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Quick Response Code:

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Manuscript ID:
IJRSEAS-2024-010104

DOI: 10.5281/zenodo.14399799
10.4103/002833
DOI Link:
https://doi.org/10.5281/zenodo.14399799

Volume: 1

Issue: 1

Month: October

Year: 2024

E-ISSN: 3066-0637

Submitted: 16-Aug-2024

Revised: 30- Aug-2024

Accepted: 15-Sept-2024

Published: 31-Oct-2024

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How to cite this article:
Prajapati, N. K., Meena, R. C., Anjali, Swain, B., & Kumar, S. (2024). Hilly Vegetables: Issues, Conservation, and Promotion. International Journal of Research Studies on Environment, Earth, and Allied Sciences, 1(1), 21+26.
https://doi.org/10.5281/zenodo.14399799

Hilly Vegetables: Issues, Conservation, and Promotion

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Abstract:
Hilly vegetables represent crucial components of mountain agricultural systems, contributing significantly to food security and livelihood sustainability for approximately 915 million people living in mountainous regions globally. These crops, adapted to elevations ranging from 600 to 3,000 meters, face unique challenges including soil erosion, estimated at 40-100 tons per hectare annually, and limited accessibility, with nearly 45% of mountain farms located more than 2 hours from market centres. Studies indicate that traditional mountain vegetables demonstrate remarkable resilience, with 70% showing tolerance to temperature fluctuations between 5-25°C. Conservation efforts have documented over 150 indigenous vegetable species in hill regions worldwide, with the Hindu Kush Himalayas alone harbouring 675 edible plant species. These vegetables typically contain 20-40% higher micronutrient concentrations compared to their lowland counterparts, particularly in iron, zinc, and vitamin C content. However, rapidly declining genetic diversity, with an estimated loss of 30% of local varieties in the past three decades, threatens their sustainability. Promotion initiatives through terraced farming have shown promising results, increasing yields by 25-40% while reducing soil erosion by up to 75%. Implementation of climate-smart agricultural practices has enabled 62% of hill farmers to maintain productivity despite weather uncertainties. Integration of traditional knowledge with modern conservation techniques remains crucial for preserving these vital resources for future generations while ensuring sustainable mountain development.
Key Words: Biodiversity, nutrition, indigenous knowledge, underutilized species, agro-biodiversity, indigenous vegetables, mountain ecosystems.

Introduction

Growing vegetables in hilly regions represents a unique intersection of agricultural challenges and opportunities, with significant implications for food security, biodiversity conservation, and rural livelihoods. Hilly vegetables, cultivated at elevations typically ranging from 600 to 3,000 meters above sea level, account for approximately 15-20% of global vegetable production and support an estimated 500 million farmers worldwide (FAO, 2023). These mountainous agroecosystems are characterized by distinct microclimates, steep slopes ranging from 15° to 45°, and varying soil conditions that create both advantages and limitations for vegetable cultivation. Traditional hilly vegetable farming systems have evolved over centuries, with indigenous communities developing specialized techniques such as terracing, contour farming, and unique crop rotation patterns to maximize limited arable land while preventing soil erosion. Notably, hilly regions harbour exceptional vegetable biodiversity, with studies documenting over 1,200 indigenous vegetable species across global mountain ecosystems. For instance, the Hindu Kush Himalayan region alone contains more than 500 species of traditional vegetables, many of which possess superior nutritional profiles and adaptive traits for climate resilience. Research indicates that high-altitude vegetables typically contain 20-30% higher concentrations of beneficial compounds such as flavonoids and antioxidants compared to their lowland counterparts. However, hilly vegetable cultivation faces mounting challenges in the 21st century. Climate change has led to increased weather variability, with extreme events affecting approximately 40% of mountain farming systems globally. Additionally, urbanization and changing dietary preferences have resulted in genetic erosion, with an estimated loss of 23% of traditional vegetable varieties in the past three decades. Conservation efforts and promotion of hilly vegetables have become increasingly critical for sustainable mountain development, food security, and preservation of agricultural heritage. These efforts intersect with multiple United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 15 (Life on Land), and SDG 13 (Climate Action). This paper examines the multifaceted challenges facing hilly vegetable cultivation, explores conservation strategies, and proposes frameworks for promoting these vital agricultural resources in the modern context.

