ICIMOD Working Paper 2016/5

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Agrobiodiversity in the Sikkim Himalaya

Sociocultural significance, status, practices, and challenges

The Mountain Institute India
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The International Centre for Integrated Mountain Development (ICIMOD) is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas (HKH) – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – based in Kathmandu, Nepal. Globalization and climate change are having an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream and downstream issues. ICIMOD supports regional transboundary programmes through partnerships with regional partner institutions, facilitates the exchange of experiences, and serves as a regional knowledge hub. It strengthens networking among regional and global centres of excellence. Overall, ICIMOD is working to develop economically- and environmentally-sound mountain ecosystems to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now and in the future.

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Acronyms and Abbreviations

BMC	:	Biodiversity Management Committee
CBD	:	Convention on Biological Diversity
CITES	:	Convention on International Trade in Endangered Species
DESME	:	Directorate of Department of Economics, Statistics, Monitoring, and Evaluation
DNA	:	Deoxyribonucleic Acid
EM	:	Effective Microorganisms
FAO	:	Food and Agriculture organization of the United Nations
FEWD	:	Forest, Environment, and Wildlife Department, Government of Sikkim
FSADD	:	Food Security and Agriculture Development Department
GBPIHED	:	GB Pant Institute of Himalayan Environment and Development
GDP	:	Gross Domestic Product
GIAHS	:	Globally Important Agricultural Heritage Systems
GIZ	:	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCCDD	:	Horticulture and Cash Crop Development Department
HYV	:	High Yielding Variety
ICAR	:	Indian Council of Agricultural Research
IPR	:	Intellectual Property Rights
IUCN	:	International Union for Conservation of Nature
MDGs	:	Millennium Development Goals
MEA	:	Millennium Ecosystem Assessment
NABARD	:	National Bank for Agriculture and Rural Development
NAP	:	National Agroforestry Policy
NBAGR	:	National Bureau for Animal Genetic Resources
NBPGR	:	National Bureau for Plant Genetic Resources
NBSAP	:	National Biodiversity Strategy and Action Plan
NTFP	:	Non Timber Forest Products
PLEC	:	People, Land, and Environment Change
SBA	:	State Biodiversity Authority
SBAP	:	Sikkim Biodiversity Action Plan
SAARC	:	South Asian Association for Regional Cooperation
TMI	:	The Mountain Institute
UNFCCC	:	United Nations Framework Convention on Climate Change

Executive Summary

The Sikkim Himalaya is part of 34 globally significant biodiversity hotspots and 22 agrobiodiversity hotspots in India. It encompasses a variety of agroecological zones, with varying dominant farming systems in different zones: pastoralism and agropastoralism in the alpine and trans-Himalayan zones (4,000–5,500 m); mixed farming (subsistence agriculture) in the temperate zone (2,500–4,000 m); traditional agroforestry systems in the subtropical to warm temperate zones (600–2,500 m); and terrace rice cultivation-based mixed farming in the subtropical zones (300–1,700 m).

Indigenous farmers in the Sikkim Himalaya have, through generations of innovation and experimentation, established a variety of land use systems to nurture a great diversity of both wild and domesticated plants and animals. Local agrobiodiversity features more than 126 landraces of cereals, including rice (77), maize (26), and millet (7); 18 cultivars of oilseeds; 34 cultivars of pulses/beans; 132 species of vegetables; 38 species of spices/condiments; 33 landraces of tubers/roots; and 64 species of fruit. Sikkim's traditional system of cultivation also supports more than 200 species of wild edibles, 119 species of multipurpose agroforestry trees, 52 crops with high social and cultural value, and 69 species of plants sacred to indigenous communities. It also has a diversity of land uses, with 15 to 20 field types, and specific land use categories. Similarly, there is a high diversity of domestic animals, with about 21 different local and indigenous breeds. Homesteads on marginal farms make up 40–70% of Sikkim's total landholdings and account for 50–80% of these households' requirements. Homesteads are centres of agrobiodiversity and associated traditional ecological knowledge, are traditional sources of food and nutrition, and are important contributors to food and livelihood security among farming communities.

Agriculture in Sikkim contributes about 16% of the state's GDP and supports more than 64% of the population, who sustain their livelihoods on the rapidly shrinking cultivable land available for farming. The agricultural landscape of Sikkim is undergoing rapid transformation driven by rising globalization, and genetic resources and traditional knowledge are steadily eroding. Several factors have contributed to the loss of agrobiodiversity, including the conversion of land for non-agricultural purposes (i.e., the pharmaceutical industry, hydropower projects, roads, and infrastructure) and the regular introduction of hybrid and high yielding varieties of crops. Low per capita landholdings (0.1 ha per person according to the 2011 census), rapid loss of traditional knowledge systems, outmigration of youth, increasing marginalization resulting from the allocation of land for development projects and poor access to agricultural diversity and security mechanisms also contribute to agrobiodiversity loss. Climate change impacts have been reported in the form of increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance, increased pests and diseases, and the gradual shift of crop seasons and patterns, all of which have implications for agrobiodiversity conservation and future food availability. Other key issues include the current investment priorities of the government, poor marketing mechanisms, inadequate financial resources, lack of appropriate farmer-centric strategies for the conservation of genetic resources and associated traditional knowledge, and lack of a common mechanism and supportive policies for agrobiodiversity conservation.

Both in situ and ex situ conservation of plant genetic rersources for food and agriculture are needed to maintain the region's high level of plant genetic diversity, which contributes to sustainable agricultural development. The lack of gene banks in the state, as well as in community centres, is the greatest constraint to sustaining ex situ genetic resource collection and conservation. It is imperative to develop an adaptation strategy through policies that prioritize community-based biodiversity management programmes and registers maintained by local biodiversity management committees. The Sikkim government has initiated an 'organic mission' to make Sikkim's agricultural landscape fully organic, which is likely to address some of the issues and challenges given above. Community seed banks for seed conservation and participatory plant breeding for seed development need to be prioritized across the Sikkim Himalaya through technical and financial investments. Adaptation strategies include the integration of agroforestry, farmland, and livestock into production systems; cultivation of a higher diversity of locally adaptive traditional crops and improved varieties of crops (developed by farmers); and improved water and soil management within the agricultural production system.

An agrodiversity landscape at Sang-Martam, East Sikkim

1. Introduction

The rich agrobiodiversity of the eastern Himalayas supports the production of food, fuel, and fibre, as well as a range of ecological services that support the supply of clean water, habitat for wild species, and human health. The region is recognized as one of India's agrobiodiversity hotspots (NBA 2013; Singh and Varaprashad 2008). The eastern Himalayan region is spread across a wide spectrum of ecological zones with diverse social and economic potential and biodiversity values. It harbours three of the world's 34 biodiversity hotspots, with an array of unique plants and animals of global importance (Mittermier et al. 2005; CI 2005).

Agriculture is the main source of livelihood for more than 75% of the population of Sikkim and contributes around 17% of the gross state domestic product (Kumar 2012). The Sikkim Himalaya houses a globally unique indigenous farming system and is in the process of being recognized as an associate site of the Globally Important Agriculture Heritage Programme (GIAHS) under the United Nations Food and Agriculture Organization (GIAHS 2007).

Food security in mountains is based on agriculture and is directly dependent on biodiversity. However, in recent decades, agricultural practices have focused on maximizing yields by investing in the research and development of a few high-value species, thus downplaying the importance of biodiversity (MEA 2005). Maintenance of crop diversity in farmers' fields in hotspots of plant genetic diversity is considered a 'global life insurance policy' in the Convention on Biological Diversity (CBD 2010). The innovative, biodiversity-rich farming systems developed over time by local and indigenous communities have the potential to be high yielding and sustainable, and they also support the existence of wild species by limiting the adverse effects of agriculture on habitats (Jackson et al. 2005).

Over thousands of years, indigenous communities have applied adaptive technologies for the management, utilization, and cultivation of agricultural biodiversity through learning, experimentation, and innovation. This agricultural biodiversity, or agrobiodiversity, has recently been defined by the Convention on Biological Diversity (COP 5 Decision V/5) as a "broad term that includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agroecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agroecosystem, its structure and processes"(CBD 2014).

Similarly, under the United Nations University's 'People, Land and Environment Change' project, Stocking (2002) defined agricultural diversity, or agrodiversity, as "a set of four interrelated and interacting elements consisting of biophysical diversity, management diversity, agrobiodiversity, and organizational diversity". Thus, agrodiversity could be viewed through two categories: a) it is composed of environment-adaptive technologies that emphasize skillful but non-overriding adaptation to local biodiversity, or b) it is composed of environment-formative technologies that stress the creation of substantial and enduring physical changes, creating landesque capital for crop diversity (Stocking 2002; Brookfield 2002; Brookfield et al. 2002, 2003). Broadly, agricultural diversity encompasses the natural resources, processes, and functions managed by farmers as a whole.

Scientific information on the Sikkim Himalaya in terms of the aforementioned principles of agrodiversity is generally lacking. A few isolated efforts have shown that the region houses rich agrobiodiversity in cultivated systems; however, these cultivated systems are dwindling at an alarming rate in the face of climate change, unmanaged development, and conversion of cultivated land for other purposes (Sharma and Dhakal 2011; Rahman and Karuppaiyan 2011; Sharma and Rai 2012; Ingty and Bawa 2012).

This working paper documents and discusses agrodiversity, its general characteristics, significance, status, rate of change and causal factors; ecological, social, and policy dimensions and their impacts on agrobiodiversity loss; and adaptive strategies for managing the agroecosystems of the Sikkim Himalaya.

Rationale for this Study

The Sikkim Himalaya is a landlocked mountainous region extending from below the trans-Himalayan Tibetan Plateau to temperate, subtropical, and tropical climates. The region houses a large diversity of farming systems, human societies, and ways of managing complex external pressures on sustainable land use. Apart from its global biodiversity values and the ecosystem services it provides, the region's rich agricultural biodiversity is the basis for the food security and agriculture that supports the livelihood security of indigenous communities. A detailed analysis of biodiversity management within the cultivated system is essential to understand the sustainable production of food and other agricultural products, including the wide variety of benefits it produces, such as seed, nutritional, and livelihood security.

The interaction between the environment, genetic resources, and management practices that occurs within agroecosystems have contributed to maintaining a dynamic portfolio of agricultural biodiversity. However, scientific understandings of the socioecological and socioeconomic elements of 'agrodiversity' in human-inhabited systems with respect to its management are yet to be explored.

Therefore, this study was conceptualized to document and discuss elements of agrodiversity and its contributions to traditional farming communities. It highlights the multiple dimensions and range of goods and services that agrodiversity provides. The recommendations of this study warrant immediate action to promote the sustainable use of agrobiodiversity for food security, human health, and nutrition as a contribution to the MDGs (particularly Goal 1: Poverty Alleviation). This approach to agroecosystem management can be compared to what has been recently defined as 'climate smart agriculture' (FAO 2013; FAO 2015; World Bank 2015). The Millennium Ecosystem Assessment Report (2005) confirms the contribution of agrobiodiversity to human wellbeing. Unfortunately, traditional and adaptive varieties of staple food crops in the Sikkim Himalaya are disappearing at an alarming rate.

Traditional farming at Thangu, North Sikkim

Studies on different levels of support provided to in situ and ex situ agrobiodiversity conservation are lacking in the region, and there is a growing need to assess how farmers and agricultural communities manage agrobiodiversity in different farming systems. The information generated through this study can be used to enhance understandings of local, national, and regional support mechanisms, as well as the linkages, processes, gaps, and practices related to the sustainable use and conservation of the region's agrobiodiversity.

Objectives

This publication seeks to document the findings of a study on the general characteristics of agrodiversity, its significance, status, rate of change, and causal factors; the ecological, social, and policy dimensions of agrodiversity and their impact on the loss of agrobiodiversity; and existing strategies for the management of agroecosystems in the Sikkim Himalaya. The specific objectives of the study were to document and review:

- Agricultural diversity in the various ecological zones and agroclimatic conditions of the Sikkim Himalaya
- Landraces and varieties of traditional crops in the Sikkim Himalaya and varieties introduced in existing agroecosystems
- Status and promotion of pollinator species, such as honeybees, and their role in pollinating a diversity of crops
- Existing literature on agricultural biodiversity, policies, strategies, and action plans

Methods

The study involved extensive field investigations, agrobiodiversity surveys, and interviews with both women and men farmers and officials at the Departments of Agriculture, Horticulture, Animal Husbandry, and Forest under the Government of Sikkim. The existing literature related to agrodiversity was reviewed to collect secondary information on existing crops, production, economics, markets, pollinators, and pollination. Village walks were carried out to interact with farmers in the field, better understand the dynamics of agrobiodiversity conservation and management, and to identify different land use types and land use stages for the cultivation of a variety of crops. Surveys were also conducted to document elements of agrodiversity; the diversity of field types, including traditional agroforestry systems, terrace farming, and pastoralism; and the diversity of traditional, underutilized, and lesser-known crops, as well as introduced crops such as high yielding varieties or hybrid crops.

2. Agrobiodiversity in the Sikkim Himalaya

Significance of Agrobiodiversity in the Landscapes of the Sikkim Himalaya

Sikkim and Darjeeling are part of the Eastern Himalayan Agrobiodiversity Region, one of 22 agrobiodiversity hotspots in India, and a part of globally significant biodiversity hotspots in the region. The Sikki.m Himalaya house diverse agroecosystems, farming cultures, agroclimatic regimes, traditional landraces, and local livestock breeds. Local and indigenous communities in the region have, over centuries, tested and adopted innovative strategies for conserving and harnessing native agrobiodiversity, primarily for food security and improving their livelihoods. The diversity of the landscape, landuse stages, and specific land use categories on temporal and spatial scales have provided opportunities to manage agrodiversity and nurtured human-nature relationships. A diversity of ecosystem services is bestowed by the agrodiversity elements from the local to global level (Table 1).

Crop genetic biodiversity

Of the total 5,580 plant species (including orchids, bamboos, rhododendrons, tree ferns, other ferns and fern allies, and oaks) found in the Sikkim Himalaya (SBAP 2012), around 550 species have food value and 50% of them are cultivated species. A general survey under the study revealed that farms in the study areas are repositories of diverse gene pools that consist of more than 126 landraces of cereals including rice (77), maize (26), and millet (7); 18 cultivars of oilseeds; 34 cultivars of pulses and beans; 132 species of vegetables; 38 spices/condiments, and 33 landraces of tubers/roots. As many as 64 fruit tree species are commonly grown on farms, with more than 200 species of wild edibles naturally growing in the region's farm-based, forest-based, and large cardamom-based

Different varieties of maize cultivated in Sikkim

Table 1: **Range of ecosystem services bestowed by traditional agroecosystems in spatial scales (Sharma and Rai 2012; modified after Kremen 2005)**

Ecosystem service	Spatial scale		
	Farm level (local)	Sikkim Himalaya (landscape)	Himalayas (regional)
Net primary production			
Food production, NTFPs, lesser known/underutilized crops, medicinal plants, etc.	■		
Timber, fuelwood, litter	■		
Disease and pest control	■		
Pollination and seed dispersal	■		
Soil fertility maintenance and enrichment	■		
Control of soil degradation, stabilization, and erosion control	■	■	
Fresh/clean water	■	■	
Flood control and flood mitigation	■	■	
Fresh/clean air	■	■	
Carbon sink carbon sequestration in diverse land use systems	■	■	
Biodiversity (hotspot)	■	■	■
Sacred landscape (aesthetic/cultural/spiritual value)	■	■	■

agroforestry land. The region's traditional agricultural systems also house a rich diversity of protein banks with a total of 14 landraces of 'rajma' (kidney beans) and seven landraces of rice beans, as well as 20 landraces of chilies, 55 landraces of squash, and four of ginger (Table 2). The morphological and molecular characterization, including specific descriptors for genetic differentiation, of these crops has not yet been carried out. More than 119 species of multipurpose agroforestry trees (used for timber, fuelwood, fibre, fodder, dye, soil binders in terraces, minor construction materials, etc.) have been recorded. While 52 crop species have high social and cultural importance, 69 other species are sacred to indigenous communities. Further assessment of agrobiodiversity at various levels of biological organization (i.e., genes, species, communities, ecosystems, and landscapes) will confirm the abundance and richness ofthe Sikkim Himalaya.

The existence of genetic diversity in several agricultural crops is high, including maize, rice, and millet. Some crop varieties have high genetic diversity in the 'sublandraces' category, something observed in rice and maize. Indigenous farmers in Sikkim are intelligent crop breeders who have, over the years, developed more than six sublandraces of maize such as 'pahenli makai' and 'seti makai' and three to four sublandraces of traditional rice varieties such as 'ättey' and 'bacchhi'. These sublandraces are agroclimatically adapted to the local conditions,

A 10-year-old alder-cardamom agroforestry system in West Sikkim

Table 2: **On-farm crop diversity under existing traditional farming systems based on field survey and farmers' classification**

Crops (scientific names)	Local names	Local names of landraces in practice
Rice (*Oryza sativa*)	Dhan	Timmurey, rudhwa, namphokey, pahuwa, balamsar, marshi, bachhi, krishnabhog, bagheytulasi, sikrey, tsungthangey, kalchanti, lalbachhi, bhuindhan, mansaro, taprey, nuniya, kataka, attey, sanu-attey, dudhkalam, champasari, bangi, jhapaka, phaudel, kalomarshi, taprey, chirankhey, gauriya, chinese attey, regmi dhan, kazi-dhan, japoni, pharamey-tulasi, bhotangey, rambhog, attay or thulo attay, baghay-tulasi, birimphul, champay, chirakhay-1, chirakhay-2, darmali, dhanasay, dorokhay or dahray, dudhkati, dudhkhari, ghaiya-dhan, godulay or kalo tulasi, gujari bhog, jeerasari, jholungay, kalami, ram kalam, kulchhati, kalo dhan, kalo nuniya-1, kalo nuniya-2, kataka, khimti, lamo dhan. barmi dhan, mansaro, nunia or basmati-attay, phaudel, phudungay, ramjeera, sano attey or kanchhi attey or masino attey, sirkay marsi, zornali, thakmaru, thapachini, thapray-1, thapray-2, timmuray, tulasi
Maize (*Zea mays*)	Makai	Seti-makai, rato-makai, pahenli-makai, kali-makai, pangri-makai, himali-makai, murali-makai, farashi-makai
Finger millet (*Eleusine coracana*)	Kodo	Pangdur, mudkey, chamligey, bhadaurey, kartikey, mangshirey, panchaunley, nangkatwa, tangsere
Buckwheat (*Fagopyrum tataricum*)	Phaper	Mithey-phaper, titey-phaper, kere-phaper, yapha, tambong-kere
Wheat (Triticum aestivum)	Gahu	Tho, mashi, si, toksongsi
Barley/cultivars (*Hordeum* sp.)	Jau	Jau, uwa, hoski, tingshi
Yams (*Dioscorea* spp.) Taro (*Colocasia esculenta*) Sweet potato (*Ipomea batatas*) Cassava (*Manihot esculenta*)	Tarul bhyagur	Rato-ghartarul, gittho, seto-ghartarul, ban-tarul, pataley, logo, bhyagur, rittho, wakhey, su, suthani, mithey-gittho, ool Pindalu, lankey, seto karkalo, maney, kalo karkalo, kachhu, etc. seto sakarkhanda, rato sakarkhanda Simal tarul, phul tarul
Pumpkin (*Cucurbita* spp.)	Pharsi	Lamchey thulo, lamchey sano, kalo pharsi, seto pharsi, dalley pharsi, auley pharsi, pahenley, lekali pharsi, maddhesey-pharsi, pahadey pharsi
Mustard (*Brassica* spp.)	Tori/rayo	Kalo-tori, seto-tori, pahenlo-tori, sarsewn,chringla-rayo, chilley-rayo, phoppa-rayo
Soybean (*Glycine max*)	Bhatmas	Nepali bhatmash, seto bhatmash, kalo bhatmash
Pulses and beans/ legumes (*Vinga* sp.; *Phaseolus* sp.; *Cajanus* sp.; *Vicia* sp.; *Pisum* sp.)	Dal/ simbi /bodi	Ghew simbi, singtamey simbi, sadamey simbi, harey simbi, borungey simbi, montulal simbi, nepali simbi, hiundey simbi, bakuley simbi, ghew bodi, khostey bodi, soshta bodi, tuney bodi, kalo bodi, kerau, pahenli dal, masyam dal, rahari dal, rajma, khesari, gahat, arhar, kauchhey, dudhey matar, hadey matar
Banana (*Musa* sp.)	Kera	Kabuli kera, kadali, dhushrey, chinichampa, ghew kera, malbhog, mungrey kera, nangrey kera, ban-kera, jhapari
Chili (*Capsicum* spp.)	Khorsani	Sanhili-khorsani, akabarey-khorsani, dalley-khorshani (more than two sub-types), lamchey-khorsani, bhindey-khorsani, dhindey-khorsani, jirey-khorsani, rato-khorsani, jhiney-khorsani, thado-khorsani
Citrus (*Citrus* spp.)	Suntola/ jyamir/ kagatey	Suntola, kagati, nibuwa, bimirow, bhogatey, sunkhotro, phoksey, kali jyambir, kamal, naietey jyambir, chaksi, muntola
Large cardamom (*Amomum subulatum*)	Alainchi	Ramsey, golsey, madhusey, bharlangey, chibe, seremna, ramla, sawney, ramnang, churumpho
Ginger (*Zingiber officinale*)	Aaduwa	Gorubathaney, bhainsey, majhauley, jorethangey, nangrey

and are bartered among farmers. These crops are suited to local soil types and often cultivated as supplementary crops along with other major crops.

