Advances in Asian Human-Environmental Research

Anwesha Borthakur
Pardeep Singh *Editors*

Learning 'from' and 'with' the Locals

Traditional Knowledge Systems for Environmental Sustainability in the Himalayas

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Editors
Anwesha Borthakur
University of Leuven (KU Leuven)
Leuven, Belgium

Pardeep Singh
Department of Environmental Studies
PGDAV College, University of Delhi
New Delhi, India

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Introduction

Environmental sustainability in the Global South in general and its mountain ecosystems in particular is a major concern in the present-day global environmental circumstances. The Himalaya, regarded as the most significant mountain range in the world in terms of its geographies, natural resources, biodiversity, and human population among other such attributes, is in a critical juncture where this majestic mountain range is constantly being threatened by increasing pressures from anthropogenic activities and climate change challenges. For instance, the Himalayas are highly susceptible to the impacts of climate change such as increased temperatures, changing precipitation patterns, and glacier collapses (Khadka et al. 2023; Krishnan et al. 2019). The Himalayan region, with its unique ecological and geographical characteristics, spans through several countries including India, Nepal, Bhutan, China, and Pakistan and the mountain range provides water and food security to a large share of the global population. However, at the same time, construction of roads, dams, and other infrastructural projects in the region are disrupting these vulnerable mountain ecosystems with increasing risks of landslides, avalanches, and other natural or manmade disasters (Pandey 2021; Rana et al. 2007). For example, far-reaching and adverse social and environmental repercussions are every so often linked to the economic benefits of building dams for water supply and hydropower, especially in the Global South (Nüsser 2003). There are further concerns associated with human activities like uncontrolled mass tourism (Chakraborty and Ghosal 2024). The Himalayas host some major tourist destinations in South Asia and thus, attract a significant number of tourists from all over the world. This is resulting in unsustainable tourism practices in many parts of the mountains, leading to cultural disruptions, environmental degradations, and strain on local resources among several other socio-cultural-environmental repercussions. All these activities have cascading effects on the region's natural resources, agriculture, and overall ecosystem services.

Traditional knowledge systems of the indigenous and local communities in the Himalayas have the potential to show directions in tackling the environmental sustainability and climate change challenges in the mountainous ecosystems. The United Nations Convention on Biological Diversity (CBD) in Article 8(J) defines traditional knowledge as:

> Traditional knowledge refers to the knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds.[1]

The terms, traditional knowledge, indigenous knowledge, or local knowledge are often seemed to use synonymously in scientific literature. While both traditional and indigenous knowledge could be considered as subsets of local knowledge systems, there are authors who endeavored to distinguish between traditional knowledge and indigenous knowledge. For instance, indigenous knowledge could be regarded as the knowledge of a unique society or culture and traditional knowledge as system of knowledge possessed by or prevailing in the broader community, consisting of hundreds of members (Orlovic Lovren 2019). In general, local knowledge is site-specific and it "emerges through people's practical engagement with their environmental setting" (Nüsser and Baghel 2016).

We adhere to the term traditional knowledge as per its definition in the CBD because we believe that it serves the objective of our book better as compared to the other two terms. Traditional knowledge systems incorporate the collective knowledge, practices, beliefs, and wisdom that have been developed through constant engagement with nature and natural processes over hundreds of years and subsequently passed down through generations within specific communities or cultures. Thus, these systems of knowledge are often deeply rooted in the local environment, natural resources, and cultural heritage of a particular community. These knowledge systems encompass a wide range of expertise, such as ecological knowledge including information about plant and animal species, medicinal practices, agricultural techniques, weather patterns, sustainable resource management among others. It is important to recognize the value of traditional knowledge systems, as they have often demonstrated an in-depth understanding of the surrounding ecosystems, have sustained communities for generations, and made them self-reliant and sustainable to a great extent. This makes identifying and incorporating traditional knowledge systems into development and conservation efforts crucial. Unfortunately, traditional knowledge systems are increasingly getting endangered today owing to both internal (within the knowledge system itself) and external (such as increasing urbanization, modernization, city-ward migration, etc.) factors. It is indisputable that there is an urgent need to document, protect, and incorporate traditional knowledge systems into contemporary practices for greater environmental sustainability. In this regard, this book is an attempt to document the traditional knowledge systems of the local communities in the Himalaya and acknowledge their implications for environmental sustainability in one of the most important mountain chains in the world. In other words, there is a lot to learn "from" and "with" the locals in these

[1] https://www.cbd.int/traditional/intro.shtml

mountainous regions towards finding effective solutions to the contemporary global environmental and climate crisis.

Part I of the book addresses significance of traditional knowledge systems in conservation efforts in the Himalayas. For instance, over the years, an increasing interest has been observed among the scientific community to evaluate the role of traditional ecological knowledge systems and practices in maintaining sustainable use and conservation of ecosystem services (Sinthumule and Mashau 2020). Chapter 1 of the book explores the role of such traditional ecological knowledge systems in conservation efforts in the Himalayas with the help of four case studies in both Eastern and Western Indian Himalayas. Sacred groves are omnipresent in the Himalayan region. These are primarily areas of forest patches used and protected by the local people through their cultural and religious belief systems (Rath and Ormsby 2020). In the book, Chapter 2 evaluates the biocultural and conservation role of sacred groves in Jarey Gewog, Lhuentse Dzongkhag in the Himalayan Kingdom of Bhutan. Taking the conversation on conservation and forest management further to the North-Western Himalaya in India, Chap. 3 assesses the indigenous acquaintance and perceptions of local inhabitants toward biodiversity conservation in Talra Wildlife Sanctuary in the country.