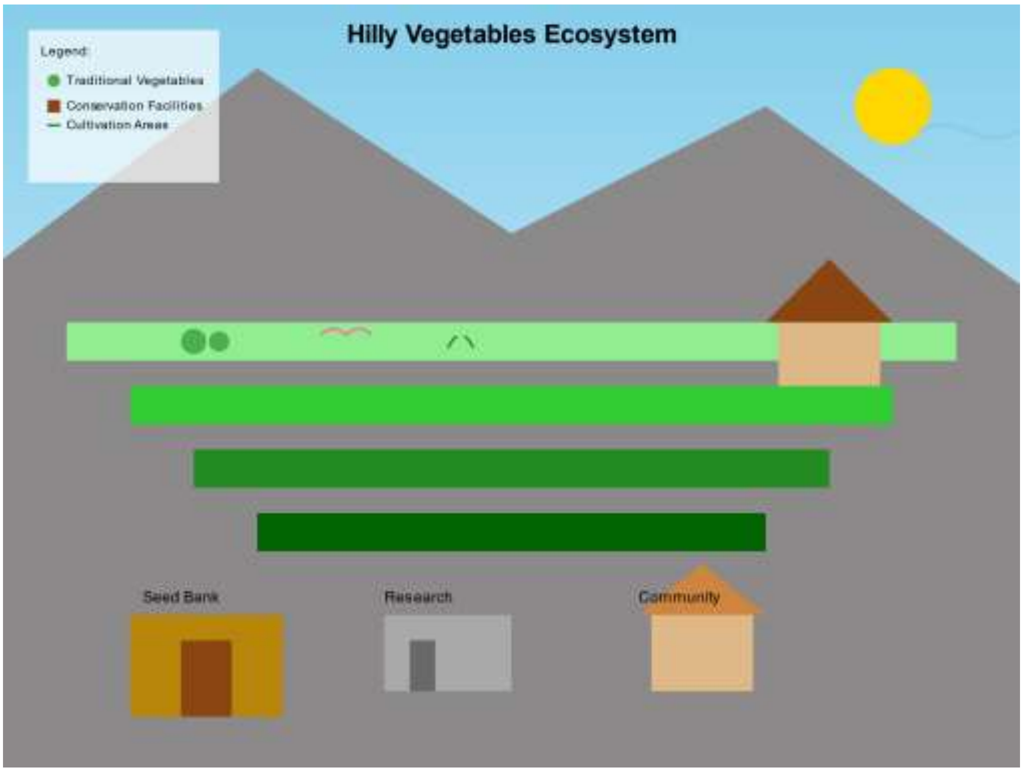

Table 1. Hilly vegetable crops from different regions around the world:

Region	Hilly Vegetable Crops
Himalayan Region	Chenopods (*Chenopodium album, C. brevifolium*), Amaranths (*Amaranthus blitum, A. tricolor*), Beans (*Phaseolus vulgaris var., P. coccineus*), Cucurbits (*Trichosanthes anguina, Sechium edule*), Mustards (*Brassica juncea, B. carinata*), Yams (*Dioscorea* spp.)
Andes	Oka (*Oxalis tuberosa, Tropaeolum tuberosum*), Chenopods (*Chenopodium pallidicaule, C. berlandieri*), Amaranths (*Amaranthus caudatus, A. mantegazzianus*), Peppers (*Capsicum baccatum, C. pubescens*), Lupins (*Lupinus mutabilis, L. albescens*), Mashwa (*Tropaeolum tuberosum*), Ulluco (*Ullucus tuberosus*)
Ethiopian Highlands	Anchote (*Coccinia abyssinica*), Enset (*Ensete ventricosum*), Mitsimame/lupins (*Lupinus* spp.), Yams (*Dioscorea* spp.), Teff (*Eragrostis tef*)
Southeast Asia	Gourds (*Benincasa hispida*), Leafy greens (*Gnetum gnemon, Sauropus androgynus*), Stink beans (*Parkia speciosa*), Yams and aroids

