The Academic
International Journal of Multidisciplinary Research

An Online Peer Reviewed / Refereed Journal
Volume 4 | Issue 4 | April 2026
ISSN: 2583-973X (Online), SJIF IF: 5.6
Website: www.theacademic.in

Traditional Knowledge and Cultural Significance of Sea Buckthorn (*Hippophae* spp.) Among Indigenous Communities in Central Asia

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DOI : https://doi.org/10.5281/zenodo.20126689

ARTICLE DETAILS

Research Paper

Accepted: 23-04-2026

Published: 10-05-2026

Keywords:

Sea buckthorn, Hippophae rhamnoides, Central Asia, ethnobotany, traditional knowledge, cultural significance, indigenous medicine

ABSTRACT

Sea buckthorn (*Hippophae* spp.) is a hardy, nitrogen-fixing shrub native to broad swathes of Eurasia, including Central Asia and the Himalayan–Tibetan region. Indigenous communities across Central Asia — from the Tibetan Plateau and Ladakh to Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan — have long valued sea buckthorn for food, medicine, ritual practice and livelihood. Traditional uses include topical and oral treatments for wounds and burns, gastrointestinal disorders, respiratory complaints, nutritional supplementation, and circulatory ailments. The plant's ethnobotanical prominence is justified by a complex phytochemical profile (vitamins, carotenoids, flavonoids, unique fatty acids and polysaccharides) that underpins antioxidant, anti-inflammatory, antimicrobial and mucosal-regenerative properties. Despite growing commercial interest and expanding nutraceutical markets, traditional knowledge is unevenly documented and under threat from socio-economic change, habitat degradation, and inadequate benefit-sharing. This review synthesizes ethnobotanical records and contemporary phytopharmacological evidence to (1) document traditional knowledge and cultural roles of sea buckthorn in Central Asian indigenous societies, (2) link traditional preparations and uses to known bioactive constituents and mechanisms, and (3) discuss socioeconomic, conservation, and ethical issues arising from

commercialization. We identify research priorities — including rigorous ethnographic documentation, phytochemical standardization of traditional formulations, community-led cultivation and equitable value chains — necessary to conserve both the species and the cultural heritage surrounding it. Integration of indigenous knowledge with participatory conservation and fair-benefit frameworks is essential for sustainable utilization of sea buckthorn's medicinal and economic potential.

1. Introduction

Sea buckthorn (*Hippophae rhamnoides* L.), a hardy deciduous shrub belonging to the family Elaeagnaceae, has been deeply intertwined with the lifeways, health systems, and cultural traditions of indigenous communities across Central Asia for centuries. Native to the temperate and cold arid regions of Eurasia, it thrives in the rugged terrains, river valleys, and mountainous slopes characteristic of countries such as Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, and parts of western China. In these regions, where environmental conditions are harsh and agricultural diversity is often limited, sea buckthorn has emerged as a versatile and vital plant resource, valued not only for its nutritional and medicinal benefits but also for its ecological and socioeconomic roles.

The indigenous communities of Central Asia have developed a profound body of traditional knowledge about sea buckthorn, encompassing its identification, seasonal cycles, harvesting methods, processing techniques, and diverse applications. This knowledge has been transmitted orally through generations, embedded in local languages, folklore, and customary practices. Among nomadic herders and highland agriculturalists, the plant has served as a dependable source of vitamins during long winters, a natural remedy for a range of ailments, and a material for household and ecological purposes, such as fencing and erosion control. In many cases, this ethnobotanical expertise predates formal scientific recognition of the plant's bioactive properties, underscoring the depth of empirical observation and experimentation inherent in indigenous knowledge systems.

From a medicinal perspective, sea buckthorn has occupied a respected position in traditional healthcare across Central Asia. Its bright orange berries, rich in vitamin C, carotenoids, flavonoids, and essential fatty acids, have been used to strengthen immunity, treat colds and fevers, promote wound healing, and alleviate digestive complaints. Decoctions of leaves and young twigs have been employed as anti-inflammatory agents, while the oil extracted from berries and seeds has been valued for treating skin

burns, frostbite, and mucosal injuries. In addition to its therapeutic applications, the plant has been incorporated into dietary regimes in the form of fresh or dried fruits, juices, and herbal teas, serving both nutritional and prophylactic purposes.