The genetic diversity of large cardamom (*Amomum subulatum*) is high, with seven species (*A. linguiforme, A. kingii, A. aromaticum, A. corynostachyum, A. dealbatum, A. costatum,* and *A. plauciflorum*) naturally occurring in the region, while local cultivars developed by indigenous plant breeders include 'ramsai', 'sawney', 'madhusey', 'bharlangey' (cultivated at elevations higher than 1,500 m), 'chibey', 'ramla', 'ramnag' (between 1,000 and 1,500 m), and 'golsai' and 'seremna' (1,000 m and below). So far, wild relatives of the cultivated large cardamom species in Sikkim have not been reported from other regions of the world, which suggests they are endemic to the eastern Himalayas. All the commercial varieties of large cardamom that belong to the species *Amomum subulatum* Roxb. of the family Zingiberaceae under the natural order Scitaminae have ecologically adapted to different elevations between 500 and 2,300 m.

In Sikkim, agrobiodiversity encompasses high-value mountain niche products (large cardamom, ginger, Sikkim mandarin, and medicinal plants) in various agroforestry systems and adjacent forests. These traditional agroforestry systems have sociocultural and customary values and also function as recharge catchments for natural streams and springs. Based on the perceptions of indigenous farmers, traditional landraces existing in these systems have superior traits compared to high yielding varities in terms of survival (in harsh geoclimatic conditions in high altitudes), resistance (to water stress/pathogens), adaptation (to changes in local climates), nutrition requirements, pest tolerance/resistance, low input requirements, and weed coexistence. Above all, agricultural biodiversity can contribute effectively to climate change adaptation and mitigation strategies and activities.

The diversity of underutilized or lesser-known plant species is very high (>250 species) in the Sikkim Himalaya. The majority of these species are considered 'poor man's food'. Sundriyal et al. (1998) reported as many as 190 fruit plant species that grow in the wild in Sikkim. Some lesser known crops that have been recently renamed 'potential crops' have been commonly grown by farmers in Sikkim as food supplements, for medicinal or cultural value, or for their capacity to adapt to stress conditions (Table 2).

Traditional farming systems of the Sikkim Himalaya are large repositories of biological diversity. They also represent four different layers of vegetation, listed below with specific characteristics:

Top layer: Multipurpose agroforestry trees important for timber, fuelwood, fodder, and NTFPs (including wild edible fruits); wind break around farms; soil binder on terraces.

Middle layer: Species of fruit (papaya, guava, banana, peach, pear, litchi, citrus), vegetables (tree tomato, drumstick, cassava), and climbers (cowpea, bitter gourd, bottle gourd, cucumber, beans, yams, chayote, pumpkin, beans)

Lower layer: Mostly vegetables (okra, chenopodium, spinach, amaranths, leafy vegetables, chilies, cauliflower, pulses, taro), and potential crops like finger millet, buckwheat, Job's tear, and ground fodder (broom grass)

Ground layer: Consists of creepers (sweet potato, etc.), root/tuber crops (radish, beetroot, turnip, carrot, onion, yams, taro), spices (coriander, ginger, turmeric, large cardamom), pulses, and medicinal herbs (tulasi, babari, mints, sesame).

Table 3: **On-farm agricultural crops and landraces/cultivars/species commonly grown in the diverse cultivated systems of the Sikkim Himalaya (based on farmers' descriptions and classifications)**

Crop (scientific name)	Local name(s)	Status	Number of species/ landraces/cultivars
Cereals			
Rice *(Oryza sativa)*	Dhan	Major	>77
Maize *(Zea mays)*	Makai	Major	26
Wheat *(Triticum aestivum)*	Gahun	Major	2
Buckwheat *(Fagopyrum tataricum, F. esculentum)*	Phaper	Major	4
Ragi *(Eleusine coracana)*	Ragi	Major	7
Barley *(Hordeum vulgare)*	Jau	Minor	3
Barnyard millet *(Echinochloa crusgalli)*	Sama	Minor	1
Foxtail millet *(Setaria italica)*	Kagunu	Minor	1
Grain amaranths *(Amaranthus hypochondriacus)*	Lattey	Minor	1
Oat *(Avena sativa)*	Jai	Minor	1
Pearl millet *(Panisetum typhoides)*	Tumri	Minor	1
Sorghum *(Sorghum vulgare)*	Junelo	Minor	1
Job's tear *(Coix lacryma-jobi)*	Bhirkauli	Minor	1

Oilseeds			
Mustard *(Brassica juncea)*	Tori	Major	3
Rapeseed *(Brassica campestris)*	Sarseun/rayo	Major	3
Soybean *(Glycine max)*	Bhatmas	Major	2
Leafy mustard *(Brassica juncea var. rugosa)*	Rayo sag	Major	4
Niger *(Guizotia abyssinica)*	Philungey	Minor	1
Sunflower *(Helianthus annuus)*	Surya mukhi	Minor	1
Perilla *(Perilla frutescens)*	Silam	Minor	1
Sesame *(Sesamum indicum)*	Til	Minor	3
Pulses/beans and related protein crops			
Common French bean *(Phaseolus vulgaris)*	Simbi	Major	14
Black Gram *(Vigna mungo)*	Kalo/pahenlo dal	Major	3
Mung dal *(Vigna radiata)*	Mungi dal	Minor	1
Rice bean *(Vigna umballata)*	Masyam	Major	7
Butter bean *(Phaseolus lunatus)*	Gheu simbi	Major	3
Broad bean *(Vicia faba)*	Bakuley simbi	Major	1
Cow pea *(Vigna unguiculata)*	Bodi	Major	4
Horse gram *(Dolichos biflorus)*	Gahat	Major	1
Vegetables			
Pumpkin *(Cucurbita pepo)*	Pharsi	Major	8
Cherry pepper and local chillies *(Capsicum* spp.*)*	Khorsani	Major	>20
Palak *(Spinacea oleracea)*	Palak	Major	1
Garlic *(Allium sativum)*	Lasun	Major	1
Onion *(Allium cepa)*	Pyaj	Major	1
Broccoli *(Brassica oleracea var. italica)*	Brocauli	Major	1
Bottle gourd *(Lagenaria siceraria)*	Lauko	Major	2
Ash gourd *(Benincasa hispida)*	Kubindo	Major	1
Chayote squash *(Sechium edule)*	Ishkush	Major	>55
Spine gourd *(Momordica subangulata var. renigera)*	Karelo	Major	2
Cauliflower *(Brassica oleracea var. botrytis)*	Phul-kopi	Major	1
Tomato *(Lycopersicon esculentum var. pimpinellifolium)*	Rambheda	Major	2
Cucumber *(Curcumis* spp.*)*	Kankro	Major	2
Sponge gourd *(Luffa acutangula)*	Ghiraunlo	Major	2
Sweet gourd *(Momordica cochinchinensis)*	Ban-karelo/chatelo	Major	1
Snake gourd *(Trichosanthes anguina)*	Chichindo	Major	1
Chenopodium *(Chenopodium album)*	Bethu	Minor	1
Watercress *(Nasturtium officinale)*	Simrayo	Minor	1
Eggplant *(Solanum melongena)*	Baigun	Major	4
Nettle plant *(Girardinia palmata, Girardinia diversifolia)*	Sisnu	Minor	3
Nakima *(Tupistra nutans)*	Nakima	Minor	1
Celery *(Apium graveolens* var. *dulce)*	Seleri	Minor	1
Poison berry *(Solanum anguivi)*	Bihi	Minor	4
Jackfruit *(Artocarpus heterophyllus)*	Rukh katahar	Major	1
Amaranthus *(Amaranthus viridis)*	Lalisaag	Minor	1
Drumstick *(Moringa oleifera)*	Sajana	Major	1
Leafy vegetables *(Brassica juncea* var. *rugosa)*	Rayo sag	Major	4
Radish *(Raphanus sativus)*	Mula	Major	3
Lady's finger *(Abelmoschus esculentus, A. caillei)*	Bhindi	Minor	4

Spices and condiments			
Large cardamom *(Amomum subulatum)*	Alainchi	Major	18
Ginger *(Zingiber officinale)*	Aaduwa	Major	5
Turmeric *(Curcuma longa)*	Besar	Major	2
Black pepper *(Piper nigrum)*	Marich	Minor	1
Cinnamom *(Cinnamomum zeylanicum)*	Sinkauli	Minor	1
Himalayan caraway *(Carum bulbocastenum)*	Bhote-jira	Minor	1
Hemp *(Cannabis sativa)*	Ganja	Minor	1
Coriander *(Coriandrum sativum)*	Dhaniyan	Minor	1
Fennel *(Foeniculum vulgare)*	Saunp	Minor	1
Garlic *(Allium sativum)*	Lasun	Minor	1
Mint *(Mentha arvensis)*	Padina	Minor	1
Niger plant *(Guizotia abyssinica)*	Philungey	Minor	1
Garden cress *(Lepidium sativum)*	Chaunsur	Minor	1
Mountain pepper *(Litsea cubeba)*	Siltimbur	Minor	1
Sweat flag *(Acorus calamus)*	Bojho	Minor	1
Nepal pepper *(Zanthoxylum armatum)*	Boke-timmur	Minor	1
Tuber/root crops			
Yams *(Dioscorea* spp.*)*	Tarul	Major	15
Potato *(Solanum tuberosum)*	Aalu	Major	2
Sweet potato *(Ipomea batatas)*	Sakhar khanda	Major	2
Tapioca *(Manihot esculenta)*	Simal tarul	Major	2
Elephant's foot yam *(Amorphophallus campanulatus)*	Ool	Minor	1
Chayote *(Sechium edule)*	Ishkush	Major	1
Taro or cocoyam *(Colocasia esculenta)*	Pindalu	Major	6
Radish *(Raphanus sativus)*	Mula	Major	3
Cana *(Cana edulis)*	Phul tarul	Minor	1
Fruits			
Banana *(Musa* spp.*)*	Kera	Major	>9
Dry galls *(Rhus chinensis)*	Bhakmilo	Minor	1
Guava *(Psidium guajava)*	Ambak	Major	4
Plum *(Prunus domestica)*	Arubakhada	Major	2
Custard apple *(Annona squamosa)*	Sarifa	Minor	1
Apple *(Malus* sp.*)*	Syau	Major	1
Peach *(Prunus persica)*	Aaru	Major	2
Passion fruit *(Passiflora edulis)*	Garandale	Major	2
Citrus *(Citrus* spp.*)*	Suntola	Major	12
Jackfruit *(Artocarpus lakoocha)*	Badar	Major	1
Mango *(Mangifera indica)*	Aanp	Major	2
Litchi *(Litchi chinensis)*	Lichi	Major	1
Areca nut *(Areca catechu)*	Supari	Minor	1
Hog plum *(Choerospondias axillaris)*	Lapsi	Minor	2
Indian crab apple *(Docynia indica)*	Mehel	Minor	1
Indian gooseberry *(Phyllanthus emblica)*	Amala	Minor	2
Papaya *(Carica papaya)*	Mewa	Major	2
Pear *(Pyrus communis)*	Naspati	Minor	2
Wood apple *(Aegle marmelos)*	Bel	Minor	2
Grape *(Vitis vinifera)*	Daakh	Minor	2
Indian hogplum *(Spondias pinnata)*	Amaro	Minor	1

Himalayan walnut *(Juglans regia)*	Okhar	Minor	1
Tejbal *(Zanthoxylum rhetsa)*	Timmur	Minor	1
Pomegranate *(Punica granatum)*	Darim	Minor	2
Avocado *(Percea amricana)*	Pumsi/phamphal	Minor	2
Pineapple *(Ananas cosmosus)*	Bhuin-katahar	Minor	2
Common persimmon *(Diospyros virginiana)*	Halwabed	Minor	1
Indian butter tree *(Diploknema butyracea)*	Chiuri	Minor	1
Chestnut *(Castonopsis hystrix)*	Katus	Minor	1
Total			445

The Indian Council of Agricultural Research stationed at Tadong, Sikkim has a collection of 50 rice, 26 maize, 12 green and 8 dalle chilies, and 55 chayote squash local cultivars which are under evaluation for morphological and molecular characterization.

The crop genetic diversity of agroecosystems in the Sikkim Himalaya is unique (Table 3) in part because of rapid vertical and horizontal agroecological variations and the diversity of farming practices, communities, and management systems. In general, a marginal mountain household consists of a matrix of homestead, rice field, dry field, and a small parcel of forest within the private landholding.

Livestock diversity

Domesticated animal production systems contribute to the region's agrobiodiversity, while also helping local communities meet domestic needs and farm requirements (draught animals, manure, milk products, meat, wool, and skin). Local breeds of these animals are well-suited to the mountain environment and support farmers and herders (Table 4). Local cow breeds like 'pahadey gai' and 'siri gai' and local goat breeds like 'sigari bakhra'

A herd of banpala sheep at Pokhari-Narkhola, West Sikkim

Table 4: **Domesticated animals and their importance in the Sikkim Himalaya**

Animal	Breed/variety	Household use/farm use
Cow	Local ('Pahadey', 'Siri')	Milk, cheese, manure, butter, procreation, and meat
Ox	Local ('Pahadey', 'Siri')	Draught animal, manure, breeding
Buffalo	Local	Milk, cheese, procreation, meat, skin
Phe-Yak	Original Tibetan breed (trans-Himalayas: Tso Lhamu, Lhonak, Lashar, Muguthang)	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Thangu and Muguthang)
Yak	Nepalese breed (greater Himalayas: Dzongri, Lhonak, Lashar, Muguthang)	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Yuksam and Dzongri)
Lho-Yak	Yaks brought from the southern part of Tibet and Bhutan (Yumesamdong-Lachung)	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Yuksam and Dzongri)
Dzo (yak-cow/bull)	Male offspring (crossbreed of cow and yak)	Travel animal along Yuksam-Dzongri trekking trail, meat
Dzomo/Urang	Female offspring (crossbreed of cow and yak)	Travel animal along Yuksam-Dzongri trekking trail, meat
Byanglung (Sheep)	Tibetan breed (found in North Sikkim: Tso Lhamu, Lhonak, Muguthang)	Wool, meat, milk, procreation
Banpale (Sheep)	Local breed (found in West Sikkim: Pokhari, Dzongri, Yambong, Narkhola)	Wool, meat, milk, procreation, rituals (sacrifice)
Goat	Chyangra (found in North Sikkim: Tso Lhamu, Lhonak, Muguthang), Singhari Bakhra between subtropical to temperate agroclimatic agroecosystems	Meat, procreation, customary rituals (sacrifice), 'khadgo-katne' (sacrifice during illness)
Horse	Local, mostly in alpine areas	Pack animal
Pig	Local sungur/bangur	Meat
Mule	Local, mostly in alpine areas	Pack animal
Dog	Tibetan mastiff	Guard yak/sheep/goat herds (greater and trans-Himalayas)
Dog	Local breed	Guarding house and agriculture field against wild animals
Cat	Local	Control of pests, especially rodents
Domestic fowl	Local	Egg and meat, customary rituals (sacrifice)
Duck/Goose	Local	Egg and meat, customary rituals (sacrifice)
Pigeon	Local	Meat, customary rituals (sacrifice)

are on the verge of disappearence from the agrobiodiversity landscapes of Sikkim. Livestock farming plays a vital role in the traditional mountain farming system and thus has a large influence on the rural economy in the Sikkim Himalaya. Subsistence-based mountain agriculture in the region is very complex, with interdependent crops, livestock, and forest resources. Nomadic rotational pastoralism with yak and sheep herding is a common practice in the alpine and trans-Himalayan zones (3,500–5,000 m).

Livestock farming is an integral part of traditional farming systems in the Sikkim Himalaya. Most farmers keep a few dairy animals, which are typically stall-fed or grazed on the farm during the winter. Forage for farm animals is collected from crop residues, grasses from farmland, and farm-forest agroforestry systems or nearby forests. Raising livestock requires considerable labour, while the net return from the farm enterprise is still minimal. Over 80% of mountain farmers in Sikkim own livestock, which provides them with supplementary income as well as other nutrient-rich animal products (Table 4). Animal husbandry in the Sikkim Himalaya is the backbone for sustenance of crop diversification and farmers' livelihoods, while off-farm labour migration is an increasing challenge. According to the 18th Livestock Census 2007, the population of cattle was 169,829, followed by goat (110,120), sheep (4,879), pig (38,930), buffalo (1,536), yak (6,468), and poultry (255,682) (Kumar 2012).

Customary rituals of animal sacrifice are still common in indigenous Lepcha, Sherpa, Limboo, Rai, Bhutia, and Chettri ethnic communities of the region, including 'khadgo katne' (sacrifice of goat/sheep during illness), 'bali dine' (sacrifice of goat/sheep), 'kulayan puja' (animal sacrifice for family deities for protection of farms, crops, and health), 'parewa udauney' (releasing a pair of pigeons when a person is ill), and 'siddha puja', 'budi-baju puja', 'sansari puja', and 'bhimsin puja' (animal sacrifice for local deities or spirits).

Sang byansi (East Sikkim), a large diversity of traditional landraces of rice are grown here

Sociocultural significance

There is a dearth of detailed social-ecological studies on the cultural landscapes of the Sikkim Himalaya. The Sikkim Himalayan landscape is a Buddhist ecocultural landscape traditionally described as 'Demazong' (the hidden valley of rice) or the 'Beyuls' and 'Ters' (the hidden treasures on earth) in the Nysol, a holy text of the Tibetan Buddhist philosophy, with clearly defined norms and well-defined boundaries for sacredness (Sharma et al. 2012a; Ramakrishnan 2008a, 2008b). The Demazong consists of diverse natural-cultural landscapes and ecosystems that have brought together a network of indigenous cultural societies and management systems into a natural continuum. It is also a Hindu ecocultural sacred landscape called 'Indrakil' (land blessed with flowers, fruits, cereals, and vegetables). Sikkim's cultural landscapes have a wide spectrum of agricultural diversity, which has been developed, domesticated, maintained, and adapted by human societies for hundreds of years.

This Himalayan landscape is also described as 'Ney-Pemathong'or 'Shangri-la', and worshipped during numerous festivals. During the Pang-Lhab-Sol festival, the mother deity Kanchenjunga is worshipped for protection from calamities. The Tendong hills are worshiped during the Tendong-Lho-Ram-Faat festival, which is observed by Lepchas and Bhutias in hopes for better rain, production, and harvest. Nepalis observe 'sansari puja', during which homage is paid to Mother Goddess Earth to support better harvest, sufficient rainfall, and a good season. The social-cultural and social-ecological functions are interdependent and deeply rooted in culture. The Demazong cultural landscape is believed to have been blessed by revered Buddhist guru Padmasambhava during the eighth century with Ters and Beyuls (Dokhampa 2003; GIAHS 2007; Sharma et al. 2012a).

