84)	Destructive root & rhizome extraction	Slow regeneration rates; acute climate change pressure (Kala, 2005)
Tropical Rainforests (Southeast Asia/ Amazon)	Fabaceae, Euphorbiaceae, Rubiaceae	0.45 – 1.20	Dermatological (0.87); Fevers/Malaria (0.91)	Uncontrolled stem and bark stripping	Habitat loss via deforestation & land conversion (Ridwan et al., 2022)
African Savanna & Afromontane	Lamiaceae, Fabaceae, Rosaceae	0.50 – 1.35	Parasitic/ Gastrointestinal (0.88)	Over-collection of bark & whole plants	Commercial over-exploitation; weak regulatory enforcement (Gonfa et al., 2020)
Arid & Semi-Arid Mediterranean	Lamiaceae, Asteraceae, Apiaceae	0.35 – 0.95	Digestive (0.82); Nervous system (0.76)	Over-grazing & intensive aerial harvesting	Habitat fragmentation & rapid desertification (Schippmann et al., 2002)

Table 2: Quantitative Ethnobotanical Metrics, Harvesting Impacts, and Threat Profiles Across Major Ecological Biomes

3.3 Threat Analysis and Conservation Status

Despite their immense pharmacological value, the systematic threat analysis indicates a critical decline in wild ethnobotanical populations. According to the extracted data cross-referenced with the International Union for Conservation of Nature (IUCN) Red List, over 20% of highly utilized medicinal plant species are currently categorized as Vulnerable (VU), Endangered (EN), or Critically Endangered (CR) (Chen et al., 2016).

The primary drivers of this biodiversity crisis are heavily anthropocentric. Destructive harvesting practices account for the most direct mortality in wild populations. Approximately 60% of commercialized medicinal plants require the extraction of underground organs (roots, rhizomes, bulbs) or complete debarking (e.g., *Prunus africana*, *Taxus wallichiana*), which effectively kills the individual plant and prevents natural regeneration (Hamilton, 2004; Schippmann et al., 2002). This localized over-exploitation is heavily exacerbated by the rapid expansion of the international herbal medicine market.

Secondary ecological threats include severe habitat fragmentation driven by agricultural expansion and rapid urbanization. Furthermore, climate change is emerging as a critical destabilizing factor, particularly for altitude-sensitive alpine flora in regions like the Himalayas. Changing temperature gradients are forcing these species to migrate upward into increasingly restricted habitats, drastically shrinking their viable ecological niches and altering their secondary metabolite yields (Kala, 2005). Concurrently, the socio-cultural threat of traditional knowledge erosion was widely reported; as younger generations migrate to urban centers, the unwritten ecological knowledge detailing sustainable harvesting windows and propagation techniques is being rapidly lost (Bala, 2020).

4. Discussion

4.1 Drug Discovery Implications: Bridging Ethnopharmacology and Modern Medicine

The passage from the classical empirical knowledge to validated standardised pharmacotherapy certainly needs systematic screening protocols based on ethnobotanical indices (Heinrich, 2000). In this review, the data presented showed the fact that ethnobotanical bioprospecting greatly enhances the ‘hit rate’ in drug discovery as opposed to the random high throughput screening of synthetic chemical libraries (Fabricant & Farnsworth, 2001). The high ICF and FL values of the plants assist the pharmacologists to focus on the most promising active leads. This helps to reduce thousands of plants to a handful of promising leads. A paradigmatic example of this approach is the discovery of artemisinin from Artemisia annua, which was directly guided by old traditional texts and finally changed the global anti-malarial therapy (Atanasov et al., 2021).

But there are some pharmacological difficulties in the transition from traditional remedies to single molecule drugs of modern medicine. Many indigenous botanical medicines use crude extracts with many constituents rather than isolated active principles. Within these complicated mixtures secondary metabolites often exhibit polypharmacological target interactions, synergistic bioactivity or enhanced bioavailability not observed for single isolated compounds (Heinrich et al., 2020). Pharmaceutical approaches based on isolates are therefore unlikely to detect such complex synergistic bioactivities. Such dynamics underscore the increasing need in the pharmaceutical industry to develop standardised phytomedicinal extracts that maintain the synergistic integrity of the original botanical preparation but also meet stringent clinical safety standards.

4.2 Strategic Conservation Trade-Offs: In-situ, Ex-situ, and Cultivation Frameworks

Long-term survival and genetic viability of ethnobotanical biodiversity relies on balancing complex conservation strategies at multiple levels of operation, each with different ecological and economic trade-offs (Chen et al., 2016; Hamilton, 2004).

Essentially, it is unsustainable to rely solely on wild harvesting for species with high demand. By contrast, a move to exclusive commercial cultivation will involve genetic and phytochemical trade-offs. Good Agricultural and Collection Practices (GACP) cultivation of plants alleviates pressure on wild populations and allows for uniform batch quality, however, cultivated plants are often lacking environmental stressors (e.g. herbivory, drought, soil competition) inducing robust synthesis of defensive secondary metabolites in the wild (Schippmann et al., 2002). Hence, a multidimensional approach is required.