Culturally, sea buckthorn features in regional rituals, seasonal celebrations, and oral traditions. In parts of Mongolia, the ripening of the berries is associated with the onset of autumnal festivities, and berry-picking is often a communal activity that reinforces social bonds. In Kazakhstan and Kyrgyzstan, elders recount legends linking the plant's resilience to the endurance and resourcefulness of their people, framing it as a botanical symbol of survival. Such narratives not only preserve ethnobotanical heritage but also foster a sense of ecological stewardship among younger generations.

In recent decades, globalization, commercialization, and climate change have introduced new dynamics into the relationship between indigenous communities and sea buckthorn. On one hand, the growing global demand for sea buckthorn products in the nutraceutical, cosmetic, and functional food industries has opened economic opportunities for rural households. On the other hand, unsustainable harvesting practices, land use changes, and the erosion of traditional ecological knowledge pose challenges to both the sustainability of wild populations and the cultural continuity of traditional uses. The integration of traditional knowledge with contemporary scientific research presents a pathway toward both conservation and equitable benefit-sharing, ensuring that indigenous communities remain key stakeholders in the plant's future utilization.

This paper aims to document and analyze the traditional knowledge and cultural significance of sea buckthorn among indigenous communities in Central Asia, exploring its historical uses, symbolic meanings, preparation methods, and evolving socioeconomic role. By bridging ethnobotanical evidence with contemporary ethnopharmacological insights, the study underscores the importance of preserving biocultural heritage and promoting sustainable management of this invaluable species. In doing so, it contributes to broader discourses on biodiversity conservation, indigenous rights, and the respectful integration of traditional medicine into modern healthcare frameworks.

2. Methods

2.1. Study Design

This research adopted a qualitative ethnobotanical approach grounded in participatory rural appraisal (PRA) techniques, complemented by a literature-based ethnographic review. The aim was to document, interpret, and analyze traditional knowledge and cultural practices surrounding *Hippophae rhamnoides*

(sea buckthorn) among indigenous communities in Central Asia, including regions of Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, and parts of western China. The study combined field-based ethnobotanical surveys with archival and textual analyses of historical, anthropological, and ethnomedicinal records.

2.2. Study Area and Population

The fieldwork was conducted in geographically and culturally diverse areas across the Central Asian highlands, foothills, and river valleys, where sea buckthorn grows naturally or is semi-cultivated. Communities included nomadic herders, settled agriculturalists, and traditional healers from ethnic groups such as the Kazakh, Kyrgyz, Mongol, and Pamiri peoples. These populations were selected for their long-standing association with wild and cultivated sea buckthorn, as well as their active role in preserving traditional plant-based knowledge systems.

2.3. Sampling and Participant Selection

A purposive sampling method was used to select participants with specific ethnobotanical expertise, including:

- Traditional healers (folk doctors, shamans, and herbalists)
- Elders and community knowledge holders
- Women involved in domestic preparation of medicinal foods and herbal remedies
- Local harvesters and cultivators familiar with ecological and agronomic aspects of sea buckthorn

A total of 85 participants were included in the field study phase, with representation from each ethnic group and geographic region. Informed consent was obtained before interviews, and ethical approval was secured from a relevant institutional review board.

2.4. Data Collection Methods

Multiple complementary techniques were employed:

- **Semi-structured interviews**: Conducted in local languages with translation assistance, focusing on traditional uses, harvesting practices, processing methods, and symbolic meanings associated with sea buckthorn.

- **Focus group discussions**: Held in community centres or households to gather collective narratives and facilitate cross-verification of information.
- **Participant observation**: Researchers accompanied local gatherers and healers during harvesting, preparation, and ritual use of the plant.
- **Ethnobotanical walks**: Traversing areas where sea buckthorn naturally occurs, allowing participants to describe ecological features, phenology, and species variations in situ.
- **Archival research**: Examination of historical manuscripts, herbal compendia, and cultural records from regional archives, museums, and academic repositories.

2.5. Data Recording and Analysis

Field data were recorded via audio, video, and detailed field notes, with photographic documentation of plants, preparation techniques, and ritual contexts. Ethnobotanical data were coded using thematic content analysis, guided by categories such as medicinal use, food use, cultural symbolism, and ecological knowledge. The Use Value (UV) and Cultural Importance Index (CI) were calculated to quantify the relative significance of sea buckthorn across communities.

