

CASE STUDIES FROM
THE HINDU KUSH HIMALAYA

PROMOTING SUSTAINABLE BIOECONOMY PRACTICES



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Promoting sustainable bioeconomy practices

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ACRONYMS

ABS	Access and benefit-sharing (mechanisms)	MAPs	Medicinal and Aromatic Plants
CARA	Climate Action for a Resilient Asia	MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
CFUGs	Community Forest User Groups	MoU	Memorandum of Understanding
CSI	Carbon Standards International	NbS	Nature-based Solutions
CSOs	Civil Society Organizations	NBRM	Nagaland Bio Resource Mission
dMRV	Digital Monitoring and Review	NBFC	Non-Banking Financial Company
DST	Department of Science and Technology (Note: often appears with SEED Division)	NDBR	Nanda Devi Biosphere Reserve
FMCG	Fast-Moving Consumer Goods	NEHU	North-Eastern Hill University
G2G	Government-to-Government	NGOs	Non-Governmental Organizations
GBPNIHE	Govind Ballabh Pant National Institute of Himalayan Environment	NTFPs	Non-Timber Forest Products
GESI	Gender Equity And Social Inclusion	R&D	Research and Development
GI	Geographical Indication	RTDTC	Rural Technology Demonstration and Training Centre
GMP	Good Manufacturing Practice	SEED	Division Science for Equity Empowerment and Development (Division)
HNBGU	Hemvati Nandan Bahuguna Garhwal University	TIME-LEARN	Technology Intervention for Mountain Ecosystem and Livelihood Enhancement through Action Research & Networking
HPPCL	Herbs Production and Processing Company Limited	TRP	The Revolution Project
HKH	Hindu Kush Himalaya	ZFHC	Zandu Foundation for Health Care
HKH-ICE	Hindu Kush Himalaya Innovation Challenge for Entrepreneurs	ZBNF	Zero Budget Natural Farming
ISO	International Organization for Standardization		
IUCN	International Union for Conservation of Nature		
LPG	Liquefied Petroleum Gas		

EXECUTIVE SUMMARY

The Hindu Kush Himalaya (HKH) region has tremendous potential to develop a sustainable, inclusive bioeconomy – the promotion of economic activity that relies on biological resources such as medicinal and aromatic plants, and forest products – to provide sustainable goods, services, and employment for local communities, which are rooted in nature-based solutions. Rich in biodiversity and cultural heritage, the HKH is home to thousands of plant species, rich traditional knowledge systems, and community-led innovations that, if harnessed responsibly, can contribute to a resilient and green economy.

This compendium, developed by the International Centre for Integrated Mountain Development (ICIMOD), through the Himalayan Resilience Enabling Action Programme (HI-REAP), highlights sustainable bioeconomy practices from across the HKH, more specifically in Nepal, India, Bhutan, and China. The comprehensive collection of bioeconomy practices presented in this compendium offers viable livelihood options for the mountain communities in the HKH region. These include the production of nature-based products, such as spices, essential oils, and turmeric; the renewal of mini-forests in urban areas; the use of medicinal plants, the making of climate-resilient textiles, etc. In discussing various aspects of the commercialisation of products that are derived from bio-resources, it highlights issues of inclusiveness and sustainability, including fair benefit-sharing, engaging local and Indigenous communities, and addressing environmental, social, economic, and gender-related challenges.

This compendium captures diverse case studies that exemplify how bioeconomy solutions – particularly bioprospecting (the identification of plants and other species from which medicines or other commercially useful products can be made), value-added product development, circular bio-innovations, and access and benefit-sharing frameworks – can support conservation goals, climate resilience, and gender-equitable livelihoods in mountain communities. Many of these cases were submitted under the [Hindu Kush Himalaya Innovation Challenge for Entrepreneurs \(HKH-ICE\)](#), an initiative designed to catalyse local innovation and entrepreneurship, and generate scalable solutions that address ecological, market, and value chain challenges across the region.

Our bioeconomy initiative aims to align with circular economy principles, promote regenerative practices that reduce environmental degradation, enhance climate resilience, and support bioprospecting efforts that conserve biodiversity while ensuring fair compensation to knowledge holders.

By documenting these community-led, nature-based innovations, this compendium provides critical insights for policy makers, researchers, and practitioners on how the mountain bioeconomy can be nurtured for inclusive green growth. It also highlights the synergies between traditional knowledge, modern science, and policy frameworks that are essential for realising a sustainable bioeconomy in the HKH and beyond.

Introduction

The Hindu Kush Himalaya (HKH) region spans eight countries and covers an area of over 4.2 million square kilometres (sq. km). It provides ecosystem services to 2.1 billion people living in both upstream and downstream areas – one-fourth of the world's population (Wester et al., 2019). This region is home to over 35,000 plant species, and to Indigenous and local communities who are the carriers of immense ethnobotanical knowledge of the region (Xu et al., 2019).

The biodiversity in the HKH underpins the food security, health, livelihoods, and cultural identity of mountain communities. However, despite its ecological richness, the region's biodiversity remains underutilised or is exploited in unsustainable ways, and is also being adversely affected by climate change, land-use changes, and socio-economic pressures (Kattel, 2022).

In response to these growing challenges, ICIMOD's Himalayan Resilience Enabling Action Programme (HI-REAP), an initiative supported by the UK Government's flagship Climate Action for a Resilient Asia (CARA) programme, is working to promote nature-based solutions (NbS) that enhance socio-ecological resilience, support low-carbon economies, and improve air quality in the region. Operating in Bangladesh, Bhutan, India, and Nepal, and drawing on knowledge from China, HI-REAP seeks to address the mounting climatic and environmental shocks – extreme weather events, floods, landslides, droughts, and biodiversity loss – that disproportionately affect the HKH region.

These environmental shocks are linked to, and in turn exacerbate socio-economic vulnerabilities, including food and water insecurity, high levels of outmigration, and gender and social inequalities. A key objective of HI-REAP is the promotion of a sustainable bioeconomy. This approach is in consonance with the programme's

objectives of supporting ecosystem-based industries and local enterprises that generate green jobs, foster value-addition for communities, and build climate resilience. By encouraging nature-positive entrepreneurship, HI-REAP aims to develop enterprises capable of delivering products and services that align with bioeconomy principles – facilitating a shift from extractive development models to a regenerative and circular economy, whereby resources are kept in use for as long as possible through reuse, recycling, and regeneration, minimising waste and environmental impacts.

The bioeconomy of the Hindu Kush Himalaya

The HKH region, with its vast biological and cultural diversity, holds significant potential for developing a sustainable bioeconomy. Within HI-REAP, the development of a bioeconomy is identified as a key nature-based solution to foster sustainable development and enhance the resilience of mountain communities.

In this context, the creation of a bioeconomy refers to the promotion of enterprises that rely on biological resources, such as medicinal and aromatic plants, agro-biodiversity, and forest products, while developing access and benefit-sharing (ABS) mechanisms to ensure equitable distribution of its benefits. This approach aims to improve the livelihoods of the custodians of natural resources, particularly Indigenous Peoples and local communities, by supporting value-added production and nature-positive entrepreneurship.

The HKH region's rich repository of medicinal and aromatic plants and traditional ecological knowledge provides a strong foundation for the development of a

bioeconomy. However, as has been discussed below, the potential of these biological assets remains underutilised due to fragmented value chains, limited access to markets, and weak policy frameworks. HI-REAP seeks to address these gaps by supporting startups and small enterprises that sustainably utilise forest and natural resources, thereby enhancing both ecological integrity and socio-economic outcomes.

HI-REAP's bioeconomy model aligns with the principles of a circular economy, promotes regenerative practices that reduce environmental degradation, and enhances climate resilience. For example, bioprospecting initiatives supported by the programme aim to identify and commercialise high-value bio-resources in a way that conserves biodiversity and ensures fair compensation to knowledge holders.

Furthermore, the integration of ABS mechanisms in the programme's work ensures that the benefits derived from the use of genetic resources and traditional knowledge are shared fairly and transparently with the local communities. This strengthens community stewardship of biodiversity and reinforces the legal and ethical frameworks for sustainable resource use.

To summarise, a bioeconomy in the HKH, as envisioned by HI-REAP, represents a transformative pathway toward inclusive green growth. It leverages the region's natural capital and cultural heritage to build resilient livelihoods, conserve ecosystems, and foster innovation grounded in equity and sustainability.

Challenges and opportunities in harnessing HKH's bioeconomic potential

The HKH region is experiencing rapid socio-ecological changes, ranging from climate change and land degradation to outmigration and rural unemployment. Traditional subsistence economies that prevail in parts of

the region are under stress, and communities face rising economic precarity. Yet, the region's rich biodiversity and traditional knowledge systems remain both undervalued and vulnerable to overexploitation, unsustainable harvesting, and extractive trade. Promoting a sustainable bioeconomy would constitute a systemic response to these challenges by revitalising local economies through value addition and enterprise development based on biological resources; reducing ecological damage through regenerative practices, circular production, and reduced reliance on external inputs; fostering inclusive growth by recognising the role of women, youth, and Indigenous communities as primary knowledge holders and resource stewards and enabling them; and strengthening resilience against climate shocks by diversifying sources of income and embedding ecosystem restoration in production systems. This transition to a bioeconomy aligns closely with NbS outlined by the International Union for Conservation of Nature (IUCN) and the UN Convention on Biological Diversity (CBD).

To further this vision, HI-REAP has developed this compendium of case studies that highlight biodiversity-based innovation, focusing on bioprospecting as a sustainable, inclusive, and innovative nature-based solution. Bioprospecting is the systematic search for useful products derived from bio-resources that can be commercially developed. It recognises traditional and Indigenous knowledge and explores opportunities for developing commercially valuable genetic and biochemical resources. Bioprospecting is very significant in the HKH due to the abundance of valuable medicinal and aromatic plants (MAPs) and non-timber forest products (NTFPs). However, rising demand, coupled with overharvesting and habitat degradation, poses a threat to the sustainability of these resources (Dhillon et al., 2002). Bioprospecting efforts also face a recurring challenge in scaling up, often due to constraints in value-chain development, limited investment, and the complexity of navigating regulatory and market systems.

Bioprospecting offers a mechanism to sustainably manage biodiversity and ecosystems in the HKH; generate equitable socio-economic benefits; strengthen resilience to climate change and ecosystem degradation; and enhance food and health security through bio-based alternatives. In practice, this means enabling mountain communities to participate in sustainable harvesting, local value addition, and ABS agreements, thereby ensuring both conservation and livelihood enhancement. Importantly, bioprospecting also allows for greater gender equity, as women in the HKH are often the primary collectors and processors of medicinal plants and yet remain underrepresented in formal value chains (Bhattarai & Ghimire, 2020).

Despite its potential, the bioprospecting sector in the HKH remains largely underdeveloped. The key challenges include fragmented value chains and poor infrastructure for processing and quality control; lack of legal clarity regarding ABS, particularly in transboundary landscapes; inadequate scientific validation of traditional knowledge and bioactive compounds (substances found in plants, etc. that can aid human health and biological processes); and weak linkages between communities and markets, with limited incentives for conservation-oriented livelihoods. Nevertheless, there are promising trends. Countries such as Bhutan and Nepal have begun piloting ABS frameworks and sustainable trade models for MAPs. In India, community-based enterprises – supported by forest departments and non-governmental organisations (NGOs) – are exploring value addition and organic certification of bio-resources. Regional collaboration has also begun via platforms such as ICIMOD's HI-REAP programme, which promotes bioprospecting as a nature-based solution. ICIMOD strives to harness the potential of bioprospecting as a nature-based solution to improve the lives of local communities, thereby contributing to sustainable development while also ensuring fair benefit-sharing.

About the compendium

ICIMOD plans to support the growth of bio-based businesses and incentivise the custodians of forest and other resources to recognise the benefits of conserving and protecting these vital ecosystems. In order to ensure positive outcomes, it is important to understand the existing practices in the region as a baseline and build from there. This compendium considers bioprospecting as an aspect of the bioeconomy that combines the proper and sustainable use of biological resources with creating sustainable livelihood options for people. The selected case studies reflect a wide spectrum of themes and applications, including:

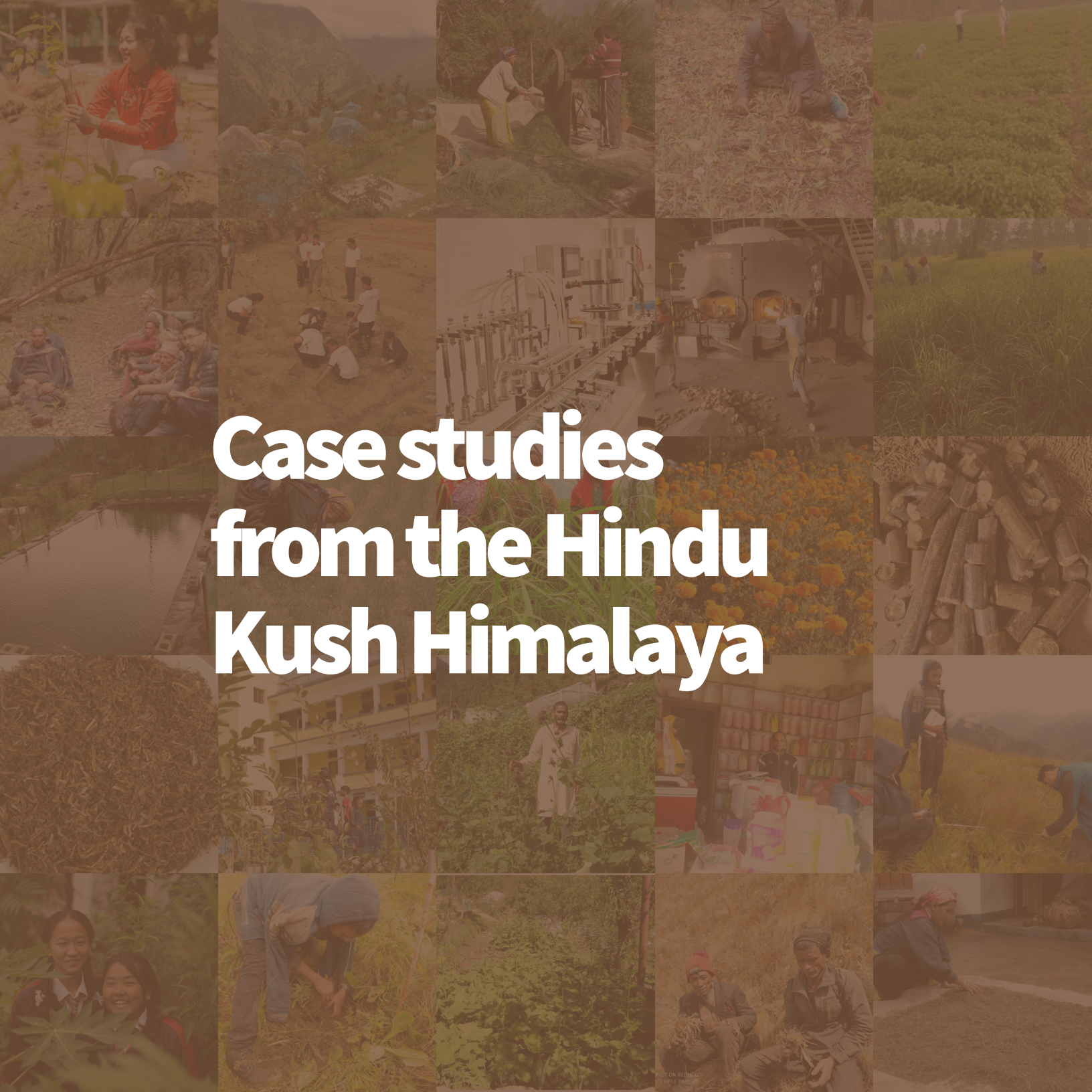
- **Bioprospecting and NbS:** The exploration of bioprospecting as a nature-based solution, and assessing the business environment, regional good practices, and country-specific opportunities.
- **Innovation and biodiversity:** Showcasing innovative approaches in bioprospecting that leverage the region's rich biodiversity to discover bioactive compounds and genetic materials, and access traditional knowledge – collective wisdom, practices, and innovations developed by local and indigenous communities over generations – driving innovation in pharmaceuticals, biotechnology, and agriculture.
- **Sustainable economic development:** Demonstrating how bioprospecting can foster sustainable economic growth, create jobs, generate revenues, and enhance local livelihoods through bio-based industries.
- **International collaboration:** Exploration of international partnerships and collaboration in bioprospecting, highlighting successful models of technology transfer, capacity-building, and market access.