Part II of the book is titled "Mountains, locals and their engagement with nature for a sustainable future." Engaging the local communities in sustainable resource management and conservation efforts has already proven to be an effective way in tackling several current global environmental challenges. Accordingly, Chap. 4 addresses the indigenous knowledge-based adaptation to support pollination service in social-ecological systems of Indian trans-Himalayan region from a climate change perspective. The community engagement could be aided by an increasing respect for and collaboration with the indigenous and local communities through preserving their valuable systems of knowledge. We must acknowledge that the traditional knowledge systems are deeply intertwined with the cultural identity of a community. They often take the shapes of stories, rituals, folklore, myths, and practices (Koopman 2023), preserving a community's cultural heritage. For generations, these communities have empowered themselves towards taking ownership of their surroundings, often leading to effective and sustainable solutions to the existing environmental, socio-economic, and health concerns. Thus, Chap. 5 is an attempt to uncover the medicinal plant resources of Dorokha in Bhutan through ethnobotanical research. Learning from the traditional knowledge practices and learning with the local communities could be crucial, for instance, for disaster risk reduction, climate resilience, conservation, and other sustainable environmental management efforts. Accordingly, Chap. 6 explores the significance of revitalizing traditional knowledge of the Himalayan indigenous tribes through an ethnoecological and ethnobotanical approach. Part II concludes with Chap. 7 which provides glimpses of traditional agroforestry practices in the Indian Himalayan Region. It is well-documented that a concerted effort involving governments, non-governmental organizations, local communities, and international partners is essential to address the environmental challenges in an ecologically important region like the Himalaya. In this regard, acknowledging the expertise of the indigenous or local communities and involving them in decision-making processes is instrumental in effective and ethical utilization of traditional knowledge for environmental sustainability.

While Part III of the book addresses the environmental challenges and peoples' responses in the Himalayas, Part IV provides possible way forward in terms of documenting traditional knowledge and situating its implications. Environmental challenges such as the climate crisis are impacting the lives of the global populace like never before. For example, for an increasing percentage of the global population, the long-term and severe impact of climate change is becoming a lived experience, resulting in a corresponding upsurge in the sum of individuals suffering psychological distress concerning the environment and climate crisis (Ogunbode et al. 2022). In this regard, it is essential to amplify the conversations on the greater environmental challenges towards situating a sustainable way forward. Within Part III, Chap. 8 explores the environmental determinism in the age of human influence among indigenous people in Singalila National Park (SNP) in the North-Eastern Himalaya in India. With an aim toward establishing new conservation areas, Chap. 9 evaluates the environmental and climate-induced threats to pheasants and their conservation status in the state of Uttarakhand in India's Western Himalaya. This study is important from environmental perspectives pertaining to both present and future implications. It is because while an alarming 25% of the 308 Galliformes species (such as pheasants, quails, and partridges) globally are listed as threatened with extinction on the IUCN Red List, the situation is more worrisome in Southeast Asia with 27% of the 76 Galliformes species listed as threatened with extinction (Grainger et al. 2018). This provides an indication of overall conservation-associated challenges in the Himalaya and human responses it calls for. Chapter 10 provides a detailed review of the traditional ecological knowledge of indigenous communities of North-East India. Home to at least 150 ethnic tribes, the North-East India not only has a wide-ranging cultural, ethical, traditional beliefs including a rich repository of traditional ecological knowledge but also it is a biodiversity hotspot (Das et al. 2023). Accordingly, an overview of the traditional ecological knowledge in the region is both judicious and topical in the present-day global environmental situations. Furthermore, currently, there are growing needs to integrate the knowledge of the local indigenous populace in any natural resource management and climate change adaptation strategies towards responding to the ever-increasing environmental and other forms of change (Mohamed Shaffril et al. 2020). Accordingly, Chap. 11 explores the association between traditional ecological knowledge and climate science. The final chapter of the book, Chap. 12, addresses the more-than-ever-relevant debates on environment and development with an aim to provide an approach for balancing progress, preserving the planet, and fostering collaboration for a sustainable future.

Overall, the book is our humble attempt to acknowledge and document the significance of traditional knowledge systems in tackling the current environmental challenges in the Himalayas. Originally, the idea for the book came from the experiences of working in a project on the Indian Himalaya titled, "Public engagement through knowledge co-production for environmental sustainability in the Indian Himalayan Region"—an individual project of the editor, Dr. Anwesha Borthakur, funded by the University of Leuven (KU Leuven) in Belgium. Together with the editor Dr. Pardeep Singh, with his experience of working on environmental sustainability concerns in India for several years, the book is developed considering the essentiality of documenting the traditional knowledge practices in the Himalayan region. The fact that both of us, the editors, are natives of the Indian Himalayan Region was helpful through our own lived-experiences and socio-cultural-environmental understandings of the region. From North-East Himalayas in India to Bhutan and Western Himalayas, we tried to incorporate studies from diverse regions within the Himalayan mountain range in order to provide the readers a holistic understanding of the current challenges and possible solutions. We hope that the book offers an account of the environmental concerns and traditional knowledge systems in the Himalaya and add to the existing literature on the majestic mountain range.

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Part III Environmental Challenges and Peoples' Responses in the Himalayas

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Part I

Traditional Knowledge Systems in Conservation Efforts in the Himalayas

To the Ones Who Listen to the Mountains: Evaluating the Role of Traditional Ecological Knowledge in Conservation Efforts in the Himalayas

Chandranshu Tiwari and Anupam Sunny

> *The disappearance of these indigenous communities is a loss for the larger society which could learn a great deal from their traditional skills in sustainably managing very complex ecological systems.*
>
> *–"Our Common Future", Brundtland Commission 1987.*

1 Himalayan Ecosystem

The Himalayan range is bordered by the Karakoram and Hindu Kush mountains to the northwest, the Tibetan Plateau to the north, and the Indo-Gangetic Plain to the south. Close to the Himalayas, the Indus, Ganges, and Tsangpo-Brahmaputra rivers, which are among the world's main rivers, originate. The combined drainage basin of these rivers is home to around 600 million people, with 53 million residing in the Himalayas. The Himalayas have had a significant influence on the cultures of South Asia and Tibet (Fig. 1). Despite occupying only 18% of India's total land area, the Himalayan Mountain chain supports over 50% of the country's forest cover and 40% of its endemic species. The resources and ecosystem services of the Himalayas

C. Tiwari
Department of Environmental Studies, Satyawati College, University of Delhi, New Delhi, India

Department of Environmental Studies, Shyama Prasad Mukherji College, University of Delhi, New Delhi, India