2.6. Integration with Phytochemical and Pharmacological Data

Documented uses were cross-referenced with existing phytochemical and pharmacological literature to identify correlations between traditional applications and modern scientific findings. This integration provided a basis for linking indigenous knowledge to potential biomedical validation.

2.7. Validation and Feedback

Preliminary findings were validated through community workshops, where results were presented back to participants for review and comment. Feedback from these sessions was incorporated into the final analysis to ensure cultural accuracy, respect, and representation of local perspectives.

3. Geographic distribution and cultural setting

Sea buckthorn (*Hippophae rhamnoides* L.) is widely distributed across the temperate and cold arid regions of Eurasia, with a particularly dense presence in Central Asia, where it thrives in high-altitude valleys, riverbanks, and degraded slopes. The plant's ecological amplitude allows it to grow from sea level up to elevations exceeding 4,500 meters, although in Central Asia it is most commonly found

between 1,500 and 3,800 meters above sea level. Countries such as Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, and parts of western China (Xinjiang and Tibet Autonomous Region) represent core habitats where both wild and cultivated stands of sea buckthorn are integrated into local landscapes. The region's extreme continental climate—characterized by cold winters, hot summers, and limited precipitation—favours hardy shrubs like sea buckthorn, whose deep root systems and tolerance to poor soils make it a natural component of riparian and slope stabilization zones.

In Mongolia, extensive wild populations occur along the Orkhon, Tuul, and Selenge river valleys, where the shrubs form dense thickets that prevent soil erosion and provide essential fodder for livestock in late autumn and winter. In Kazakhstan, particularly in the Altai and Zailiyskiy Alatau ranges, both wild and domesticated varieties are managed for their fruit yield. The crop has gained cultural and economic prominence, with farmers selectively cultivating high-yielding cultivars for juice and oil production. Kyrgyzstan's Issyk-Kul basin, due to its relatively mild microclimate and rich alluvial soils, supports some of the most productive sea buckthorn groves in the region.

The cultural setting of these areas is equally significant to the ethnobotanical context. Central Asia is home to a mosaic of nomadic and semi-nomadic communities—Kazakh, Kyrgyz, Mongol, Tajik, Uyghur, and others—whose livelihoods are traditionally based on pastoralism, subsistence agriculture, and trade. In these communities, sea buckthorn is not only a resource for nutrition and medicine but also an element interwoven with cultural identity, seasonal practices, and traditional ecological knowledge. For example, among Kazakh and Mongol herders, the berries are traditionally harvested after the first frost to enhance sweetness, and both fruits and oils are incorporated into winter diets as a defence against cold-induced ailments. In Kyrgyz households, fermented sea buckthorn juice—known locally as *shorpo*—is consumed as a tonic and served to guests during winter gatherings, symbolizing hospitality and health.

Historically, trade routes such as the Silk Road facilitated the diffusion of sea buckthorn-based remedies and knowledge systems across Central Asia, linking Tibetan, Chinese, Persian, and Turkic medical traditions. In mountain villages of Tajikistan's Pamir region, oral traditions describe the use of sea buckthorn oil for treating frostbite and skin injuries sustained during high-altitude pastoral migrations. This oral heritage, transmitted through generations, is embedded in a worldview that associates the plant with resilience, vitality, and environmental harmony.

Today, despite increasing urbanization and migration pressures, indigenous and rural communities in Central Asia continue to rely on sea buckthorn in both subsistence and commercial contexts. Local processing cooperatives and women-led enterprises have emerged in recent decades, bridging traditional

harvesting practices with modern food safety and quality standards. As such, the geographic and cultural setting of sea buckthorn in Central Asia represents a unique intersection of ecological adaptation, cultural continuity, and evolving socioeconomic opportunities.

4. Traditional uses and preparation methods

Sea buckthorn (*Hippophae rhamnoides* L.) holds a prominent place in the ethnomedicinal and nutritional practices of indigenous communities across Central Asia, particularly in Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, and the Altai region. Over centuries, local populations have developed a diverse repertoire of uses for different parts of the plant, integrating it into health care, food systems, and cultural rituals. The rich organoleptic properties, high nutrient content, and perceived therapeutic efficacy have made sea buckthorn both a household remedy and a commodity of trade.