- Community engagement and capacity-building: Illustrating community involvement in bioprospecting initiatives, including capacity-building and ABS mechanisms.
- Entrepreneurship and value chain development: Showcasing entrepreneurial initiatives that harness the potential of bioprospecting. Promoting value chain development in bioprospecting, including sustainable harvesting and the development of value-added products such as pharmaceuticals, nutraceuticals (a product from a food source that promotes nutrition and health), and beverages.

The HKH region has a strong foundation for building a regional bioeconomy that is sustainable, inclusive, and biodiversity-driven. By investing in research, incubating enterprises, and promoting policy coherence, countries such as Nepal and Bhutan can transition from being raw material suppliers to exporters of certified and high-value natural products. Programmes such as HI-REAP offer an opportunity to scale up these efforts through cross-border learning, sharing best practices and research insights

among countries, and regional alignment by harmonising policies and certification systems, and fostering public-private partnerships to build integrated value chains. Innovation hubs (collaborative spaces that foster research, creativity, and technology-driven solutions to accelerate sustainable bioeconomy development) and incubation centres (structured programmes that support early-stage enterprises with mentorship, resources, and finances to transform ideas into viable businesses) can serve as engines for the bioeconomy, catalysing entrepreneurship, attracting finance, and creating premium products. By embedding circularity, ecosystem restoration, and equity into these enterprise models, the HKH can take a lead in demonstrating how transitioning to a bioeconomy can align economic prosperity with environmental sustainability.





Case studies from the Hindu Kush Himalaya

Converting forest waste into an energy source: A2P Energy's bio-briquettes promote sustainable livelihoods in Himachal Pradesh

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Background

In the Lower Shivalik region of Himachal Pradesh, India, forests generate vast amounts of biomass such as dry pine needles, lantana (*Lantana camara*), dry leaves, and agro-residues. This accumulated forest waste is not just an untapped economic resource but also a major environmental hazard, contributing to recurring forest fires and the degradation of biodiversity. To meet the rising industrial demand for sustainable and cleaner alternatives to fossil fuels, A2P Energy, a company that generates biofuels from agri-waste and biomass, has developed a community-driven initiative to transform this waste into high-energy biomass briquettes (or bio-briquettes). The initiative involves bioprospecting and the application of scientific techniques to develop clean fuels from invasive and flammable forest biomass. This is also in alignment with India's climate and energy goals.

A2P Energy's work integrates rural communities, researchers, industrial entities, and policy influencers. A2P Energy collaborates with farmers and women's groups in the region, and helps generate employment and promotes sustainable livelihoods. Industries that use these bio-briquettes benefit from access to a clean, affordable alternative to coal and liquefied petroleum gas (LPG). The initiative positions forest waste not as a liability, but as a high-impact economic and environmental asset.

Challenges and issues addressed

The initiative tackles multiple environmental, social, and business challenges. Forest fires in Himachal Pradesh and other Himalayan states in India are a recurring problem, largely fuelled by dry pine needles, the invasive lantana plant, and more generally by a warming climate. These fires harm biodiversity, degrade air and soil quality, endanger other species, and threaten livelihoods. Lantana suppresses native flora, alters soil nutrients, and reduces crop productivity, thereby posing a serious ecological threat. A2P Energy addresses these issues by collecting and converting such biomass into clean energy, reducing the risk of fires and ecological damage.

For industries, transitioning from using coal to biofuels is a challenge due to concerns about the quality, consistency, and availability of biomass-based alternatives. Market barriers such as fragmented supply chains, high transportation costs, and limited awareness about the availability and benefits of biofuels further complicate their adoption. Additionally, sourcing native biomass sustainably while ensuring fair compensation to rural suppliers requires careful value chain management. A2P's localised model of sourcing biomass and the Clean Energy Trade (CET) platform help overcome these barriers by building efficient, transparent, and fair systems.



The solution

A2P Energy implemented a phased bioprospecting approach to develop and scale up the bio-briquette initiative. In the first phase in 2023, extensive field research was conducted to assess the viability of converting pine needles, lantana, and other invasive biomass into biofuels. In collaboration with local communities in the Lower Shivalik region, the team refined biomass collection techniques and optimised fuel quality to ensure high calorific value and moisture control by mixing different kinds of biomass meant to burn efficiently in the steam generation boilers. The bio-briquettes have been rigorously tested and validated across several sectors, proving consistent calorific value and combustion quality. Industry validation was procured to ensure the bio-briquettes met defined

standards, and they were deemed suitable for use in the cement, fast-moving consumer goods (FMCG), and electricity industries.

In the second phase, A2P Energy focused on building a decentralised, community-based supply chain. Training sessions were conducted to equip farmers and rural workers, especially women, with skills in sustainable biomass collection and processing. Local hubs were set up to collect, store and sort biomass, thereby improving logistical efficiency and product quality control. In addition, A2P Energy launched its CET platform to digitise procurement and sales, enabling real-time, fair trade between suppliers and industrial buyers. Through this digital platform, A2P Energy has formalised trade in biomass, ensuring transparency, fair pricing, and traceability. The initiative is supported by government

agencies and international partners, including a United Nations agency. Green financing mechanisms are being explored to expand operations and ensure long-term sustainability of the initiative.

Results

The initiative has resulted in considerable economic, environmental, and social benefits. Economically, it is projected to generate over 52,500 working hours of rural employment annually, while creating 16 direct jobs and more than 50 indirect jobs in biomass handling, processing, and logistics. Households whose members have been employed now benefit from an additional income stream, making them economically more resilient and independent.

Environmentally, the replacement of coal with bio-briquettes in cooking and heating is expected to reduce carbon dioxide (CO₂) emissions by approximately 10,000 metric tonnes per year. Removing pine needles and lantana from forests across more than 500 hectares (ha) has helped mitigate the risk of fires, which would maintain biodiversity and ecological stability. Among industry, A2P Energy's bio-briquettes have been adopted by major FMCG players seeking greener fuel sources. The CET platform has facilitated trading in over 35,000 metric tonnes of biomass and biofuel to date, solidifying market confidence in this model.

Socially, the project empowers rural women as entrepreneurs and climate stewards. By participating in biomass collection and processing, women are enhancing household incomes and gaining new leadership roles in local conservation efforts. A participant remarked, "This initiative gave me not just work, but purpose – protecting our forests while supporting my family."



Replacing coal
with bio-briquettes
is expected to
cut CO₂ emissions by

10,000
metric tonnes annually.

Summary and key takeaways

A2P Energy's bio-briquette initiative is a good example of sustainable bioprospecting that combines climate action, livelihood development, and the principles of a circular economy. By converting forest waste into useful energy products, the initiative addresses environmental hazards and also aids economic empowerment among Himalayan communities. It supports bioeconomic goals by creating market value from biological resources and promotes a carbon-negative enterprise model by replacing coal use and using biomass waste.

The key takeaways of the project have been threefold: the importance of scientific validation to build trust within industry; the use of digital platforms such as CET for transparency in supply chains; and the vital role of community participation in scaling up sustainable energy solutions.

The model has strong potential for replication in other forested, biomass-rich regions across the HKH, such as in Nepal and Bhutan. It contributes directly to several Sustainable Development Goals (SDGs), including SDG 7 (Affordable and clean energy), SDG 13 (Climate action), and SDG 15 (Life on land). To maximise their impacts, future efforts should focus on scaling up production, improving branding and market linkages, and advocating supportive policies, including carbon incentives and green financing. A2P Energy's work sets a precedent for integrating NbS into industrial energy systems while fostering inclusive rural development.

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Project Fragrant Chamoli: Supporting land regeneration, rural employment, and natural resources in Uttarakhand

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Background

In the Himalayan state of Uttarakhand, vast stretches of land have become barren due to invasive weeds such as lantana (*Lantana camara*) and eupatorium (*Eupatorium perfoliatum*). This has resulted in biodiversity loss, degraded soil quality, and reduced incomes for farmers. Many villages in Uttarakhand's Chamoli District lack alternative livelihood opportunities, particularly tourism, a major source of income in other parts of the state. The situation is compounded by frequent destruction of crops by wild animals, limited knowledge of sustainable agriculture among farmers, and scarce economic opportunities for women.

In response to these intertwined challenges, Agrinet Foods & Beverages Pvt. Ltd., an agrifoods company, launched Project Fragrant Chamoli in January 2023. The initiative aims to regenerate degraded Himalayan landscapes, generate climate-resilient rural livelihoods, and foster sustainable land use through bioprospecting. By combining ecological restoration, women-led biochar production, and the cultivation of aromatic plants such as lemongrass (*Cymbopogon flexuosus*), rosemary (*Salvia rosmarinus*), and chamomile (*Matricaria chamomilla*), Agrinet has created a 'soil to oil' supply chain that is transparent, circular, and inclusive.

Challenges and issues addressed

The project faced varied environmental, logistical, and financial challenges. The mountainous terrain limits the use of agricultural machinery, requiring manual labour for many farming activities. The remote location and poor connectivity of these villages pose serious barriers to market access, necessitating produce to be cultivated at scale for it to be economically viable. Another significant challenge is access to affordable finance for farmers as well as Agrinet to set up a primary processing unit. Agrinet's essential oils processing unit, for instance, is financed through a non-banking financial company (NBFC) at an annual interest rate of 18 per cent. This is burdensome, especially considering lemongrass' six-month gestation period from planting to harvest, which demands working capital or longer-term investment grants. In addition to these financial constraints, the absence of a dedicated state or national scheme for clearing invasive weeds and restoring degraded lands has left communities without institutional support. Farmers also suffer from a lack of knowledge about marketable crops and sustainable cultivation practices.



The solution

Agrinet implemented a two-phased solution in the villages of Dungri, Kunjo, Maikot, Swing, Nori, and Kunj in Chamoli District that promoted ecological restoration, economic empowerment, and climate resilience. In the first phase, invasive weeds are cleared and converted into biochar using low-cost Kon-Tiki kilns (inexpensive kilns typically made from easily available materials) operated by local women. Research is being conducted to refine the use of biochar as a carbon-neutral fuel, cattle-feed additive, and industrial heating source. Each batch of biochar is monitored through a digital monitoring and review (dMRV) system aligned with Carbon Standards International, a Switzerland-based company that develops solutions for the production of certified biochar. This initiative both generates carbon credits (a tradable permit that represents the right to emit one tonne of carbon dioxide equivalent, which can be bought or sold by companies to meet emissions reduction targets), with

1 tonne of biochar sequesters
3 tonnes of CO₂, with

40%

of carbon credit revenues going
back to the village.

a target of 3,000 biochar carbon credits over 12 months, and also enhances soil health. Agrinet has partnered with Circonomy Pte Ltd., a Singapore-based company that deals in biochar and carbon credits, to manage carbon sinks and aims to sequester 1,500 metric tonnes of carbon dioxide in one year.

In the second phase, lemongrass, rosemary, and chamomile have been cultivated on the regenerated lands. To date, over 200 acres have been reclaimed and



farmed by 300 smallholder farmers, with employment provided to more than 100 women. A notarised buyback agreement ensures that farmers are paid a fair price of INR 1.5 per kilogramme (kg) of lemongrass. With an estimated annual yield of 27,000 kg per acre, farmers can earn up to INR 40,000 per acre each year. Agrinet provides them with farming tools such as brush cutters and tillers. It also trains farmers in zero budget natural farming (ZBNF) techniques including the application of biofertilisers such as *bijamrita* and *jiwamrita*, mulching, and cow-based bio-inputs. Lemongrass is processed into essential oil in a semi-automatic distillation unit established in Dungri Village, which ensures 78 per cent citral content and meets pesticide-free standards. The waste from the process is repurposed as mulch or cattle feed, contributing to a circular and zero-waste agricultural model.

Results

The project has delivered significant socio-economic and ecological benefits. Approximately 200 acres of degraded land have been transformed, benefiting 300 farmers who earn INR 20,000 a year on average typically from cultivating just half an acre. This has generated considerable employment, with six women employed full-time by Agrinet at salaries between INR

200 acres

of degraded land have been transformed,
benefiting 300 farmers

6,500 and 7,500 a month and more than 100 women engaged on daily wages, generating over 7,300 workdays. Four men are also employed full-time, contributing over 2,100 workdays.

It has also contributed to youth employment, with eight local youth hired under the project. The project prioritises gender equity and social inclusion (GESI), with participation by women and youth from Scheduled Caste communities. In economic terms, household incomes have diversified: from dairy production (INR 4,000/month) and lemongrass farming (little under INR 2,000/month on average), in addition to work under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) provided by the state (INR 1,600/month). Wages for daily labour have increased by 33 per cent, with women now earning the same amount (INR 200/day) for six hours of work instead of eight.