A. Sunny (✉)
Department of Environmental Studies, Satyawati College, University of Delhi, New Delhi, India
e-mail: anupamsunny@satyawati.du.ac.in

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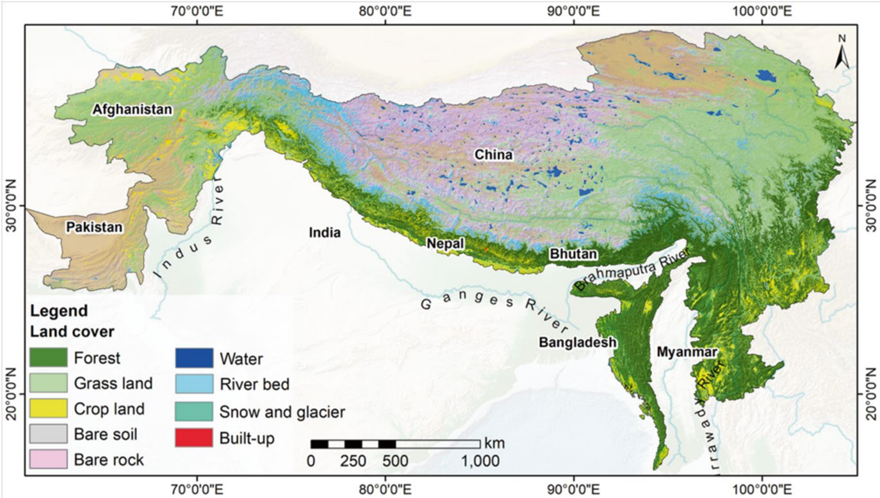

Fig. 1 Geographical depiction of Hindukush Himalayas (HKH) including Indian Himalayan Region

are not only vital for the 115 million mountain dwellers but also for a much larger population residing in the nearby Indo-Gangetic plains. The underdeveloped economies of the hill people and the threat to the environmental benefits of the Himalayas for the entire planet can be attributed to a decline in farm production, loss of biodiversity and terrestrial carbon stocks, hydrological imbalances, soil erosion, and other related issues.

The Himalayas, comprising the primary Himalaya and trans-Himalaya biogeographic zones, represent the youngest mountain range on Earth. The Himalayan range consists mainly of raised sedimentary and metamorphic rock. Its formation is the result of a continental collision or orogeny along the convergent boundary (Main Himalayan Thrust) between the Indo-Australian Plate and the Eurasian Plate, as per the understanding of plate tectonics. The Himalayan range is divided into four major tectonically active regions from north to south by four significant tectonic junctures: the Trans Himadri Thrust, the Main Central Thrust (MCT), the Main Boundary Thrust (MBT), and the Main Frontal Thrust (Apollo 2017; Tiwari 2023). The entire mountain range is also crisscrossed by numerous major and minor faults, contributing to its tectonic instability. The Himalayan mountains are rising over 1 cm annually as the Indian Plate moves north. Stretching over a 2400 km (1500 mi) arc from west-northwest to east-southeast, the Himalayan Mountain range gives rise to the Arakan Yoma highlands in Myanmar and the Andaman and Nicobar Islands in the Bay of Bengal. Nanga Parbat, located just south of the northernmost curve of the Indus River, serves as its western anchor.

The trans-Himalayan zone encompasses over three million square kilometers, including the Tibetan plateau in China, Afghanistan, Pakistan, and India. The Himalayas cover a significant portion or entirely cover the emerging nations of South Asia, namely Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Within the Indian Himalaya, there are 59 million hectares, of which 22 million hectares are degraded (Rao and Saxena 1994). Different Himalayan subregions experience varying degrees of land degradation with diverse causes and effects. The Himalayas are composed of parallel mountain ranges, namely the Sivalik Hills, the Lower Himalayan Range, the Great Himalayas (the highest and central range), and the Tibetan Himalayas in the north. While many people perceive the Karakoram as existing separately from the Himalayas (Apollo 2017).

Situated in the heart of the vast arc of the Himalayan Mountains, the peaks of Dhaulagiri and Annapurna in Nepal, towering at 8000 meters (26,000 ft), are separated by the Kali Gandaki Gorge. The Kora La pass, located at the head of the Kali Gandaki, serves as the lowest point on the ridgeline between Everest and K2, dividing the Himalayas into Western and Eastern parts in terms of both environmental and orographic characteristics. Eastward from Annapurna, in Tibet, lie the equally imposing peaks of Manaslu and Shishapangma, reaching a height of 8000 meters (5.0 miles) (Dimri et al. 2020).

The Himalayas' climate, rainfall patterns, altitude, and soils have significant impacts on the local flora and fauna. The climate at the mountain's base is tropical, while the highest elevations remain perpetually covered in ice and snow. Along the southern face of the range, rainfall gradually increases from west to east. This diverse range of altitudes, rainfall levels, and soil conditions, combined with an extremely high snow line, supports a variety of distinctive plant and animal groups. Notably, extremophile species thrive in environments characterized by extreme cold and high altitude, where atmospheric pressure is low (O'Neill et al. 2020).

The altitudinal fluctuation in the Indian Himalayan Region (IHR) leads to variations in natural resources, including water availability and climate. The region's ties to the land and its economy are undoubtedly susceptible to global changes, whether driven by climate shifts, land use alterations, biological invasions, or global economic pressures. While the pace, scope, and potential impacts of climate change remain uncertain, its profound influence on the region's rural landscape's biological and socioeconomic structure is undeniable (Rao et al. 1999; Rao et al. 2003; Maikhuri et al. 2009). The Himalayas are not only home to 115 million mountain dwellers who heavily rely on its resources and ecosystem services but also impact a much larger population residing in the neighboring Indo-Gangetic plains. The region's environmental benefits face risks due to deforestation, loss of biodiversity, depletion of terrestrial carbon stocks, declining agricultural productivity, escalating hydrological imbalances, and soil erosion—all interconnected challenges (Rao et al. 2003).