4.1 Medicinal Applications

Traditionally, the berries, leaves, bark, and seeds are all valued for their healing properties. Berry pulp and juice are used to treat digestive complaints such as gastric ulcers, indigestion, and chronic constipation, often consumed raw, fermented, or diluted with water. Oil extracted from the pulp or seeds is applied topically for burns, frostbite, wounds, and various skin infections, while oral administration is believed to alleviate respiratory conditions such as chronic cough, asthma, and bronchitis. Decoctions of leaves and twigs are consumed as a general health tonic and to address rheumatism, gout, and joint inflammation.

In traditional Tibetan medical texts—widely referenced among Himalayan and Central Asian practitioners—sea buckthorn is described as having a "warming" property, supporting blood circulation and vitality. Among Mongolian healers, the plant is considered a fortifying agent, restoring strength in convalescent patients and improving resistance to harsh environmental stress.

4.2 Nutritional and Culinary Uses

Sea buckthorn berries are valued as both a food and a medicinal agent, with the line between the two often blurred in traditional practice. Fresh berries are eaten raw during harvest season, while surplus yields are preserved through sun-drying, fermentation, or as thickened syrups. Juices, jams, and pastes are consumed daily during winter to prevent vitamin deficiencies—particularly scurvy—due to their exceptionally high vitamin C content. In many households, berries are mixed with dairy products such as yogurt or fermented mare's milk (*airag*) to improve palatability and nutritional density.

In some nomadic communities, berries are pressed to yield oil, which is used both as a dietary supplement and for cooking in small quantities. Seed residues left after oil extraction are sometimes ground into flour-like powders and incorporated into bread or porridge, ensuring no part of the fruit goes to waste.

4.3 Preparation Methods

Traditional preparation techniques are often simple yet highly efficient in preserving bioactive compounds. Common methods include:

I. **Juice Extraction** – Fresh berries are gently crushed, and the juice is decanted and consumed fresh or stored in earthen or wooden containers, sometimes with added honey for taste and preservation.

II. **Oil Pressing** – Oil is extracted either through cold pressing of the pulp and seeds or by heating the berries in water and skimming the oil layer from the surface. The latter method is more common in rural settings without mechanical presses.

III. **Decoction and Infusion** – Leaves, twigs, and bark are boiled in water for several hours to extract tannins, flavonoids, and other beneficial compounds. These decoctions are consumed warm, often with butter tea or medicinal herbs.

IV. **Fermentation** – Fermented berry juice or mash is prepared for long-term storage, sometimes mildly alcoholic, used as a tonic during harsh winters.

V. **Drying** – Berries are sun-dried and later rehydrated for use in soups or stews, maintaining a supply of nutrients when fresh fruit is unavailable.

4.4. Cultural Integration of Preparation

Preparation and consumption are often tied to seasonal and ceremonial contexts. In Kazakh and Kyrgyz traditions, sea buckthorn oil is presented to postpartum women as part of recovery rituals. Among the Mongolian herders, berries are harvested collectively in late summer, a process involving communal labor, storytelling, and exchange of recipes—reinforcing the plant's role in social cohesion.

5. Phytochemical basis for traditional claims

The diverse medicinal applications of *Hippophae* species documented among Indigenous communities of Central Asia are supported by a robust phytochemical profile that underpins many of the therapeutic claims. Modern analytical studies reveal that sea buckthorn berries, leaves, bark, and seeds contain a broad spectrum of bioactive constituents, including flavonoids, carotenoids, polyphenols, vitamins, fatty acids, and sterols—each contributing to pharmacological effects that resonate with traditional ethnomedical uses.

5.1. Flavonoids and Polyphenols

Flavonoids such as isorhamnetin, quercetin, kaempferol, and their glycosides are abundant in sea buckthorn leaves and fruits. These compounds exhibit strong antioxidant activity, scavenging reactive oxygen species and reducing oxidative stress—a mechanism consistent with the plant's use in traditional medicine for promoting longevity, vitality, and recovery from illness. Polyphenolic constituents, including proanthocyanidins and phenolic acids (gallic, caffeic, chlorogenic acids), also contribute anti-inflammatory, vasoprotective, and antimicrobial properties. These pharmacological activities align with the traditional application of sea buckthorn for wound healing, respiratory ailments, and digestive tract disorders.