And from an ecological perspective, biochar produced from cleared lantana enhances soil organic carbon when blended with organic manure. One metric tonne of biochar sequesters three metric tonnes of CO₂, with 40 per cent of the carbon credit revenues redirected to the village in the form of pre-finance. Approximately 4 million seedlings have been planted, with plans to plant 2 million more in 2026. The project also promotes agroecological models by intercropping lemongrass with chamomile and native fruit trees and spices, thereby enhancing pollinator activity and soil biodiversity.

Summary and key takeaways

Project Fragrant Chamoli exemplifies a replicable, climate-resilient model for promoting bioprospecting-led livelihoods. By restoring degraded landscapes and creating inclusive employment rooted in sustainability, Agrinet has contributed to empowering rural communities, particularly women, and improved local ecosystems. The biochar initiative demonstrates the viability of converting invasive species into a valuable soil enhancer and source of carbon credits. The cultivation and processing of lemongrass demonstrate how sustainable agriculture can be scaled up in fragile mountain regions using zero-waste principles. These efforts support the broader bioeconomy by generating economic value from ecological restoration, linking regenerative farming with carbon finance, and improving soil health to sustain biological productivity and ecosystem services.

The integration of blockchain technology, through the use of a third-party blockchain system, and dMRV ensures transparency and traceability, enhancing trust in the supply chain. Agroecological diversification, organic farming practices, and alignment with schemes like the MGNREGA further support the model's long-term viability. With institutional support, this model can be scaled up and out across the Himalayan region in partnership with NGOs, civil society organisations (CSOs), local communities, and concerned enterprises.

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Chamomile cultivation:
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Bioprospecting high-altitude medicinal and aromatic plants for the promotion of sustainable livelihoods and conservation in Uttarakhand

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Background

The Indian Himalayan Region is rich in medicinal and aromatic plants (MAPs), which are traditionally used for food, nutrition, healthcare, and income generation. In high-altitude areas, where agriculture is limited and income opportunities are scarce, MAPs have long supported rural livelihoods. Among the 1,748 recorded medicinal plant species in the region – including herbs, shrubs, and trees – many are endemic, such as jambu (*Allium stracheyi*) and caraway (*Carum carvi*), yet are also

threatened by anthropogenic pressures including over-exploitation of the natural habitat, indicating both their ecological importance and the urgency for conservation.

In the high-altitude villages of the Nanda Devi Biosphere Reserve (NDBR) in Uttarakhand, species such as small alpine onion (*Allium humile*, or ladum as it is locally known), Himalayan angelica (*Angelica glauca*), jambu, and caraway (locally known as *kala jeera*) have traditionally been used as spices, vegetables, and medicinal resources. Recognising their ecological and

economic value, the Department of Environmental Sciences at Hemvati Nandan Bahuguna Garhwal University (HNBGU) in Srinagar, Uttarakhand initiated a bioprospecting programme in partnership with Zandu Foundation for Health Care (ZFHC) to promote the sustainable cultivation, value addition, and conservation of these species. This initiative has aimed to combine traditional knowledge and scientific research to enhance livelihoods and protect the biodiversity in these remote Himalayan landscapes.

Challenges and issues addressed

The overharvesting of MAPs from alpine meadows by the local communities, limited awareness about cultivation practices, and the lack of market linkages have traditionally constrained the economic potential of these resources. Many farmers are reliant on seasonal and unsustainable collection of MAPs from the wild, leading to ecological degradation and resulting in inconsistent incomes. There was also little knowledge about the nutritional and medicinal value of these species, further limiting their market appeal.

Additional challenges included the remoteness of the region, lack of access to technology for post-harvest processing, and the absence of structured value chains to support local entrepreneurship. These barriers prevented communities from realising the full potential of MAPs as livelihood resources and contributed to the declining conservation status of several high-value species.

The solution

To address these challenges, the project built demonstration plots and carried out capacity-building and action research in high-altitude villages such as Suraithota and Tolma in Chamoli District (Figure 1). Adopting a participatory approach, farmers were trained in the cultivation and domestication of jambu, small



alpine onion, caraway, and Himalayan angelica, along with training in agronomic practices tailored to their native alpine environment. They were selected based on their interest and traditional knowledge, ensuring both inclusivity and sustainability, as the cultivation of these species will decrease the pressure on forest resources and also enhance the livelihoods and incomes of local communities.

A chemical analysis of the selected species was carried out. It revealed their rich nutritional profiles – including carbohydrates, proteins, lipids, vitamins, phosphorus, potassium, calcium, and iron – which was shared with the community to raise awareness of their market potential. After initial field trials, farmers successfully shifted from wild collection of these plants to organised cultivation. Seedlings were distributed to farmers to enable cultivation on a large scale. Over time, the cultivation spread across several hectares, with jambu being grown on the largest area (6.97 ha) and with the highest yields (584 kg/ha), followed by caraway, Himalayan angelica, and small alpine onion/ladum. Alongside cultivation, value-addition practices such as shade drying, grinding, and packaging were introduced, enhancing the product shelf life, market appeal, and profitability of the processed spices.

Results

The project has generated significant economic, ecological, and social benefits. Farmers have made substantial gains in income through the cultivation and sale of value-added MAP-based spices. The net

Farmers now earn up to

₹2.77 lakh

per hectare from alpine onion cultivation.

returns per hectare for small alpine onion reached INR 277,180, while kala jeera, Himalayan angelica, and jambu generated INR 247,070, INR 196,304, and INR 128,828 per hectare, respectively. The value addition doubled the retail prices of most spices – from INR 1,000/kg in their raw form to INR 2,000–3,000/kg after processing (see Table below).

Ecologically, the shift from harvesting these plants in the wild to their planned cultivation has reduced pressure on natural habitats, helping conserve endangered species and restore alpine meadows. The deployment of scientific processing and sustainable harvesting methods ensures minimal ecological disturbance and supports long-term resource management. Socially, the initiative has strengthened local communities, particularly in remote areas, by building capacities, creating income opportunities, and reviving traditional knowledge systems. The products developed under this initiative have been sold in platforms such as the Uttarakhand Herbal Expo and the International Bioresource Conclave in Imphal and thereby gained attention, and were appreciated by national stakeholders (the National Medicinal Plant Board and Ministry of Ayush) and policy makers.

Market price and returns on MAPs used as spices/condiments before and after value addition

Parameter	Alpine onion	Jambu	Himalayan angelica	Caraway
Cost of raw or unprocessed materials (INR/kg)	1,000 ± 50	1,000 ± 48	1,800 ± 52	2,200 ± 64
Cost of local value-added spice (INR/kg)	2,000 ± 60	2,000 ± 58	2,700 ± 72	3,000 ± 80
Net returns (INR/kg) after value addition	1,000	1,000	900	800

Summary and key takeaways

This case study highlights the successful integration of traditional knowledge and scientific bioprospecting that has transformed local MAPs into viable livelihood resources. The participatory approach enabled knowledge transfer, community ownership, and long-term sustainability. The cultivation of jambu, small alpine onion/ladum, caraway/kala jeera, and Himalayan angelica not only augmented household incomes but also contributed to biodiversity conservation and the development of rural enterprises.

With the right institutional support, MAP-based value chains such as these can transition from small-scale subsistence activity to structured bio-based industries that integrate sustainable sourcing, processing, and commercial distribution.

Key lessons include the importance of capacity-building, local value addition, and structured market access. The success of this initiative in the NDBR has catalysed its replication in other high-altitude areas such as Darma Valley and Milam Valley in Uttarakhand, where communities have begun adopting similar cultivation and marketing strategies. There is significant scope for wider commercialisation, branding, and export of these high-value herbal spices. This case study demonstrates how underutilised bio-resources can be harnessed for rural transformation while ensuring ecological resilience.

Bioprospecting opportunities through the restoration of urban forests in Nepal

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Background

Urban reforestation is gaining urgency in Nepal due to the environmental hazards posed by rapid urbanisation and the effects of air pollution and climate change on people's health. According to a recent study, Nepal's urban settlements expanded from 17 per cent in 2011 to 66 per cent in 2017. This dramatic growth, but without adequate urban infrastructure and open spaces, is exacerbating ecological degradation and putting added pressure on natural systems (Bhattarai et al., 2023). Urban forests as an alternative to urban green spaces are essential for mitigating these effects, yet they continue to receive low priority in policy circles and limited financial or human resource allocation (Lamichhane & Thapa, 2012).

Despite this, communities in Nepal are increasingly recognising the value of green urban spaces and are advocating for the restoration of forests using fast-growing, resilient native species (Joshi, 2023). Among the promising approaches to maximise biodiversity in small urban spaces is the Miyawaki approach, an innovative forest restoration method developed by the Japanese botanist Akira Miyawaki. This approach creates dense, multilayered native plant species that grow rapidly and provide a wide range of ecological, economic, and social benefits (Daou et al., 2024; Schirone et al., 2011).

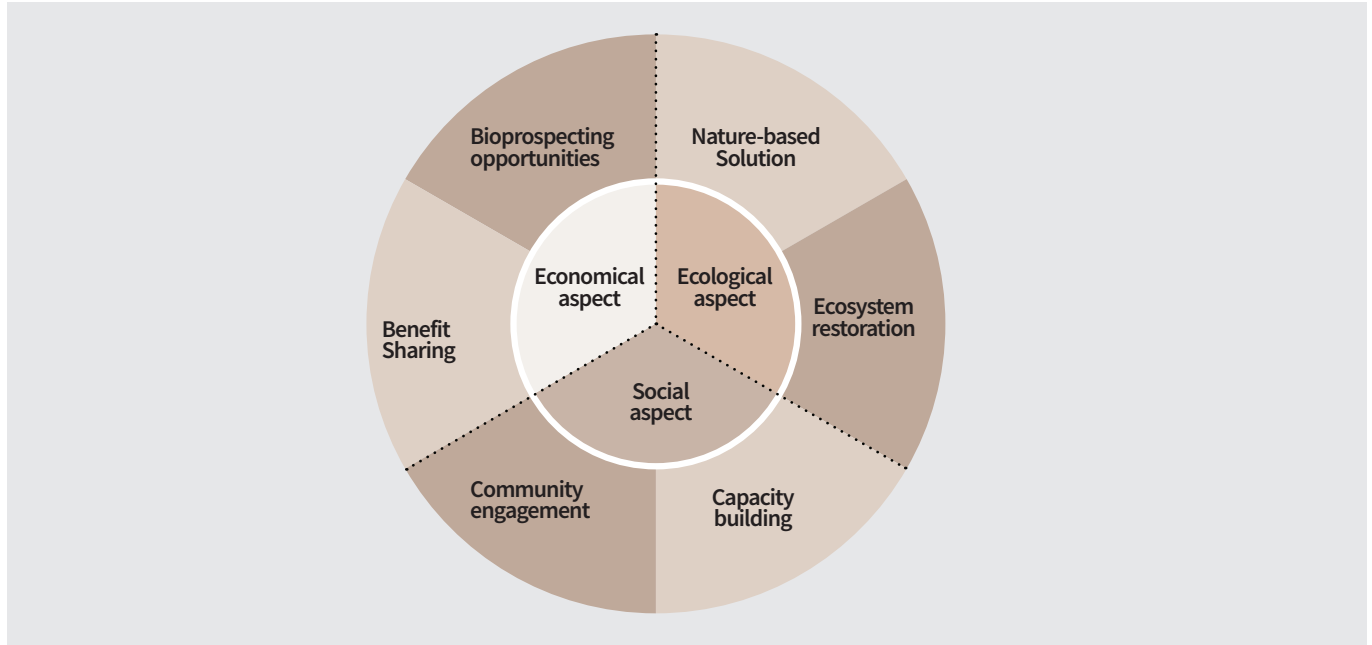
Nepal's urban settlements expanded from 17% in 2011 to **66 %** per cent in 2017

The Revolution Project (TRP), a youth-led organisation, has adapted the Miyawaki approach to create pocket forests in various urban areas of Nepal. These forests integrate human and natural systems by using native plant species that provide both ecological value and sustainable livelihoods. TRP has restored native flora in sites such as Swayambhu, Boudha, Pepsi Cola, Teku, and Kalimati in and around Kathmandu, thereby transforming degraded lands into thriving ecosystems, while also empowering local communities with new skills and resources.

Challenges and issues addressed

Urban reforestation in Nepal faces several challenges. Foremost among them is the degradation of urban green spaces due to unplanned development, which leaves limited land for forest restoration. The poor soil quality in cities often makes it difficult to identify suitable sites

Different facets of urban restoration by TRF in Nepal



for growing plantations. There is also a chronic shortage of native tree saplings in Kathmandu, necessitating organisations such as TRP to source planting material from other districts, such as Sindhupalchowk. This increases the cost of implementation, putting a strain on limited resources. Another challenge is the cost of soil testing, which is necessary for ensuring the suitability of sites for the Miyawaki technique, because inappropriate conditions can limit the success of reforestation efforts.

Notwithstanding these logistical and ecological challenges, TRP has been restoring sites, while adopting a participatory, community-driven approach. However, gaps in collaboration and a lack of structured investment in native nurseries continue to restrict the potential for scaling up. Addressing these barriers is critical to achieving the long-term sustainability of such projects and expanding urban forest restoration to other parts of Nepal, such as the Terai region.





The solution

TRP's solution involves a step-by-step implementation of the Miyawaki approach, beginning with a needs assessment and identifying appropriate sites in collaboration with local communities. Sites are selected based on their ecological viability and potential for planting diverse native trees. TRP emphasises maximising plant diversity, with species selected based on their ecological functions, medicinal value, aromatic properties, and economic potential. Over 30 native species have been prioritised, including Nepali hog plum (*Choerospondias axillaris*), Indian gooseberry (*Phyllanthus emblica*), broom grass (*Thysanolaena latifolia*), champak (*Magnolia champaca*), night-blooming jasmine (*Cestrum nocturnum*), and timmur (*Zanthoxylum armatum*). These plants serve multiple purposes; they provide fruit, essential oils, medicinal extracts, and material to make brooms, products that have market and livelihood potential for local communities.

The Miyawaki approach structures the forest in layers – shrubs, sub-trees, trees, and canopy species – to promote dense growth and ecological balance. Nutrient-rich

organic matter is added to the soil to enhance fertility. Participatory training sessions were conducted to inform local stakeholders about forest restoration techniques and the long-term benefits of biodiversity. This participatory process helps nurture a sense of ownership, making it more likely that the project's implementation and maintenance will be successful. Once the site is chosen and ready, 2–3 saplings are planted per square metre, and straw mulch applied to retain moisture and support early growth. The result is a rapidly regenerating, dense, and biodiverse forest, with varied potential benefits.