Status of Agrodiversity and Practices in the Sikkim Himalaya

Agrodiversity goods and services

The agrodiversity of the Sikkim Himalaya provides many goods and services that are of vital importance for human wellbeing and the functioning of ecosystems. Ecosystem goods and services in the region's mountain environment largely support mountain communities. They are also in high demand among people from the plains as they are a source of fresh water and home to pristine natural landscapes that hold, among other things, immense recreational value. The land use systems and agrodiversity of the Sikkim Himalaya provide the basis for the delivery of tangible benefits such as food, energy, and fresh water, as well as intangible non-use values to mountain societies, including spiritual, religious, and aesthetic values (Sharma and Rai 2012b). These services are divided into four categories based on MEA (2005) and Rasul et al. (2011):

- **Supporting services:** The agrodiversity of the landscape supports primary and secondary production, biogeochemical cycling of nutrients, provision of habitats, and agrobiodiversity, which is necessary for sustaining the goods and services that mountain societies obtain from these ecosystems.
- **Provisioning services:** The agrodiversity of the landscape provides agricultural products such as food (crops, roots, tubers, seeds, nuts, fruits, fodder, spices, etc.), construction materials (timber), energy (fuelwood), fibre (wood, textiles), and medicinal and aromatic plants.
- **Regulating services:** The agrodiversity of the landscape and forest ecosystems are critically important for carbon sequestration; water and climate regulation; pollination; protection from natural hazards such as floods, landslides, and avalanches; water and air regulation; and disease and pest regulation.
- **Cultural services:** Agrodiversity in the Sikkim Himalayan Demazong/Indrakil sacred landscape is of great spiritual, cultural, and aesthetic importance. Traditional mountain societies play a key role in conserving and protecting these ecosystems for present and future generations.

The array of ecosystem services varies across spatial scales. These ecosystem services strengthen resilience and can help overcome climate uncertainties and enhance adaptive capacity, thus reducing vulnerability, from the local level to the regional level. The concept of agricultural diversity was initially adopted in the People, Land, and Environment Change (PLEC) project of the United Nations University, which was implemented on three continents (Brookfield et al. 2003). Agrodiversity consists of four principal elements with distinct functional attributes (Table 5).

Table 5: **Elements of agrodiversity in the Sikkim Himalaya (modified from Stocking 2002).**

Agrodiversity categories	Description
Biophysical diversity	The diversity of natural environments endowed to traditional mountain farms, including the natural resource base required for production. It also refers to the natural resilience of the biophysical environment, soil characteristics, plant life, and other biota in agroecosystems. The physical and chemical aspects of soil, hydrology, and climate and the variability and variation in these elements.
Management diversity	The management methods for land, water systems, and biota for crop and livestock production, and the maintenance of soil fertility and structure. It also refers to the physical, biological, and chemical methods of managing agroecosystems.
Mountain agrobiodiversity	The diversity of species and varieties grown on mountain farms that are useful to humans, with emphasis on integrated farming that combines crops, plants, and animals. It also includes the variety of species or biota that is indirectly useful to humans and managed within the system.
Organizational diversity	How mountain farmers operate, manage, and own their farms, and the manner in which natural resource endowments are used from the source according to situation and time. This also includes agricultural labour, assets, reliance on off-farm employment, household size, farm size, farmers' institutions, share cropping, labour share and exchange, and the barter system.

Ecological zonation of agrodiversity in the Sikkim Himalaya

The agrodiversity of the Sikkim Himalaya can be categorized into four prominent systems based on ecological indicators including the social, economic, and ecological conditions; traditional knowledge systems; biophysical and management diversities; and land use types. These systems occur at different agroecological zones covering diverse ecosystems between elevations of 300 and 5,500 m.

1. Pastoralism/agropastoralism in the alpine and trans-Himalayan zones (4,000–5,500 m)
2. Mixed farming (subsistence agriculture) in the temperate zones (2,500–4,000 m)
3. Traditional agroforestry systems in the subtropical to warm temperate zones (600–2,500 m)
4. Terrace rice cultivation-based mixed farming in the subtropical zone (above 300 m)

Pastoralism/agropastoralism in the alpine and trans-Himalayan zones (4,000–5,500 m)

People in the cold, trans-Himalayan deserts of Lhonak Valley, Muguthang, Thanggu, Tso Lhamo, and Lashar Valley in north Sikkim engage in rotational pastoralism and agropastoralism (nomadic yak and sheep/goat grazing) at altitudes between 3,500 and 5,000 m. This example reflects not only the importance of agrodiversity but also of the judicious management of wildlife habitats of endangered species such as blue sheep, Himalayan tahr, and the critically endangered snow leopard (Table 6).

The Muguthang area of Lhonak Valley, the Tso Lhamu Plateau, and Lashar Valley have been home to the agropastoralist 'Dokpas' for centuries. Nomadic Dokpa pastoralists are guardians of trans-Himalayan ecosystems and offer a unique example of how people survive in drought and freezing landscapes through mobile livestock production systems. Their economic activity is restricted to the herding of yak *(Bos grunniens)*, 'dzos' (cow-yak hybrids) sheep *(Ovis aries)*, and goat (*Capra hircus*, pashmina type) in the plateaus and meadows of north Sikkim

Semi-domesticated Tibetan breed of yak at Gurudongmar, Tsholhamu Plateau, North Sikkim

Table 6: **Adaptability of management systems and their attributes of agrodiversity in the Sikkim Himalaya**

<table>
<tr><th>Management systems</th><th>Attributes of agrodiversity</th></tr>
<tr><td>Alpine/trans-Himalayan agropastoralism (>4,000 m)</td><td>• Yak, sheep, goat, dzo and horse grazing-based transhumance
• Rotational grazing, sharing of grazing pastures, seasonal movement of animals as per resource availability
• Forage production for lean season
• During non-snow seasons, communities grow potato, cabbage, leafy vegetables, barley, medicinal and aromatic plants in the Lhonak Valley (Muguthang area), Dambuchey-Bamzey area, Thanggu, and Tsongmo area
• A variety of animal products (alpine cheese, yak butter, meat, wool, traditional carpets, etc.)</td></tr>
<tr><td>Traditional agriculture practices (2,500–4,000 m)</td><td>• The diversity of crops and land use options for agricultural diversification shrinks in this altitudinal range
• Agropastoralism is the main livelihood option; medicinal plants, potato, cabbage, some oilseeds, and some beans/peas are grown in these areas
• Lachen, Lachung, and Upper Dzongu in North Sikkim; Phadachen, Zaluk, and the 15-mile Tsongmo area in East Sikkim; Ravang and Damthang area in South Sikkim; and Okhrey, Hiley, Yuksam, Uttarey, and Ribdi-Bharyang in West Sikkim are potential areas for vegetable and potato production</td></tr>
<tr><td>Traditional agriculture practices (300–2,500 m)</td><td>• The diversity of crops and associated species is high in this range
• A large number of landraces of rice, maize, buckwheat, beans, pulses, finger millets, yams and tubers, and ginger are grown in rotation
• Intercropping (mandarin-based, ginger-maize, rice-soybean, pulses-turmeric, maize-potato, and vegetable crops are practised as understorey crops)
• Incorporation and cultivation of high-value cash crops (e.g., large cardamom, Sikkim mandarin, ginger, and potato) in the different agroecological zones under integrated farming
• Green manuring and plantation of nitrogen-fixing species (e.g. Alnus nepalensis, Albizia spp., Erythrina spp., and legume crops).</td></tr>
<tr><td></td><td>Agroforestry systems
• Diversification of agroforestry systems such as farm-based agroforestry, forest-based agroforestry, and high-value cash crop-based agroforestry (large cardamom, Sikkim mandarin, ginger, broom-grass)
• Agroforestry ensures multiple production options and services</td></tr>
<tr><td>Land resource management</td><td>Organizational and management diversity
• Most of the cultivated land in mountainous areas is under diverse agroforestry systems to reduce soil erosion and ensure substantial production
• Terrace-based agriculture
• Multipurpose trees and fodder grasses like Alnus or broom grass (Thysanoleana agrostis) and napier grown on terrace risers
• Farmers are establishing shelter belts at the edges of agricultural farms to mitigate landslides and soil erosion and to maintain water recharge
• Conservation tillage with raised bunds at the terrace risers to prevent soil erosion and water runoff</td></tr>
<tr><td>Water resource management</td><td>• The springs and streams are conserved as the centre of sacred sites where the protective deity dwells, with traditional and customary rituals performed on auspicious days by different indigenous communities. They are managed to ensure water retention and protection within farm-based agroforestry for potable water and water for irrigation in villages
• Plantation of water retaining species in and around the springs developing the catchment</td></tr>
<tr><td>Livestock management</td><td>• Livestock grazing in the protected areas and reserve forest areas was banned by the Government of Sikkim during 2000–2005, and, thus, the farmers have initiated stall feeding of farm animals
• Farmers grow diverse tree and grass fodder species to feed farm animals
• Winter penning of livestock farms is done to ensure farm nutrients and reduce labour costs for manure carriage from the sheds
• Many farmers have converted cultivated farms into farm-based agroforestry for growing fodder species (tree/understorey grasses) due to labour shortage</td></tr>
</table>

(NBSAP 2002). Adapting to harsh climatic conditions over several centuries, 'Dzumsa' (a traditional, local self-governance institution in north Sikkim) and the Dokpas have indigenously regulated and managed the grazing regimes of the greater Himalayas and transition zones, and in trans-Himalayan meadows. The Dzumsa specifies dates for the movement of herds from one location to another based on the lunar calendar. The Dzumsa strongly controls rotational grazing, resource management, and regeneration. Irregular herding or shifting of livestock from one pasture to another outside of specified dates is unlawful, resulting into fines levied by the Dzumsa. Grazing regimes are chosen depending on the availability of forage in pasture areas, the number of grazing animals, snowfall events, and appropriate seasons (TMI India 2010).

As many as 23 Dokpa families manage 90% of the yak population in north Sikkim. Wool, meat, cheese, fat ('tsilu'), skin, and fur of yak and sheep are marketable products to exchange for cash (TMI India 2010). Since 1975, the Dokpa have been restricted to a limited patch of the vast Tso Lhamo, Lhonak, and Lashar plateaus. Earlier, herders were able to openly move across these valleys into the Tibet Autonomous Region of China and back through the Nyima La or Naku La pass, which is no longer possible. Over the last two decades, new generations of herders have started migrating to cities for better education and employment opportunities. This has resulted in a labour shortage for grazing, and yak and sheep owners have recently started employing paid herders.

The landscape in the alpine and trans-Himalayan region is habitat for several flagship species, including the snow leopard, eastern kiang, blue sheep, and Himalayan tahr. Pastoralism is widespread within the same wildlife habitats. Approximately 2,000 km^2 of land is under grazing, with 619 km^2 recorded under yak grazing across Sikkim and 166 km^2 recorded under sheep grazing in north and east Sikkim (TMI India 2010).

In Lachen, Thangu, Lhonak, and the Tso Lhamu Plateau, the collection of medicinal aromatic and dye plants (MADPs) and other non-timber forest products (NTFPs) is primarily regulated and controlled by the Lachen Dzumsa and the Muguthang Dzumsa (an extension of Lachen Dzumsa). The most often collected species of medicinal importance are *Ophiocordyceps sinensis, Nardostachys grandiflora, N. jatamansi, Podophyllum hexandrum, Rhododendron setosum, R. nivale, R. decipiens, R. anthopogon, Picrorhiza kurroa, Saussurea gossypiphora, Aconitum ferox, A. bisma, A. heterophylla, Meconopsis* spp., *Juniperus recurva, Ephedra gerardiana, Rheum nobile, Swertia multicaulis,* and *Rhodiola himalensis*. In the alpine region around Kupup-Gnathang, Yumthang-Yumesamdong, Dongkila, and Thengu-Byamzey, indigenous communities collect wild spinach, *Ophiocordyceps sinensis*, mushroom (*Agaricus* spp.), nettle (*Urtica* sp.), wild onion, ferns, *Orchis latifolia, Swertia multicaulis, S. chirayita, Saussurea gossypiphora, Rhodiola himalensis, Panax pseudogensing, Rhododendron setosum, R. lipidotum, R. anthopogon, Podophyllum hexandrum, Berginia ciliata, Aconitum* spp., *Artemisia vulgaris, Abies densa, Juniperus recurva, Cardamine macroflora,* and *Arisaema griffithii*.

Around Thangu and Muguthang (3,600–4,300 m), indigenous herders farm a variety of crops, including potatoes, radish, medicinal plants, oilseeds, and leafy vegetables from May to September, as the area remains under snow during the winter season. Herders grow a variety of grass fodder during the monsoon, which can be stored for lean seasons, including winter.

Mixed farming (subsistence agriculture) in the temperate zones (2,500–4,000 m)

In the temperate zone between 2,500 and 4,000 m, ethnic communities, mostly Lepcha, Bhutia, Manger, Limboo, and Sherpa, practise subsistence agriculture by cultivating a variety of crops and fruits. Barley, wheat, potato, cabbage, apple, maize, peas, beans, millets, and medicinal plants are the principal crops. Local communities in locations like Phadamchen, Dzongu, Sindrabong, Chunzom, Chongri village, Gnom, Tsong, Hungry, Dubdi, Labdang-Kurjee, Pokhari-Narkhola, Lachen, Zema, the Lachung Valley, Sindrabong village, Yambong, and Yuksam-Khyongtey collect a variety of NTFPs that have considerable importance in terms of food, medicine, fodder, or fibre. Many of these NTFPs are also sold in local markets. Commonly collected NTFPs are important species used by indigenous communities, including fern shoots, mushrooms (*Agaricus* spp.), bamboo shoots, nettle (*Urtica* spp.), wild onion, *Arisaema speciosum*, *Iris* spp. *Dioscorea* spp., *Heracleum wallichii*, 'majhito'(*Rubia manjith*), *Piper* spp., *Swertia chirata*, *Juniperus* spp., *Rhododendron thomsonii, R. setosum, R. anthopogon, Orchis latifolia, Edgeworthia gardneri, Picrorhiza* spp., *Aconitum* spp., *Nardostachys* spp., *Rheum austral, Berginia ciliata, Taxus wallichiana, Dactylorhiza hatagiria*, and *Astilbe rivularis* (Sharma and Dhakal 2011). Sharma (2016) has listed as many as 39 wild edible mushroom found in the agroforestry systems in Sikkim.

Traditional agroforestry systems in the subtropical to warm temperate zones (600–2,500 m)

Agroforestry is increasingly important in adaptation strategies that enhance resilience to the adverse impacts of rainfall variability, shifting weather patterns, reduced water availability, and soil erosion. Agrodiversity landscapes in Sikkim are dynamic. Traditional farming practices – agri-horti-pastoral systems, agri-silvi-pastoral systems, horti-silviculture systems, agri-horti-silvipastoral systems, livestock-based mixed farming, sericulture-based farming, and bamboo-based farming are designed and redesigned on a rotational basis according to situation, requirements, and time. These systems are broadly categorized as farm-based, forest-based, alder-large cardamom-based, forest-large cardamom-based, or *Albizia*-mix tree-mandarin-based agroforestry practices (Table 6).

Farm-based agroforestry

Under farm-based agroforestry, farmers manage multipurpose tree species for fodder, fuel, and timber within and around cultivable land and in terrace risers for soil stabilization, and they practise intercropping under tree canopies (Table 7). This agroforestry consists of 'sukha-bari' (rainfed fields) with maize-potato, maize-ginger, and other crops, and 'pani-khet' (wet rice-based fields) with rice followed by winter crops and vegetables. Management of fodder trees and food production is critical in maintaining livestock.

Forest-based agroforestry

Forest-based agroforestry is developed on parcels of farm-forest land that also have bamboo groves. On this land, farmers grow multipurpose trees and conserve timber species for basic construction and repair requirements of households (Table 8). For seasonal water regime management, control of excessive flooding and erosion, and the stabilization of slopes, agroforestry plots are developed along the ridges and furrows, vertically through the slopes, and horizontally between the slopes. Drainage along the slopes in traditional cultivated systems cuts across the farmland from higher to lower altitudes, thus providing a regular source of irrigation. The terraced, cultivated slopes are then protected from four sides by the agroforests.

Large cardamom-based agroforestry

Large cardamom-based agroforestry is divided into two categories: alder-based and forest-based. Large cardamom (*Amomum subulatum*) is a high-value, low-volume, low labour-intensive, and non-perishable cash crop cultivated in the Sikkim Himalaya, Bhutan, and eastern Nepal. Himalayan alder (*Alnus nepalensis*) is an excellent tree associate to large cardamom for its appropriate shade, N_2-fixation ability (155 kg per hectare per year), and nutrient rich litter (Sharma et al. 2009). With scientific understanding and adequate analysis of the community management system, the practice can be economically remunerative, environmentally sound, and ecologically sustainable (Sharma et al. 2002a, 2002b) with comparatively high carbon sequestration potential (Rai and Sharma 2004). This is an inventive self-reliant agroforestry system and an example of harnessing a mountain niche that also provides basic ecosystem services.

Table 7: **Agrodiversity consisting of major agroforestry practices in the Sikkim Himalaya**

Agroforestry systems	Agroforestry practices
Agri-horti-silvi pastoral system	**Farm-based agroforestry** • Multi-layered vegetation structure with fodder species, shrubs and under-storey crop based garden agroforestry, multiple intercropping in terraced productive zones and woody perennials and multipurpose species at the edges of farmland for soil erosion control, forming protective belts and windbreaks • Homesteads involving animal husbandry, traditional beekeeping, vegetable crops, protein banks, and underutilized and lesser known crops • Trees and ground shrubs/herbs or other agroforestry species such as *Thysanoleana* species for soil conservation
Agri-silvi-pastoral system	**Farm forest-based agroforestry** • Multipurpose trees species for fodder, fuel and timber and bamboo groves, and animal feed bank and for other productive needs • NTFPs and minor forest products, and medicinal plants or other plantation crops and pasture lands, water sources conservation • Soil conservation and reclamation
Horti-silviculture system	**High-value cash crop-based agroforestry** • Large cardamom-based agroforestry: Alnus-large cardamom and mixed tree species-based large cardamom • Ecologically adaptive and socially accepted multifunctional trees such as *Albizia* spp., *Alnus nepalensis* and mixed-tree species agroforestry and understorey of commercial cash crop large cardamom • Ground fodder and NTFPs, medicinal plants • Trees, shrubs and ground grasses for soil conservation • Sikkim mandarin-based agroforestry • Multilayer arrangement of fruit orchards and fodder trees, intercropping of understorey traditional crop varieties, potential crops, protein banks, yams, taros, etc. • Vegetable crops, traditional beekeeping, animal husbandry and trees for fodder in the appropriately designed terraces • Sikkim mandarin, multipurpose trees and N_2-fixing *Albizia* spp.