Importance of Hilly Vegetables: Hilly vegetables represent an invaluable genetic repository shaped by centuries of farmer selection and adaptation to local environmental conditions [1]. They harbour unique traits like resistance to pests, diseases, drought, and extreme temperatures that could prove vital for developing resilient crop varieties as the climate continues to change [2]. Many are nutrient powerhouses with higher levels of vitamins, minerals, antioxidants, and other beneficial phytonutrients compared to their commercialized counterparts [3, 4]. These crops are deeply interwoven with the cultural identities, traditional knowledge systems, and food ways of indigenous and local hilly communities [5]. Their cultivation and use represent a profound connection to place, heritage, and the passing down of agricultural wisdom across generations. Losing hilly vegetables means losing irreplaceable linkages to this biocultural diversity. Beyond their nutritional and cultural significance, hilly vegetables can contribute to the economic empowerment of marginalized mountain communities through niche market opportunities for high-value specialty crops [6]. Their lower input requirements compared to commercial vegetables may also make them more economically viable under the constrained resources of many hilly households [7].

Key Threats and Challenges

Yet hilly vegetable landraces face a litany of threats that have already resulted in the loss of an unknown number of these genetic resources and the traditional knowledge surrounding them. Among the key drivers of this crisis:

Climate Change: Many hilly regions are experiencing amplified effects of global warming like unpredictable weather patterns, reduced seasonal snow cover, and increased incidents of drought, flooding, and other extreme events [8]. The narrow ecological niches that hilly vegetables adapted to over centuries are rapidly shifting, impacting their cultivation.

Land Use Changes: Urbanization, deforestation, mining, and infrastructure projects are steadily encroaching on and fragmenting the agricultural landscapes where these crops are grown [9]. Unsustainable agricultural practices like monocropping and overexploitation of marginal lands have also degraded the environments to which hilly vegetables are adapted.

Changing Dietary Preferences: The proliferation of cheap, subsidized commodity crops and processed foods is altering traditional diets and food cultures, particularly among younger generations [10]. As hilly vegetable consumption declines, so does incentive and knowledge for their cultivation.

Agricultural Policies: Government policies, extension services, research priorities, and development interventions have long favoured a handful of widely-grown commercial crops over nutritious traditional and local varieties [11]. This makes it harder for hilly vegetable growers to access resources, markets, and support.

Socioeconomic Pressures: Poverty, lack of access to productive resources like quality seeds and irrigation, rural-urban migration of youth, and the drudgery of hilly farming all contribute to the abandonment of hilly vegetable cultivation by native communities [12].

Lack of Awareness: There is limited scientific data, documentation, and awareness about the availability, potential benefits/uses, and best cultivation practices for many underutilized hilly vegetables [13]. This knowledge gap hinders efforts to conserve and promote them.
Climate change vulnerability assessments indicate that a significant percentage of the world's hilly vegetable diversity is at risk of extinction within this century without concerted conservation efforts [14]. Allowing the erosion of these genetic resources would represent an incalculable loss of agricultural biodiversity, cultural heritage, and untapped potential for improved nutrition and economic opportunities.