Results

The restoration work carried out by TRP has resulted in visible social, ecological, and economic benefits in a short period of time. It was first implemented in the Chakhandol Community Forest in Kathmandu in 2019, a site previously dominated by non-native species. Following the planting of endemic species, the forest became more biodiverse, with native flora reviving and fauna returning. Forest user groups observed species that had not been seen in the area for years, indicating a positive ecological shift. Local residents also began

to enjoy its benefits, using *parijat* flowers (jasmine, or *Nyctanthes arbor-trystis*), consuming jamun, and benefiting from the forest's cooling effects during the hot summer months.

In Swayambhu, on the outskirts of Kathmandu, a forest area that had been deteriorating, with thinning Sal trees, was revitalised in 2023. Today, the revived forest is appreciated by both residents and pilgrims visiting the heritage site and is also a source of food for monkeys. According to Professor Keshav Shrestha of Swayambhu, the forest's regeneration has added significant ecological value to the area.

The project also demonstrates promising economic and bioprospecting potential. The planting of fruit-bearing trees and medicinal herbs lays a foundation for future income generation. Community members, especially women, benefit from harvesting and selling products such as broom grass and essential oils. TRP is now working on quantifying these benefits and integrating bioprospecting into its capacity-building efforts. With the active participation of local organisations and other stakeholders, the forest patches established in 2022 and 2023 now serve as models for urban reforestation and sustainable community development.

Summary and key takeaways

TRP's implementation of the Miyawaki approach in urban areas in Nepal highlights how forest restoration can promote ecological regeneration along with economic and social benefits. The project has transformed small, degraded plots of land into dense, self-sustaining forests that support biodiversity, provide livelihoods, and engage communities across generations. By planting high-value native species with medicinal, aromatic, and nutritional uses, the project opens new avenues for bioprospecting and green enterprises. This initiative also stands out as an urban bioeconomy innovation, demonstrating how degraded city spaces can be transformed into hubs for

the development of nature-based products, such as herbal remedies, essential oils, and broom grass, while also enhancing urban resilience.

Challenges such as the availability of saplings, poor soil conditions, and limited funding remain, but TRP is trying to address them by partnering with nurseries and exploring the creation of its own seedling supply chain. Its participatory model ensures that communities are equipped with the knowledge and responsibility to sustain the forests. Looking ahead, the project has high potential for replication across urban and semi-urban areas, especially as the demand for pocket forests grows. With strategic investment and support, TRP's model can play a vital role in building climate-resilient cities and unlocking nature-based livelihood opportunities.

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Sancho: A herbal product that promotes sustainable business and dignified employment

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Background

Nepal is well known for its rich plant biodiversity because of its diverse climate and steep altitudinal gradients. Nepal has about 11,393 species of plants, including flowering and non-flowering plants. It is estimated that Nepal potentially has approximately 2,000 varieties of MAPs and NTFPs. Around 819 of these have been identified as medicinal plants, of which over 165 are commercially traded. However, unsustainable extraction practices, fragmentation of habitats, and limited value-added processing threaten ecological integrity and hamper socio-economic opportunities in rural areas.

The Herbs Production and Processing Company Limited (HPPCL), established by the Government of Nepal in 1981, sought to address these challenges in its own way. It has developed Sancho, an innovative essential oil formulation derived from a blend of pure Himalayan essential oils – from mint (*Mentha arvensis*), eucalyptus (*Eucalyptus sp.*), cinnamomum leaves (*Cinnamomum tamala*), prickly ash (*Zanthoxylum armatum*), wintergreen (*Gaultheria fragrantissima*), and lemongrass (*Cymbopogon flexuosus*) – produced in the company's own processing units. Sancho, manufactured by HPPCL in Koteshwor, Kathmandu, has a varied range of applications; it is used for colds, stuffy nose, headaches, and related ailments.

HPPCL is the first government company in Nepal to harvest MAPs and produce medicinal extracts and essential oils for the pharmaceutical, food, beauty, and wellness industries, both within Nepal and abroad. The company has been combining traditional knowledge with modern techniques to produce high-quality herbal products for domestic and international markets ever since 1998–1999.

HPPCL's main objective in producing Sancho is upscaling the sustainable collection, cultivation, processing, and manufacturing of MAPs and essential oils products, thereby generating employment and enhancing the socio-economic status of low income, underprivileged, and landless people in Nepal.

Challenges and issues addressed

The Sancho initiative by HPPCL faces several significant challenges in its operations and efforts to expand markets. A primary obstacle is inconsistent access to global markets, stemming from HPPCL's status as a government company; this requires it having to obtain permissions from the Ministry of Finance to participate in international trade fairs. This bureaucratic process has limited the company's ability to market and sell its

Women make up

70%

of HPPCL's manufacturing workforce and lead in cultivation too.

herbal products in global markets. The brand also has to contend with counterfeit products flooding the market, as the rising demand for herbal remedies has attracted local imitators. It also has to compete with established international brands from India and China, known for their competitive pricing and manufacturing expertise.

Quality control presents another challenge, as securing acceptance in international markets requires consistently high-quality essential oils and herbal products. While HPPCL has established a good manufacturing practice (GMP) production unit, constraints persist regarding access to internationally accredited laboratory facilities and other resources needed for comprehensive quality testing of fast-moving consumer goods. This directly restricts market linkages and export potential. Related to this is the challenge of value addition – while Sancho's formulation benefits from blending various essential oils, the lack of advanced processing infrastructure and technology hampers efforts to enhance product value and differentiation.

Regulatory hurdles and product certification issues also create substantial trade barriers. Meeting complex international standards like GMP and organic certifications, along with obtaining necessary export licenses, proves particularly challenging. The absence of a domestic regulatory body that meets international certification standards makes explicit the urgent need for institutional development in Nepal's herbal



products industry. Compounding these challenges is limited research and development (R&D) capacity in the country, particularly in areas such as smart agricultural practices, essential oil extraction processes, value-addition techniques, and product branding. Financial constraints and the lack of internationally accredited laboratory resources severely restrict investment in these critical R&D areas, hindering innovation and quality improvement efforts that could enhance its global competitiveness.

The solution

HPPCL has developed a comprehensive, community-centred business model that combines commercial success with sustainable development. The initiative focuses on environmental restoration and livelihood creation in regions abundant with MAPs. The company currently engages over 500 seasonal workers in

cultivation and processing, and has also initiated contract farming arrangements with approximately 700 households on farms located in the tropical and mid-hill regions of the country. This enables farmers to utilise fallow periods between cereal crops to cultivate medicinal herbs, thereby generating supplemental incomes for them that often exceeds that from traditional crops.

HPPCL's model strongly emphasises women's empowerment, with female workers constituting 70 per cent of the manufacturing workforce and women having an active role in cultivation. Such employment promotes financial independence and fosters leadership development within rural communities. The company partners with marginalised social groups, including the Tharu, Musahar, Chamar, and Majhi communities across multiple districts, and offers them comprehensive support through seed distribution, technical guidance, and guaranteed purchase agreements for their harvests.

The production processes combine the cultivation of essential oil-bearing plants with modern processing techniques, utilising shade drying and steam distillation methods to extract essential oils. Despite currently operating without a formal profit-sharing mechanism, HPPCL ensures fair compensation through stable employment and reliable market access for contracted growers. The Sancho product line has achieved strong domestic penetration as a trusted remedy for common colds and respiratory ailments.

Looking ahead, HPPCL is pursuing several strategies to enhance competitiveness:

- **Market expansion:** The company is strengthening its distribution networks through partnerships with government agencies such as the Food Management and Trading Company Limited to reach rural markets, while exploring premium international channels.

- **Quality certification:** It is transitioning to automated GMP-compliant production and pursuing certification for selling organic products in European and North American markets.
- **Brand protection:** The company is implementing digital marketing strategies to differentiate authentic Sancho products from counterfeit alternatives.
- **Sustainable practices:** It is promoting organic cultivation methods and utilising the by-products of processing as biofuel, creating a circular production system.

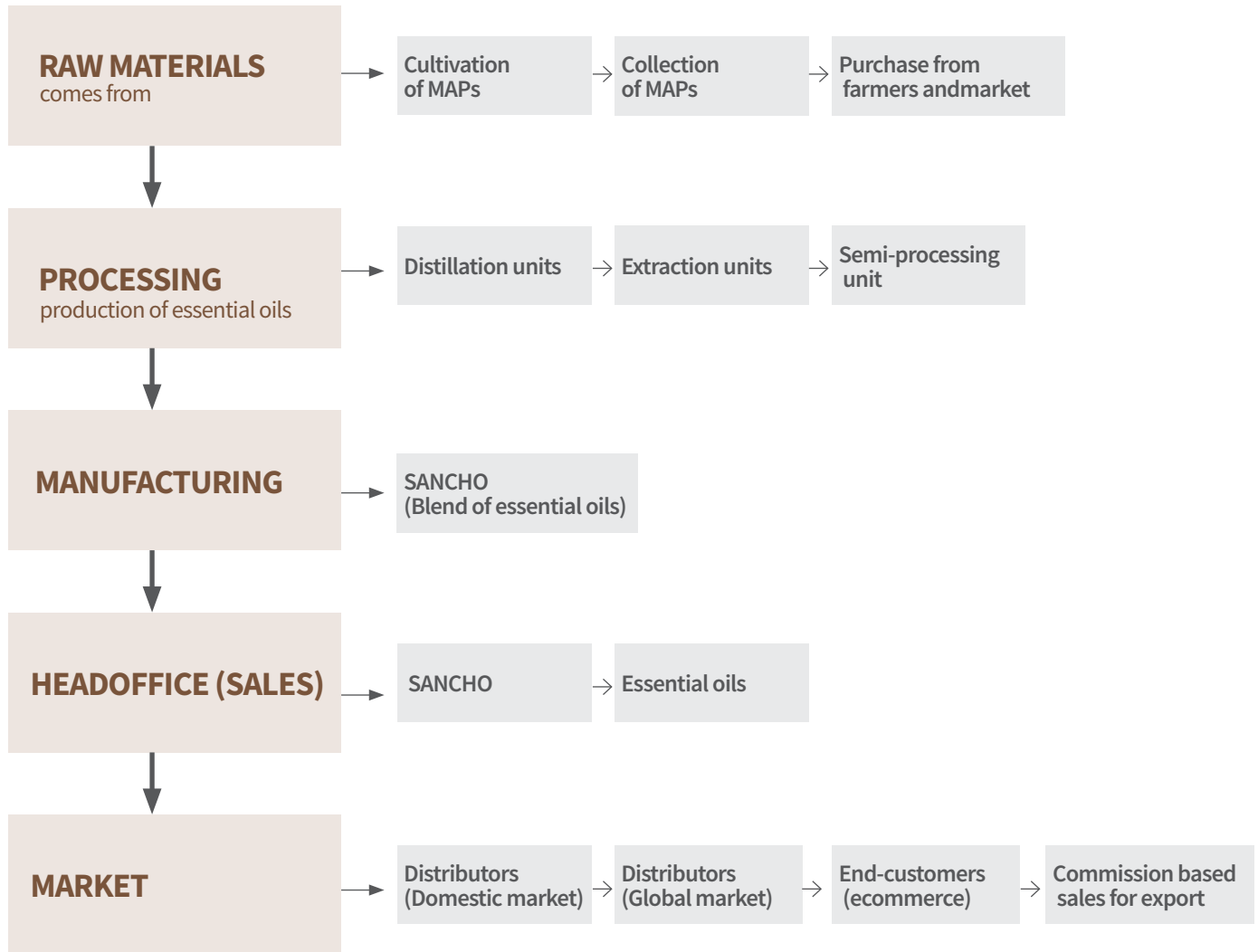
The company has also made significant infrastructural investments, including GMP-compliant manufacturing facilities (see Figure below), funded through government loans, while participating in capacity-building programmes offered by various ministries.

Results

HPPCL's Sancho initiative has delivered measurable impacts that have economic, social, and environmental dimensions. Financially, the product has demonstrated remarkable revenue growth; this was especially the case during the COVID-19 pandemic when heightened health awareness drove demand to an all-time high, with sales reaching 10 million bottles in one fiscal year. Post-pandemic, Sancho has maintained that momentum, and the company is currently targeting the sale of 7 million five-millilitre (ml) packs a year at a retail price of NPR 50 per pack, reflecting consistent year-on-year growth.

The company has also created substantial employment opportunities, directly and indirectly supporting over 1,200 jobs across various sectors. In processing plants, the employment of mechanical engineers, distillation unit operators, and quality assurance specialists has expanded to meet production needs. Its manufacturing facilities have increased their workforce to achieve annual production targets, employing both skilled and unskilled

BUSINESS MODEL





workers, including production line workers and plant operators. Growing demand for the product has also spurred jobs in sales and distribution, to enhance market reach across Nepal.

The business model has proven financially sustainable, with a strong return on investment due to efficient, high-quality production and growing market demand. The selling price of NPR 50 per 5-ml pack, combined with increasing sales volumes, ensures profitability even in competitive markets.

Market expansion has also happened, with Sancho gaining brand recognition beyond Nepal. Strategic distribution partnerships have enabled penetration into neighbouring markets such as India, Bangladesh, and Bhutan, while exports to Europe, the USA, and Sweden highlight the brand's global appeal. Collaborations with government agencies, such as the Food Management and Trading Company Limited and the Salt Trading Corporation Limited, have further strengthened domestic and rural market access.

The initiative has also fostered socioeconomic empowerment, particularly of women and marginalised communities. Seasonal employment in cultivation and processing has benefited rural communities, approximately 700 contract farming households; many of those who are employed are underprivileged women. By integrating sustainable farming practices, HPPCL ensures environmental conservation while supporting livelihoods. The company minimises waste by repurposing plant debris as biofuel and organic manure, reinforcing its commitment to the principles of a circular economy.

Sancho has evolved into a flagship herbal brand with a growing international presence. Its success demonstrates how sustainable business practices can drive profit, social equity, and environmental stewardship simultaneously, setting a benchmark for Nepal's herbal products industry.

Key takeaways

The Sancho initiative demonstrates how Nepal's medicinal herbs have the potential to promote sustainable growth while providing employment to, and empowering rural communities. The key takeaways are the importance of local resource utilisation, community engagement, and the need for quality certification in building a competitive herbal brand. Ethical sourcing and the economic inclusion of underprivileged women enhance both social impact and market credibility. Sancho also has the potential to serve as a flagship product within Nepal's emerging economy, with opportunities for green certification, branding, and marketing as a high-value herbal product in regional and global markets.

To scale up this success, policy makers should:

- Establish a national certification body to standardise herbal products
- Invest in R&D, processing infrastructure, and farmer training
- Simplify export processes and promote government-to-government (G2G) trade partnerships
- Develop accredited testing labs and support organic certification

By implementing these measures, Nepal can position itself as a leader in sustainable herbal products while uplifting rural livelihoods and preserving the country's biodiversity.