1.1 Causes of Degradation of the Himalayan Ecosystem

The South Asian countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan are part of the group of emerging nations in the region. These countries are predominantly or entirely covered by the expansive mountain range called the Himalayas. Within the Indian Himalaya alone, there is a total area of 59 million hectares, out of which 22 million hectares are degraded, as reported by Rao and Saxena (1994). The extent, causes, and impacts of land degradation vary across different subregions of the Himalayas, as stated by Rao et al. (1999).

Despite their apparent seclusion and inaccessibility, the Himalayas have not escaped the consequences of human-driven biodiversity loss. For countless years, people have inhabited the highlands of the Himalayas. However, the recent improvement in access to the global market has heightened the demand for natural resources in the region. Consequently, human settlements have expanded into some of the most productive and biologically diverse areas, as highlighted by Singh (2006).

Currently, the natural habitat of the Himalayan region is fragmented due to the continuous growth of the population. This has resulted in significant logging and clearance of forests and meadows for agricultural purposes. Legal and illegal logging frequently occurs on extremely steep slopes, leading to substantial erosion. Although the general upper limit for cultivation on monsoon-exposed slopes is around 2100 meters, crops like barley, potato, and buckwheat are cultivated at higher altitudes in inner valleys and transmontane regions. Notably, population centers with an agricultural base above this elevation, such as Jumla, Kashmir, Lahoul, and Ladakh, exist. During the summer, areas are often cleared for livestock. Additionally, forest lands face threats from the use of fire for land clearance, as these burns can sometimes become uncontrollable. In Nepal, as well as the Indian states of Sikkim, Darjeeling, and Assam, large-scale deforestation and habitat fragmentation have occurred due to the conversion of forests and grasslands for agriculture and urbanization. Many regions within the hotspot have experienced severe damage to their surviving habitats. Overgrazing by domestic animals such as cattle and domesticated yak is common in both lowland and alpine environments. Delicate alpine meadows suffer from excessive exploitation for traditional medicine, as collectors of medicinal plants often uproot the entire plant, impeding its regrowth, as mentioned by Singh et al. (2019).

The forest ecosystems have also been significantly impacted by the collection of fuelwood and the exploitation of non-timber forest products, both for internal use and export. Unplanned and poorly managed tourism has further contributed to ecosystem degradation. Additionally, the political disturbances, often taking the form of insurrections, pose a threat to the integrity of some protected areas, as discussed by Sandhu and Sandhu (2015).

1.2 Impact of Urban Development

The growth of towns and metropolitan centers can be attributed to various factors, including emigration from rural areas, valleys, and plains, the development of ecotourism and adventure tourism, as well as recent social instability. While agriculture still plays a significant role in the region’s economy, rural households are increasingly opting to migrate to urban areas in order to generate income, leading to a greater share of non-farm income in family earnings.

As recently as 1981, towns or cities were inhabited by less than 10% of the Himalayan population. However, by the year 2000, the urban population had quadrupled, reaching 20% (Zurick 2006; Tiwari 2023). This rapid urbanization, coupled with the transformation of the economy and changes in land use and land cover, is reshaping the Himalayas. The construction of buildings, extensive roadcuts on steep hillsides, and unregulated urban development, often involving excavation in geologically unstable areas, have resulted in an increase in the frequency and severity of hazardous events such as hillside collapses, landslides, debris flows, and rock slides. Consequently, the lives of millions of people are at risk (Haigh and Rawat 2011; Fort 2015).

In Uttarakhand, over 30% of the population resides in urban areas, surpassing the average of 25% for all Himalayan States, making the Himalayas the most densely populated and rapidly urbanizing mountain ecosystem worldwide (Census 2011; Tiwari 2023). This accelerated urbanization can be attributed to factors such as increased rural outmigration, improved road connectivity, rural markets, and a remarkable growth in tourism. Even previously inaccessible areas have experienced rapid urbanization due to the expansion of domestic tourism, marketing efforts, and the demand for new tourist destinations. Consequently, urban settlements in Uttarakhand have undergone significant growth in terms of size, area, number, and complexity, accompanied by substantial development of urban infrastructure in towns and their surrounding areas (Tiwari et al. 2018; Tiwari 2023).

Remarkably, despite a lack of government policy, more than 60% of new construction has taken place in environmentally vulnerable zones, particularly areas prone to landslides and floods. This has resulted in a 33% expansion of the built-up area in these mountain cities over the past two decades, rendering most of these locations highly susceptible to various geohydrological hazards. The unrestricted growth of urban areas into forests, disturbance of natural drainage systems, and approval of cutting and excavation on hill slopes to facilitate infrastructure development have significantly increased the occurrence of landslides. In Himalayan towns, building safety is not given high priority, despite theoretical restrictions on construction in areas with slopes exceeding 50%, which are largely disregarded in practice. Despite the theoretical prohibition on construction activities in Himalayan towns with slopes exceeding 50%, building safety is not considered a priority in these areas. In practice, almost all locations violate this regulation. Between 2011 and 2021, the percentage of the urban population residing in landslide-prone areas, steep slopes, lower river terraces, and slums increased by 6%, 8%, 14%, and 14% respectively. The rapid and extensive land use changes associated with urban expansion have resulted in the disruption of ecosystem services. These changes have also disturbed the hydrological cycles in the highlands. Research indicates that metropolitan areas generate significantly higher surface run-off compared to other land use types.

Case Study I: Joshimath

On the Rishikesh-Badrinath National Highway (NH-7), Joshimath serves as a stopover for travelers overnighting at the tourist spots of Auli and the Valley of Flowers as well as Badrinath and Hemkund Sahib shrines. The town, which is at an altitude of 1890 m, is also the starting point of many well-known Himalayan treks. As a result, there are now numerous hotels and resorts in the region (Bathla 2023).

In the metropolis of 20,000 people, homes and other man-made structures have been developing cracks over the past few months. As a result, many families were eventually forced to leave their homes and relocate to safer areas. The loss of water, oil, natural gas, or mineral resources from the soil causes subsidence, which is a gradual settling or lowering of the surface. Subsidence has been reported in Joshimath for a variety of reasons, including unauthorized construction, excessive population, impeding the natural flow of water, and hydropower activities. The town's surrounding perennial streams and heavily worn rocks with poor cohesive qualities render the region susceptible to landslides and subsidence. But despite the experts' warnings, unanticipated development projects like NTPC's Tapovan-Vishnugad hydro project, Char Dham road project, and Helang bypass by the BRO have continued. Only now, when sinking in Joshimath has reached a dangerous level, have all of these projects been put on hold.