Table 8: **Multipurpose agroforestry tree species in the Sikkim Himalaya and their uses**

Scientific name (family)	Local name	Distribution (m)	Contrn./repairs agri. tools	Farm/ household use	Medicinal importance/ wild edibles
Artocarpus lackoocha (Moraceae)	Badar	300–1,500	T, TH	FD, FW	WE, AM, MMU, Edible fruits, fruits barks as MMU
Albizia stipulata (Mimosaceae)	Rato siris	300–1,600	T, HP	LC, FD	MMU
Albizia odoratissima (Mimosaceae)	Kurkur siris	300–1,600	T, HP	LC, FD	MMU
Albizia procera (Mimosaceae)	Seto siris	300–1,300	T, HP	LC, FD	MMU
Albizia lebbeck (Mimosaceae)	Harde siris	300–1,200	T, HP	LC, FD	MMU
Aegle marmelos (Rutaceae)	Bel	300–800	–	–	Edible fruit, MMU
Artocarpus integra (Moraceae)	Rukh katahar	300–1,500	TH,	FD, FW	Fruits, MMU
Bridelia retusa (Euphorbiaceae)	Gayo	300–1,600	HP	FW, FD	MMU
Exbucklandia populnea (Hamamelidaceae)	Pipli	800–2,200	T, HP	FW, FD	Leaves, bark as MMU
Bauhinia purpurea (Caesalpiniaceae)	Tanki	300–1,500	–	FD, FD, PK	Young flowers in pickles, flower, bark as MMU,
Bauhinia vahlii (Caesalpiniaceae)	Bhorlo	300–1,500	–	FD, FW Leaves in Ghooms*	Fruit as MMU Leaves for packing edibles
Bauhinia variegata (Caesalpiniaceae)	Seto koiralo	300–1,200	–	LC, FD	Flower buds in pickles, flower, buds, bark as MMU
Brassiopsis mitis (Araliaceae)	Chuletro	300–1,800	–	FW, FD	Bark and young buds as MMU
Citrus reticulata (Rutaceae)	Suntola	300–1,300	–	–	Edible fruit (HVC)
Celtis tetranda (Euphorbiaceae)	Khari	300–1,700	MHI, Bee hive	FD, FW	WE
Callicarpa arborea (Verbenaceae)	Guenlow	300–1,000	Yoke of plough, Dandee	FD, FW, LC	Bark as MMU
Cordia obliqua (Boraginaceae)	Bohori	300–800	–	FW, FD	Fruit and back as MMU
Ficus hispida (Moraceae)	Khasreto	300–1,300	–	FW, FD	WE, Fruit as MMU
Ficus semicordata var. *monata* (Moraceae)	Rai khanyu	300–1,700	–	FW, FD	WE, Fruit and bark as MMU
Ficus cunia (Moraceae)	Khasre Khanyu	300–1,500	–	FD, FW	WE, Fruit juice, leaves as MMU
Ficus nerifolia (Moraceae)	Dudhilo	1,000–2,200	–	FD, FW	WE, Fruti as MMU
Ficus auriculata (Moraceae)	Chillo pate Nebaro	500–1,900	–	FW, FD	WE, Fruit, young leaves as MMU
Ficus infectoria (Moraceae)	Kabro	300–1,500	–	FD, FW	WE, bark, leaves, flowers MMU
Ficus glomerata (Moraceae)	Dumri	300–1,500	–	FD, FW	WE, fruit and leaves as MMU
Ficus glaberrima (Moraceae)	Pakhri	300–1,200	HP	FW, FD	WE, bark and young leaves, fruits as MMU
Grewia vestita (Tiliaceae)	Syalphoshro	300–1,200	HP, MHI	FD, FW	WE, bark as fibre, fruit as MMU
Juglans regia (Juglandaceae)	Okhar	900–1,600	T, HP	FD	WE, Bark and leaves as MMU
Litsea polyantha (Lauraceae)	Kutmero	300–1,800	–	FW, FD	Bark as MMU
Mangifera indica (Anacardiaceae)	Aanp	300–1,500	HP, Bee hive	FD	Fruit
Moringa oleifera (Moringaceae)	Sajana	300–900	–	FD	Fruits edible, bark and roots as MMU
Morus alba (Moraceae)	Kimbu	300–1,200	T, HP, Bee hive	FW, FD	WE, MMU
Melia azadirach (Meliaceae)	Bakaiano	300–1,800	MHI	FW, HD	Entire plant as MMU
Pyrus pashia (Rosaceae)	Mehel	800–2,200	–	FD, FW	WE, Jam prepared from fruits, MMU
Prunus cerasoides (Rosaceae)	Painyu	300–2,000	HP	FD, FW	WE, Stem, bark, gnus as MMU
Rhus semialiata (Anacardiaceae)	Bhakmilo	300–1,900	–	FD	Fruits and gulls boiled to make traditional sauce, used as MMU

Stereospermum sauveolens (Bignoniaceae)	Padari	300–800	Bee hive	FD, FW	Roots and flowers as MMU
Abies webbiana (Pinaceae)	Gobrey sallo	1,700–4,600	T	—	MMU
Alnus nepalensis (Betulaceae)	Uttis	700–2,200	T, LC	FD	—
Anthocephalus chinensis (Rubiaceae)	Kadam	300–1,200	T	FW	MMU
Artocarpus faxinifolius (Moraceae)	Madaney	300–1,600	HP	FD	—
Bischofia javanica (Phyllanthaceae)	Kainjal	300–1,500	T	FD, FW	MMU
Bombax ceiba (Bombaceae)	Simal	300–1,100	T	FW, FD	MMU
Boehmeria regulosa (Urticaceae)	Darr	300–1,700	TH	FD, FW	Theki best to keep milk, curd and ghee
Castanopsis tribuloides (Fagaceae)	Musure katus	1,500–2,300	T, HP, LC	FW, FD	WE, MK
Castanopsis hystrix (Fagaceae)	Patle katus	1,500–2,400	T, HP, LC	FW, FD	WE, MK
Castanopsis indica (Fagaceae)	Dhalne katus	300–1,500	T, HP,	FW, FD	WE, bark as MMU
Choerospondias axillaris (Anacardaceae)	Lapsi	200–1,100	T, HP	FD	WE, MMU
Diploknema butyracea (Sapotaceae)	Chiuri	300–1,400	Bee hive, HP	FW, FD	WE, fruit, bark as MMU
Duabanga gradiflora (Sonnerataceae)	Lampatey	300–1,600	T, HP	FD, LC	–
Eleocarpus lanceafolius (Elaeocarpaceae)	Bhadrakse	900–1,600	—	FD	WE, Fruit as MMU
Engelhardtia spicata (Juglandaceae)	Mahuwa	200–1,600	T, HP	FD, FW	Dry flowers, bark as MMU
Erythrina arborescens (Fabaceae)	Faledo	300–1,700	T, HP	FD, FW	Leaves and bark as MMU
Ficus hookeriana (Moraceae)	Nebaro	600–2,000	—	FD, FW	WE, fruit as MMU
Ficus benghalensis (Moraceae)	Barr	300–1,600	T, HP	FD, FW, LC	WE, Fruit as MMU
Ficus elastica (Moraceae)	Labar	300–1,800	T, HP	FD, FW	WE, Bark, sap as MMU
Ficus cyrtophylla (Moraceae)	Kalo khasrey	300–1,800	—	FD	WE, Fruit as MMU
Garuga pinnata (Burseraceae)	Dabdabe	300–1,400	T, HP	FD, LC	Bark and flower as MMU
Gynocardia odorata (Flacourtiaceae)	Gantey	300–1,700	—	Oils edible	WE, Oils is edible and used as MMU
Acer campbeli (Aceraceae)	Kapasey	900–1,900	T, HP	FD	Fruit as MMU
Acer oblongum (Aceraceae)	Phirphirey	800–1,800	T, HP	FD	—
Juglans regia (Juglandaceae)	Okhar	500–1,500	T, HP	FD	WE, Fruit, Bark as MMU
Jambosa formosa (Myrtaceae)	Ambakey	300–1,300	MHI, LC	FD, FW	WE, bark, fruit as MMU
Jambosa kurzii (Myrtaceae)	Ambakey	300–1,300	MHI, LC	FD, FW	WE, bark, fruit as MMU
Litsea polyantha (Lauraceae)	Kutmiro	300–1,600	—	FD, FW	Bark as MMU
Mangifera sp. (Anacardiaceae)	Chuchey Aanp	300–1,500	HP	FD	WE, Fruit as MMU
Michelia champaca (Magnoliaceae)	Auley chanp	1,200–1,900	T	FD	Bark, Flower, roots MMU
Morus macroura (Moraceae)	Kimboo	300–1,400	T, HP, MHI	FW, FD	WE, bark, fruit as MMU
Oroxylum indicum (Begoniaceae)	Totalo	300–1,100	—	FD	Flower as vegetable, Bark, root, gnus, MMU
Purularia edulis (Santalaceae)	Amphi	400–1,500	Oils extracted from fruits	FD	WE, oils from fruit as MMU
Phyllanthus embilica (Euphorbiaceae)	Amla	300–1,500	—	FD	Fruits for pickles, Fruit and seeds MMU
Pandanus nepalensis (Padanaceae)	Tarica	300–1,700	—	—	WE, Fruit as MMU
Pterospermum acerifolium (Sterculiaceae)	Hatipailey	300–1,500	MHI	FD, FW, Leaves for Ghum	Root as MMU
Quercus lineata (Fagaceae)	Phalanth	300–1,000	HP	FW, FD, LC	WE, Fruit as MMU
Quercus lamellosa (Fagaceae)	Bajranth	800–1,800	T, HP	FW, FD, LC	WE, Fruit as MMU
Quercus fenestrata (Fagaceae)	Arkhaulo	800–2,000	T	FD, LC	WE, Fruit as MMU
Rhus insighnis (Anacardeceae)	Kaghbhalayo	300–2,000	—	FD	Poisonous causes blister, irritation

Schima wallichii (Theaceae)	Chilauney	300–900	HP, T, HP, Plough	FW	Bark juice MMU
Spondias pinnata (Anacardiaceae)	Amaro	300–900	—	FW, FD	WE, Fruit and bark as MMU
Terminalia bellerica (Combretaceae)	Barro	300–1,000	T, HP, AN	FW, FD	WE, Fruit, bark as MMU
Terminalia chebula (Comretaceae)	Harro	300–1,000	T, HP, AN, Plough	FW, FD	WE, Fruit in Ayurvedic preparation and MMU
Terminalia myriocarpa (Combretaceae)	Pani saaj	300–1,200	T, HP	FD	Bark as MMU
Acer oblongum (Aceraceae)	Phirphirey	1,000–3,000	T, HP, MHI	FD, FW	Flower as MMU
Betula edulis (Betulaceae)	Lekh saur	1,500–3,600	T, HP, LC	FW, FD	Bark and root as MMU
Beilschmiedia roxburghiana (Lauraceae)	Tarsing	500–1,700	T	FD	MMU
Cinnamomum impresinervium (Lauraceae)	Sisi	600–1,800	Leaves in tea	DW	WE, Leaves, Bark, root as MMU
Endospermum chinense (Euphorbiaceae)	Seti kath	500–1,900	—	FD, FW	Bark and flower as MMU
Engelhardtia acerifolia (Juglandaceae)	Auley Mahuwa	300–1,800	T, HP	FD, FW	Bark, flower as MMU
Ehretia wallichianiana (Boraginaceae)	Lekh bohori	700–2,000	—	FD, FW	Leaves, bark as MMU
Edgeworthia gardeneri (Thymelaceae)	Argeli	1,700–3,000	Fibre to make ropes	—	Lokta for local paper, bark as MMU
Ficus nemoralis (Moraceae)	Dudhilo	1,000–2,000	—	FW, FD	WE
Glochidion acuminatum (Euphorbiaceae)	Lati-kath	700–2,000	T, MHI	FD, FW	Flower and bark as MMU
Leucosceptrum canum (Lamiaceae)	Ghurpis	1,400–2,300	—	FD, FE	MMU
Lyonia ovalifolia (Ericaceae)	Angeri	500–1,800	—	FD	MMU (Poisonous plant)
Mechilus odoratissima (Lauraceae)	Kaulo	300–1,700	T, HP, MHI	FD	Fruit and Bark as MMU
Michelia excelsa (Magnoliaceae)	Mithey chanp	1,200–2,000	T, HP	FD	Flower as MMU
Michelia indica (magnoliaceae)	Auley chanp	900–1,800	T, HP	FD,	Flower as MMU
Macaranga pustulata	Malato	300–1,600	—	FD, FW	Root and bark as MMU
Mechilus edulis (Lauraceae)	Lapche kaulo	1,200–2,150	T,	FW, FD	WE, MK
Michelia champaca (Magnoliaceae)	Rani chanp	1,500–2,300	T, HP	FD	Flower as MMU
Ostodes paniculatus (Euphorbiaceae)	Bepari	300–1,200	LC	FD	Oils from fruits, MMU
Pittosporum nepaulense (Pittosporaceae)	Khorsaney	300–1,600	T, HP	FD	Fruit as MMU
Prunus nepalensis (Rosaseae)	Arupatey	300–1,500	—	FD, FW	WE, MMU
Quercus lamellosa (Fagaceae)	Buuk	1,400–3,000	T, HP	FD, FW	WE, Fruit as MMU
Quercus pachyphylla (Fagaceae)	Sugurey Katus	600–1,900	T, HP	FD, FW	WE, fruit as MMU
Rhododendron arboreum (Ericaceae)	Laligurans	1,500–3,300	—	FD	Flowers as MMU, Gurans wine is prepared
Symplocus theifolia (Symplocaceae)	Kharaney	600–1,800	HP	FW	Bark as MMU
Symplocos racemosa (Symplocaceae)	Kharaney	1,400–2,000	AN	FW	Bark as MMU
Sauraria unduana (Saurariaceae)	Rato gogoun	1,500–2,000	—	FW, FD	WE, Fruit and bark as MMU
Sauraria roxburghii (Saurariaceae)	Auley gogoun	1,200–1,600	—	FD, FW	WE, fruit and bark as MMU
Toona ciliata (Meliaceae)	Tooni	1,500–2,500	T, HP, MHI	FW	Bark, Flowers as MMU
Vibernum erubescens (Caprifoliaceae)	Asarey	1,400–2,300	AN	FD, FW	WE, MMU

MMU = multiple medicinal uses; FW = fuelwood; FD = fodder; T = timber; HP = poles for houses and livestock sheds; LC = leaves used for mulching and composts; TH = theki (milled pots for keeping curd, or churning pots); WE = wild edible; PK = flowers used as pickles; PA = plough ard; PF = Horizontal beam plough; TP = traditional plough; MK = marketable; HYV = high value cash crop; MHI = minor house implements; AN = plough handle ('anauu)

Albizia-mixed tree species-mandarin-based agroforestry

Albizia-mixed tree species-mandarin is another promising agroforestry system. Under this system, Sikkim mandarin, a high-value cash crop, is intercropped with maize, pulses, ginger, buckwheat, finger millet, pulses, oilseeds, taro, and yam on unirrigated 'bari' land. Sikkim mandarin and ginger are potential high-value, labour-intensive cash crops, while large cardamom cultivation is a low labour-intensive practice. *Albizia* is widely grown with other agroforestry trees in mandarin-based farming. Diverse crops and other associated tree species are maintained in the system for other subsistence requirements and socioecological benefits.

Terrace rice cultivation-based mixed farming in the subtropical zones (above 300 m)

The flat land riverbanks, traditionally called 'thang', and the typically terraced slopes in the lower hills contribute to the large genetic pool of traditional varieties of rice (Sharma et al. 2009). The landscape is a complex and highly evolved system, with high levels of socioeconomic and soioecological efficiency that illustrate the value of traditional ecological knowledge in the sustainable management of natural resources (Rai 2007). Some of the dry-land rice varieties (ghyya-dhan, takmaru, bhuindhan, marshi, etc.) and wet rice (gauria, krishna bhog, and mansure) have largely disappeared from the system, while irrigated rice varieties still cultivated (attey, timmurey, jhapaka, krishna bhog, bacchhi, nuniya, mansure, baghey-tulasi, kataka, champasari, sikrey, and taprey) are adapted to agroecological zones between 300 and 1,800 m.

Traditional varieties of rice (e.g., krishna bhog, nuniya, and kataka) are famous for their aroma, medicinal importance, and fine grain (Sharma and Liang 2006). Farmers grow a variety of pulses and beans along the raised bunds and terrace risers. During the winter, after rice is harvested, farmers grow maize, wheat, buckwheat, oilseeds, and vegetables. In between the terraced open rice fields and along the slopes, large cardamom-based and forest-based agroforestry systems are managed. The landscape mosaic consisting of open cropped compartments surrounded by multifunctional agroforestry is characteristic of unique agroecosystem management. This type of system, in addition, supports water conservation and flood control and provides nutrients and biomass to the farm and homestead. Under changing climatic conditions and cropping patterns, crop seasons have been gradually changing over the last two decades (Table 8).

Agrodiversity elements are supported by traditional irrigation practices, management regimes, and diversified cropping systems with diverse crops – including medicinal plants; wild edibles; and a large number of underutilized potential crops, semi-domesticated crops, and their wild relatives. Livestock are mostly stall-fed because of limited grazing pasture. In Sikkim, household land parcels are classified into different sections for establishing agroforestry, terraces for growing crops, and for resource allocation and utilization – primarily managed by farm families. Further, local and indignoeus farmers derive a variety of food and other associated products, as well as crop residue that is used for various purposes (Table 9).

Table 9: **Local traditional food products and the importantce of crop residue**

Important crops	Derived local and traditional products	Crop residue
Rice	Bhat, sel roti, gilo roti, chieura, khir, chamrey, pulao, dhakaney, murai, puwa, champa, bhati jhand, rakshi	• Paral stored and used to feed livestock during lean seasons • Gundri, gajara, pira • Making thatch roofs • Dhanko-bush for cattle feed after cooking
Maize	Bhat, hariyo makai, bhungrey roti, tawa roti, bhuteko makai, chieura, satu, phyaplo, khole	• Dhod stored and used to feed livestock during lean season • The dhod are sometimes collected and stored at the terrace edges to decompose
Wheat	Bhat, roti, pau roti, daliya, champa	• Naruwa is stored and used to feed livestock during lean season • Naruwa used for mushroom cultivation
Finger-millet	Roti, jaand, rakshi, kodako dhindo	• Naruwa is stored and used to feed livestock during lean season
Buckwheat	Roti, phuraula, dhindo	• Naruwa is used to feed livestock during winters immediately after harvest

Agrobiodiversity and Local Food Systems

Agrobiodiversity has an important role in local food systems as well as food and nutritional security in the Sikkim Himalaya. Different plant species are used for food, including cereals, millets, pulses, oilseeds, cultivated fruits and vegetables, spices, and wild edible fruits and vegetables. The indigenous and local communities of Sikkim have developed a large number of ethnic foods that represent their indigenous knowledge for using different plant- or animal-based products. Daily food composition primarily consists of 'dal-bhat-tarkari-chatni' (lentils-rice-vegetables-instantly prepared pickles) with the addition of 'mohi', 'dahi', or 'gheu' (buttermilk, yogurt, or butter). In addition to 12 different fermented products that are regularly consumed throughout the year by different ethnic communities in Sikkim, there are a number of traditional food products that are regularly consumed by different ethnic communities as a part of their menu. Tamang and Tamang (2014) have listed as many as 83 non-fermented ethnic foods from the Sikkim Himalaya, some of which have been commercialized and have become popular among different communities across the eastern Himalayas.

In addition to crops cultivated on local farms, a large number of wild plants are also used to prepare traditional food items. Some of the plants used are nettle (*Girardinia diversifolia*), 'chinday' (*Pentapanax leschnaultii*), greater yam (*Dioscorea alata*), 'koiralo' (*Bauhinia variegata*), 'halhalay' (*Rumex nepalensis*), 'kabra' (*Ficus virens*), 'kanney cheu' (*Pleurotus sajor-caju*), 'kukurdainu' (*Smilex zeylanica*), 'laharay timbur' (*Xanthoxylum oxyphyllum*), 'lapsi' (*Choerospondis axillaries*), 'nakima' (*Tupistra nutans*), 'patle sishnu' (*Urtica parviflora*), 'shimrayo' (*Rorippa nasturtium-aquaticum*), 'sauney ningro' (*Diplazium maximum*), 'sil timbur' (*Litsaea citrata*), and 'tite ningro' (*Diplanzium laxifrons*). The ethnic communities of Sikkim prepare a number of fermented and non-fermented foods including as many as 15 different local instant pickles depending upon the season (Table 10).