Additional resources

<https://www.ratopati.com/story/208418> (success of Sancho during the COVID-19 pandemic) (in Nepali)

<https://www.youtube.com/shorts/6ptu7gy-llw> (product description)

HimGra®: A sustainable bioprospecting innovation for climate-resilient textiles

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Background

The global fashion and textile industries are among the largest contributors to environmental degradation, with their production processes contributing to excessive water consumption, chemical pollution, and greenhouse gas emissions. To address these challenges, HimGra®, derived from wild Himalayan plant fibres, has emerged as an innovative bioprospecting option for sustainable and climate-resilient fibre production. It is cultivated without fertilisers, pesticides, or irrigation, and offers a low-impact alternative to conventional fibres such as cotton and linen.

HimGra® is grown in some rain-fed, barren lands of Uttarakhand's Himalayan region, where climate change – in the form of erratic rainfall and rising temperatures – and increased soil degradation is increasingly affecting traditional agriculture. The fibre is processed using a patented, waterless technology, minimising both water usage and the carbon footprint typically associated with textile production, discussed below.

Challenges and issues addressed

Conventional textile fibres such as cotton and linen are resource-intensive to grow and environmentally harmful. Cotton, in particular, requires substantial irrigation water and pesticides, contributing to groundwater depletion

90%

of HimGra® beneficiaries are women, through SHGs, cooperatives, and smallholder farms.

and chemical run-off. Linen is relatively less resource-intensive, but still depends on water- and energy-intensive processing methods.

HimGra® addresses these issues by growing naturally on degraded, rain-fed lands, and without synthetic or chemical inputs. Its waterless extraction technology also eliminates the hazard of severe water pollution associated with conventional fibres. Furthermore, it helps address the economic marginalisation and vulnerability to climate change faced by rural hill communities in Uttarakhand. HimGra® offers a nature-based livelihood alternative that supports women-led self-help groups (SHGs) and smallholder farmers, thereby reducing outmigration and promoting economic resilience.

The solution

HimGra® offers a bioprospecting solution with multiple benefits:

- Suitable and sustainable fibre processing: HimGra® fibres are compatible with both short-staple and long-staple yarn systems, and are also suitable for high-speed rapier weaving, a process that is known to be faster and more efficient. The fibre blends well with cotton, viscose, wool, and silk, enabling its application across luxury fashion fabrics. The patented waterless extraction process eliminates the use of chemicals and thereby also reduces the carbon footprint of fibre production.
- Circular economy and the utilisation of byproducts: HimGra® supports a circular economy approach through the generation of eco-packaging materials made from fibre waste; deriving medicinal and aromatic extracts from residual plant matter; and the generation of bio-based composites for technical and industrial applications.

Results

The cultivation and use of HimGra® have resulted in significant socio-economic and environmental gains. In terms of socio-economic impacts, the HimGra® model supports SHGs, cooperatives, and smallholder farmers, with 90 per cent of the beneficiaries being women. On average, an acre of HimGra® cultivation benefits ten rural women and four handloom weavers. In one notable example, a women-led SHG in Uttarakhand increased its members' average income by 40 per cent in a year, expanding their activities into fibre processing, eco-packaging, and the development of bio-products, both medical and for personal care. The environmental gains too have been varied. The cultivation of HimGra® reduces groundwater usage by a remarkable 80 per cent compared to linen. Its cultivation avoids the emission of 396 kg of CO₂-equivalent for every 100 kg of fibre. The plant has deep roots and this improves soil stability and prevents erosion. According to a published report, the cultivation of HimGra® results in reduced greenhouse gas emissions, zero water pollution, and enhanced biodiversity (Greenr, 2024).

It has also received recognition at the national and state levels for its efforts. The Ministry of Textiles, Government of India, has awarded HimGra® the Textile Innovation Challenge Prize in March 2025, and the Government of Uttarakhand has acknowledged its contribution to sustainable development in the state.

Summary and key takeaways

The experience of HimGra® exemplifies how bioprospecting can promote green innovation, climate adaptation, and rural economic development. The key takeaways include the following:

- Low-input, zero-carbon cultivation is a viable alternative to growing resource-intensive fibre.
- Waterless, chemical-free processing significantly reduces water pollution and greenhouse gas emissions.
- Women-led community engagement strengthens local economies and supports gender equity.
- Efforts at developing a circular economy maximises the value from plant by-products.

HimGra® also contributes to the transformation of the textile industry by offering a scalable, bio-based alternative that feeds into sustainable industrial value chains and aligns with global climate goals. With a planned expansion to cover a thousand acres and an annual production target of 600 tonnes, HimGra® is poised for scaling up as a premium, sustainable textile input.

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Valorisation of sericulture and mulberry by-products to promote green livelihoods in Yanbian, China

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Background

Yanbian County, located in the mountainous Sichuan Province of China, has a centuries-old tradition of sericulture and mulberry cultivation. The industry once served as a primary source of livelihood for thousands of rural households. With its unique geography, in which the Guosheng, Yongxing, and Huimin Rivers meet in Yumen Town, Yanbian has historically enjoyed a fertile environment ideal for mulberry growth. Situated in a sun-drenched river valley with a prolonged frost-free period, the region supports an exceptional eight-month production cycle that allows for six seasons of silkworm rearing annually. The mountainous landscape, with elevations between 1,200 and 1,800 masl, features fertile red-yellow soil and accessible river irrigation that are optimal for robust mulberry growth. However, as modern economic pressures mounted and traditional farming practices declined, the region's once-thriving sericulture industry faced a sharp downturn. Soil degradation, other environmental stresses, and shifting market dynamics further pushed farmers away from mulberry cultivation toward cash crops such as walnuts and loquat.

To counter this decline, local government officials in Yanbian adopted a novel bioprospecting approach that reimagines the mulberry and sericulture value chain. Rather than relying solely on mulberry leaves for rearing silkworms, they decided to explore the full potential of the mulberry tree and its by-products. This new strategy

Mulberry

health products and raw silk are exported to Japan, Romania, Italy, India, and Pakistan.

sought to combine traditional knowledge with modern scientific practices, and to revitalise the local economy while improving ecological resilience. The initiative is a robust example of how rural communities can adapt traditional industries into sustainable livelihood systems using nature-based innovation.

Challenges and issues addressed

Yanbian's traditional sericulture sector faced multifaceted challenges. Market competitiveness declined with globalisation, making it harder for local producers to profit from raw silk. At about the same time, environmental degradation due to monocultural practices and soil exhaustion had reduced agricultural productivity. The limited use of mulberry solely as silkworm feed also restricted the potential for economic diversification, even as the younger generation was abandoning farming in search of more remunerative urban employment.

These socio-economic shifts resulted in declining mulberry cultivation and the abandonment of a landscape that once supported biodiversity and generated incomes. Furthermore, the lack of innovation in processing and marketing agricultural by-products limited the farmers' ability to add value to what was often considered waste. Without appropriate intervention, the collapse of this key economic activity risked deepening rural poverty and ecological damage in the region.

The solution

Yanbian's strategic shift toward bioprospecting, initiated by local officials, has enabled local farmers to fully utilise the mulberry tree and its by-products, in the process transforming waste into value-added products and revitalising the sericulture sector. This initiative that began in 2020 was supported by cooperatives and agricultural agencies. One of the key innovations carried out was the extraction of anthocyanins – powerful antioxidants – from mulberry pomace, previously a waste product of the production of mulberry juice. These compounds are now used in health supplements, cosmetics, and pharmaceuticals, creating new income streams for farmers and processors.

Another innovation involved repurposing silkworm pupae – previously discarded after silk reeling – into ingredients for high-end cosmetic products. Rich in protein and fatty acids, these pupae are now processed into skincare items that are marketed domestically. Meanwhile, the region's broader portfolio – including premium raw silk and fresh mulberries – has successfully entered international markets such as Japan, Italy and Romania. For instance, fresh mulberries are exported to Japan, while high-grade raw silk is shipped to over 10 countries, including Italy,

Romania, India, and Pakistan. This innovation not only reduces waste but enhances the economic value of the sericulture cycle.

Additionally, mulberry branches, once left to decay, are now used as a substrate for cultivating edible fungi such as oyster and beech mushrooms. This provides farmers with an additional income source and contributes to circular agriculture, as the spent substrate is later applied to fields as a natural fertiliser. Finally, mulberry leaves have been reintroduced into the market as nutritional culinary products, in tea, soups, and health food supplements, leveraging their antioxidant-rich profile.

Taken together, these interventions exemplify a circular, low-waste system rooted in ecological knowledge. They are supported by cooperatives, agricultural extension agencies, and local governments to ensure scale, quality, and equitable market access.

Results

The impacts of bioprospecting in Yanbian, particularly the identification of plants and other species used to develop medicines and commercially valuable products, have been profound, both ecologically and economically. The complete valorisation of mulberry trees in the area has reduced agricultural waste, improved soil quality, and decreased reliance on chemical fertilisers. Using mulberry branches for mushroom cultivation and mixing the enriched substrate into the soil has led to better land management and the restoration of biodiversity. The extraction of anthocyanins and conversion of pupae into cosmetics have added commercial value and reduced post-harvest loss, strengthening the local green economy.

Socially, these innovations have diversified rural incomes, reduced economic vulnerability, and rekindled the interest of youth in agriculture. The success of diversified product lines has significantly strengthened the local

economy. While mulberry-based health supplements and cosmetic products have captured shares in the national market, the enhanced quality of fresh mulberries and raw silk has successfully opened up global markets, with exports reaching Japan, Romania, Italy, India, and Pakistan. The economic stability engendered by the diversification of livelihoods has helped reverse rural outmigration and restored community pride in traditional practices, reimagined through science.

Farmers, especially women, have become more involved in cooperatives, and several young entrepreneurs have returned to Yanbian to launch businesses based on mulberry products. Local governance and cooperative structures have ensured equitable benefit-sharing, knowledge exchange, and sustainable growth.

Summary and key takeaways

Yanbian County's initiative in transforming the use of the mulberry tree is a valuable example of how traditional agriculture-based industries can be reimagined through sustainable bioprospecting. By expanding the value chain of the mulberry tree – from leaves to branches, pomace, and silkworm pupae – the initiative has generated 'green' livelihoods, strengthened local economies, and restored ecological health. The key lessons include the importance of linking traditional knowledge with scientific innovation, and the effectiveness of cooperative models in ensuring inclusive growth.

By transforming agricultural residues into marketable products, the initiative exemplifies a low-waste bioeconomy model that maximises resource efficiency, reduces environmental impacts, and fosters circular economic activity in rural contexts. The case study also illustrates the scalability of bioprospecting practices. With appropriate policy support, development of markets, and technical training, other regions with similar agricultural legacies and environmental challenges can replicate Yanbian's model. Importantly, this initiative highlights

the role of bioprospecting not only as an ecological or economic good, but as a transformative rural development strategy with broad sustainability benefits.

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Resource-based livelihoods and hill-specific technologies bring new hope to disaster-hit Kedar Valley

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Background

The Kedar Valley in Uttarakhand, a hub of pilgrimage tourism, once supported diverse livelihood options, including hospitality services, transport, and small-scale trade. An extreme flood event in June 2013 extensively damaged infrastructure, settlements, livestock, and agricultural land, severely disrupting the local economy.

This led to an acute precarity of livelihoods, particularly among communities dependent on tourism-linked services and natural resources. In response, the Govind Ballabh Pant National Institute of Himalayan Environment (GBPNIHE), and Department of Environmental Sciences, Hemvati Nandan Bahuguna Garhwal University (HNBGU), supported by the Technology Intervention for Mountain Ecosystem and Livelihood Enhancement through Action Research & Networking (TIME-LEARN) programme of the Science for Equity Empowerment and Development (SEED) Division, Department of Science and Technology (DST), Government of India, implemented a series of technology-based interventions aimed at diversifying and stabilising income sources in the area. By harnessing local bio-resources and introducing hill-specific, cost-effective technologies—which they did through the Rural Technology Demonstration and Training Centre (RTDTC)

at Triyuginarayan Village in Rudraprayag District, located at 2,200 metres above mean sea level (masl) – the initiative sought to build resilience and promote sustainable livelihoods in disaster-affected areas.

The solution

The GBPNIHE, Garhwal Regional Centre initiated technology-led skill development programmes for local people at the RTC in order to strengthen local livelihoods. They did so by tapping the potential of locally available bio-resources through science and technology interventions, thereby adding value to local resources and skills, and aiding in the creation of mini and micro enterprises. Need-based, hill-specific technologies were scaled up and delivered, which were adopted and replicated by the people locally to augment their livelihoods and generate incomes in the Kedar Valley.

Under the action research project, 15 appropriate, cost-effective, and hill-specific technologies – including protected cultivation (via the use of polyhouses, a type of greenhouse, shade net houses, etc.), organic composting, and biofertiliser, off-farm technologies, and other on-site supporting technologies—were installed and demonstrated. These technologies have been adopted and replicated in nearby villages as well by local people

15 appropriate

cost-effective, and hill-specific technologies are installed and demonstrated.

to enhance their livelihoods and generate incomes. The RTC also trained local people in other livelihood activities such as water harvesting, multipurpose tree plantation, bamboo propagation, drip irrigation, and handicraft-making. The RTC also sought to introduce these technologies to increase yields via methods such as the use of polyhouses, polypits, vermicomposting, and bio-composting. It also promoted income-generating activities such as the cultivation of vegetables and other cash crops, integrated fish farming, floriculture, and mushroom cultivation. Under protected conditions that protects crops from severe stresses of low temperatures, frost, and pathogens in hill conditions, a 4–5-fold increase in the yields of vegetables and ornamental flowers has been reported by GBPNIHE.

During 2017–2019, ten skill development and training programmes under DST, along with five in-house programmes and several externally funded projects

under GBPNIHE, were organised. As many as 758 people (356 women and 402 men) from 20 villages of Kedar Valley participated. The programmes covered such diverse areas as the bioprospecting of agro-based and wild bio-resources, the cultivation of MAPs, and water resources management.

Thirteen potential wild, edible bio-resources, for example, caraway/Meridian fennel (*Carum carvi*), the Indian bay leaf (*Cinnamomum tamala*), etc., were identified for local value addition and the development of edible products. The project trained farmers and local youth in the sustainable harvesting of these resources and the preparation of edible products such as juices, squash, jams, jelly, pickle, spices, and condiments while also maintaining quality control. This is potentially a source of income as they can be sold in local markets during the pilgrimage season.

An appropriate technology package of practice has been developed to support the cultivation of gainda (*Tagetes erecta*) between May and November. This is done by raising seedlings under protected and open conditions as a stage towards its large-scale cultivation in the villages located along the routes of Kedar Dham. This would benefit local people via livelihood diversification.