Conservation Strategies

In situ (On-Farm) Conservation: The most effective way to conserve hilly vegetable genetic diversity is through supporting its continued cultivation and evolution within its native environments by local farming communities [15]. Various initiatives around the world are working to maintain this traditional reservoir of crop diversity:

Participatory Plant Breeding and Seed Exchanges: Partnerships between researchers, NGOs, and indigenous farmers enable the collaborative selection, improvement, and dissemination of locally-adapted hilly vegetable varieties [16]. Seed fairs and community seed banks help facilitate seed exchange networks.
Incentives and Value Capture: Developing market opportunities and branding for specialty hilly vegetables increases financial incentives for their cultivation [17]. Certification schemes like geographic indications and appellations can capture premiums. Direct marketing and agrotourism provide supplemental income.

Strengthening Traditional Management: Initiatives like the Globally Important Agricultural Heritage Systems program work to dynamically conserve traditional agricultural landscapes, practices, and knowledge linked to hilly vegetable cultivation [18].

Ex situ Conservation: Complementing on-farm efforts are ex situ conservation approaches that maintain backup copies of hilly vegetable diversity in off-site facilities like gene banks, botanical gardens, and seed libraries:

Gene Banks: Organizations like the World Vegetable Centre, NBPGR (India), and European cooperatives curate seed collections representing hundreds of hilly vegetable varieties [19]. Cutting-edge facilities preserve this diversity through seed storage, cryopreservation, and in vitro culture.

Botanical Gardens and Field Collections: These living repositories display and maintain hilly vegetable landraces, allowing research on their traits and helping raise public awareness [20]. They also serve as backup sites for reintroducing diversity back to farming communities.

Documentation and Digitization: Efforts to comprehensively catalogue hilly vegetable traits, cultivation practices, ecological preferences, uses, and related indigenous knowledge through databases and digitization of herbarium specimens play a key role in backing up this information for future study and use [21].

A major challenge to ex situ conservation is the laborious and resource-intensive process of collecting and maintaining hilly vegetable diversity from often remote and marginalized regions [22]. There are also concerns about the incomplete capturing of genetic diversity through ex situ sampling, and the inability of static collections to fully represent the continued evolution that occurs under dynamic farmer cultivation [23]. As such, a complementary conservation approach combining robust ex situ and in situ/on-farm components are advocated.

Promotion and Mainstreaming

While conserving hilly vegetables is vital, simply maintaining backup samples has limited impact for enhancing food security and sustainable livelihoods. A multi-pronged strategy is needed to actively promote and mainstream the cultivation and use of these crops:

Production Research and Extension: Generating data on production practices, environmental adaptation, nutritional traits, and economic viability can help optimize hilly vegetable yields and incentivize their cultivation [24]. Research must be paired with outreach efforts by agricultural extension networks to disseminate best practices to remote mountain communities.

Value Addition and Marketing: Processing hilly vegetables into value-added products like pickles, chutneys, and ready-to-cook mixes can reduce post-harvest losses and create higher-value commercial opportunities [25]. Connecting growers to wider markets through cooperatives and branding campaigns is also key.

Food System Inclusion: Integrating nutritious and climate-resilient hilly vegetables into institutional food procurement (e.g. schools, hospitals), emergency food aid, and supplemental nutrition programs can provide stable demand while improving community food security and public health outcomes [26].
Dietary Diversification: Promoting dietary diversity through awareness campaigns, recipe books, cooking demonstrations, chef partnerships, and food festivals celebrates local food cultures and creates demand for hilly vegetables among urban consumers [27]. Targeting youth helps keep food traditions alive.

Policy Interventions: An enabling policy environment that incentivizes hilly vegetable cultivation, commercialization, and consumption is essential [28]. This includes reform of agricultural subsidies, research funding allocations, genetic resources laws, and development programming to be more inclusive of neglected and underutilized crops.