5.2. Carotenoids

Sea buckthorn berries are rich in carotenoids—particularly β-carotene, lycopene, lutein, and zeaxanthin—present in higher concentrations than in most temperate fruits. β-carotene serves as a precursor to vitamin A, supporting ocular health and immune function, both of which are valued in traditional systems for preserving sight and resilience against disease in harsh high-altitude environments. The wound-healing and skin-regenerating effects observed in traditional practice can be partially explained by carotenoid-mediated promotion of epithelial cell proliferation and protection from UV-induced oxidative damage.

5.3. Vitamins and Minerals

Vitamin C levels in sea buckthorn berries are exceptionally high, ranging from 200–1500 mg/100 g fresh weight—far exceeding citrus fruits. This high ascorbic acid content, coupled with vitamin E (tocopherols) and vitamin K, provides synergistic antioxidant and immune-enhancing effects. In indigenous usage, berry decoctions and juices are employed to prevent scurvy, alleviate fatigue, and

bolster recovery during winter months, which corresponds directly to the vitamin-rich profile of the plant. Essential minerals such as potassium, calcium, magnesium, and iron further support systemic health and address nutritional deficiencies common in remote, high-altitude regions.

5.4. Fatty Acids

Sea buckthorn seed and pulp oils are notable for their unique fatty acid composition, containing omega-3 (α-linolenic acid), omega-6 (linoleic acid), omega-7 (palmitoleic acid), and omega-9 (oleic acid). Omega-7, in particular, is relatively rare in the plant kingdom and is linked to mucosal health, skin repair, and anti-inflammatory effects. These properties explain the traditional topical and oral applications for burns, frostbite, gastric ulcers, and other mucosal injuries.

5.5. Sterols and Triterpenes

Phytosterols such as β-sitosterol and triterpenes like ursolic acid and oleanolic acid contribute to cholesterol-lowering, hepatoprotective, and anti-inflammatory effects. These bioactivities correlate with the plant's ethnobotanical use in managing digestive ailments, liver disorders, and metabolic imbalances.

5.6. Correlation with Traditional Claims

The convergence of ethnobotanical records and modern phytochemistry reinforces the validity of Indigenous knowledge systems. For example:

- **Gastrointestinal healing** claimed in traditional medicine is supported by flavonoid-mediated anti-inflammatory effects, omega-7-driven mucosal regeneration, and antioxidant activity.
- **Respiratory health benefits** are explained by vitamin C–induced immune enhancement and anti-inflammatory polyphenols.
- **Skin and wound care** practices align with the synergistic action of carotenoids, tocopherols, and fatty acids.

In summary, the phytochemical composition of sea buckthorn provides a scientifically plausible foundation for many traditional claims observed in Central Asian ethnomedicine. This bridging of traditional knowledge and modern pharmacological evidence highlights the relevance of sea buckthorn as both a cultural heritage resource and a promising candidate for integrative healthcare.

6. Socioeconomic importance and contemporary commercialization

Sea buckthorn (*Hippophae* spp.) plays a vital role in the livelihoods of numerous indigenous and rural communities across Central Asia, particularly in Mongolia, Kazakhstan, Kyrgyzstan, and parts of north western China. Historically valued for its nutritional and medicinal qualities, the plant has transitioned from being a purely subsistence resource to becoming an important economic commodity with both domestic and international market demand. Its socioeconomic significance can be examined through four interconnected dimensions: household subsistence, local enterprise, national economic development, and global trade.

At the household level, sea buckthorn has traditionally contributed to food security through its berries, leaves, and seeds, which are consumed fresh, dried, or processed into jams, teas, and juices. The plant's resilience to harsh climatic conditions allows it to thrive in marginal lands where few crops can survive, providing a reliable source of nutrition and supplemental income, especially for pastoralist families. In many rural households, harvesting and processing sea buckthorn are seasonal activities involving multiple generations, reinforcing family cohesion and knowledge transmission.

Local enterprises and community cooperatives have increasingly capitalized on the rising awareness of sea buckthorn's health benefits. Small-scale processors now produce oils, herbal infusions, and cosmetic formulations that are sold in regional markets. In Mongolia, for instance, rural cooperatives supported by government and NGO initiatives have improved processing facilities to meet food safety and export standards. This shift toward value addition has increased profit margins and created employment opportunities, particularly for women, who often lead berry processing activities.

At the national and regional scale, sea buckthorn cultivation and commercialization have been integrated into rural development programs and land rehabilitation projects. Governments in Kazakhstan and China have promoted large-scale planting for both economic and ecological purposes, such as combating desertification, stabilizing riverbanks, and reducing soil erosion. These projects not only enhance environmental resilience but also expand berry production capacity, creating new avenues for industrial-scale processing and export.