Table 10: **Traditional foods prepared by ethnic communities in the Sikkim Himalaya.**

Food diversity	Ingredient/crop used	Ethnic communities
Fermented food products		
Jaand	Fermented beverage made from finger millet, rice, wheat, cana, barley, and cassava root.	Bhutia, Lepcha, and Nepali ethnic communities comprising of Rai, Limboo, Tamang, Manger, Gurung, Sherpa, Majhi, Jogi, and Bhujel
Rakshi	Fermented product of finger millet, rice, wheat, and cana	Bhutia, Lepcha, and Nepali ethnic communities comprising of Rai, Limboo, Tamang, Sherpa, Manger, Gurung, Sherpa, Majhi, Jogi, and Bhujel
Gundruk	Fermented product prepared from green leaves of oil seeds (*Brassica campestris, B. juncea, .B. juncea* var. *rugosa*), or leaves of *Colocasia*	All Nepali ethnic communities, Bhutia, and Lepcha
Arakha hengmawa	Local wines made from millet and maize	Rai community
Sinki	Fermented product prepared from radish	All Nepali ethnic communities, Bhutia, Lepcha
Kinema	Fermented product prepared from soybean	Bhutia, Lepcha, and Nepali communities comprising of Rai, Limboo, Tamang, Manger, Gurung, and Sherpa
Meso	Fermented pickle prepared from bamboo shoots	Nepali, Bhutia, Lepcha
Mulako achar	Fermented pickle product prepared from radish	All Nepali ethnic communities, Bhutia, and Lepcha
Khalpi	Fermented pickle prepared from matured cucumber	All Nepali ethnic communities
Goyang	Fermented product prepared from Magane saag (*Cardamine macrophylla*)	Sherpa communities
Rota/selroti	Rice flour fermented overnight and deep fried forming a ring	Initially a traditional Nepali cuisine, now consumed by all ethnic communities
Chhurpi (hard)	Fermented dairy product prepared from cow/ yak milk	Dokpas, Bhutia, and Lepcha
Chhurpi (wet)	Fermented dairy product prepared from butter milk	Initially a traditional food item of Brahmin/Chettri, now consumed by all ethnic communities

Non-fermented food products		
Kwanti	Soup prepared from the sprouted seeds of a variety of legumes/pulses	Prepared and consumed by Newar communities
Lakhamari	Wheat flour and sugar	Prepared and consumed by Newar communities
Chatamari	Rice flour	Prepared and consumed by Newar communities
Chhwelaa	Boiled, cooked buffalo meat curry	Prepared and consumed by Newar communities
Kachila	Raw minced meat, mixed with spices and mustard oil	Prepared and consumed by Newar communities
Yomari	Steamed rice dumpling with spices	Prepared and consumed by Newar communities
Wa	Roasted pulses and soybean	Prepared and consumed by Newar
Sargemba	Blood sausage from yak or sheep's blood	Rai and Limboo community
Momu	Steamed dumpling prepared from wheat flour and meat/vegetable	Initially a Tibetan food, now consumed by all ethnic communities
Chambray	Rice fried with butter/ghee	All ethnic Nepali communities
Chiura	Beaten rice	Nepali, Bhutia, and Lepcha
Kodako dhindo	Cooked millet; porridge, staple food	Nepali, Bhutia, and Lepcha
Makaiko dhindo	Cooked corn; porridge, staple food	Nepali, Bhutia, and Lepcha
Kodako roti	Pancakes made out of millet flour	Nepali, Bhutia, and Lepcha
Phaparko roti	Pancakes made out of buckwheat flour	Nepali, Bhutia, and Lepcha
Phuraulah	Fried balls made out of buckwheat flour mixed with vegetable pieces	Brahmin, Chettri, and Newar
Dandeura	Fried balls made out of rice	Brahmin, Chettri, and Newar
Mesepra	Balls made out of pulses flour mixed with vegetable pieces, sundried and kept for lean season, used as vegetable	Brahmin, Chettri, and Newar
Phyaplo	Immature corn seeds crushed to make pancakes	Brahmin and Chettri
Khir	Rice cooked in milk	Brahmin, Chettri, and Newar
Dhulo achar	Powdered pickles made out of dried seeds of pumpkin, oilseeds, soybean, perilla, nigar, and sesame	Brahmin, Chettri, and Newar
Khichro	Pulses mixed with rice and cooked together; eaten at occasions	Brahmin and Chettri
Dhakaney	Rice fried in butter and cooked in milk	Brahmin, Chettri, and Newar
Phando	Fried pulses/soybean flour; eaten as curry	All Nepali communities
Khuzom	Wheat, millet, maize; baked on hot stone; staple food	Prepared and consumed by Lepcha communities
Sorongbeetuluk	Rice and nettle; cooked as porridge; staple food	Prepared and consumed by Lepcha communities
Ken-tsong	Maize flakes	Bhutia
Champa	Barley flour	Bhutia and Lepcha
Thukpa	Noodle soup	Tibetan and Bhutia
Phituk	Rice/barley flour, porridge with meat	Bhutia
Shyaphaley	Wheat flour meat; stiff, fried, mixed with meat	Bhutia
Tsampa	Ground roasted barley grains	Bhutia
Thukpa	Boiled stew/soup, mixed with minced meat	Bhutia and Lepcha
Wachipa	Rice cooked with burnt feather and meat of chicken	Rai community
Bungchipa	Rice cooked with a herb giving the taste of wachipa	Rai community
Zhero	Prepared from wheat flour, deep fried	Bhutia and Tamang
Zebre	Rice, butter, milk, molasses; sweetened rice rings	All Nepali ethnic communities

Cropping System and Soil Fertility Maintenance

Across the subtropical and warm, temperate agroclimatic zones, the maize-based farming system consists of maize as the main crop, followed by rice, finger millet, black gram, soybean, field pea, mustard, vegetables, ginger, turmeric, yams and other tuber crops. Similarly, under rice-based farming, rice is the main crop, followed by maize, mustard, field pea, potato, wheat, and vegetables as secondary crops (Table 11). Under Sikkim mandarin-based farming, intercropping with ginger, maize, wheat, buckwheat, mustard, field pea, beans, pulses, and a variety of vegetables is practised. Large cardamom-based agroforestry houses a diversity of multipurpose trees, such as *Alnus nepalensis, Albizia* spp., timber species, fodder/fuelwood species, and NTFPs grown as shade trees and for various social and ecological functions. Under farm-based agroforestry, maize, ginger, tubers, cowpea, vegetables, and pineapple are grown as main crops, while fruit trees and fodder plants (trees, shrubs, and grasses) are grown on the terrace edges.

Soil fertility in the farm is mostly maintained by adding farm manure (cow dung, goat dung, poultry waste, farmyard manure, or mixed compost made up of crop residues or weeds). Green manuring, mainly by growing legumes and other nitrogen-fixing (*Flemingia microphylla, Sesbania* spp., *Albizia* spp., *Erythrina arborescens, E. stricta, Alnus nepalensis*) or non-nitrogen-fixing species (*Adhatoda vasica, Artemisia vulgaris, Walsura trijuga, Sapium* spp., and *Eupatorium* sp.), is a traditional practice of farmers in the Sikkim Himalaya. The collection and use of forest litter, farm or kitchen waste, and, more recently, biofertilizers such as *Azolla* spp. is common for maintaining soil fertility on the farmland, which is in use in the farms in Community Development Blocks under Kalimpong Sub-Division of West Bengal state of India. Farmers enhance the farm production system by using tree foliage or weeds as mulch and fertilizer for food crops. Fast-growing, nitrogen-fixing species such as *Flemingia macrophylla, Leucaena leucocephala, Glyricidia sepium*, and *Tephrosia candida* are commonly used in traditional farming systems across northeast India (Malsawmdawngliani et al. 2012).

Buckwheat (mithe phapar) cultivation at Lingee-Payong village, South Sikkim

Table 11: **Cropping patterns in the Sikkim Himalaya.**

Physiographic region	Land type	Cropping system
<1,000 m (Tropical–sub-tropical)	Irrigated (khet) system during monsoon followed by winter crops	Rice+legumes – wheat/oilseeds/buckwheat Rice+legumes – vegetables/potato
	Non-irrigated (rain-fed)	Ginger+maize – potato Maize – buckwheat – fallow Maize – finger millet – wheat Maize – wheat/pulses/beans Maize+yams+colocasia/tapioca – cowpea+beans
1,000–2,000 m Warm Temperate	Irrigated (khet) system during monsoon followed by winter crops	Rice – potato/oilseeds/buckwheat Rice – barley – fallow Rice – maize – oilseeds Rice – vegetables/buckwheat
	Non-irrigated (rain-fed)	Buckwheat – wheat Potato – buckwheat/mixed vegetables Maize+ginger – mustard Maize+ginger– potato Maize+colocasia+yams–finger millet–fallow
>2,000–3,500 m Cold Temperate	Non-irrigated (rain-fed)	Buckwheat – wheat Potato – buckwheat Potato – peas + mixed vegetables
	Non-irrigated (rain-fed)	Potato – fallow Barley – fallow Maize – finger millet Radish/cabbage – fallow
3,500–4,300 m Alpine and Trans-Himalayas	Rain-fed (May–September)	Potato – fallow Oilseeds, leafy vegetables – fallow Medicinal plants – fallow

Farmers in the lower and middle hills manage steep slopes (30–45°), where they grow wet rice on the irrigable terraces and protein banks (pulses, cowpeas, and soybean) on the raised bunds, mainly during the monsoon season. During the spring and through the winter, dry crops such as maize, oilseeds, potato, finger millet, buckwheat, wheat, or a variety of vegetables or ginger, a highly nutrient exhaustive high-value cash crop, are grown. In other areas where water is unavailable for irrigation, indigenous farmers have designed dry terraces where they grow ginger, turmeric, maize, legumes, millet, colocasia, tapioca, and yam under multipurpose trees raised along the edges. Sloping land use systems are repositories of highly diverse cereals, tubers, bamboos, and agroforestry trees. During excessive rainfall, soil subsidence, mudslides, and land degradation are frequent in areas with tall terraces that are 3–6 m in height.

The repair and maintenance of the terrace land use system is labour intensive, and demands that farmers develop comprehensive farm budgeting. Expert farmers have advanced skills and traditional ecological knowledge for identifying ideal and feasible measures that can be adopted using local resources to effectively repair and manage the damages. The effect of random landslides and flooding can increase the disparities between the rich and poor owing to their differential adaptive and management capabilities (Johnson et al. 1982).

Soils in Agroecosystems

Proximity to the Bay of Bengal and direct exposure to the southwest monsoon make this region the most humid part of the Himalayas. Sikkim enjoys a wide range of climate, physiography, geology, and vegetation, which also influences the formation of different kinds of soils. The hills of Sikkim mainly consist of gneissose and half-schistose rocks, producing generally poor and shallow brown soils. The soil is coarse, with large concentrations of iron oxide, and ranges from neutral to acidic, making it deficient in mineral nutrients. This type of soil tends to support evergreen and deciduous forests. The rocks consist of phyllites and schists, which are much younger in age and highly susceptible to weathering and erosion. This, combined with the state's heavy rainfall, causes extensive soil erosion and the loss of soil nutrients through leaching. The soils of Sikkim belong to three orders, seven suborders, 12 great groups, and 26 subgroups. It is observed that Inceptisols are dominant (42.84%), followed by Entisols and Mollisols occupying 42.52% and 14.64%, respectively (Das et al. 1996; FEWMD 2007).

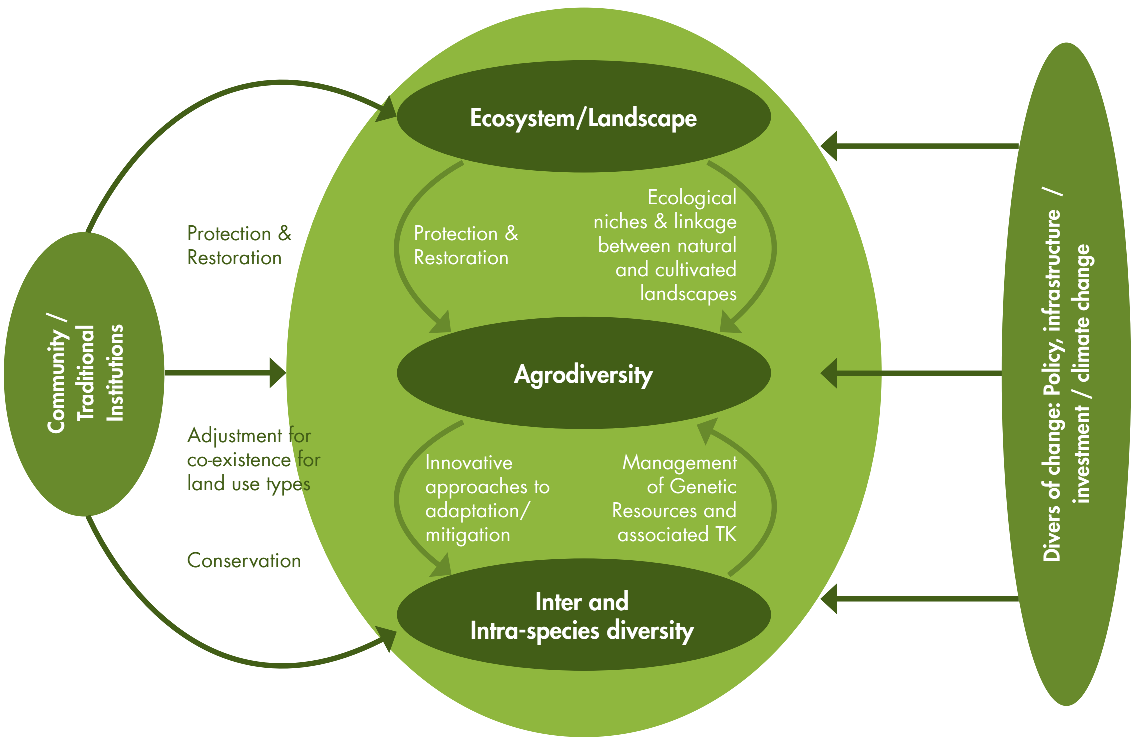
An amalgamation of conditions under the influence of heavy rains has generated soils that are moderately to strongly acidic in reaction; have low exchangeable bases; are rich in organic matter (Avasthe and Avasthe 1996); are high in available zinc, copper, iron, and manganese contents; and are deficient in available boron and molybdenum (Avasthe and Avasthe 1995). Soils also reveal considerable fixations of applied phosphorus. These conditions do not encourage normal crop growth without the use of appropriate amendments to overcome soil acidity and obtain response from the applied nutrients.

Agrodiversity and Forest Ecosystems

In the agricultural landscapes of the Sikkim Himalaya, the resources and services of natural forests and cultivated areas complement each other under an integrated management system. Under rotational agroforestry systems, it is sometimes difficult to differentiate between cultivated and natural landscapes. On cultivated fields, where crops are planted, wild species are also recruited and tended. Various forms of forests and individual trees, though not planted, are cared for, managed, and used for food, fuel, medicine, timber, and various other necessities. Thus, agrodiversity exists between and within natural and cultivated systems, and their complementarity supports agrobiodiversity for the protection, maintenance, restoration, and conservation of species and genetic diversity in a number of ecosystems (Figure 1).

Natural forests (wildlife sanctuaries, national parks, reserve forests, etc.) and large cardamom-based or forest-based agroforestry systems provide services essential for the resilience of cultivated areas, including erosion control, microclimate regulation, pest regulation, and pollination. NTFPs grown within the agroforestry systems and in the natural forest areas adjacent to cultivated systems provide alternative sources of food and income during periods of crop failure, low productivity, or excessive drought and unfavourable weather conditions. The indigenous communities harvest wild vegetables, fruit, medicinal plants, tubers, and other edibles from the forest during the year, especially when they are facing food scarcity.

Figure 1: **An ecosystem approach for dynamics of agrodiversity adaptation and drivers of change in the Sikkim Himalaya**



A woman seed saver showing a variety of seeds preserved above the fire place, Lingee, South Sikkim

The diverse multipurpose species grown in agroforestry systems or naturally growing in forest areas are able to tolerate wind, high temperatures, and drought and are becoming increasingly important to communities. As large cardamom in the eastern Himalayan region has been declining over the years, farmers have adopted the rotational farming system by re-establishing agroforestry practices with broom grass, medicinal plants, fodder, timber, fruit trees, or alder to rejuvenate soil fertility, generate income, and build ecosystem resilience.

Role of Women in Agrobiodiversity Conservation

Women are the custodians of traditional ecological knowledge and agrobiodiversity across the Himalayas. Women, more so than men, are concerned with the protection and conservation of agrobiodiversity, adaptive varieties that are ecologically suitable to different land use types, seed saving, and sharing among families in a community. Women play a considerable role in agrobiodiversity management for seed selection, preservation, exchange, and cultivation, and in making decisions on marginal farms.

Mountain women are highly knowledgeable about seed preservation and the parts of a farm under different types of land use categories where a given variety can perform better. For example, 'kholyang' is a type of field with a water source and water available for irrigation, so farmers would cultivate a type of paddy that requires more water. Women in villages have been promoting the cultivation of indigenous roots and tuber crops, organic agriculture, integrated pest management, and seed bank establishment at the household level. Women groups are also involved in ecosystem protection, restoration, and, above all, decision making. As repositories of knowledge, women have helped maintain the resilience of traditional and local food systems through a strategy of diversification within the landscape and agricultural system or farm (Dhakal 2012).

In situ and Ex situ Conservation

In situ, or on-farm, conservation of agrobiodiversity on cultivated farms is the only option available in the Sikkim Himalaya, and is primarily passed down through generations of indigenous farmers. On-farm conservation is a highly dynamic form of management of plant and animal genetic resources that allows the processes of both natural and human selections to continue to function in agro- and forest ecosystems. Ex situ efforts to conserve and manage the gene pools through seed banks, cryopreservation, DNA storage, and pollen storage involve advanced technologies require well-developed facilities (storage, laboratories, and information) that are yet to be established in the eastern Himalayan region. The Convention on Biological Diversity (CBD) views in situ and ex situ conservation as complementary; however, technology extension for ex situ conservation is lacking in the region. There is a need to establish gene banks in the Sikkim Himalaya and germplasm collections in the region's community centres, without which there will continue to be constraints to sustaining ex situ genetic resources. Improvements to both in situ and ex situ conservation of plant genetic resources for food and agriculture are necessary to maintain a high level of plant genetic diversity, which will support sustainable agricultural development in the region.

Homesteads

A homestead in a marginal farm in Sikkim consists of organic production systems including cereals (rice, maize, and wheat) and pseudocereals (sorghum, rye, millet, buckwheat, amaranths, and chenopods), legumes (horse gram, beans, pulses, and soybean), oilseeds (rapeseed, mustard, and niger), vegetables (leafy vegetables, coriander, spices, cucurbits, and yams), fruits and nuts (banana, jackfruit, figs, litchi, tamarind, guava, pineapple, peach, pear, plum), medicinal or aromatic plants, roots and tubers, and multipurpose trees depending on land availability. The size of a household homestead ranges from 0.2 to 2 ha. A large diversity of useful crops (60 to 75 species recorded) makes homesteads a place for germplasm conservation (Sharma 2012). About 40–70% of the total landholdings in Sikkim consist of homesteads on marginal farms, which provide more than 50–80% of household requirements. Homesteads are traditional sources of food and nutrition and are important contributors to food security and livelihood of farming communities. Diversification of crops is a traditional practice of the ethnic communities and is critical for the sustenance of marginal households during environmental uncertainty. The crops grown in homesteads are consumed for subsistence needs, and the surplus is sold in the nearby 'haats', or local weekly markets. Homesteads are the basic units of agrobiodiversity and the custodians of seed banks of a large number of horticultural/fruit/tuber crops, and they often provide significant economic benefits to marginal farmers.

Homesteads are supported by livestock rearing, which is closely related to the on-farm management of agrobiodiversity. Livestock provide a significant share in terms of labour, manure for the field, milk, meat, and wool. Production of manure (dung and kitchen waste) in the marginal household range from 5–12 tonnes per year. Soil fertility is mostly maintained through livestock-based manure and farmyard manure. More than 80% of the farmers have local livestock breeds.