Although Joshimath has had building cracks before, this time they are deeper and wider, causing crater-like openings in certain spots, which has caused a great deal of anxiety and panic among the locals (Joshi 2023; Bathla 2023). The settlement, which was established on landslide-deposited loose soil, soft loose rocks, and moraine (material left behind by retreating glaciers), lacks an organized drainage system.

The Dhaliganga and Alaknanda rivers, as well as permanent streams, border the south and north and west and east, respectively, of Joshimath, which is located on the middle slopes of a hill. It is affected by subsidence and landslides at the same time. The region was also affected recently by the floods of June 2013 and the glacial lake burst in February 2021, which claimed 204 lives of hydropower project personnel. Extreme rainfall events have altered the flow and expanded the channels of mountain streams, increasing the instability of the slope. Currently, the town's already vulnerable ecosystem is being put in even greater danger by road and hydropower projects.

An 18-person expert team led by Garhwal Collector MC Mishra issued a report in 1976 that issued a warning against development and construction in the region. *"Joshimath is a deposit of sand and stone — it is not the main rock — hence it was not suitable for a township. Vibrations produced by blasting, heavy traffic, etc., will lead to a disequilibrium in the natural factors,"* The Uttarakhand State Disaster Management Authority (USDMA) and the Geological Survey of India have both issued warnings against major projects and construction in the area throughout time (Shankar 2023).

2 Traditional Ecological Knowledge

Traditional civilizations stand out for their deep links to the natural world and its resources. For their survival, they are reliant on the environment and biodiversity (Ramakrishnan 1996). The social, cultural, and spiritual aspects of this relationship with nature and natural resources are just as important as the economic one (Ramakrishnan 1996, 2007). Ecosystems maintain a dynamic equilibrium that is based on nonlinear processes like cycles and fluctuations. In order to properly evaluate a wide variety of issues pertaining to the interactions between nature and people, traditional ecological knowledge is an important theme. By sharing varied traditions of environmental knowledge, different groups of people in various places of the world perceive and interact with nature in different ways.

Their worldviews, ethics, and religious beliefs all influence their perceptions and knowledge to some extent. Indigenous peoples and traditional ecological wisdom have garnered a lot of attention from academics and popular movements in the research of environmental ethics and religion to an ecologically viable society. Traditional ecological knowledge incorporates a society's worldview and religious practices. Along with its practices, every culture group shares a variety of environmental ideals and ethics. Although a group's environmental relations are not constant, they are impacted by daily interactions as well as their worldview and ethics.

2.1 Introduction and Explanation of TEK

The state has established protected areas as the main strategy for wildlife conservation, restricting community access to resources and emphasizing law enforcement. Protected areas managed by the state offer little opportunity for significant citizen involvement. Local populations continue to bear the brunt of conservation efforts, which breeds resentment that is made worse by wildlife-related injury and fatalities, damage to crops and animals, and few options for compensation or mitigation. Traditional ecological knowledge is ingrained in taboos and traditional belief systems; it serves as a "library of information" and educates people to deal with dynamic changes in the ecosystem (Berkes et al. 2000).

These knowledge systems connect the present to the past, strengthening resilience in complex socio-ecological systems as a result of accelerating global change and decreased environmental services (Rai and Mishra 2022).

It was thought that with the development of technology and the economy, traditional ecological knowledge would only be of folklore importance and would be lost. Many communities still practice traditional ecological knowledge, and some have even adapted to changing ecological and socioeconomic conditions. Successful informal institutions for the management of natural resources are frequently created by social groups that have a stable membership, long-term habitation, and a high reliance on natural resources. Traditional cultures' growing knowledge systems enhance people's ability to respond to disruptions and retain environmental services (Rai and Mishra 2022).

Traditional ecological knowledge is different from scientific ecological knowledge in that it depends heavily on regional social systems. These social processes might be conceptualized as a hierarchy, moving from local ecological knowledge to social institutions, cultural internalization mechanisms, and worldviews. Institutions, defined as laws that are really followed, give communities the tools they need to act on their local knowledge and apply it to generate a living from the environment (Berkes et al. 2000). Institutions and knowledge both need methods for cultural internalization in order for learning to be stored in the collective memory of the social group. A society's fundamental morals, cultural values, and governing principles take their form from its worldview or cosmology.

2.2 Conservation Importance of TEK

Beyond biophysical, ecological, and economic issues, this link also takes into account social, cultural, and spiritual considerations. Since they take an integrated approach to the ecosystem and the social system, they may develop agricultural practices that are environmentally friendly and make sustainable use of natural resources. Through a series of compromises, their ancient institutional structures have always been oriented towards ecological caution. Instead of a short-term strategy to maximize production, the goal should be the sustainable use of natural resources to deal with environmental risks. Their ultimate goal has always been to balance productivity concerns with environmental hazards in order to utilize natural resources sustainably.

The manipulation of biodiversity-centered TEK developed by the community through an experienced process still controls, to a significant extent, the dynamics of land use in the highlands. Diversification of the landscape is prioritized over uniformity of the landscape. In the past, this strategy has helped to preserve the delicate mountain terrain. It is now much more important in the context of measures for adapting to climate change since diversification will make mountain societies less susceptible to these uncertainties. The connections between traditional mountain societies and nature have been weakened as a result of shifting human population dynamics and a variety of external pressures on mountain-based natural resources. This has led to mountain societies' economic marginalization and, frequently, to social upheaval.