A water harvesting tank with a capacity of 0.2 million litres was constructed at the RTC. It is presently catering to the drinking water and kitchen garden needs of 15 households, and has helped increase vegetable production by 28–35 per cent in the Dhaknu area of the Triyuginarayan Village, a benefit available through the year. This perennial availability of drinking water has also reduced the drudgery of women and reduced the incidence of water-borne diseases. It has also resulted in a saving of about INR 1.25 lakh (INR 0.125 million) for 15 households in the construction of drinking water pipelines.

In Triyuginarayan Village, twenty-nine households adopted the large-scale cultivation of tagara (*Valeriana wallichii*), a rhizome herb used in cosmetics. GBPNIHE initiated buy-back arrangements with companies such as Emami for marketing these products. A small nursery for multipurpose tree species such as the Nepalese alder (*Alnus Nepalensis*) and birch (*Betula pendula*) was established in the RTDTC, Triyuginarayan for the distribution of their saplings to the local community

and farmers towards the restoration of the once-flooded rural landscape in the valley, adopting agroforestry and ecological restoration approaches.

Results: Viable livelihoods through bio-enterprises

Such interventions towards the diversification of livelihoods, using local resources and skills, have changed the lives of affected people in the region and strengthened the local economy. For instance, Vineeta Devi, Omkar Gairola, and Rama Prasad Bhatt of Triyuginarayan Village and many other farmers in nearby villages affected by the 2013 disaster, were trained in fabrication and the use of cost-effective polyhouses, and nursery techniques for the improved production of vegetables such as tomato, hybrid cucumber, capsicum, peas, green vegetables, etc. GBPNIHE, Garhwal Regional Centre has estimated that the cultivation of off-season vegetables in a polyhouse has provided local farmers an additional annual income of approximately INR 29,000 per household on average.



Yogesh Joshi is a graduate and unemployed youth of Sankri Village of Guptakashi. He was trained in value addition of locally available agro- and wild bioresource-based edible products. In 2017, he started a micro-enterprise and is now earning a profit of INR 5,67,000 per year by selling various value-added products involving trained, skilled people from Sankri Village itself. Similarly, Laxmi Prasad Ghildiyal of Triyuginarayan Village and six youth from nearby villages who lost their tea shops, restaurants, horses, and ponies in the 2013 floods, started a small micro-enterprise focused on the development of edible products in 2016 using local agro and wild bio-resources. From this, they earn an average annual income of about INR 375,985 per household.

In an unusual move, the initiative also introduced combining growing medicinal plants and horticultural produce to increase yields and farmers' incomes. Seedlings were distributed to the villagers for the large-scale cultivation of medicinal plants. The RTC developed value-added products from MAPs and wild edible plant species from the area. About 85 households in the area

One micro-enterprise in Sankri village reported a profit of

5,67,000
per year

have started small-scale income-generating activities through the year based on locally available bio-resources, as well as for their own consumption. This provides them an additional annual average income of about

In Triyuginarayan Village itself, Raghunath Gairola, who lost a pair of horses and a buffalo in the 2013 disaster, has been growing medicinal plants and off-season vegetables in a nursery, from which he earns about INR 48,260 a year.

Summary and key takeaways

The action research project has sought to address livelihood and socio-economic development-related challenges in Kedar Valley. It has also explored appropriate and affordable technologies and opportunities for the sustainable development of disaster-affected rural landscapes of Kedar Valley.

The project adopted a bottom-up approach towards skill development and the implementation of enabling technologies based on Indigenous knowledge. It sought to link management practices and informal institutions; supplement and complement people's worldview with scientific knowledge; and involve people in all stages of technology development, implementation, and sustainability evaluation keeping in view socio-economic

and ecological considerations. By fostering the creation of bio-based micro-enterprises dependent on local resources and rooted in traditional practices, the initiative contributes to building resilient livelihoods and inclusive economies in fragile mountain ecosystems.

The capacity-building and skill development of stakeholders of disaster-affected villages of Kedar Valley via onsite training regarding livelihood enhancement, along with simple technological interventions, has helped provide viable alternatives to local people to reduce their dependence on forest resources and has promoted climate-resilient technologies. It has also contributed to addressing various Sustainable Development Goals and mountain development in an inclusive and sustainable manner.

Sustainable bioprospecting for green livelihoods: Hemp as a catalyst for sustainable development in Uttarakhand

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Background

The state of Uttarakhand, situated in India's northern Himalayan belt, is characterised by its diverse altitudinal range, from 300 to over 7,000 masl. Its rugged topography contributes to the state having distinct climatic zones and considerable ecological diversity. Its economy is predominantly agrarian, with over 65 per cent of the population dependent on agriculture. Yet, only 14 per cent of its land is cultivable due to the prevalence of steep slopes and a rocky terrain. Fragmented and small landholdings, averaging just 0.68 ha per household, further constrain agricultural productivity in the state.

Uttarakhand has witnessed an alarming trend of outmigration in recent decades; Census 2011 data revealed that 40 per cent of the state's population has migrated out in search of livelihoods. The Uttarakhand Migration Commission (2018) identified 734 villages as 'ghost villages', particularly in districts such as Pauri, Garhwal, and Almora, where negative population growth has been recorded in recent years. This exodus has resulted in abandoned agricultural fields, adversely affecting food security and economic resilience in the region. Concurrently, climate change-induced challenges such as glacier retreat, unseasonal rainfall, more frequent forest fires, and landslides have further exacerbated agrarian distress.

Hemp cultivation, historically practised in the region, offers a viable alternative to conventional crops, given its ability to thrive in marginal lands with minimal water and chemical inputs. However, ambiguities in policy and the absence of a structured value chain have restricted its potential for widespread adoption (Refer to the below diagram). This case study explores the role of hemp as a catalyst for sustainable rural development and climate resilience within a bioprospecting framework.

Challenges and issues addressed

Outmigration from Uttarakhand is driven by economic stagnation and the lack of employment opportunities in the state's rural economy. As farming has become increasingly unviable, youth and other working-age individuals are compelled to migrate to urban centres, leaving behind an ageing rural population. The repercussions of this migration are severe: neglected farmlands, diminishing traditional knowledge, and weakened local economies.

Agricultural productivity is further constrained by fragmented landholdings, the absence of market linkages, and inadequate support infrastructure. Farmers lack access to consistent pricing mechanisms, suffer from crop losses due to wildlife intrusion, and receive minimal

The challenges and issues of hemp farming in Uttarakhand



government assistance for value addition. The cumulative effect is a decline in rural incomes, reinforcing migration patterns.

Climate change is altering the Himalayan agro-ecological landscape. Irregular precipitation patterns, depleting water sources, and an increasing incidence of extreme weather events pose significant risks to traditional farming systems. Studies by the Potsdam Institute in Germany and The Energy and Research Institute (Potsdam Institute for Climate Impact Research and TERI, 2021) project that Uttarakhand's average temperature will rise by 1.6–1.9°C between 2021 and 2050. The retreat of Himalayan glaciers threatens the state's long-term water security, further endangering its agricultural sustainability.

The solution: A decentralised approach to hemp value addition

Hemp (*Cannabis sativa*) has historically been cultivated in Uttarakhand for its fibre and seeds. Unlike many other crops, hemp is well-suited to the Himalayan terrain due to its resilience, low water requirement, and capacity to improve soil fertility.

The global hemp fibre market, valued at USD 7.55 billion in 2022, is projected to grow at a compound annual growth rate (CAGR) of 33.57 per cent, reaching USD 73.55 billion by 2030 (Kings Research, 2024), underscoring the enormous economic potential of hemp-based industries.

Hemp cultivation presents several agronomic and economic advantages. As a naturally pest-resistant plant, it requires minimal pesticide inputs, making it an environmentally sustainable alternative to conventional cash crops. Additionally, hemp fibre and seeds have diverse applications in textiles, bioplastics, construction, and health products, hence providing varied market opportunities for rural producers. However, the absence

Hemp fibre processing in the Himalaya



of processing infrastructure, restrictive policies, and knowledge gaps hinder the realisation of hemp's full potential in Uttarakhand.

To overcome these barriers, KumaonKhand Agro-Innovations and Hospitality Pvt. Ltd. has developed a decentralised 'multi-micro hub and spoke' model aimed at fostering local value chains for hemp. This approach integrates traditional farming knowledge with inexpensive, region-specific technological interventions to enhance productivity and market access for farmers.

Goals and benefits of multi-micro hubs for the hemp value chain in Uttarakhand



Decentralised micro-hubs:
Set up small hemp processing units for drying, threshing, decortication and dehulling.



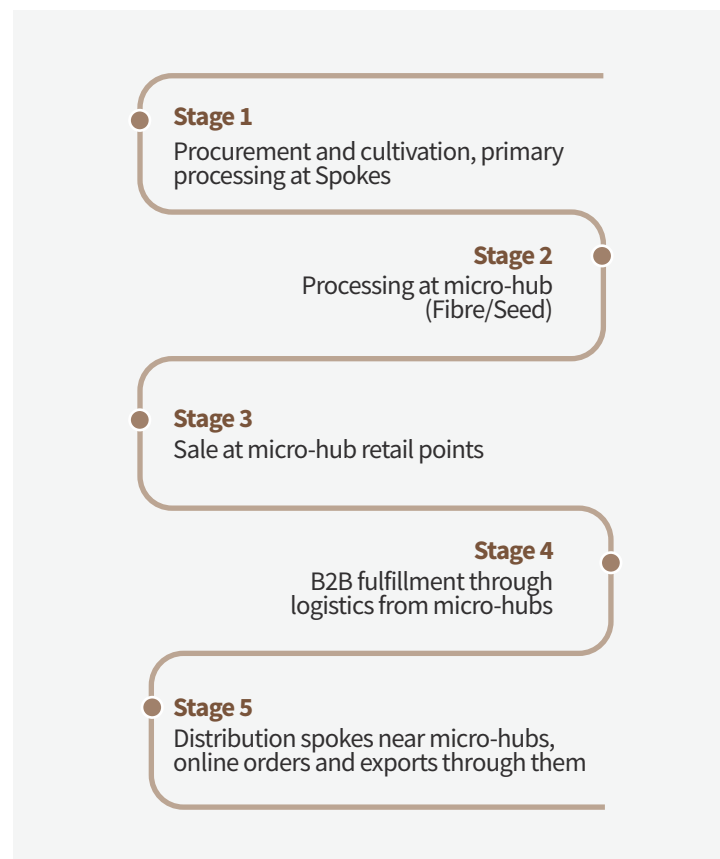
Strategic partnerships:
Collaborate with licensed cultivators and secure MoUs for sustainable sourcing.



Farmer-led growth:
Expand farmer engagement from 400 to 1,200 in Almora, reaching 2,500+ in Bageshwar and Pithoragarh.

Central to this model is the establishment of micro-processing units within villages. This reduces logistical constraints and increases farmer participation in value-added processes. The deployment of fibre to yarn processing technology such as solar-assisted electric motors enables cost-effective and sustainable production. Furthermore, by engaging over 400 women farmers, the initiative promotes gender-inclusive development and contributes to social equity within rural communities.

Direct market access is facilitated through strategic partnerships with eco-conscious brands and industries such as Bare Necessities (a zero-waste lifestyle brand) and Patagonia (a sustainable outdoor apparel company). As the intermediaries are eliminated, farmers receive fairer compensation, and the supply chains are more transparent. The project has also encouraged the utilisation of hemp stalks, previously discarded, thereby increasing farmer revenues and reducing waste.



Results

Since its inception, the KumaonKhand initiative has engaged over 3,000 farmers across Almora, Bageshwar, and Pithoragarh districts. With direct procurement mechanisms, hemp seed prices have risen from INR 80–100/kg to INR 170/kg over the last four years, thereby improving farmer incomes. Additionally, micro-entrepreneurs have been empowered to facilitate raw material aggregation and logistics, fostering localised economic growth (see the below figure).

Industrial hemp also has the capacity to sequester 8–15 tonnes of CO₂ per hectare annually, making it a useful climate mitigation strategy. The use of solar-assisted processing technology further reduces the sector's carbon footprint, aligning with the principles of sustainable development. By reducing dependence on water-intensive crops, hemp cultivation enhances agroecological stability and contributes to regenerative agricultural practices.



BAGESHWAR - HEMP FIBRE

- Engaged **1000+ farmers**, and plans fibre processing units
- Targeting **100+ tonnes** of hemp fibre processing by 2035
- Indo-Tibetan border villages engaged with **Geographical-Indexed value-addition**

KASARDEVI - HEMP SEED

- Worked with **400+ women farmers**, 10+ SHGs/FPOs, processed 7 tonnes of hemp seeds by 2025
- Launched The Hemp Store in 2021 with **40+ Stock Keeping Units**, generating around **₹1 Cr revenue since 2022**

India's domestic hemp industry requires 150,000 tonnes of fibre annually, yet current production remains below 1,000 tonnes, with most fibre still being imported from China (Shah, 2022). By investing in scalable, community-driven processing solutions, the KumaonKhand model aims to bridge this gap in demand and supply, positioning the Himalayan region as a key player in the global hemp value chain.

Summary and key takeaways

The success of the KumaonKhand initiative underscores the need for policy support in streamlining hemp licensing and expanding research into high-yielding, low-tetrahydrocannabinol (or THC) hemp varieties. Scaling up this model will require investments in infrastructure, farmer training, and the development of markets for hemp. Viewing hemp cultivation as part of broader climate resilience policies can enhance its role as a sustainable, climate-friendly agricultural solution.

With its wide-ranging applications, from textiles and bioplastics to health products and green construction, hemp serves as a multi-use bioresource that can contribute significantly to the diversification of India's emerging industrial bioeconomy.

This case study highlights the transformative potential of industrial hemp in addressing Uttarakhand's dual crisis of livelihood distress and climate vulnerability. The key lessons include the effectiveness of decentralised processing, the necessity of gender-inclusive economic models, and the role of regulatory frameworks in enabling growth of the industry. Future efforts should focus on policy advocacy, technological innovations, and expanding market linkages to maximise hemp's socio-economic and environmental benefits.

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CASE

10

Sustainable bioprospecting to build green livelihoods: *Ophiocordyceps sinensis* in Bhutan

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Background

Bhutan, a Himalayan kingdom known for its rich biodiversity and commitment to the notion of gross national happiness, is increasingly promoting the sustainable use of its natural resources through its growing bioeconomy sector. The country is globally recognised for its trade in the caterpillar fungus (*Ophiocordyceps sinensis*), which contributes significantly both to rural incomes and national revenues, making it one of Bhutan's most valuable natural products.