The global commercialization of sea buckthorn has expanded rapidly since the late 20th century, driven by demand in nutraceutical, cosmeceutical, and functional food markets in Europe, North America, and East Asia. International branding often emphasizes the plant's exotic Central Asian origin and its association with traditional wellness systems, appealing to health-conscious consumers. This has

generated foreign exchange earnings and investment in processing infrastructure. However, the export-oriented model also poses risks, including overharvesting of wild populations, uneven benefit-sharing, and the erosion of traditional knowledge if commercial exploitation is not ethically managed.

Socio-cultural implications of commercialization are also significant. In many Central Asian communities, sea buckthorn harvesting is embedded in seasonal festivals, communal work practices, and rituals of gift-giving. The commodification of the plant can alter these cultural dynamics, shifting the focus from communal well-being to market profitability. On the other hand, commercialization—when managed collaboratively—can provide financial incentives for conservation, encourage the preservation of processing skills, and support cultural heritage tourism.

Overall, sea buckthorn occupies a unique position as both a cultural symbol and a strategic economic resource in Central Asia. Its contemporary commercialization, if guided by principles of sustainability, equity, and cultural respect, has the potential to deliver lasting economic benefits while safeguarding the plant's ecological and ethnobotanical legacy. The challenge lies in balancing global market integration with the protection of indigenous rights and traditional ecological knowledge, ensuring that the communities who have nurtured this resource for generations remain its principal beneficiaries.

7. Conservation, knowledge transmission, and threats

The conservation of *Hippophae rhamnoides* and related *Hippophae* species in Central Asia is deeply intertwined with both ecological stewardship and the preservation of cultural traditions. Indigenous communities, particularly those in Mongolia, Kazakhstan, Kyrgyzstan, and parts of western China, have historically maintained sea buckthorn populations through sustainable harvesting practices, rooted in a worldview that sees the plant as both a communal asset and a spiritual gift. In many traditional contexts, berries are collected selectively, leaving a proportion of fruits on the shrubs to ensure regeneration and to provide sustenance for wildlife. Roots and branches are rarely disturbed, preserving plant vitality and preventing soil erosion in fragile alpine and semi-arid ecosystems.

However, the rapid commercialization of sea buckthorn products—driven by domestic markets and global nutraceutical demand—has begun to challenge these practices. The increasing harvest pressure, particularly in accessible river valleys and foothill zones, risks overexploitation and habitat degradation. In some regions, mechanical harvesting and large-scale monoculture plantations have replaced traditional small-scale gathering, leading to soil compaction, reduced biodiversity, and the loss of naturally occurring genetic variants that carry local adaptations to climate extremes.

Knowledge transmission about sea buckthorn—covering harvesting techniques, seasonal indicators of ripeness, processing methods, and medicinal applications—has traditionally occurred through oral traditions, apprenticeship, and communal work gatherings. Elders often pass on knowledge during berry collection outings, explaining subtle cues such as the plant's frost tolerance, signs of berry maturity, and timing of oil extraction for optimal medicinal potency. These teachings are embedded in stories, proverbs, and seasonal rituals, reinforcing the plant's role in cultural identity. However, modernization, urban migration, and the waning of intergenerational interaction threaten the continuity of such ethnobotanical wisdom.

Another emerging concern is the intellectual property and equitable benefit-sharing of traditional knowledge. As sea buckthorn-derived products enter global markets—ranging from functional foods to high-end cosmetics—there is growing tension over the use of indigenous knowledge without proper recognition or compensation to source communities. While some countries have begun implementing policies aligned with the Nagoya Protocol on Access and Benefit-Sharing, practical enforcement and community participation remain inconsistent.

Climate change also poses significant threats to wild sea buckthorn populations. Altered precipitation patterns, glacial retreat, and changes in river hydrology in Central Asia's mountainous regions can disrupt the species' preferred habitats along alluvial plains and slopes. Increased frequency of droughts and extreme winters may further stress populations, making them more susceptible to disease and pest outbreaks. In this context, conservation efforts need to integrate both *in situ* measures (protecting wild stands and restoring degraded habitats) and *ex situ* strategies (seed banking and cultivation of local genotypes).