There is potential for synergy between local people and conservation managers as a result of the identification of informal institutions and their capacity for conservation. To address environmental changes and problems, multi-stakeholder, indigenous community-led partnerships and collaborations that incorporate traditional ecological knowledge are required (Janaki et al. 2020; Rai and Mishra 2022). In order to plan and implement conservation measures that are in keeping with regional norms and practices, it can be helpful to have a deeper understanding of traditional communities from a cultural perspective. Stories that are consistent with indigenous ideas might also facilitate more effective communication on conservation, as people frequently react more favorably to feelings, customs, and cultural beliefs than to scientific facts. Furthermore, growing population pressure in the Indian Himalayan Region puts increasing pressure on the state machinery, reaching out to the native stakeholders and their experience might help alleviate the demands on the State. Indian Himalayas offer a crucial study system to understand the importance of sustainable development and lessons learned here can be vital for attaining India's SDG journey as a whole (Fig. 2).

2.3 Types of TEK and Its Application for Land Management in the Himalayas

Our understanding of TEK is based on the potential advantages that traditional societies may get from their surroundings in terms of economic, ecological, and socio-cultural benefits, both concrete and figurative (Ramakrishnan 2007): (a) Economically, mountain societies can offset periods of food scarcity by cultivating traditional crop varieties, lesser-known food-valued animals, and wild medicinal plants; (b) Socio-ecologically, mountain societies' management of biodiversity promotes ecosystem resilience and improves people's capacity to adapt to environmental change, preserve soil water regimes, and maintain hygienic conditions. (c) Socio-culturally: Mountain people's sociocultural, spiritual, and religious beliefs are based on the idea of sacred species, sacred groves, and sacred landscapes, all of which can be crucial for biodiversity conservation.

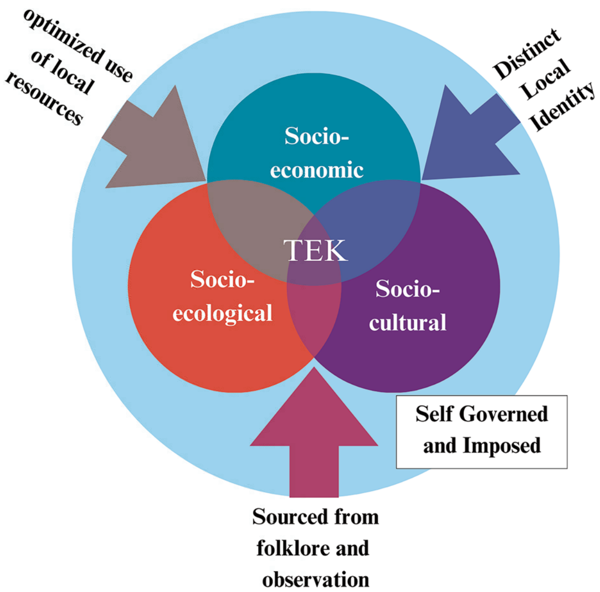

Fig. 2 Core-elements of Traditional ecological knowledges and its interlinkages with SDGs (Adapted and Modified from Das et al. 2023)

2.3.1 Socio-economic Applications TEK

In the Indian Himalayas, more than 90% of the population lives in villages that are structured as separate socio-ecological systems (Singh et al. 2008). A variety of agricultural and forest ecosystem types are managed by local communities to create the village landscapes, which are encircled by woods that are under the control of public authorities. Traditional crop-livestock mixed farming, which is the mainstay of the local population's economy, is heavily reliant on trees for animal waste and feed. Changes in the quantity and/or quality of livestock feed and manure may accompany changes in the structure and functions of the forest ecosystem, which may then lead to changes in the agroecosystem. Similar to how variations in manure input rates in agriculture may vary grazing/lopping schedules in forests, changing the structure and functions of the forest ecosystem.

The extensive TEK that the various tribal tribes are aware of and practice has made it feasible to conserve biodiversity and other natural resources in IHR over a long period of time. According to Ramakrishnan (2007), these communities' connections with natural resource access and sustainable conservation have been led by their TEK. For their food security, nutrition, and subsistence survival in India's mountain ecosystems, the local community of the state uses TEK for biodiversity protection and other natural resources (Ramakrishnan 2007; Singh and Pandey 2011; Das et al. 2023).

Case Study II Traditional Water Management System in NE India

In NE India, traditional irrigation techniques and water-saving habits are prevalent. These irrigation systems have historically been run by farmers and indigenous tribes and are quite site-specific. Since people started settling in the NE highlands, sustainable water management has been practiced extensively in NE India (Ghosh et al. 2010; Das et al. 2023). The indigenous communities of NE India build diverse water storage facilities, crop irrigation equipment, and pipe-laying tactics using locally accessible materials like bamboo and stones. These conventional irrigation methods offer a suitable framework for the efficient management and conservation of natural resources. Such comprehensive data can be incorporated into contemporary irrigation systems to provide integrated models for achieving various SDG targets.

Based on their local knowledge, the Adi tribe in Arunachal Pradesh's East Siang district builds traditional water-collecting structures like Yeung Linsang and Linkup (also known as Carsick locally) (Pattanaaik et al. 2012; Das et al. 2023). The terrace paddy fields in the valley are watered using this irrigation technique by tapping the steam water close to its place of emergence and then running the water through the bench terraces. Without causing soil erosion, water continuously flows from the terrace at the higher elevation to the lower ones. Yeung Linsang and Linkup restrict the perennial streams in order to direct the water to low-lying areas for the growth of paddy during the kharif season and profitable vegetable crop production during the following Rabi season. This indigenous irrigation method can provide cost-effective, environmentally friendly, and sustainable water resource management even though the water collection structures were built in accordance with traditional beliefs.

In Meghalaya, areca nut or mixed orchards as well as the betel leaf or black pepper crops are typically watered using a bamboo drip irrigation system. Perennial springs on the hilltops are gravity-fed to the lower regions via bamboo pipelines (Ghosh et al. 2023). The bamboo channel sections direct and transport water to the plot site, where it is dispersed without leaking into the branches, which are again constructed and put out using various types of bamboo pipes. Controlling the placements of the intake pipes also affects how much water flows into the lateral pipes. The final stage of water application involves the use of reduced channel sections and diversion devices. The water can be deposited close to the plant's roots thanks to the last channel segment. From the water diversion site to the application point, there are around four to five distribution phases. Water for betel leaf plants is temporarily diverted from streams into extremely complex bamboo canal systems. A month before the monsoon, in March, betel leaf is sown. The bamboo pipe system is only used in the winter when irrigation water is needed. As a result, these bamboo systems are prepared before the start of winter, and no water is directed into them during the monsoon.