Indigenous Perspectives and Rights

Any efforts to conserve and promote hilly vegetables must be done in full partnership and with the free, prior and informed consent of indigenous peoples and local communities who have historically cultivated and held traditional knowledge about these crops. Too often, the intellectual property rights and sovereignty of native stewards have been disregarded or exploited as their genetic resources and knowledge are commercialized and appropriated. Biocultural protocols and codes of ethics that enshrine principles of access and benefit sharing, recognition of ancestral tenure rights, and traditional custodianship over genetic resources and associated knowledge must be established [29]. Community biodiversity registers documenting local crop diversity and related traditional knowledge can aid in asserting these rights [30]. Respecting indigenous food sovereignty and self-determination is also critical. Rather than imposing top-down solutions, interventions should be farmer-led and oriented towards strengthening traditional food systems [31]. Participatory methodologies that embrace indigenous values, customary laws, and cosmological beliefs regarding seed and land can engender more sustainable and culturally-appropriate hilly vegetable conservation.

Looking Forward

The future viability of hilly vegetable landraces depends on amplifying current conservation and promotion efforts. Key priorities include:

Scaling Up In-Situ/On-Farm Efforts: Expanding participatory seed selection, seed saving, and community seed-banking initiatives to more communities. Developing innovative financial incentives and market linkages to make hilly vegetable cultivation economically viable.

Bolstering Ex-Situ Preservation: Gap analyses to identify missing or under-represented diversity. Enhancing the efficiency and cost-effectiveness of collecting missions. Improving coordination and safety duplication among gene banks globally.

Agricultural Research: Characterizing useful traits of hilly vegetables like nutritional properties, climate resilience, and yield components. Leveraging new tools like genomics and bioinformatics to accelerate crop improvement. Developing low-input, sustainable production practices.

Documentation and Dissemination: Comprehensively inventorying hilly vegetable diversity and associated indigenous knowledge through databases and publications. Raising awareness through education campaigns, culinary promotion, agrotourism highlighting traditional practices.

Enabling Policies: Reforming legal/policy frameworks, institutions, economic incentives, and R&D priorities to be more inclusive of neglected and underutilized species. Strengthening farmers' rights and biocultural property protections.

Climate Change Response: Identifying and prioritizing conservation of hilly vegetables at highest risk from climate impacts. Breeding for enhanced resilience using seeds with useful trait variability saved in gene banks.

Conclusion:

Hilly vegetable landraces represent an irreplaceable wellspring of agricultural biodiversity and biocultural heritage. Their continued evolution and sustainable utilization offer tremendous potential for addressing food insecurity, malnutrition, rural poverty, climate change resilience, and the revitalization of healthy food traditions around the world. By combining cutting-edge science with indigenous knowledge systems and prioritizing the rights and leadership of local custodians, we can realize a future where hilly vegetables fulfil their promise as cornucopias of nutrition, income, and environmental adaptation for mountain communities and beyond. It is a moral and pragmatic imperative that we urgently mobilize resources to conserve and celebrate these long-overlooked botanical treasures before they are lost forever.

Table 2. Nutritional Value of Selected Hilly Vegetables (per 100g edible portion):

Vegetable	Protein (g)	Vitamin A (µg RE)	Vitamin C (mg)	Iron (mg)	Zinc (mg)
Chenopodium album	4.1	180	75	8.2	1.1
Amaranthus blitum	3.8	291	61	6.5	0.8
Benincasa hispida	0.6	3	13	0.4	0.2
Gnetum gnemon	4.7	7770	34	3.8	0.5
Parkia speciosa	8.1	40	2	2.3	0.9
Coccinia abyssinica	2.2	71	11	1.8	0.3

Table 3. Cultivation Aspects of Selected Hilly Vegetables:

Vegetable	Elevation Range (m)	Annual Rainfall (mm)	Soil pH
Chenopodium spp.	1200-4000	500-1500	5.5-7.5
Amaranthus spp.	800-2500	600-1800	6.0-7.5
Gnetum gnemon	600-1200	1500-3000	5.0-6.5
Ullucus tuberosus	2800-4200	600-1000	5.5-7.0
Tropaeolum tuberosum	2500-4000	700-1500	5.8-7.2
Lupinus mutabilis	2400-3800	400-800	5.6-7.8

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