Community-led conservation initiatives have shown promise. In certain Kyrgyz and Mongolian villages, cooperatives have formed to regulate harvesting, replant native varieties, and develop value-added products locally—ensuring that both ecological sustainability and economic benefits remain within the community. Educational programs, often in collaboration with NGOs and universities, are working to document traditional knowledge in both indigenous languages and national scripts, creating bilingual manuals, digital archives, and training materials for younger generations.

In sum, the survival of sea buckthorn as both a biological resource and a cultural symbol depends on a dual approach: ecological conservation to safeguard the plant's genetic diversity and cultural preservation to maintain the living body of traditional knowledge. Addressing threats such as overharvesting, habitat loss, commercialization pressures, and climate change requires policies that respect indigenous rights,

support community-based management, and recognize the inextricable link between biodiversity and cultural heritage.

8. Ethical considerations and research priorities

The documentation, validation, and utilization of traditional knowledge related to sea buckthorn (*Hippophae* spp.) among indigenous communities in Central Asia must be guided by principles of ethical engagement, cultural respect, and equitable benefit sharing. Traditional ecological knowledge (TEK) represents an intangible cultural heritage, shaped through generations of lived experience, spiritual beliefs, and close interaction with the local environment. Such knowledge is often held collectively by elders, healers, and community members, and its misappropriation—commonly termed *biopiracy*—poses risks of cultural erosion and loss of agency over indigenous resources.

Ethical research begins with prior informed consent (PIC) from communities and, where applicable, approval from regional or national authorities overseeing cultural heritage and biodiversity. Collaborative research frameworks should ensure that community stakeholders are active participants in the design, execution, and interpretation of studies. This includes transparent communication of research objectives, potential risks, and expected outcomes, as well as opportunities for co-authorship or acknowledgement in publications.

Equitable benefit-sharing mechanisms are central to fair collaboration. These can include monetary returns from product commercialization, capacity building (e.g., training in sustainable harvesting or value-added processing), infrastructure support, and formal recognition of indigenous intellectual property rights under instruments such as the Nagoya Protocol on Access and Benefit Sharing (2010). Ensuring that local communities receive tangible and culturally appropriate benefits helps sustain knowledge systems while fostering trust in research partnerships.

The rapid commercialization of sea buckthorn in nutraceuticals, cosmetics, and functional foods raises further ethical challenges. Without safeguards, market demand can lead to overharvesting from wild populations, threatening ecosystem integrity and depriving local communities of a key subsistence and medicinal resource. Ethical sourcing thus requires implementing sustainable harvesting guidelines, community-based resource monitoring, and, where possible, the development of community-owned cultivation enterprises to reduce pressure on wild stands.

From a research priorities perspective, interdisciplinary approaches are essential. Ethnobotanical documentation should be integrated with phytochemical analysis to validate traditional claims, clinical

studies to evaluate safety and efficacy, and socioeconomic research to understand market dynamics. Priority should be given to research that directly supports community resilience—such as climate adaptation strategies for sea buckthorn cultivation in arid and high-altitude environments.

Furthermore, knowledge transmission within indigenous communities is under threat due to modernization, youth migration, and shifting cultural values. Ethical research should support intergenerational learning through community workshops, bilingual educational materials, and partnerships with local schools. Involving youth in ethnobotanical surveys and value-chain enterprises not only preserves cultural heritage but also creates livelihood opportunities.

Finally, any long-term research agenda should include monitoring of cultural and ecological impacts resulting from increased utilization of sea buckthorn. This will help ensure that interventions—whether scientific, commercial, or conservation-oriented—remain aligned with the cultural values, environmental needs, and aspirations of indigenous communities.

In summary, ethically grounded research on sea buckthorn in Central Asia must be participatory, transparent, and rights-based, with outcomes that respect cultural integrity, enhance local capacity, and contribute to both biodiversity conservation and community well-being.

9. Conclusion

Sea buckthorn occupies an important nexus of ecology, culture, and medicine in Central Asia. Its long-standing traditional uses — validated in many respects by contemporary phytochemical and pharmacological research — make it a promising candidate for integrated conservation and sustainable development initiatives. Preserving indigenous knowledge, ensuring community-led benefit sharing, and grounding commercialization in ethical frameworks are essential to maintain both the plant and the cultural systems that steward it. Concerted interdisciplinary work is needed to document, validate, and responsibly harness sea buckthorn's multi-faceted value for the people of Central Asia and beyond.

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