2.3.2 Socio-ecological Applications of TEK

Numerous complex agroecosystem typologies still persist in the country's mountain systems, many of them with biodiversity equivalent to that of natural ecosystems (Ramakrishnan 2007). Forests, established agriculture, and shifting agriculture are the three main land-use types that can be distinguished in a village's landscape. According to Singh et al. (2008), settled agriculture was further subdivided into four agroecosystem types: shifting agriculture system (SAS), rainfed agroforestry system (RAS), rainfed crop system (RCS), and irrigated crop system (ICS). Traditional civilizations control agricultural biodiversity at the species and sub-species levels to maximize productivity in a particular ecological context while also adjusting to expected and unanticipated environmental uncertainties.

Case Study III Traditional Medicines Bhotiya System

Bhotiyas are an ethnic community of Mongoloid origin. They live in the high-elevation areas of the Indian Central Himalayas along the borders with Nepal and Tibet, an area of racial mixing and cultural blending. They exhibit strong racial and cultural similarities to Tibetans, which is possibly why the 'Bhotia' region is known as *Bod* or *Bhot*, which are synonyms for Tibet. The Bhotias used to visit and trade with Tibet before the Chinese takeover. For generations, the Bhotias traded with Tibet, bringing goods like salt, borax, wool, gold, mule teams, lambs, and goats. This trade was discontinued and the migration route across the Indian border was closed after China occupied Tibet in 1962 (Anthwal et al. 2010; Chauhan 2014).

People who lived in the Himalayas' isolated, inhospitable high altitudes were not exposed to any type of medical care until the 1960s. They were therefore entirely reliant on the Bhotiya system of conventional medicine. The native Bhotiya treatment primarily targeted conditions including stomach and digestive system issues, dysentery and diarrhea, liver dysfunction, kidney stones, fever, blood purification, common cold and cough, skin conditions, and bodily vigor and vitality. The

Bhotiyas place a lot of trust in the accumulated knowledge of plants and their applications. These people employ medicinal plants for their effectiveness, lack of access to traditional medical care, and cultural preferences. They also have a solid understanding of both the beneficial and harmful effects of plants. However, as socioeconomic and cultural norms change, this vast knowledge of medicinal plants that have been verbally passed down from their ancestors' generation is gradually dwindling and deteriorating.

The Bhotia people use conventional treatments and medications as well. Long ago, they would travel to the jungle to gather important herbs and plants that could be utilized as medicine. Modern medications were not available at the time. The government's laws and the Department of Forest's regulations forbid routine harvesting of plants and herbs from the forest. This deters the Bhotias from using these medicinal herbs extensively. They do, however, obtain a few plants and employ them in conjunction with their elders to treat a few minor diseases. Many elderly people still harvest therapeutic herbs from the jungle when they have the time and chance in modern times. The names and uses of the medicinal plants can be found here (Table 1).

However, the usage of herbal remedies is dwindling as modern pharmaceuticals gain popularity. There is a reduction in the knowledge of medicinal plants, which is now only held by seniors. The younger generation is not familiar with these plants and does not recognize them.

2.3.3 Socio-cultural Application of TEK

The residents of the Himalayas have deep reverence for the abundant flora, animals, and lakes found in the region, leading to strict prohibitions on harvesting or exploiting them. Consequently, numerous commercially significant tree and animal species are safeguarded, fostering a robust genetic reservoir and serving as a safeguard against extinction. The exploration of indigenous knowledge, ethnoecology, and ethno-forestry provides valuable insights into the cognitive foundations behind this practice.

The rational assimilation of human experiences and acquired knowledge manifests in the form of religious beliefs, traditions, and culture. Within these traditional societies, ecological wisdom is embedded in taboos, symbols, and cosmologies, serving as a means to educate younger generations about conservation. Through religious or ceremonial representations, these practices have effectively aided in the sustainable management of their resources.

Case Study IV Sacred Groves

There is a tonne of myth, tradition, and lore around forests. Societies that have a deep relationship with forests often have a healthy respect for them, are in awe of their beauty and majesty, and occasionally experience dread and fear due to the strong spirits that dwell there. For indigenous and other populations that live in the forest, they have been a lifeline.

One of the earliest types of conservation is the use of sacred groves (SGs) and temple woodlands. In the midst of the country's damaged landscapes are small

Table 1 Traditional medicines in the Bhotiya community (Adapted from Chauhan 2014; Bhandari et al. 2016)

No.	Local name of herb	Botanical name of the herb	Use
1	Atees/ Atis	*Aconitum Heterophylum*	Stomach ache, fever, to stop bleeding, burning in stomach, gastric problems
2	Dolu	*Rheum emodi*	Boils and 'phunsis', Pain in limbs; Stomach ache; Swelling Pain in Bones; Injury
3	Katuki/ Kutki/ Kedar Karvi	*Picrorhiza Kurrooa*	Fever, stomachache, dysentery, constipation
4	Hathraji	*Dactylorhiza hatagirea*	Burns and injuries
5	Balchad	*Nardostachys Jatamansi*	Dandruff for healthy hair
6	Shee	*Anselia aptera*	Stomach problem and dysentery in kids
7	Meetha Jad	*Aconitum atrox*	Painkiller
8	Van-ajwain	*Thymus serpyllum*	Cold, cough and gastric problems. Clear bowel movement. Respiratory problems.
9	Kut	*Saussurea costus*	Stomachache, gastric, appetizer
10	Van-Tulsi	*Origanum vulgare*	Extract of the plant used in bronchitis, colic, and diarrhea
11	Buthkesh	*Selinum vaginatum*	To increase lactation in cows.
12	Bhujlees	*Betula utilis*	Injury and pain
13	Choru (Ghandhrayan)	*Angelica glauca*	Gastric problem, digestion.
14	Jambu-faran	*Allium stracheyi*	Gastric
15	Kala Jeera	*Carum carvi*	Preservative
16	Varmula		Dysentery
17	Khulya ((Pahari Palak)	*Rumex nepalensis*	Leaves infusion given in dysmenorrhoea and stomach-ache
18	Chir	*Pinus roxburghii*	Used as crack cream, saw-dust with honey used in asthma and bronchitis
19	Mamiri	*Thalictrum foliolosum*	Roots used in Ophthalmia, fever and colic.
20	Kingore	*Berberis aristata*	Juice from the bark of stem and roots known as 'Rasaut' dropped in Ophthalmia, roots-infusion given in fever
21	Kingore	*Berberis lycium*	Bark and stem or roots yields 'Rasaut' used in eye treatments, barks and roots orally taken to relieve jaundice
22	Giloei	*Tinospora cordifolia*	Stem and leaves juice used in general debility and urinary troubles, leaves extract regarded as an emetic.
23	Kharik	*Celtis australis*	Bark paste applied on bones, pimples, contusions, and joint pains.
24	Bhang, Bhangla	*Cannabis sativa*	Leaves and flowers used as an intoxicating agent and narcotic.