Thus, homesteads in the Sikkim Himalaya are dynamic production systems where farmers make changes every season or year. Their contribution to conservation ensures the maintenance of adapted materials, which provide

A typical home-garden at Sumik-Linzey, East Sikkim

direct benefits to the owners and users of homestead products. The genetic diversity maintained is part of this contribution. Homesteads also help conserve biodiversity at ecosystem, inter-species, and intra-species or genetic levels. They provide complex, multilayered environments in which farmers can maintain large numbers of useful plant or animal species over many years. They may also provide a basis for the in situ maintenance of significant amounts of intra-species (genetic) diversity of useful species.

Maintenance of agroecosystem diversity and genetic diversity in homesteads depend on farmer management, environmental characteristics of the garden, and species biology. The amount and distribution of the genetic diversity of different characters (e.g., morphological, biochemical, or molecular) within and between farms also vary according to the characters measured and the ways in which each is affected by farmer management, environment, and species biology (Eyzaguirre and Watson 2001). Understanding the ways in which farmers manage planting materials, maintain identifiable populations and varieties, and exchange or mix materials will be especially important for analysing and understanding the dynamics of agrodiversity.

Pollinator Diversity: Status and Promotion

The most important pollinators in the forests and agroecosystems of the Sikkim Himalaya are bees, butterflies, wasps, bats, beetles, and rodents. Among the different types of pollinators recorded, the most common and effective pollinators belong to the groups Hymenoptera (bees and wasps) and Lepidoptera (butterflies and moths) (Singh et al. 2011). The native honeybees *Apis cerana* subsp. *cerana, A. cerana* subsp. *himalaya*, *A. dorsata*, *A. laboriosa,* the relatively uncommon and threatened *A. florea* ('kathyauree'), and stingless bees *Trigona* sp. ('putka') are potential pollinators for almost all cereal crops, pulses, fruit trees, cash crops, and agroforestry/ forest species occurring in the region. Other important pollinators are bumblebees (*Bombus haemorrhoidalis, B. braviceps), Megachile lanata, Episyrphus balteatus (hover fly), Macroglossum stellatarum* (hawk moth), and *Aethopyga siparaja* (crimson sunbird), which are the most effective pollinators for large cardamom (Sinu et al. 2011) and other farm fruits and crops. Deka et al. (2011) reported that two bumblebees, *Bombus haemorrhoidalis* and *B. breviceps*, are predominant pollinators of large cardamom.

Trigona (putka) bees at their hive entrance. Putka honey is expensive and used as medicine

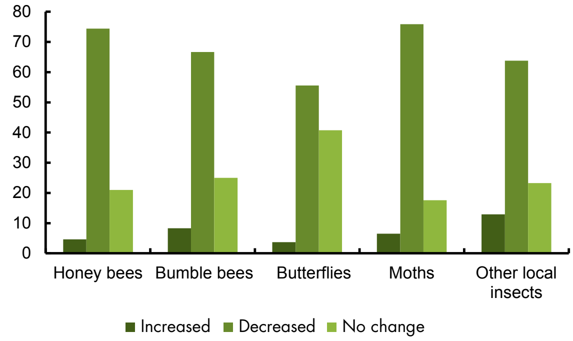
A bumblebee pollinating large cardamom flowers

The agroecosystems of the Sikkim Himalaya bestow great potential for pollinator species of birds and butterflies. Birds and butterflies are considered bioindicators and are used as surrogate taxa to predict the health of an ecosystem (Kremen 1992). Nearly 50% of the total 1,400 butterflies recorded on the Indian subcontinent by Haribal (1992) are found in Sikkim. Acharya and Sharma (2012) have identified 689 butterfly species, 1,500 moth species, and 574 bird species (45% of the total bird species found on the Indian subcontinent) from Sikkim. In a study undertaken by TMI India, a total of 125 species (22% of the total avifauna reported from Sikkim) have been recorded in large cardamom-based agroforestry systems and 211 in Sikkim mandarin and farm-based systems (TMI India 2015).

For centuries, mountain communities have domesticated pollinators to benefit their agricultural crops. Beekeeping ('mauri palan', or 'putka palan') is an integral part of the traditional farming systems of Sikkim and is important to people's socioeconomic, cultural, agroecological, and spiritual lives (Table 12). Honey collection is still practised in some remote villages, especially in forested areas and near cliffs. Local and indigenous farmers keep native species of honeybees, mostly *Apis cerana* in log hives made from local wood, which are mostly hung against walls of houses. A few households also keep bees in wall hives. Beekeeping brings additional income to households, and honey can be sold for USD 15 per kilogramme for honeybee honey and USD 112 per kilogramme for putka honey.

As a result of climate change, indigenous farmers of the Sikkim Himalaya have suffered a tremendous decline in the number of pollinator insects (Figure 2). Similarly, large cardamom growers have confirmed that rising temperatures, long dry spells, and fluctuating rainfall patterns have transformed or destroyed insect microhabitats, especially those of pollinator species, and have altered the breeding patterns and privacy of insects (Sharma 2013; Partap et al. 2014). It is widely believed that decreases in the population of insect pollinators in the Sikkim Himalaya is due to a variety of factors including the excessive promotion of polyhouses in agricultural farms; changes in cropping patterns; land use changes; unregulated development activities such as road construction, building construction, and hydropower projects; pollution; temperature fluctuation; and an accumulation of dust particles in the air.

Figure 2: **Peoples' perception (%) of the current status of different potential pollinator species in Sikkim Himalayan agroecosystems (n=200)**



A large number of subtropical and temperate fruits (mandarin, peach, plum, pear, guava, banana, etc.), high-value cash crops (large cardamom), oilseeds (rapeseed and mustard), pulses and beans ('kalo dal', 'pahenlo dal', 'singtamey simbi'), vegetables (squash, chilies, radish, etc.), and lesser known crops (buckwheat, NTFPs) are either dependent on or benefited by pollinator species. Pollinator species contribute to sustainable agriculture in the region, and seed production for diverse crops is only possible when pollinator species are conserved in cultivated systems. The Sikkim Himalayan agriculture systems are purely traditional and organic by default. The Government of Sikkim has declared that farming in the state shall be made fully organic by 2015 (Sharma and Acharya 2013). Application of pesticides, insecticides, and inorganic fertilizers for crop prodution has been reduced by more than

Table 12: **Values associated with beekeeping in the agrodiversity rich traditional farming systems of the Sikkim Himalaya**

Aspects	Socioeconomic/ecological values
Social	• Honey is used as medicine for various ailments, and usually bartered with neighbours to help cure illness and injuries • Bartering with neighbours and local shopkeepers in exchange for seeds, household/food items, and farm labour is still in practice • Offered to guests/relatives
Religious and spiritual	• Honey is used during religious rites and festivals by the tribal communities • It is offered to the local deities
Environmental	• Honeybees are important pollinators for crops, vegetables, trees, and fruits in the farm • They are the mediators for gene flow and agents for creating genetic diversity • Indicator for ecosystem health • Support agriculture production systems
Health and medicinal	• Honey is used as medicine during fever, pneumonia, cough/cold, body ache, and joint pain • Honey is given to pregnant women, weak and elderly people as a rich nutrient supplement • Applied on wounds for quick recovery • Used as a medicinal tonic, energizer, and appetizer

Source: Partap et al (2014)

A foraging honeybee (*Apis cerana*) pollinating large cardamom flower

90%, except for in floriculture, which is another flourishing economic activity in Sikkim. As observed by indigenous farmers, the promotion of plastic-based agriculture has led to a decline in pollinator species.

Beekeeping with the indigenous honey bee *Apis cerena* is a potential rural household industry. It is a low-cost enterprise and can be a subsidiary income source for marginal households. Over the last ten years, the Horticulture Department, Government of Sikkim, has distributed around 10,000 movable bee boxes to farmers at subsidized rates to improve beekeeping in the state. Over 4,000 farmers have been trained in practical and theoretical aspects of beekeeping since 2009 (Annual Reports 2009–2012).

The rich agrobiodiversity in the Sikkim Himalayan agricultural system is directly dependent on pollinator species. The people's perception have revealed that pollinator species are declining in mountain agroecosystems (Figure 2). The declining state of the pollinator population will have serious consequences for crop productivity. There is need for more research and development work on pollinator biology, the nature and dynamics of pollination, and innovative methods for climate adaptation. Subsequently, the situation can be revived by developing a strong policy with a strategic action plan for the conservation of pollinator species in the region, followed by multistakeholder involvement.

Initiatives for the Popularization of Sikkim Himalayan Agriculture

GIAHS initiative

In 2002, the FAO started an initiative for the dynamic conservation of Globally Important Agricultural Heritage Systems (GIAHS). The GIAHS initiative promotes public understanding, awareness, and national and international recognition of heritage agricultural systems. Sikkim Himalayan agriculture systems are now recognized as candidate sites of the GIAHS initiative. This initiative has recognized Sikkim Himalayan agriculture as a remarkable agroecosystem, which will contribute to validation of the region's traditional farming systems and the associated traditional ecological knowledge from the regional to global level (Sharma et al. 2009; GIAHS 2007).

A proposal for recognition of Sikkim Himalayan agriculture systems by the GIAHS was developed in 2007 by the United Nations University, Tokyo. The proposal was endorsed by the Government of Sikkim through expert consultation with ICIMOD and was submitted to the GIAHS. In 2009 the Sikkim Himalayan agriculture system was recognized as a candidate site of GIAHS. However, formal recognition under the GIAHS through proper official procedure is still pending.

Organic Mission

In 2003, the Government of Sikkim conceptualized the idea of turning traditional agriculture organic by 2015. This new approach to agriculture was aimed to create integrated and environmentally and economically sustainable production systems that promote soil, plant, animal, and environmental health and wellbeing. According to the government's "Concept Paper and Action Plan 2003", the new policy on organic farming aims to promote the technically sound, economically viable, environmentally non-degrading, and soically acceptable use of natural resources – land, water, and genetic – for sustainable agricultural development.

With a view of transforming Sikkim into a 'fully organic state', which entails converting 74,313 ha of land according to organic principals and practices, the Sikkim State Organic Board was formed in 2003. A policy ban on chemical fertilizers, insecticides, and pesticides was enforced the same year. The Government of Sikkim eventually launched the Sikkim Organic Mission in 2010 to benefit 62,000 farming families who own an average of 1.9 ha of farmland (FSADD and HCCDD 2012).

Since its inception in 2010, the Sikkim Organic Mission has steadily accelerated the certification, marketing, human resource development, and sustenance of organic enterprises. A total of 4,607 ha of farmland were certified as organic in Sikkim before 2014. During 2010/2011 and 2011/2012, around 38,000 ha were outsourced to different service providers for the development of an internal control system and simultaneous certification. As of January 2016, 74,313 hectares (almost all the cultivated land available) have been certified organic and Sikkim is officially and fully a organic farming state of India. Over the years, effective micro-organism (EM) composting, EM Bokashi, EM fermented plant extract, and EM-5 have been demonstrated in 396 biovillages as ways to enrich soil fertility (HCCDD Annual Report 2009, 2010, 2011, 2012).

Land Use Systems and Food Production

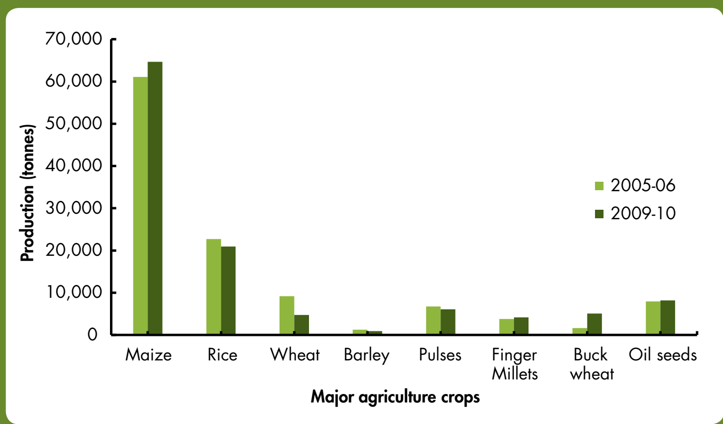
Land use patterns

Eighty-one per cent of Sikkim's total geographical area is under the administrative control of the Forest, Environment, and Wildlife Management Department. The land available for cultivation in Sikkim was 12.3% in 1990/1991, including current and fallow land. In 2010, the net cultivated area of Sikkim remained roughly around 79,000 ha (11.1%), including large cardamom plantations (Table 13). Because the state of Sikkim doesn't have a land use policy, agricultural land is being rapidly transformed into non-agricultural land, primarily for development activities like the establishment of pharmaceutical industries and hydropower projects (Sharma and Acharya 2013). Thus the land available for farming agriculture is only around 8% in the state.

Crop production

The agriculture crop production in Sikkim significantly increased from 1975/1976 (49,050 tonnes) to 2009/2010 (115,770 tonnes), with a maximum share of maize (55.88%), followed by rice (18.08%), oilseeds (7.08%), and the remaining share taken by wheat, barley, pulses, finger millet, and buckwheat (DESME 2002; 2004–05; 2005–06; 2009–2010; FSADD 2010; Dewan 2011). Maize, finger millet, oilseeds, and buckwheat production slightly increased in 2009/2010, while the production of other crops decreased compared to 2005/2006 (Sharma and Acharya 2013) (Figure 3).

Figure 3: **Agricultural crop production in Sikkim**



(Data source: FSADD 2010)

Table 13: **Land use pattern of Sikkim from 1976–2001 (Sharma and Acharya 2013)**

Classification	1976–77		1980–81		1990–91		1995–96		2000–01	
	Hectares	(%)*	Hectares	(%)*	Hectares	(%)*	Hectares	(%)*	Hectares	(%)*
Net area sown	64,927	9.15	78,381	11.04	63,254	8.91	62,043	8.74	63,250	8.91
Area under current fallow	501	0.071	4,428	0.62	3,906	0.55	5,078	0.72	3,910	0.55
Other uncultivated area excluding fallow land	4,925	0.69	4,560	0.64	10,830	1.53	9,807	1.38	10,830	1.53
Fallow other than current fallow	944	0.13	9,474	1.34	9,204	1.30	29,573	4.17	9,200	1.30
Cultivable wasteland	1,153	0.16	681	0.10	9,807	1.38	2,389	0.34	9,810	1.38
Land not available for cultivation	6,613	0.93	11,604	1.64	14,300	2.02	12,494	1.76	14,300	2.01
Total operated land	79,062	11.14	109,068	15.37	111,302	15.69	121,384	17.11	111,300	15.68
Forest area	285,210	40.19	256,533	36.15	298,000	42.00	312,700	44.07	265,000	37.34

*Indicates the percentage distribution of different land use heads.
Note: The total geographical area of Sikkim is 709,600 hectares.
Source: FSADD 2010.

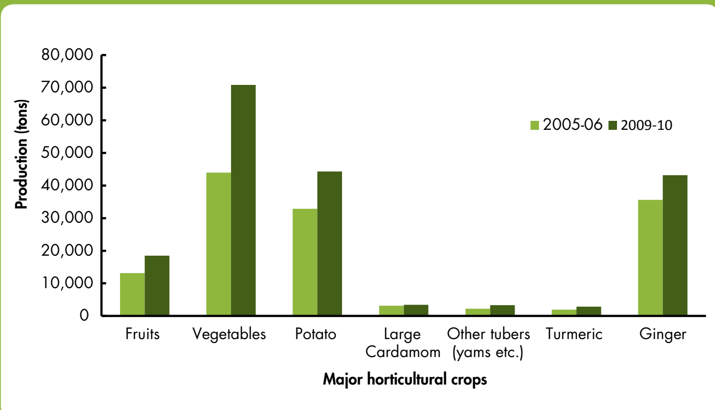
Turmeric cultivation at Bering Busty, East Sikkim

Similarly, horticultural crop production also increased significantly from 1975/1976 (1,900 tonnes) to 2009/2010 (186,413 tonnes) with a maximum share of vegetables (38.01%) followed by potato (23.76%) and ginger (23.17%), and the remaining share taken by large cardamom, tubers, turmeric, and fruits (DESME 2002; 2006; 2004–05, b; 2005–06; 2009-2010; FSADD 2010; Dewan 2011). The production of major horticultural crops increased from 2005/2006 to 2009/2010, except for large cardamom, which did not show a significant increase (Sharma and Acharya 2013) (Figure 4).

Crop productivity

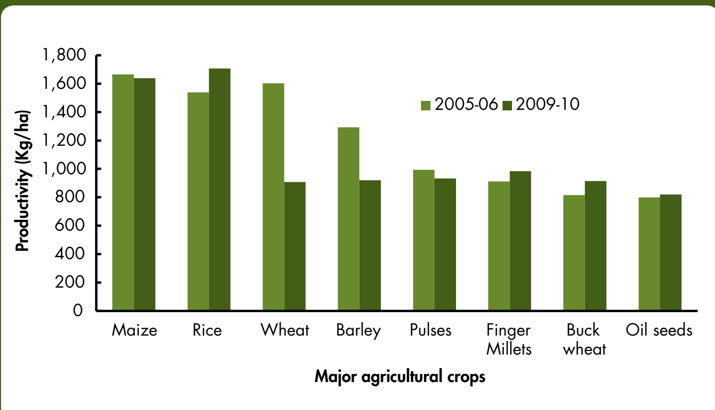
Crop productivity (production per unit area) in Sikkim was far below the national and regional averages for major field crops. The productivity of rice and maize increased two to three times between 1975/1976 and 2009/2010, but still remains below the national average. The productivity of barley, pulses, and finger millets showed lower productivity over national averages. The productivity of maize in 2009/2010 was 1,638 kg per hectare, followed by rice (1,706 kg per hectare), while the productivity of other crops such as wheat, barley, pulses, finger millet, buckwheat, and oilseeds ranged between 800 and 900 kg per hectare (Figure 5) (DESME 2002; 2004–05; 2005–06; 2009–2010; FSADD 2010; Dewan 2011).

Figure 4: **Horticultural crop production in Sikkim**



(Data source: DESME 2002; 2004-05; 2005-06; 2009-2010; FSADD, 2009-10)

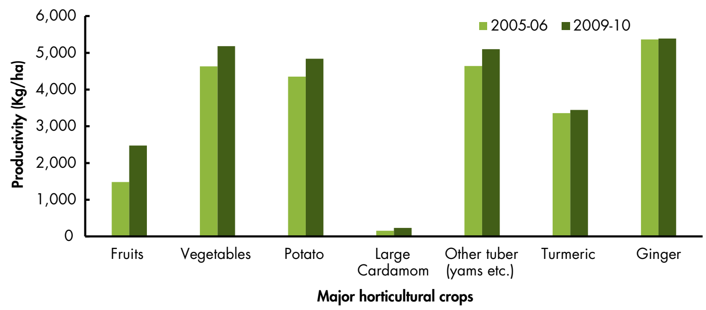
Figure 5: **Agricultural crop productivity in Sikkim**



(Data source: Sikkim: The People's Vision, Government of Sikkim 2001; Annual Progress Report 2009-10 Food Security and Agriculture Development Department, Government of Sikkim).

It is interesting to note that there was insignificant variation in the productivity of horticultural crops (except tubers), which was recorded below the national average (Figure 6). The productivity of subtropical fruits such as guava, papaya, litchi, avocado and temperate fruits such as pear, peach, plum, and Lachung apples was 9,886 tonnes, making total fruit production in the state 13,136 tonnes during 2005/2006. The productivity of horticultural crops like ginger was 5,390 kg per hectare, followed by vegetables (5,180 kg per hectare), tubers (5,101 kg per hectare), and potato (4,840 kg per hectare). Sikkim is still unable to meet the demand for fruit domestically, and must import fruits from other areas (Sharma and Acharya 2013).

Figure 6: **Horticulture crop productivity in Sikkim**



Data source: DESME 2002; 2006-07; Sikkim: The People's Vision, Government of Sikkim 2001; Annual Progress Report 2009-10, Horticulture and Cash Crop Development Department, Government of Sikkim.

Among all the crops in Sikkim, maize production was highest until 2010. Crop production consistently showed significant increases from 1975 through 2009/2010. The production of maize and rice doubled over the 35 years after 1975, whereas the production of wheat, pulses, buckwheat, and oilseeds showed manifold increases. However, considering the resident and floating population in the state in 2009/2010, there was a deficit of nearly 72,000 tonnes of food grains, 12,500 tonnes of pulses, and 3,500 tonnes of oilseeds (Sharma and Acharya 2013).