Ophiocordyceps is among the world's most expensive mushrooms, fetching up to USD 7,200–10,900 per kg in international markets. Bhutan sold over 659 kg worth BTN 414.74 million (approximately USD 5 million) through regulated auctions in 2022, providing an annual average income of up to USD 24,500 per household in high-altitude communities (Department of Agricultural Marketing and Cooperatives, 2022).

Mangala is a Thimphu-based start-up that is seeking to redefine the *Ophiocordyceps sinensis* industry in Bhutan through sustainable bioprospecting, rooted in traditional knowledge and supported by scientific innovation. The company promotes ethical harvesting, environmental conservation, and economic empowerment of mountain

Ophiocordyceps is among the world's most expensive mushrooms, fetching up to

USD

7,200–10,900

per kg in international markets

communities. Operating within an ABS framework in Bhutan, Mangala has emerged as a model enterprise in the country's growing bioeconomy sector.

The initiative operates in Bhutan's alpine highlands, including remote areas such as Lunana in Gasa District in northwestern Bhutan, where the caterpillar fungus has long been a source of livelihood for high-altitude communities. However, increasing global demand has led to unsustainable collection practices, endangering fragile ecosystems and threatening traditional income streams. Mangala was founded in 2024 in response to these challenges, with a business model that prioritised sustainability.



Challenges and issues addressed

Mangala faces multiple, interconnected challenges in promoting sustainable growth. Key among these is the ecological degradation caused by many years of overharvesting, which has stressed the fragile alpine ecosystem where Cordyceps is found. Although Bhutan has since introduced regulatory frameworks for Cordyceps, the residual environmental impacts remain substantial.

Financial constraints also hinder this company's progress. As a nature-based enterprise, Mangala does not fit the risk profile of conventional financial institutions, limiting its access to capital. Additionally, the company competes with imported and synthetic Cordyceps-based products, often marketed aggressively and sold at lower prices, undermining local producers.

Operationally, Bhutan's complex regulatory environment – marked by time-consuming licensing, approval, and export processes – poses further hurdles for a small business such as Mangala. The seasonal availability of Cordyceps also affects regularity in supply and pricing, leading to market fluctuations and limited product availability.

The solution

To address these challenges, Mangala has adopted multiple strategies. At the core of its operations is the sustainable harvesting of Cordyceps, through community-based training and capacity-building programmes. These initiatives equip local harvesters with knowledge about low-impact collection techniques, ecological responsibilities, and sustainable resource management.

Mangala has also diversified its products to include Cordyceps-based value-added goods such as extracts, capsules, teas, honey, and cosmetics. These products are less dependent on seasonal harvests and also appeal to a broader consumer base. A dedicated processing unit in Thimphu ensures high product quality through the cleaning, sorting, and drying of Cordyceps, adhering to international health and safety standards.

The company operates under fair trade principles and adheres to government-regulated harvesting guidelines, specifically the Forest and Nature Conservation Rules and Regulations 2023, which govern ethical collection practices. To ensure credibility and trust in the markets it operates in, Mangala carries out scientific validation

through accredited institutions such as Equinox Labs in Mumbai, India, making quality assurance a core component of its product development pipeline.

Results

In a span of six months, Mangala has generated BNT 2 million in revenues and created over 15 jobs, becoming an important economic actor in the local context. There has been a rise in the incomes earned by highlander harvesters, due to the fair-trade agreements and benefit-sharing.

Environmentally, the company has promoted the sustainable management of *Cordyceps sinensis* by training local harvesters in responsible collection methods. These efforts align with Bhutan's national conservation goals and contribute to SDG 8 (Decent work and economic growth), SDG 12 (Responsible consumption and production), and SDG 15 (Life on land).

Mangala has also strengthened consumer trust by emphasising traceability, ethical sourcing, and quality assurance. Certifications such as 'fair trade' and 'organic' further enhance its reputation. The company is now expanding its global reach through e-commerce and strategic partnerships in key markets including the USA, Europe, West Asia, and Association of Southeast Asian Nations (ASEAN) countries, while exploring innovative pricing strategies to enhance accessibility and consumer adoption.

Summary and key takeaways

Mangala exemplifies how sustainable bioprospecting can serve as a viable model to generate green livelihoods. By integrating traditional knowledge with scientific innovation and ethical business practices, the company has addressed ecological and economic challenges in a holistic manner.

Mangala has generated
BNT

2 million

in revenues and created over 15 jobs

The key takeaways include the importance of:

- Embedding sustainability in product development and harvesting methods
- Empowering local communities through equitable benefit-sharing and training
- Diversifying product lines to reduce reliance on seasonal resources
- Leveraging digital platforms to reach global consumers
- Collaborating with the government and financial institutions to unlock green finance opportunities
- Looking ahead, strategic partnerships, improved marketing outreach, and streamlined regulatory processes will be crucial for scaling up Mangala's efforts and ensuring long-term sustainability.

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Sustainable bioprospecting of Lakadong turmeric in Meghalaya, India

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Background

Lakadong Village, located about 40 kilometres (km) east of Jowai in the West Jaintia Hills District of Meghalaya, India, is renowned for its Lakadong turmeric variety (*Curcuma longa L.*), which contains the highest curcumin content for any turmeric variety in the world. The turmeric was awarded the geographical indication (GI) tag in 2023, which certifies the product's origin in the West Jaintia Hills, underscoring its unique qualities and regional authenticity, and in turn promoting local culinary heritage.

Lakadong turmeric, a perennial, rhizomatous herbaceous plant native to the Indian subcontinent and Southeast Asia, thrives in temperatures between 20°C and 30°C and requires high annual rainfall. It is cultivated within a 20-km radius of Lakadong Village, primarily under the Laskein Community and Rural Development Block, situated about 90 km east of Shillong, the capital of Meghalaya. This region, with an elevation ranging from 600 to 1,200 masl, has a montane subtropical humid climate and receives up to 8,000 mm of rainfall a year on an average, mostly from mid-May to September. The soil here is red, sandy, or excessively drained coarse loam, which is critical to maintain the high level of curcumin in the turmeric rhizome.

The area is primarily inhabited by the Pnar tribal community, also known as the Jaintia, along with other Indigenous communities such as War, Bhoi, and Biate. The Pnar language is commonly spoken, and the Jaintia community follows a matrilineal system, whereby one's identity and family lineage are inherited through one's mother.

To harness the potential of this unique turmeric variety, a women-led, community-based processing and value addition facility was established in 2009. The facility was created in the premises of the Life Spice Cooperative Society, a registered organisation under the Meghalaya Cooperative Societies Act, 2015. It was primarily developed by the Department of Botany, North-Eastern Hill University (NEHU), Shillong, with financial support from the Department of Biotechnology (DBT), Government of India. The bioprospecting activities started with the production of turmeric oleoresin, following an appropriate ABS mechanism.

Challenges and issues addressed

During 1990–2010, the expansion of coal mining in the Jaintia Hills, combined with a lack of awareness about the high curcumin content of the Lakadong variety compared

to other local turmeric types such as Lachein, Lasyein, Laskein, and Ladaw, resulted in a sharp decline in its cultivation. The low market price, poor productivity, and absence of post-harvest infrastructure for transportation, handling, processing, packaging, and marketing further worsened the situation, resulting in significant post-harvest losses.

By 2008, these challenges confined Lakadong turmeric cultivation to the Nongbah–Shangpung belt of the West Jaintia Hills, covering approximately 2,500 ha. The variety was even under threat of extinction due to its limited and fragmented cultivation.

In response to this threat, the authors of this case study, along with Prof. Pramod Tandon, then Vice-Chancellor of NEHU, initiated a conservation and sustainable utilisation programme in 2009 for Lakadong turmeric. The plan was to conserve the variety by leveraging its high value for use in the cosmeceutical, food, and pharmaceutical industries.

The primary issues addressed were the low market price—INR 17 per kg in 2009—and extremely low productivity of the variety.

The solution

To overcome these challenges, the Life Spice Cooperative Society conducted organic farming demonstrations over a five-year period across 76 ha involving 184 farmers from 15 villages. The interventions included high-density planting using 2 tonnes of seed per hectare, the application of vermicompost, improved agronomic practices such as soil working and maintaining specific gaps during planting, post-planting care, and seed preservation techniques to prevent infestation from pathogens. These efforts enabled farmers to achieve a productivity level of 10 tonnes per hectare by the fifth year compared to 2–3 tonnes per hectare following conventional organic cultivation practices.

For post-harvest processing and value addition, the Life Spice Cooperative Society – led by its President Kong Priece and supported by 137 women farmer SHGs – established the first community-led turmeric processing plant in Meghalaya. The plant, which follows strict protocols regarding hygiene, produces turmeric leaf oil, turmeric powder, and oleoresin, a concentrated extract. Whereas the DBT provided funding for the equipment, support for infrastructure such as the buildings and water supply was provided by the Meghalaya Rural Development Society, under an International Fund for Agricultural Development (IFAD) project.

The manufacturing equipment was fabricated at reduced costs by two private companies, Suan Scientific Instruments Pvt. Ltd., based in Kolkata, West Bengal and Techno-Chemical Pvt. Ltd. in Calicut, Kerala. The processing plant began producing turmeric leaf oil, turmeric powder, and oleoresin in late 2013 and early 2014. Repeated training sessions were delivered for members of the Self-Help Groups (SHGs) and the cooperative regarding processing and value addition techniques, and product marketing was facilitated by Techno-Chemical Pvt. Ltd.

The economic viability of oleoresin production is evident: at current prices, 1 kg of oleoresin, worth at least INR 3,500, and byproducts such as International Organization for Standardization (ISO)-standard turmeric powder and turmeric oil worth INR 2,000, can be extracted from 50 kg of fresh turmeric, which costs INR 1,750, priced at INR 35 per kg. This results in a large net profit (after deducting management costs and other associated costs), since the revenues are at least twice the cost of the raw turmeric. The prices of turmeric oleoresin vary in the range of USD 22–30 per kg (for 35 per cent curcumin) to over USD 1,000 per kg (for 99 per cent purity). The Laskein facility has the capacity to produce the highest quality of oleoresin with 96–99 per cent purity. The cost–benefit ratio of turmeric cultivation without value addition has been analysed in Singh et al. (2020), underscoring the economic benefits of value-added products.

The two common products – turmeric powder and flakes – are sold directly to consumers or traders.

In 2018, the Government of Meghalaya launched Mission Lakadong, with an outlay of INR 755.8 million, in order to scale up Lakadong turmeric production and expand its value chain. Through Mission Lakadong and other external projects, the Government of Meghalaya has established collective marketing centres equipped with washers, dryers, and grinders, leading to an increase in the production of turmeric powder and enhanced returns for farmers. A detailed value chain analysis of Lakadong turmeric in Meghalaya can be found in Singh et al. (2020).

To address the ongoing issues in raw material procurement, collection, and aggregation, and challenges of manpower turnover affecting oleoresin and leaf oil production, the Mission Lakadong initiative has provided working capital and upgradation of machinery. A sustainable land management project funded by the German development bank Kreditanstalt für Wiederaufbau (KfW) supports the organic production components of the plant through a matching grant. Additionally, the Society is now planning to manufacture a novel, patented, high-value food supplement–water-soluble curcumin.

To ensure benefit-sharing, the Society signed a memorandum of understanding (MoU) with Techno-Chemical Pvt. Ltd., agreeing on a 70:30 net profit-sharing ratio, with 70 per cent going to the community. All three products are now profitable, and the turmeric processing plant is undergoing renovations for ISO and organic certification.

Results

This initiative by the Life Spice Cooperative Society influenced government policies significantly which led at large expansion of turmeric production in Meghalaya. The state government's Mission Lakadong aimed to cover 6,070 ha and produce 50,000 tonnes of turmeric, and

increase yields from 6 tonnes to 8 tonnes per hectare. It also led to the GI tag for Lakadong turmeric and formal recognition of its value addition potential. It was declared the 'one district one crop' for West Jaintia Hills District. The success of the initiative also encouraged private entrepreneurs and start-ups, such as Zizira, which now trades Lakadong turmeric globally.

Summary and key takeaways

The case of Lakadong turmeric illustrates the power of bioprospecting as a nature-based solution for sustainable livelihoods and biodiversity conservation. The key takeaways include the importance of integrating bioresource-based science and technology with grassroots entrepreneurship and policy support. Partnerships with educational institutions and private industry, access to finance, and the implementation of government-backed programmes such as Mission Lakadong, were crucial. This initiative shows that community-led bioprospecting can yield tangible economic, social, and environmental benefits.

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Bioprospecting for green livelihoods: Sustainable *jatamansi* harvesting in Nepal's alpine meadows

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Background

Nepal's alpine Himalayan forests and rangelands are exceptional biodiversity hotspots. They are a source of more than 40 key NTFPs, including MAPs, which contribute critically to the incomes of the rural poor. In recent years, MAPs have presented an increasingly important opportunity for rural forest-dependent communities to use natural resources while maintaining forest ecosystems and supporting social and cultural values.

Harvested and traded internationally, these NTFPs and MAPs are part of an increasingly important economic sector. Nurturing these wild plant products – and the forest-based economy more generally – also complements the management and conservation of other important values, such as biodiversity, ecosystem services, wildlife habitats, and the maintenance of clean air and water. These wild plants are among the most important regenerative forest products among various natural resources in Nepal.

However, these MAPs, and their associated high-altitude landscapes, face multiple threats such as unsustainable and premature harvesting, frequent forest fires, and uncontrolled grazing. In this context, the interventions by Asia Network for Sustainable Agriculture and Bioresources (ANSAB)

More than

40 key NTFPs

contributes critically to the incomes of the rural poor.

Nepal and TRAFFIC International to support local communities in the sustainable management of Himalayan wild plants and rangelands in the alpine meadows of Nepal – in Patarasi Rural Municipality of Jumla District, and Mugum Karmarong Rural Municipality of Mugu District, Karnali Province, more specifically—is a significant endeavour for preserving the delicate ecological balance in the area and for the benefit of local communities.

The rural communities in these regions depend on *jatamansi* collection (spikenard; *Nardostachys jatamansi*) as a major source of livelihood. However, overharvesting/unsustainable harvesting, illegal trade, and the lack of scientific harvesting practices have led to a decline in its abundance, triggering the need for sustainable management practices.

Recognising these challenges, bioprospecting initiatives have been introduced by ANSAB Nepal and TRAFFIC International that focus on sustainable harvesting, the development of a registration system for *jatamansi*



harvesters, value chain development, and the amendment of community forest operational plans with improved conservation practices.

This case study explores the implementation of sustainable harvesting techniques, community-based resource management, and value addition for promoting green livelihoods while ensuring the conservation of jatamansi and biodiversity in Nepal.