(continued)

Table 1 (continued)

No.	Local name of herb	Botanical name of the herb	Use
25	Anjir	*Ficus palmata*	Fruits used in digestive disorders
26	Kandali	*Urtica dioica*	Young branches or twinges as green vegetables especially in the winters, supposed to be a hot-diet for winters, also used in sciatica, rheumatism
27	Banj	*Quercus oblongata*	Gum of the tree medicinally used for digestive disorders
28	Safed Fulki	*Stellaria media*	Plant paste applied on burns, boils and wounds
29	Udsalap	*Paeonia emodi*	Roots and petals infusion given in whooping cough, intestinal spasms, and diarrhea.
30	Suchali	*Malva verticillata*	Roots used in whooping cough, leaves decoction stimulates vomiting.
31	Vanafsa	*Viola biflora*	Plants used to relieve bronchitis, cold, and cough.
32	Indrian	*Trichosanthes tricuspidata*	Roots juice used as an emetic, roots and fruits commonly used to relieve bronchitis, asthma, diabetes
33	Aiyaar	*Lyonia ovalifolia*	Seeds paste applied on wounds and boils
34	Burans	*Rhododendron arboreum*	Flowers and barks used in digestive and respiratory disorders
35	Silpara, Silphori	*Bergenia ciliata*	Rhizomatous parts used as tonic, febrifuge and in digestive disorders
36	Aaru	*Prunus persica*	Leaves and bark infusion used to relieve cough and cold
37	Khubani	*Prunus armeniaca*	Seed-oil used in fever and piles
38	Melu	*Pyrus pashia*	Ripe fruits used in digestive disorders
39	Hinsar	*Rubus biflorus*	Roots-decoction given in diarrhoea
40	Gangoor	*Rubus nepalensis*	Root paste externally applied on burns and scalds
41	Shia-Kant	*Mimosa himalayana*	Leaves used in cough, bronchitis and urinary complaints
42	Sambar	*Desmodium elegans*	Root-infusion smelled in epilepsy, roots also used as carminative
43	Saknya	*Indigofera cassioides*	Leaf-powder taken in malarial fever
44	Bel-chapru	*Ampelocissus rugosa*	Paste of leaves and branches applied in bone fracture
45	Timroo	*Zanthoxylum armatum*	Leaves and fruits chewed for mouth wash and tooth care. Also, soup made from seed epicarp with salt is taken against gastric problems, common cold, and cough.
46	Bhilmori, Kathibuthi	*Oxalis corniculata*	Leaf juice dropped in cataract and conjunctivitis
47	Chiratta	*Swertia alata*	Plant extract used as a tonic
48	Safed Chireta	*Swertia ciliata*	Plant extract given in the treatment of malaria

(continued)

Table 1 (continued)

No.	Local name of herb	Botanical name of the herb	Use
49	Dhatura	*Datura stramonium*	Seeds medicinal as toxicant
50	Makoi	*Solanum nigrum*	Fruits useful in diarrhoea, fever and eye treatment. Plant extract used inpiles and dysentery
51	Amarbel	*Cuscuta europaea*	Plant extract used in skin diseases
52	Bhirmoli	*Callicarpa macrophylla*	Heat treated leaves used externally in rheumatic pain
53	Neelkanthi	*Ajuga bracteosa*	Extract of leaves used in malarial fever. Plant extract used as a tonic, astringent, and febrifuge
54	Pudina	*Mentha longifolia*	Leaves used in indigestion and vomiting
55	Akulbir	*Verbascum thapsus*	Extract of plants taken in bronchitis and asthma, seeds used as narcotic
56	Shila-Puspha	*Corallodiscus lanuginosus*	Leaves used against kidney stones
57	Sumaya	*Valeriana jatamansi*	Roots used as an aphrodisiac and in mental disorders
58	Kunjaa	*Artemisia roxburghiana*	Plant extract used as an antipyretic, tonic and also rubbed on skin allergy
59	Bugla, Agela	*Anaphalis adnat*	Leaves and heads paste applied on cuts, wounds and boils
60	Marchya-ghas	*Galinsoga parviflora*	Plant used as an antidote of nettle stings
61	Liskura	*Siegesbeckia orientalis*	Decoction of plant with rice water taken in diarrhea and bowel complaints
62	Dubla, doob	*Cynodon dactylon*	Roots taken in fever and in internal injury
63	Sirau	*Imperata cylindrica*	Roots used as tonic, woolly hairs of the inflorescence used for staunching the wounds and for stuffing purposes

forest patches with big trees, lianas, and shrubs that depict the narrative structure of well-maintained woods. These forests, despite being sparse and dispersed, have two things in common: they are sacred, and they inspire faith in a deity. Therefore, any forest or vegetation strand that local communities value and conserve for cultural and spiritual reasons might be referred to as a sacred forest (Anthwal et al. 2010).

There are over 100,000 sacred groves in India due to the country's rich natural and cultural heritage. The sacred groves are crucial for protecting the endangered flora and wildlife from extinction in addition to being used by the indigenous people for cultural or spiritual practices. As a result, they could also be regarded as among the top spiritual and cultural activities for preserving biodiversity, restoring damaged ecosystems, and using natural resources sustainably.