Landholdings

In 1971, the per capita landholding in Sikkim was 0.31 ha. This figure decreased to 0.27 ha in 1981, 0.17 ha in 1991, and 0.12 ha in 2001, resulting in a decline of 61.29% in 25 years (Table 14). The distribution of landholdings in Sikkim is skewed. In 1991, the lowest strata of landholders – marginal farmers representing about 50% of the population – held only 10.3% of the total operational land area. Marginal farmers in East Sikkim had the highest concentration of landholdings in terms of the number (56%) and area (12.8%). In contrast, only 2.3% of farmers had landholdings greater than 10 ha; however, these farmers owned 20.2% of the operational area. North Sikkim had the highest number of large farmers, who, with 5% of the operational holdings, owned 30% of the operational land within the district. The per capita land availability of different types of land also declined rapidly over time as a consequence of mounting population pressure and the conversion of agricultural land for non-agricultural purposes (Table 13).

Farmers' landholdings have decreased rapidly with increasing fragmentation of families and land conversion and acquisitions by the government. As a result, by 2005/2006, around 91% of households had less than 1 ha of land. Only 6% of households had up to 2 ha of land. Around 0.6% of households had 8 ha of land, and around 0.1% had 25 ha of land (Table 14). This trend is rapidly increasing.

Table 14: **Number of households with different categories of land in Sikkim (2005-2006)**

Land category	<1 ha	Marginal up to 2 ha	2 to 4 ha	Up to 8.5 ha	>25 ha
Barren land	8,808	580	170	52	22
Dry field	55,926	4,085	1,227	360	80
Rice field	6,053	271	137	50	-
Land under floriculture	556	10	05	01	04
Orchard land	1,315	26	14	07	02
Large cardamom	14,476	1,060	321	143	37
Land available for other purposes	187	17	05	04	-
Total	87,321	6,049	1,879	617	145

Source: Calculated from DESME 2006; 2005-06

High yielding varieties

Traditionally, Sikkim has had rich local germplasms of arable crops. With the advent of cash-based agriculture, new crop varities, including high yielding varities, were introduced to the traditional farming systems of Sikkim to increase crop productivity. Between 1975/1976 and 2009/2010, the area coverage of HYVs increased significantly (Table 15). Initially, HYVs of rice, wheat, and maize were brought to farmers. During the 1990s and 2000s, HYVs of turmeric, oilseeds, and barley were introduced. HYVs of buckwheat and millet were also introduced in Sikkim; however, they were not accepted or adopted by farmers. With the advent of an organic agricultural policy in Sikkim, local germplasms have slowly started gaining importance, as they contain the most suitable varieties/ landraces/strains for the region's low input conditions.

Table 15: **Coverage of high yielding varieties (HYVs) of three major crops in Sikkim (1975/1976 to 2009/2010)**

Period	Crop	Area coverage (ha)	HYV coverage (ha)	% coverage of HYV varieties
1975/1976	Rice	11,400	800	7.01
	Wheat	150	120	80.00
	Maize	28,500	4,000	14.03
1980/1981	Rice	14,800	2,000	13.51
	Wheat	6,850	6,500	94.89
	Maize	30,200	7,000	23.17
1985/1986	Rice	15,900	3,400	21.38
	Wheat	7,200	6,800	94.44
	Maize	38,100	8,600	22.57
1990/1991	Rice	18,610	5,400	29.01
	Wheat	7,950	7,500	94.33
	Maize	40,780	14,000	34.33
1995/1996	Rice	15,940	6,778	45.52
	Wheat	8,240	8,200	97.38
	Maize	39,400	16,720	42.43
2000/1901	Rice	15,219	6,480	42.57
	Wheat	7,215	5,930	82.18
	Maize	39,903	15,880	39.79
2005/2006	Rice	14,740	5,573	37.81
	Wheat	5,740	5,559	96.80
	Maize	36,700	12,166	33.15
2009/2010	Rice	12,270	2,605	21.22
	Wheat	5,200	3,480	66.92
	Maize	39,500	8,780	22.22

Source: DESME 2002; 2004-05; 2005-06; 2009-2010; FSADD 2009-10; Dewan 2011)

Threats to Agrobiodiversity Conservation and Protection

Changing ecological, economic, and sociocultural dimensions

There are numerous examples of the impacts that loss of agrobiodiversity in marginal lands caused by sociocultural and economic changes has had on sustainability. Similar changes are reported from the central Himalayas (Maikhuri et al. 2001). Declining agrobiodiversity in marginal areas in the Sikkim Himalaya is directly or indirectly related to changing ecological, socioeconomic, and policy dimensions (Table 16). Management dimenions vary in different land use systems. Agroforestry systems and traditional mixed farming in the Sikkim Himalaya have high ecological adaptability, resilience, and opportunities for sustainability. These agroforestry systems have been a source of food and environmental security for resource-poor farmers. Traditional communities trade agroforestry products on global markets and contribute to reducing global warming through carbon consumption in the cardamom-based, farm-based, and farm-forest-based agroforestry systems they have developed.

Table 16: **Farmers' perceptions of management dimensions of principal land use systems in the Sikkim Himalaya**

Dimensions and factors	Farm-based Agroforestry	Forest-based Agroforestry	Large cardamom-based Agroforestry	Traditional mixed farming
Ecological dimensions				
Soil loss	VH	L	VL	VH
Irrigation	Rainfed	Rainfed	No irrigation	Irrigated/Rain fed
Nutrient loss	VH	L	VL	VH
Tillage	VH	No tillage	No tillage	VH
Source of nutrients	M	H	VH	H
Carbon sequestration	H	VH	VH	H
Soil fertility maintenance	M	M	VH	L
Carrying capacity of land	H	VH	VH	H
Agrobiodiversity	H	VH	L	VH
Chances of alien species	H	VH	L	H
Diseases and pests	H	L	VH	H
Greatest challenge for farmers at present	Land degradation, productivity decline	Shortage of land	Viral/fungal infestation in large cardamom, decline in moisture regime	Viral infestation, dieback, greening virus, yield decrease
Availability of medicinal plants	H	VH	H	H
Vegetation regeneration	M	VH	VL	M
Ecological complexity, resilience and functioning	Complex, ecologically fragile	Complex, ecologically sustainable	Complex, ecologically sustainable	Complex, ecologically fragile
Economic dimensions				
Labour input	H	L	M	H
Manure input	VH	L	VL	VH
Management cost	VH	L	L	VH
Production potential of crops	M	M	VH	M
Yield Benefits (monetary)	M	L	VH	H
Sociocultural dimensions				
Management approach	Multipurpose trees and understorey crops	Multipurpose trees, bamboo groves grown	Trees and understorey crops grown	Trees and understorey crops grown
Cultural values of practice	VH	VH	VH	VH
Cropping pattern	Two times or more	Tree crops and NTFPs	One understorey crop	Two times or more
Post-harvest technology	Traditional, multiple harvest	Multiple harvest	One time harvest	Traditional, multiple harvest
Livestock integration	Livestock as a part of practice	Grazing/ fodder for livestock	No livestock	Livestock as a part of practice
Labour availability for farming	VL	VL	VL	VL
Adaptability of the system	VH	VH	VH	VH
Organizational capacity	M	M	M	M
Conservation approach	Food sustainability	Cultural importance, often private sacred forest	Economic return	Economic return and food
Sustainability	Multipurpose trees and crop diversity conserved	Multipurpose trees, wild edibles /NTFP diversity conserved	Large cardamom genetic diversity conserved	Multipurpose trees and crop diversity conserved
	Rotational	Rotational	Rotational	Dynamic and rotational

VH=Very High, H=High, M= Medium, L=Low, VL=Very Low

Climate change

Climate variation has contributed to unpredictable or erratic rainfall patterns, drying of local springs and streams, and prolonged and extreme drought-like situations during the winter in some years. It also plays a role in the migration of some crops to higher elevations, shifts in sowing and harvesting times of local crops, the emergence of diseases and pests in crops and fodder species, and losses in crop productivity. Such events have given rise to constraints in the management of khet and bari systems, and declining crop yields (e.g., cardamom, ginger, orange, rice, maize, wheat, buckwheat, etc.) resulting into rising questions of food insecurity, mainly among farmers living in highly inaccessible areas. Farmers in the Sikkim Himalaya have observed temperature rise and untimely rainfall, as well as the impacts on their agriculture. Extreme climatic conditions have had severe impacts on the high-value large cardamom crop, including the emergence of viral diseases such as 'chirkey' and 'furkey' and the fungal disease Colletotrichum blight, which have contributed to declines in productivity.

Rice, maize, and wheat are important staple crops for marginal farmers, who are most vulnerable to the changing situation in Sikkim. Similarly, among high-value cash crops in the traditional farming systems of the Sikkim Himalaya, large cardamom is the most vulnerable after ginger and broom grass.

Extensive field-based study and questionnaire surveys were carried out to identify indicators of climate change in the Sikkim Himalaya. According to local and indigenous farmers, several crops are seriously threatened by climatic variations, while a few crops are still able to adapt to the changing situation in Sikkim (Table 17).

Table 17: **Farmers' perceptions of the indicators of climate change impacts on agrobiodiversity elements in the Sikkim Himalaya**

Crops	Indicators of change
Cereals and pulses	Several traditional varieties of rice disappeared from the systems, such as punaro kanchi attey, kagey tulasi, thulo attey, ghaiyya dhan, sanu tulasi, seto tulasi, thulo marshi, tauli dhan, baghey tulasi. The roots are infected with termites when the rice is fruiting. In maize, pest infestation (kali pokey) has not been seen in the last ten years.
Large cardamom	The major threats to large cardamom include the spread of the fungal disease *Colletotrichum* blight, which appears in the advent of pre-monsoon showers (April–May) and progresses rapidly during the rainy season (June–August). The emergence of viral diseases, commonly called 'chirke' and 'foorkey', since the early 1980s has drastically reduced cardamom production (by up to 60%) and the plantation area (by almost 50%).
Ginger	The biggest challenge for ginger cultivation has been controlling soil-borne diseases, soft rot, dry rot, and bacterial wilt. Other challenges include producing enough manure, manpower for cultivation, and marketing. In the sub-tropical belt, ginger cannot be cultivated due to stem rot and blight.
Chayote	Shrinking leaves and blight have been observed in the last five years.
Broom grass	Broom grass is a multipurpose agroforestry species in mountain farming systems across the Himalayas. In the last ten years, this grass has developed yellowing of leaves and leaf blight. During the winter, especially after October, broom grass bushes develop this disease and dry out. Thus, this fodder species remains non-palatable to farm animals.
Mandarin orange	Productivity drastically declined after 2008 owing to weak management of old diseased trees. In addition, the majority of old plantations are suffering from viral and other disease infestations.
Fodder species	Farmers have witnessed declines in tree fodder production in recent years. One reason is pests like 'jhusiley kira' (caterpillers), which have been eating all the leaves before they mature for harvesting, especially during lean seasons. Some of the affected trees include *Artocarpus lakoocha* (badar), *Ficus cunia* (khasreto), *Ficus benghlensis* (pate bar), *Ficus ruxborgii* (nibaro), *Ficus lacor* (kabro), *Ficus semicordata* (khanew), *Ficus nemoralis* (dudilo), *Ficus hispida* (khasreto), *Morus alba* (kimbo), *Bauhinia ascicula* (koiralo), *Ficus hirta* (khasre khanew), *Ficus clavata* (lute khanew), *Bauhinia purpurea* (tanki), *Litsea monopetala* (kutmero), *Saurauia roxburghii* (auley gogun), *Saurauia asciculata* (gogun), *S. griffithi* (tatey gogun), *S. nepaulensis* (gogun), and *S. punduana* (auley gogun),
Grass fodder	Colonization of invasive species has resulted in declining productivity of common fodder species such as *Digitaria sanguinalis* (ghogey banso), *Paspalum conjugatum* (chitre banso), *Panicum repens* (phurkey), and *Thysanolena agrostis* (amliso)
Emergence of weeds in cultivated farms	Common weeds in maize are *Eleusine indica* and *Setaria galuca*. Common weeds in rice are *Cyperus eragrotis*, *Hydrodoctyle helplansis*, *Paspalum pasploides*, *Echinocloa crusgalli*, *Echinocloa colonum*, *Cyperus rotundus*, *Cynodon dactylon*,and *Ageratum conyziodes*. Common weeds in wheat are *Chenopodium album*, *Amaranthus* sp., *Cynodon dactylon*, *Polygonum capitata* etc. Common weeds in potato and mustard are *Polygonum capitata*, *Cyperus rotandus*, *Cyperus iria*, *Cynodon dactylon*, *Drymaria cordata*, *Spilanthus paniculata*, *Sida rhimbifolia*, and *Gnaphalium affine*.

Source: Sharma and Rai (2012)

Climate change variations have also resulted in the colonization of invasive species, which is an emerging threat to crop diversity. Agroforestry ground cover has been gradually occupied by *Eupatorium odoratum*, *E. adenophorum*, *Ageratum houstonianum*, *Erigeron karvinskianus*, *Galinasoga parviflora*, *Erichthites valarianiifolia,* and *Gleolaria maxicana*, with cases of *Lantana camara*, *Bidens bipinnata*, and *Ageratum conyzoides* in cultivated farms. In 1998, the GB Pant Institute of Himalayan Environment and Development developed biocomposting and pit composting techniques that make use of these unwanted weeds. Nutrient analysis showed that the compost from these species has high nitrogen and phosphorus content. This compost was used to grow vegetables in the Mamley Watershed in south Sikkim, and was found to be effective. Farmers of Jaubari and Namchi in south Sikkim were then trained to make biocomposts, which proved to be beneficial (GBPIHED 2001).

The mountainous terrain of the Sikkim Himalaya is geologically unstable with steep topography, extreme climatic conditions, and turbulent rivers (e.g., Teesta, Rangeet, and Rongpo) that make it vulnerable to natural calamities. Examples of natural disasters in the region include the cloudburst of 30 July 2013 and earthquake of 11 September 2011. The 2013 cloudburst event near Sangkhola and Rangeet on the Indo-Nepal border led to a devastating flash flood and landslide in west Sikkim. The young mountain systems of Sikkim are also prone to landslide events, which occur every year, mostly during the monsoon and post-monsoon seasons. The remoteness of traditional agricultural landscapes, poor accessibility due to poor infrastructure, declining livelihood options, and the influence of globalization have increased vulnerability.

Introduction of hybrid varieties

Soon after Sikkim became the twenty-second state of India in 1975, traditional crop production systems started to give way to cash crop-based agriculture. New crop varieties from the plains, improved and hybrid varieties, and high yielding varieties (HYVs) were introduced to the traditional farming systems of Sikkim to increase crop productivity (Sharma and Acharya 2013). About 56,970 ha of Sikkim is covered by rice, wheat, and maize, of which more than 30% is occupied by HYVs. The indigenous germplasms of Sikkim are disappearing rapidly for several reasons: the conversion of agricultural land to non-agricultural uses, the rising use of plastic in homesteads, floriculture in prime agricultural land, and the introduction of HYVs. The diversity of hybrid and HYV crops introduced to the pristine mountain environment of Sikkim poses risks to local food security, adaptive capacity, and human wellbeing (HCCDD Annual Reports 2009, 2010, 2011, 2012). Although indigenous farmers have not accepted improved crops, HYVs are now taking over homesteads, agroforestry systems, and other farmlands (Table 18). Dry land rice landraces, such as 'ghaiyadhan', 'thakmaro', 'bhuindhan', 'marsi', or the wet rice 'guriya', have largely been replaced by HYVs, and may soon fall into extirpation.

Table 18: **HYV of crops introduced in the traditional farming landscapes of the Sikkim Himalaya**

Crops	Hybrids, HYVs or improved varieties introduced
Rice	Pant rice-10, VL-85, VL-62, VL-82, VL-206, PD-10
Maize	Navjot, Aparanji Mixed, Swan Mixed, Devki Mixed, Shankar C-1415, Shankar C–1837
Wheat	Sonalika, UP-262, VL-738, HD-2687, PBW-343
Finger millet	Endaph-9, VL-Mandua-146, Maski-5
Barley	VL-46, VL Barley-1
Buckwheat	VL Unal-7, PRB9001
Kidney bean (rajma)	PDR-14 (Udaya), VL Rajmah-63, Kannauri, Jwala
Rice bean	PRR-2
Mustard	Pusa Bold Agrani
Yellow mustard (sarsoon)	Sikkim Sarson-1, B-9
Soybean	PK-1042, PK-1024
Popcorn	Madhurai Queen, Golden, Amber, Amber Mixed
Masoor dal	Pant Masoori-4, VL Masoor-4, Sapna
Arhar dal	ICPH, Pusa-85
Moong dal	K-851, PCM-11, Pragya
Aduwa	Rio-de-Jeneiro, Nadia, Maran, Djarja, PGS 35, SG666

The Sikkim government's priority in the agricultural sector is to increase per unit productivity, which is low compared to regional and national averages. To bridge this gap, the government has been making efforts to expand the area under high-yielding varieties. The Agriculture Department has the mandate to implement a number of schemes, including macro-management of agriculture through integrated crop development programmes, integrated nutrient management, natural resource management, and the Rastriya Krishi Vigyan Yojana. From 2008 to 2009, around 26,112 ha of agricultural land (35% of the total cultivation area of Sikkim) was brought under HYVs (FSADD 2010). The seeds of major traditional crops such as rice, wheat, maize, soybean, and mustard have been replaced by HYVs, leading to the disappearance of traditional landraces. At Daramdin, a major rice growing area in west Sikkim, about 30 traditional landraces of rice have been replaced by HYVs; 'marshi' is now the only traditional variety cultivated.

HYVs and hybrids are competing with the traditional crop diversity. More than 40 improved varieties have been introduced in the traditional farms of Sikkim, which will eventually replace the highly adaptive indigenous genetic varieties (Table 17). There have been considerable changes in traditional farming systems, with modern approaches involving monocropping of HYVs, although these approaches neither recognize the value of traditional farming for risk avoidance nor recognize the constraints of maintaining a continuous flow of necessary inputs such as fertilizers, improved seed production, and management of the network of family farming. Traditional agriculture in the Sikkim Himlayan region is operated primarily by farming households through an informal network of smallholder farmers, who continually respond to changes and challenges, creating new innovations to sustain and increase production.

In Sikkim, HYVs are gradually replacing traditional cultivars, which may result in the elimination of centuries of accumulated experiences and ecological knowledge of cultivation, ignoring the socioeconomic and socioecological significance of these crops. The displacement of traditional crops will eventually result in the disappearance of unique germplasms from the region.

Man-made pressure on agroecosystems

Over time, mountain farmers have created and maintained crop genetic diversity through the domestication and selection of a wide range of landraces and varieties of crops depending upon the type of soil. The existence of such large gene pools, inducing semi-domesticated and wild varities of crops, enables farmers to adapt to changing climatic conditions and socioeocnomic pressures from unplanned development. Several factors are putting growing pressure on mountain farmers in the Sikkim Himalaya, including rapid increases in the non-farm population, rising demand, marginalization, and poverty; land degradation from conversion and erosion; the promotion of HYVs and the resulting disappearance of indigenous varieties; economic disparity; and environmental change. These pressures affect natural habitats that are home to wild relatives of crops, as well as domesticated animals, high-value cash crops (e.g., large cardamom, Sikkim mandarin, ginger, medicinal plants, etc.), and farmers, who maintain a significant amount of crop genetic diversity and animal genetic diversity.