Challenges and issues addressed

The key challenges in both study sites regarding the sustainable management of wild plants and rangelands were: the chronic disturbances in the forests and meadows due to frequent forest fires, uncontrolled grazing, premature harvesting, and invasion by alien species. Climate change poses a significant threat as well, as it is altering ecosystems and adversely affecting rangelands and ecosystem health. In addition, there is overharvesting of natural resources, driven by the increasing and diversifying international trade. The lack of simplified and decentralised procedures for the management of high-altitude resources, and the

vulnerability of species and rangelands to excessive commercial harvesting, does not augur well for the sustainable management of these resources.

Limited action research, limited financial resources, and inadequate infrastructure hinder the implementation of sustainable practices. There is also a lack of collaboration between stakeholders, including international organisations, which could provide the necessary support and resources to scale up successful initiatives. Some key challenges and constraints are discussed below.

- **Overharvesting and habitat degradation:** Traditional harvesting involved uprooting the entire plant, leading to the depletion of wild populations.
- **Limited awareness and training:** Harvesters lacked knowledge of sustainable practices, causing long-term damage to natural populations.
- **Lack of community governance structures:** Many harvesting sites lacked formal management systems for regulating collection and trade.



- **Low economic returns:** Due to the absence of value addition, local collectors received minimal financial benefits, while middlemen and exporters profited significantly.
- **Regulatory and certification barriers:** The lack of proper documentation, traceability, and certification made it difficult to access premium markets, limiting economic incentives for sustainable harvesting.
- **Through the Himalayan Plants for People: Sustainable Trade for Biodiversity and Development project,** these challenges were addressed via the delivery of awareness-raising and capacity-building training sessions to the local forest-dependent communities; however, many challenges remain to be addressed.

The solution

The project adopted a multi-stakeholder approach to promote the sustainable harvesting of jatamansi and enhance the economic resilience of local communities. Central to this was the training and capacity-building of local collectors on sustainable harvesting techniques,

including root division methods (in which a portion of the plant's root system is dug up, divided, and replanted) that support natural regeneration and encourage selective harvesting.

The initiative actively engaged and empowered community forest user groups (CFUGs) to develop and implement community-based resource management plans and sustainable harvesting guidelines, ensuring regulated and ecologically responsible collection. To enhance local value retention, community members were trained in processing and primary value addition techniques such as drying, oil extraction, and packaging, enabling them to access higher-value and responsible markets in the USA and Europe through certified trade companies and private sector entities such as Himalayan Bio-Trade Limited.

Complementary efforts focused on building market linkages and pursuing organic and fair-trade certification to help community enterprises secure premium prices in national and international markets.

Furthermore, policy advocacy and collaboration with government agencies such as the Ministry of Forests and Environment, the Department of Forests and Soil

Conservation, and the Department of Plant Resources have helped create an enabling environment for the sustainable harvesting of jatamansi and for trade regulation, ensuring that ecological goals are supported through institutional mechanisms.

Results

The implementation of the sustainable harvesting of jatamansi and value chain development in the alpine meadows of Jumla and Mugu districts yielded substantial ecological, economic, and institutional benefits.

Most notably, the adoption of scientifically-informed harvesting practices significantly reduced pressure on wild jatamansi populations, contributing to the conservation of biodiversity and preservation of fragile, high-altitude habitats.

Enhanced ecological stewardship was closely tied to improved socio-economic outcomes. Through the integration of value-added processes – including drying, oil extraction, and improved packaging – local collectors and community enterprises experienced measurable increases in earnings, ranging between 30 and 50 per cent. For example, in Jumla District, harvesters earned NPR 650 per kg of jatamansi in 2021–2023, compared to NPR 450 per kg in previous years.

Community empowerment emerged as a key outcome of the initiative. CFUGs took on a central role in resource governance, actively managing and monitoring harvesting activities to ensure adherence to sustainable practices. This decentralised and participatory model of resource management not only strengthened institutional capacities at the local level but also fostered greater accountability and ownership among community members.

The project also facilitated improved market access through capacity-building regarding certification processes and the establishment of direct market

In Jumla,
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of jatamansi in 2021–2023, compared to NPR 450 per kg in previous years.

linkages. As a result, community enterprises were able to market jatamansi-derived products at competitive, often premium, prices, particularly in niche organic and fair-trade segments. These economic incentives reinforced conservation objectives while supporting rural livelihoods.

At the policy level, the initiative helped shape regulatory frameworks. Evidence and experiences from the field informed the development and revision of sustainable harvesting guidelines at both the provincial and national levels. These policy outcomes underscore the broader systemic impact of the intervention, reinforcing the need for integrated approaches that couple conservation with community welfare.

Overall, the initiative under the Himalayan Plants for People: Sustainable Trade for Biodiversity and Development project demonstrates a viable model for balancing biodiversity conservation with rural economic development in high-altitude ecosystems.

Summary and key takeaways

Sustainability was integral to the initiative, primarily through fostering community ownership of natural resources. The establishment of community-based management systems empowered local stakeholders to govern and monitor the use of jatamansi, ensuring its sustainability in the long term.

Capacity-building was another critical aspect; continuous training sessions equipped local harvesters with the necessary skills to implement sustainable harvesting practices and maintain ecological balance.

Additionally, market-driven incentives—facilitated through linkages with certified buyers—benefited local communities economically, creating the motivation to adhere to sustainability standards. The integration of this into policy frameworks further ensured long-term sustainability, as the formal recognition of sustainable harvesting guidelines by government agencies helped institutionalise the approach. This could also promote scaling up and out across other alpine meadows and rangelands in the HKH region. Future efforts should

include increased investment in climate-resilient infrastructure, expanded ethical market access for sustainably sourced products, and continuous capacity-building of local, forest-dependent communities. The model developed in Jumla and Mugu districts can be replicated in other high-altitude areas rich in MAPs. Strengthening regional collaboration for knowledge-sharing and harmonising policies across jurisdictions can enhance the impact and sustainability of such initiatives.

By scaling up all these efforts, broader regions can benefit from both ecological conservation and economic empowerment, reinforcing the viability of sustainable harvesting practices across the HKH.

Sustainable collection of indigenous medicinal plants and the development of value chains in Nagaland

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Background

Nagaland, located in Northeastern India, is widely recognised for its remarkable biodiversity and the extensive traditional knowledge systems of its Indigenous communities (Changkija et al., 2010). Its distinct mountainous topography and climatic conditions create an environment conducive to the growth of a variety of medicinal plants, many of which have long been used in local health and wellness practices. Approximately 80 per cent of the state's population resides in rural areas, with many households relying on forest-based medicinal resources, not just for treating ailments but also as nutritional supplements. In regions where access to modern medicine is limited or prohibitively expensive, communities have continued to use herbal treatments passed down through generations (Imchen & Jamir, 2011). These plants are primarily collected from the wild or cultivated in jhum fields (a traditional form of slash-and-burn agriculture) and home gardens.

Despite the widespread reliance on medicinal plants, there has been limited research and development focusing on value addition and ABS mechanisms in Nagaland (NBRM, 2009). Farmers in the state are mostly small-scale and marginal, cultivating diverse crops primarily for domestic consumption. With the increasing national and global demand for natural and herbal products, Nagaland stands at the cusp of an opportunity to transition its traditional use of medicinal plants – such

Approximately

80%

of the state's population resides in rural areas

as nutgall (*Rhus semialata*), prickly ash (*Zanthoxylum armatum*), tree bean (*Parkia Roxburghii*), and crepe ginger (*Cheilocostus speciosus*) – into a viable, sustainable, and scalable livelihood model. An initiative by the Nagaland Bio Resource Mission (NBRM) aims to introduce sustainable cultivation and collection practices, establish market linkages, and develop viable enterprises through structured value chains and equitable ABS frameworks, while preserving biodiversity of its flora and fauna, including endemic species, and cultural heritage.

Challenges and issues addressed

Despite the state's rich bio-resources, the medicinal plants sector in Nagaland faces persistent challenges. A major challenge is the lack of investment, largely attributed to an unregulated market, fluctuating prices, and the absence of reliable value chains. Middlemen often dominate trade in medicinal plants, exploiting cultivators, resulting in reduced incomes for farmers (Changkija et al., 2010). Furthermore, although there

have been mechanisms introduced to prevent their overexploitation, such as community-based conservation and capacity-building, several high-value plant species continue to be harvested unsustainably (Limasenla & Lea, 2020). The market itself remains underdeveloped and ambiguous, particularly for species that are not cultivated commercially but hold significant economic value.

The absence of technical knowledge and limited experience in areas such as value addition, storage, packaging, and marketing has further impeded the sector's development. Additionally, weak linkages between producers and buyers discourage smallholders from scaling up cultivation. These constraints – coupled with limited documentation of indigenous plants and the threats of bio-piracy, climate change, and habitat loss – have hindered the sector's full potential. Recognising these gaps, the NBRM has developed strategies to improve market access, foster transparent trading practices, and help build capacities of the relevant local stakeholders.

The solution

The proposed initiative by NBRM seeks to transform Nagaland's medicinal plants sector and thereby generate viable livelihoods for local communities by focusing on value addition, enterprise development, and the integration of ABS frameworks. By adopting a cluster-based approach, the project aims to promote the cultivation and sustainable use of medicinal plants, NTFPs, and neglected and underutilised crops. It emphasises adherence to good agricultural practices, good collection practices, and good storage practices to ensure high-quality, traceable products.

The initiative involves introducing economically viable medicinal crops for crop diversification, promoting community entrepreneurship, and enhancing local capacities through training and technical support. It will seek to provide employment to women

and unemployed youth in particular via fostering development of enterprises that make herbal products. The strategy includes training stakeholders in best agronomic practices, improved processing, and packaging techniques. The goal is to establish efficient market mechanisms, enhance local skills, and create equitable value chains. With the increasing demand for herbal products in India and globally, this model not only offers income generation opportunities but also supports biodiversity conservation and the sustainable use of native flora.

Results

Though its implementation is ongoing, this initiative's expected outcomes are multi-faceted. Community awareness of the ecological and economic value of medicinal plants is anticipated to increase, promoting more sustainable harvesting practices. The conservation and management strategies introduced are expected to improve biodiversity and ensure more sustainable resource use. Economically, local communities will benefit from diversified income opportunities through the establishment of plant-based enterprises. These new livelihood options are particularly critical in rural areas, offering both economic empowerment and food security.

Furthermore, the initiative is designed to strengthen community capacities for natural resources management and foster their long-term stewardship. Pilot projects regarding the cultivation and processing of selected plants such as nutgall, prickly ash, tree bean, and lemongrass (*Cymbopogon citratus*) will demonstrate best practices and serve as scalable models (Imchen & Jamir, 2011). The integration of ABS mechanisms ensures that local communities benefit equitably from the commercialisation of their resources, strengthening their participation in bioeconomy value chains. Ultimately, the project aims to catalyse a shift from subsistence-based use of the forests to enterprise-driven biodiversity conservation.

Summary and key takeaways

This case study draws attention to the immense potential of Nagaland's rich medicinal plant diversity as a driver for sustainable livelihoods. By combining traditional knowledge with structured value chains and policy mechanisms such as ABS, the initiative by NBRM seeks to foster ecological sustainability and expand economic opportunities in Nagaland (Jamir & Tsurho, 2017). The project highlights the importance of community engagement, capacity-building, and value addition in transforming underutilised bio-resources into marketable products.

With proper infrastructure, market linkages, and policy support, such initiatives can address rural unemployment, enhance women's participation in green enterprises, and contribute to biodiversity conservation. The programme's model can also serve as a blueprint for similar biodiversity-rich regions in need of sustainable development solutions.

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Conclusion and ways forward

This compendium highlights the potential of varied bio-resources in regions of Nepal, India, Bhutan and China, through case studies from these regions. The case studies demonstrate that the HKH is uniquely positioned to develop a bioeconomy model that is rooted in its rich biological diversity and indigenous knowledge. The compendium presents compelling evidence that sustainable bioprospecting can simultaneously address ecological degradation, economic vulnerabilities, and social inequities, while building green, climate-friendly, and resilient futures for mountain communities.

Viewed together, the case studies demonstrate the viability and versatility of bioprospecting as a pillar in HKH's bioeconomy. However, scaling up and sustaining these models over time require strategic interventions at multiple levels. Moving forward, the following priorities are key to nurturing a regenerative, inclusive, and innovation-driven bioeconomy in the HKH:

1. Invest in research, development, and innovation: Enhance the scientific validation of traditional knowledge, pharmacological studies, and bioresource potential. Build regional research networks and innovation hubs that prioritise high-value MAPs, sustainable processing techniques, and zero-waste product development.
2. Scale up the development of local enterprises: Support grassroots entrepreneurs, particularly women and youth, through tailored capacity-building, incubation services, and access to patient capital. Strengthen cooperatives and producer organisations as value chain actors and custodians of biodiversity. Create a critical

mass of small entrepreneurs to be visible at both the policy level and have increased bargaining power at the market level.

3. **Enable cross-border collaboration:** Foster regional alignment on bioeconomy practices through knowledge exchange platforms such as HI-REAP. Promote cross-border trading in certified products, harmonised standards, and regional branding to enhance market access and resilience. Align bioeconomy strategies with national development priorities, climate adaptation plans, and biodiversity frameworks, which will be crucial for institutional uptake and policy coherence across the region.
4. **Improve market linkages and branding:** Facilitate access to niche and premium markets through traceable supply chains, digital platforms, and sustainable branding.
5. **Mainstream gender equity and social inclusion:** Recognise and enhance the role of women, indigenous peoples, and marginalised groups as key actors in a sustainable bioeconomy. Ensure equitable participation, benefit-sharing, and leadership opportunities through targeted programmes and safeguards.
6. **Leverage green financing and ABS mechanisms:** Tap into opportunities in green/climate finance and ABS to scale up bio-based enterprises while ensuring a fair distribution of benefits.

Each case study reflects a convergence of science, tradition, entrepreneurship, appropriate technology, and community ownership. Together, they illustrate the immense potential of nature-based solutions to drive transformative progress toward sustainable and inclusive development. Yet, realising this potential at scale will require continued commitment from governments, development partners, private sector actors, and other sections of civil society. It requires investing in research and development, developing local enterprises, enabling policy, developing market linkages, and ensuring gender equity and social inclusion.

As the region navigates the dual crises of biodiversity loss and climate change, this is the time to invest in a mountain bioeconomy that values ecosystems, empowers communities, and delivers shared prosperity. Bioprospecting should be recognised not only as a conservation approach but as a viable livelihood and enterprise strategy that lies at the heart of a resilient mountain bioeconomy. With strategic action, the HKH can lead the way in demonstrating how bioprospecting and regenerative enterprise can redefine development pathways anchored in sustainability, equity, and innovation.

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