Conservation Strategy	**Primary Mechanisms**	**Technical Advantages**	**Operational Trade-Offs & Limitations**	**Applicable Species Examples**
In-situ Conservation	Protected areas, sacred groves, community forest reserves	Preserves natural evolutionary processes, ecological interactions, and population genetics	Highly vulnerable to poaching, climate extremes, and conflicting land-use policies (Hamilton, 2004)	Wild populations of *Taxus wallichiana*, *Nardostachys jatamansi*
Ex-situ Conservation	Botanical gardens, seed banks, cryopreservation repositories	Guarantees genetic germplasm security against catastrophic wild extinction events	High long-term maintenance costs; potential loss of adaptive wild traits and ecological relationships (Chen et al., 2016)	Recalcitrant-seeded woody flora, highly endangered endemic taxa
Commercial Cultivation (GACP)	Farming integration, Good Agricultural Practices (GAP)	Takes harvest pressure off wild populations; ensures standardized batch quality and reliable yield	Requires agronomic expertise; may alter phytochemical profiles; potential land competition with food crops (Schippmann et al., 2002)	*Withania somnifera*, *Curcuma longa*, *Artemisia annua*
Biotechnological Propagation	Micropropagation, somatic embryogenesis, hairy root cultures	Enables rapid clonal multiplication and highly controlled secondary metabolite synthesis	Requires specialized laboratory infrastructure, prohibitive capital investments for developing regions (Atanasov et al., 2021)	High-value, slow-growing species (*Panax ginseng*, *Rauvolfia serpentina*)

Table 3: Comparative Analysis of Conservation Interventions and Trade-Offs for Threatened Ethnobotanical Species

4.3 Policy, Ethics, and Access & Benefit Sharing (ABS) Compliance

Commercialisation of ethnobotanical knowledge is at the complex intersection of international trade, intellectual property law and human rights. Historically, corporate bioprospecting was a classic example of unethical exploitation, whereby traditional remedies and natural chemical scaffolds were patented for commercial gains without due credit or economic benefits to indigenous communities who were the initial knowledge stewards (CBD, 2010). This is a practice that is infamously known as 'biopiracy'.

The compliance with the Nagoya Protocol through the Convention on Biological Diversity (CBD) is an ethical absolute of the modern ethnobotanical research to break these extractive paradigms. The Protocol creates a legally binding international legal framework for access and benefit-sharing (ABS) (CBD, 2010). Compliance requires the researchers and pharmaceutical entities to conform to three basic operational principles:

1. **Prior Informed Consent (PIC)**: The prior, free and informed consent of the local authorities and the holders of traditional knowledge shall be obtained before the collection of biological resources or traditional knowledge.
2. **Mutually Agreed Terms (MAT):** Legal agreements should be in place to define the scope of the research, ownership of intellectual property and rights to commercialisation.
3. **Fair and Equitable Benefit Sharing:** An ambitious framework to share economic benefits (royalties), to facilitate technology transfers and to support local capacity development programmes.

4.4 Community-Based Resource Management (CBRM)

Top-down conservation policies are usually doomed to failure unless integrated with activities at the grassroots level. The best models of governance are the Community-Based Resource Management (CBRM) models as this allows indigenous groups to be the main custodians of the local biodiversity. Connecting conservation to economic incentives in the form of premium prices for sustainably wild-harvested botanicals or cooperative-owned agroforestry businesses, for example, can turn conservation into an important economic asset to local livelihoods rather than a regulatory burden (Hamilton, 2004; Ridwan et al., 2022).

Conclusion

Ethnobotanical plant species are important center of human cultural heritage, natural product chemistry and ecological stability. This review summarises how these botanical resources fulfil most of the primary health care needs of the developing world and also act as essential structural scaffolds for modern pharmaceutical discovery. Concerted and urgent action is needed to reverse the alarming decline of wild medicinal flora through destructive harvesting, habitat fragmentation, commercial over-exploitation and climate change.

To safeguard these priceless biological gifts, we need to move the paradigm from extractive to inclusive, community-based governance systems. Policy-makers and conservationists should focus on scaling-up Good Agricultural and Collection Practices (GACP) and commercial agroforestry with strong support for in-situ and ex-situ conservation networks, in an effort to reduce the pressure on wild populations. Moreover, the commercialising of the traditional ecological knowledge should be done ethically and strictly following the Access and Benefit-Sharing (ABS) mechanisms under the Nagoya Protocol to protect the intellectual property of indigenous people and to ensure fair economic returns.

Future research should focus on polypharmacological synergies of traditional multi-component extracts, biotechnological propagation of critically endangered taxa and climate resilient cultivation strategies. And it is this marriage of traditional wisdom and modern scientific innovation that will guarantee that botanical therapeutics will be available for generations to come.

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