Policies and agrobiodiversity governance

In India, the conservation, protection, and promotion of biodiversity and agrobiodiversity elements and products are governed and guided by the Geographical Indications of Goods (Registration and Protection) Act 1999, Protection of Plant Varieties and Farmers Rights Act 2001, Indian Biological Diversity Act 2002 (Rules 2004), and the Patent Act 1970 (Patent Rules 2003, amended in 2006), as well as the National Bureau of Plant Genetic Resources (NBPGR), National Bureau of Animal Genetic Resources (NBAGR), and the Indian Council of Agricultural Research

Varieties of yams are sold in Laal Bazar, Gangtok, Sikkim

(ICAR). The majority of Indian states, including Sikkim, have framed their own biological diversity rules to ensure the conservation and protection of traditional knowledge and genetic resources arising within their territories. As a result of these national and subnational legal frameworks, an institutional infrastructure was established for the conservation, sustainable use, and equitable sharing of benefits arising out of genetic resources and the associated traditional knowledge. India is also a signatory to several multilateral environmental agreements that obligate the state to promote the conservation of genetic resources (e.g., World Trade Organization/General Agreement on Tariffs and Trade and Agreement on Trade-Related Aspects of Intellectual Property Rights 1948, Convention on Biological Diversity (CBD) 1993, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) 1976, United National Framework Convention on Climate Change (UNFCCC) 2004/2012, and Nagoya Protocol 2011).

The Sikkim Biodiversity Strategy and Action Plan (2002) has highlighted a comprehensive action plan for the conservation of alpine and trans-Himalayan areas. The plan treats communities as central to the development process. The Government of Sikkim has also initiated the Indo-German climate change adaptation project through the Rural Management and Development Department (Tambe 2009), which considers cultivated systems as a component. The Sikkim Biodiversity Action Plan (2012) highlights strategies recommended for agrobiodiversity conservation, protection, and promotion. It has given a set of responsibilities, with corresponding time frames, to research and development agencies (e.g. Indian Council of Agricultural Research (ICAR), National Bank for Agricultural and Rural Development (NABARD), National Biodiversity Authority, Department of Agriculture Research and Education under the Ministry of Agriculture and Farmers Welfare, and the National Bureau of Animal Gentic Resources), including the Agriculture, Horticulture, and Animal Husbandry Departments of the Government of Sikkim, to ensure that markets are available for organically farmed local crop varieties (SBAP 2012). These agencies are also tasked with the certification and preservation of local germplasms of field and horticultural crops by screening them for desirable characters, identification of agrobiodiversity hotspots and cropping systems, and promotion of on-farm conservation through training programmes and incentives. With the declaration of Sikkim as an organic state in 2003 and the launch of the Sikkim Organic Mission, the organic certification process has been widely initiated. Organic agricultural production systems are being promoted through incentives, and the capacity of rural farmers is improving (IPR 2013).

The traditional farming systems of the Sikkim Himalaya have considerable potential for adapting agricultural production systems to generate environmental services and to realize their benefits. In the Himalayan region, programmes on payment for ecosystem services will need to be implemented across large numbers of producers and agricultural landscapes to realize economies of scale in transaction/production costs and risk management. Such programmes must be designed to support and enhance existing best practices, innovations, and adaptation approaches to improve livelihoods, production, market linkages, and equity in rural communities.

Adaptation Strategies to Reduce Climate Change Impacts

In the Sikkim Himalayan region, climate change has been observed in the form of increased intensity and frequency of storms, drought and flooding, altered hydrological cycles, and precipitation variance that have implications for agriculture systems and future food availability. It is important to assess the potential impacts on rainfed agriculture in relation to irrigated systems in order to plan adaptation strategies. There are several areas where adaptation measures can be designed and implemented, and some strategies are discussed below.

Agrobiodiversity promotion

The effects of climate change on the region’s agrobiodiversity also have severe impacts on food production systems and the nutrition and livelihoods of mountain people. The selection of crops and cultivars with tolerance to abiotic stresses (e.g., high temperature, drought, flooding, pests, and disease) can allow for the harnessing of genetic variability in new crop varieties, but this is only possible if government programmes have the required capacity and long-term support. Risk-coping production systems resilient to land and water disturbances require diversified structures in space and time such as crop rotation, agroforestry, crop-livestock association, and crop-fish systems, as well as the use of hedges, vegetative buffer strips, and other farm landscaping practices. Accomplishing this

A large diversity of pulses are sold at Laal Bazar, Gangtok, Sikkim

can have an enormous impact on adaptation to drought, heavy rain, and wind (FAO 2007). Traditional mountain farmers know that greater crop diversity and mixed farming (crops and livestock) offer considerable protection against farming risk, including climate-related risk. In order to prevent the loss of crop production in farming practices, farmers develop a range of different crop types, or even cultivars of the same crop with differing drought or pest resistance traits.

Promotion of agroforestry systems

Traditional agroforestry systems are increasingly important adaptation strategies for enhancing resilience to the adverse impacts of climatic variations, including shifts in crop seasons, rainfall variability, changing weather patterns, reduced water availability, and increasing soil erosion. They are critical centres of genetic diversity for food and human wellbeing, and they contribute to biodiversity, including agrobiodiversity, in cultivated systems. In mountain systems, traditional agroforestry systems are recharge areas for spring catchments. Agroforestry can become an important tool to build the resilience of farmers and rural people against threats of climate change and natural calamities. This can also help in greening rural employment and rural development opportunities (NAP 2014).

Spring revival and water harvesting

In the last seven years, the popular 'Dhara-Vikas' initiative has been implemented to revivie drying springs, streams, and lakes and has shown considerable success, with the revival of 50 springs and four lakes in 20 drought prone gram panchayats – showing promising results and the potential to be scaled up and mainstreamed in ongoing programmes in the Himalayan region (Sharma et al. 2012; Tambe et al 2012, 2013). Farm-based rainwater harvesting and irrigation systems have to be revived so that they can play an important role in augmenting the water supply in environemnts prone to water stress, especially in the dry areas of Sikkim's south, east, and west districts. Dhara Vikas is a robust climate adaptation strategy for drought-prone districts of Sikkim. Dhara Vikas (meaning, spring-shed development) is helping to alleviate the problem of rural water scarcity by reducing the surface runoff of rainwater and allowing more water to percolate down to recharge underground aquifers, which, in turn, ensures increased discharge from springs. Besides its significant impact on crop patterns and yields, the programme has also worked on developing a village spring atlas and a water source atlas for the state. A study conducted by The Mountain Institute India found that water security issues in the region are inclusive of water access, availability, resources, livelihood dynamics, and economic status, which was was significantly correlated with elevation along the altitudinal transect (TMI India 2016).

Soil and land management

Improved management of soil and land within cropping systems can help communities cope with adverse climatic conditions. This will enable farmers to diversify crops and cropping patterns. Indigenous farmers have rich traditional ecological knowledge that can be combined with innovation for better crop, soil, and land management practices.

Land management by terracing and the cultivation of suitable trees on the terrace edges is key in maintaining mountain farming systems. Development of stone walls in terracing, establishment of hedgerows using different agroforestry species, and diversion channels to manage situations of too much water during rainy seasons are some coping strategies. Climate change adaptation for agricultural cropping systems requires a higher resilience against both excess water (due to high intensity rainfall) and lack of water (due to extended drought periods). A key element to respond to both problems is soil organic matter, which improves and stabilizes soil structure so that soils can absorb higher amounts of water without causing surface runoff, which could result in soil erosion and, further downstream, in flooding. Soil organic matter also improves the water retention capacity of the soil during extended drought periods. Mountain farmers practising traditional farming systems have rich knowledge and techniques on low-cost soil and water conservation measures that are easily implemented and that will reduce land degradation and improve agroecosystems.

Organic agriculture in traditional farming systems

The declaration of the Sikkim Organic Mission by the Government of Sikkim in 2010 was done with the objective of addressing the basic requirements of an organic crop production system, wild crop harvesting, organic livestock management, and processing and handling of organic agricultural products. Organic agriculture with due recognition of traditional farming systems will bring in opportunities for mountain farmers in Sikkim. An increasing number of small-scale farmers in Sikkim have adopted biocomposting or vermicomposting – non-traditional methods of improving the nutrient content and water holding capacity of the soil. Mulching, the use of nitrogen fixing species, and the application of farmyard manure are traditional methods for enhancing soil fertility. Such techniques can improve the cultivation of stress-tolerant crops, crop diversifcation, and productivity. Both traditional and innovative farm techniques can strengthen the resilience of local food systems.

In traditional farming systems, a number of methods are used to maintain soil productivity such as intercropping, crop rotation, and fallowing. Farmers often replace or exchange seeds or farms to experiment with suitability and resilience under changing agroenvironmental conditions. These practices continue to ensure food and livelihood security in the face of increasing climate change and variability. The promotion of diverse homesteads in traditional farming systems would ensure family food supply in areas significantly affected by climate change variations. For the Sikkim Himalaya, two types of adaptation strategies for enhancing the resilience of homesteads can be planned: 1) in drought-prone regions, the resilience of traditional homestead gardens is strengthened through the intercropping of fruit trees with vegetables, micro-irrigation, and organic fertilizers; and 2) improvement of animal husbandry for livestock production would enhance the household economy and manure production in areas with low productivity.

Pastoralism in the alpine and trans-Himalayan region

Pastoralism and agropastoralism are the main livelihood options of the majority of indigenous communities in the alpine and trans-Himalayan region of the Sikkim Hmalaya. Resource governance and management of grazing regimes are done by the traditional indigenous institution 'Dzumsa' (Sharma and Dhakal 2011). The Dzumsa of Lachung and Lachen in north Sikkim is a strong customary and traditional institution of local governance that has been protecting the high-altitude areas including the trans-Himalayan Tibetan Plateau from externalities and eventualities (Sharma and Rai 2012). In the cold desert environment of Tsho-Lhamu, Lhonak Valley, and Lashar Valley, around 23 'Dokpa' families have been practising a nomadic lifestyle, managing almost 90% of Sikkim's yak population. Yak production is the base of the economy for Dokpas, Lachenpas and Lachungpas, with other major activities including tourism and the collection and trade of medicinal plants and yartsagunbu, a caterpillar fungus that has high international market demand for its medicinal use.

Rotational grazing, indigenous regulation of resources and pastoralism, and conflict resolution are local adaptation practices established by the Dzumsa. This shows a unique example of community ownership, self control, and wellbeing, which has increased the sustainability of resources in the wake of changing conditions. Traditional pasture and herd management systems include the conservation of natural ecosystems through extensive ranching and rotational grazing, and keeping a mixture of cattle, goats, and sheep .

Enhancing pollination services

The farmers in the Sikkim Himalaya have observed declines in pollinator populations. This has resulted in declines in the productivity of a number of crops. During the past few years, apple production in Himachal Pradesh, India, has been continually declining, which is also the case in Lachen and Lachung valley in north Sikkim. A study has shown that this decline in productivity is due to pollination failure. The is partially attributed to the decline in the number of trees that can provide compatible pollen and the lack of pollinators (bees, butterfies, and moths). To overcome the lack of insect pollinators, farmers are renting honeybees, decreasing the use of pesticides, and pollinating crops by hand (Partap and Partap 2002; 2009).

To promote sustainable agriculture, it is important to understand pollinator-plant relationships as an ecosystem service. As observed by farmers, the promotion of plasticulture has exerted negative impacts on pollinator species. Therefore, the conservation and restoration of natural areas, including the diversity of agroforestry systems, is necessary to optimize pollinator services in agricultural systems.

Access and Benefit Sharing and the Protection of Traditional Knowledge and Genetic Resources

The Nagoya Protocol on Access and Benefit Sharing is an international treaty that builds on and supports the implementation of the Convention on Biological Diversity – in particular one of its three objectives: the fair and equitable sharing of benefits arising from the utilization of genetic resources. This landmark agreement is relevant to a variety of commercial and non-commercial sectors that use and exchange genetic resources. India signed the Nagoya Protocol on 11 May 2011 and ratified it on 9 October 2012.

The formation of biodiversity management committees (BMCs) as the lowest formal institution for the implementation of the Indian Biological Diversity Act and Rules is in process. The constitution of BMCs takes place within gram panchayat units or municipalities. The Indian state of Kerala has completed the formation of BMCs, and 495 of the total 670 proposed people's biodiversity registers have been developed with complete documentation of genetic resources and associated traditional knowledge. BMCs are constituted for the purpose of promoting the sustainable use and documentation of biological diversity including preservation of habitats, the conservation of landraces, folk varieties, cultivars, domesticated stocks and breeds of animals, and micro-organisms, and chronicling knowledge related to biological diversity. In Sikkim, the Sikkim State Biodiversity Board (SSBB), in collaboration with TMI India and the Forest Department, has constituted 27 BMCs and is in the process of documenting genetic resources and associated traditional knowledge in the people's biodiversity register. However, this process needs to be accelerated for the effective conservation of the state's agrobiodiversity and to avoid biopiracy and misappropriation. Access and benefit sharing arrangements are slowly picking up in India, with one of the success stories so far being a case in which benefits were provided to the Kani tribe of Kerala for their knowledge of the use of a plant ('arogya pachha', *Tichophus zeylanicus*) as a health invigorator (Chaturvedi 2007).

The Indian legislative framework for the protection of biodiversity, genetic resources, and associated traditional knowledge is covered by the Patents Act 1970 (amended in 2005); the Patents Rules 2003 (amended in 2006); the Geographical Indications of Goods (Registration and Protection) Act 1999 (Rules 2002); the Biodiversity Act 2002 (Rules 2004); and Protection of Plant Varieties and Farmers Rights Acts 2001. Under the Patent Act 1970 (Patent Rules 2003, amended in 2006), section 3(p), inventions which count as knowledge or an aggregation or duplication of known properties of traditionally known component(s) (e.g., traditional knowledge already in the public domain, such as the wound healing properties of turmeric) are excluded. However, any value addition that

A woman grinding buckwheat at Payong village, South Sikkim

uses traditional knowledge leading to a new process or product with industrial applicability (e.g., extraction of azadirachtin from neem) can be patented. The rich genetic resources and the associated traditional knowledge developed and tested through trial and error over centuries by indigenous communities in Sikkim have yet to be properly documented. The Protection of Plant Varieties and Farmers Rights Act (2001) of India recognizes farmers as breeders, making them eligible to register the crops they have developed under the specific category of 'farmer variety'; however, the farmers' groups in the country are at a crossroads as to whether to register varieties developed by them and come into the fold of this intellectual property system or to stay out of it (Bhutani 2012). Patents and plant variety protection are two different forms of intellectual property rights in India, both providing exclusive monopoly over rights of creation of new plant varieties for commercial purposes in a given period of time. A patent is the right granted to an inventor to bar others from making, using, or selling the patented inventions for 20 years. Patented inventions are those that fulfill the patentability criteria of novelty, non-obviousness, and industrial use. Plant variety Protection provides rights to plant breeders for protecting the genetic makeup of a specific plant variety having novelty, distinctiveness, uniformity, and stability (Dewan 2011). However, a holistic mechanism for safeguarding the rights of traditional knowledge holders is still lacking for Himalayan agricultural systems in India, and, therefore, knowledge and resources from the remote agrobiodiversity and traditional knowledge hotspots of northeast India are still vulnerable to biopiracy.

Women selling local vegetables on Haat days at Laal Bazar, Gangtok, Sikkim

3. Conclusion

The Sikkim Himalaya is a treasure trove of agricultural biodiversity in traditionally managed landscapes, and it is a part of one of India's agrobiodiversity hotspots. Sustainable agriculture and management of crop diversity depend entirely on the sustainable management of surrounding land uses in the natural ecosystem. Degradation of the adjacent system severely impacts the economic, social, and environmental conditions of the region.

Over the years, the process of globalization has posed a grave threat to the agrobiodiversity of the Sikkim Himalaya. Monocultures and cash crop-based farming are spreading in market connected villages, and high yielding hybrids are taking over the traditional landraces, while development activities are rapidly converting agricultural land to non-agricultural purposes. Poor scientific understanding of traditional farming systems and related sociocultural and socioeconomic issues and lack appropriate policy for promotion and conservation of 'original agriculture systems' seriously impede the identification of solutions for sustainable agricultural development in the region.

The erosion of agrobiodiversity is due to a number of factors such as the degradation of agricultural landscapes, introduction of modern and uniform plant varieties in place of mixed farming system with traditional varieties, destruction of habitat due to development activities, changing food habits and attitudes of the consumers, cultural erosion, younger generations' disenchantment with agriculture, and migration to cities or towns for employment, causing fields to be abandoned or neglected. Other factors affecting agricultural biodiversity are the supply of high yielding variety seeds and other inputs at subsidized rates by the government; attraction to cash crop monocultures such as floriculture, poly-house culture, one crop-one village policy, etc. for profit maximization; and, above all, the lack of incentives for the promotion and marketing of traditional crops.

Marginal farmers alone do not have the capacity to solve the above problems. The best that can be done is to support efforts by smallholder farmers to conserve local agrobiodiversity wherever possible. Long-term solutions demand greater political commitment, policy development and enforcement, a participatory approach, and a bottom-up approach. The Sikkim Organic Mission is one step that is expected to enhance the livelihood strategies of farmers, particularly in areas under high ecological, climatic, and economic stress and risks respecting the centuries old traditional system of farming systems. The mission is also expected to empower farming communities, which is essential to support effective on-farm conservation. This process will ensure and encourage farm-level decision making on the management of genetic resources and associated traditional knowledge.


A woman cleaning young nettle shoots for making vegetable

4. Recommendations

Policies and programmes for agricultural promotion in the Sikkim Himalaya must go beyond the sectoral approach to achieve long-term development goals. The current sectoral approach is better suited to tropical areas in the plains and mostly untested under mountain circumstances. Therefore, formal institutions that implement such policies and programmes have a decisive role to play in ensuring the sustainability of agricultural systems and practices. Two dimensions of sustainable mountain agriculture should be taken into account for management planning. The first dimension is the communities' traditional ecological knowledge in maintaining the sustainability of mountain agriculture, which entails incorporating sustainability as a policy or programme goal. The second dimension is mountain community-centric participatory planning and decision making in the agricultural sector.

It is very important to conserve and protect landscapes, systems, and practices that sustain agrodiversity for the welfare of current and future generations. The promotion and improvement of genetic resources of traditional crop cultivars and scientific validation of farmers' participatory breeding practices and associated knowledge are other priority areas. To promote agrodiversity conservation in the region, there is a need to enhance scientific documentation of various types of land use/land cover, practices and ecological knowledge systems, as well as socioecological and cultural dynamics. There is also a need to document pollination systems, including pollination requirements of various crops, pollinators and their biology – particularly those relevant to indigenous agrobiodiversity as well as linkages with crop productivity.

As agricultural land is rapidly shrinking, it is necessary to retain arable land by imposing a complete ban on the conversion of land for non-agricultural purposes. This would ensure the land security of marginal farmers in Sikkim and elsewhere in the region. In 2007, a process was initiated to accord recognition of Sikkim Himalayan Agricultural Systems under the FAO's Globally Important Agricultural Heritage Systems (GIAHS) initiative. The proposal needs to be submitted officially in order to complete the process.

To design on-farm conservation strategies, it is imperative to identify specific agroecological niches and maintain a record of existing crops, cropping systems, and the communities maintaining them. It is also important to identify and declare the locations of genetic reserves, gene sanctuaries, and/or genetic gardens for both domesticated and wild species of food value and other socioecological and socioeconomic importance. Further, there is a need to emphasize the in situ conservation of traditional landraces, ex situ conservation of base collections in field gene banks, and in vitro storage and cryopreservation of important germplasm, for which tissue culture protocols can be developed. Similarly, the characterization and conservation of indigenous livestock and poultry resources need to be emphasized, as they have many valuable genes that are resistant to disease and support adaptation.

The Agriculture, Horticulture, and Animal Husbandary departments of the Government of Sikkim should develop a strategic policy to prioritize community-based biodiversity management and community-based biodiversity registration through biodiversity management committees. Community seed banks for seed conservation and participatory plant breeding and animal breeding for seed development need to be prioritized across the Sikkim Himalayan region through appropriate technical and financial support. Indian national policies and legislations have categorically emphasized access and benefit sharing, intellectual property rights, and farmers' rights for local and indigenous communities, who have, and will continue to, be engaged in conserving and managing plant and animal genetic resources.

A hi-tech polyhouse supported by Agriculture Department, Government of Sikkim for growing vegetables at Hee-Busty, West Sikkim

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