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Agrobiodiversity in the Kangchenjunga Landscape

Status, threats, and opportunities

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Agrobiodiversity in the Kangchenjunga Landscape

Status, threats, and opportunities

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Contents

Abbreviations and acronyms

GBPNIHE	Govind Ballabh Pant National Institute of Himalayan Environment
GIAHS	Globally important agricultural heritage sites
HKH	Hindu Kush Himalaya
IBA	Important bird and biodiversity area
ICIMOD	International Centre for Integrated Mountain Development
IUCN	International Union for Conservation of Nature
KL	Kangchenjunga Landscape
NTFPs	Non-timber forest products
NCD	Nature Conservation Division
RECAST	Research Centre for Applied Science and Technology
RDS	Regional Database Initiative
UNESCO	United Nations Educational, Scientific and Cultural Organization

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We hope this document will serve as valuable reference material for researchers, development workers, NGOs, academic institutions, and government line departments that are working to promote conservation and the sustainable utilization of agrobiodiversity in the landscape and beyond.

Executive summary

The Hindu Kush Himalaya (HKH) region has a great diversity of flora and fauna that supports the livelihood and well-being of one fourth of humanity. The HKH hosts four of the 36 'biodiversity hotspots' of the world and is a storehouse of rich agrobiodiversity. The Kangchenjunga Landscape (KL) is a transboundary complex with an area of 25,086 km^2. It covers parts of eastern Nepal (21%), Sikkim and parts of northern West Bengal in India (56%), and the western and south-western parts of Bhutan (23%). It is home to about 7.2 million people of different ethnic communities and social groups. The varied agro-climatic conditions in the KL support rich agrobiodiversity. Agrobiodiversity is the basis of food, medicine, textile, fibre, fuelwood, and other resources essential for human survival. This paper focuses on plant, animal and fungi diversity, which is a vital element of agrobiodiversity.

The Kangchenjunga Landscape houses rich diversity of plants – including crops, wild edible species, and non-timber forest products (NTFPs); animals; and birds. Our study recorded 5,204 plant species, 242 animal species, and 618 bird species in the landscape. About 750 species of plants, both cultivated and wild, are used by the local people of the KL for various purposes. These include cereals and pseudo cereals – including rice, maize, wheat, barley, buckwheat, and millets; oil seeds; beans and pulses; vegetables; spices/condiments; tubers/roots; fruits; wild edibles; and multipurpose agroforestry trees. KL-India has the highest diversity of agricultural crops with around 235 species, followed by KL-Nepal, which has 159 species, and KL-Bhutan, which has 52 species. People in the landscape rear a variety of livestock – cattle, buffalo, goat, sheep, pig, yak, horses, mules, dogs, and domestic fowl including ducks, geese, and pigeons. Farmers maintain rich agrobiodiversity on their farms, which helps them adapt to climate, socioeconomic, and other changes.

Integrated crop–livestock farming is the mainstay of the majority of people in the landscape. Black cardamom is the most popular cash crop and a significant source of household income. NTFPs have great potential for trade in the landscape but haven't been adequately commercialized due to limited market information, value addition opportunities, and technology.

Agrobiodiversity in the landscape has been declining in recent years. Local people and researchers attribute this decline to both natural and anthropogenic pressures. Broadly, these drivers can be categorized as: i) environmental – e.g., climate change, land use and land cover change, and invasive and alien species; ii) social – e.g., demographic change, urbanization, and rural development; iii) economic – e.g., global market, tourism, wildlife trade, and hydropower; iv) cultural – e.g., erosion of culture, taboos, loss of traditional knowledge systems, customary practices; and v) governance and institutions. Factors that have threatened agrobiodiversity in recent times include changes in consumers' food preferences; replacement of traditional crops and varieties with higher yielding ones; commercialization of agriculture; climate change; introduction and promotion of improved breeds of livestock; shortage of fodder resources; and shortage of labour due to outmigration of male members of the household. Unsustainable harvesting of important NTFPs and the absence of a legal transboundary trade facility have also been identified as major constraints for ecological management in the landscape.

Decline in agrobiodiversity narrows down the food choices of mountain communities and affects their food and nutrition security as well as their resilience to change. However, the landscape has opportunity to revitalize traditional crops and native livestock, which can help people achieve nutrition security as well as protect agrobiodiversity for environmental sustainability and ecosystem resilience. This would require efforts in the areas of research, development, and policy. Political commitment, policy development and enforcement, and a participatory bottom-up approach are critical for long-term solutions. Participatory action research as well as scientific research programmes need to be strengthened and the necessary research infrastructure put in place. The status and trends of agrobiodiversity should be consistently monitored and research findings disseminated to all concerned parties. Viable harvesting practices, value chain development at the local, national, and regional levels, and sustained marketing of products should be promoted for income generation and livelihood improvement. Training and awareness raising on agrobiodiversity management should be provided at all levels (policy makers to the general public).

KEY MESSAGE

The Kangchenjunga Landscape, which covers parts of western Bhutan, Sikkim and parts of northern West Bengal in India, and eastern Nepal, has rich agrobiodiversity. Its wide array of agricultural resources sustains the lives and livelihoods of its diverse communities. However, the wealth of agrobiodiversity in the landscape is increasingly threatened by natural and anthropogenic pressures.

SECTION I

Introduction

Agrobiodiversity of the Hindu Kush Himalaya encompasses an enormous array of biological resources such as crops, livestock, wild and non-cultivated crops, and rangelands.

Mountains are key features of the earth's surface and host a substantial proportion of the world's species (Antonelli et al., 2018). Mountain ecosystems are characterized by high aggregations of small-ranged species and are centres of endemism and diversity (Rahbek et al., 2019). As such, mountains across the world support about half of the world's biological diversity (Chettri et al., 2010; Dimitrov et al., 2012; Xu et al., 2019). Agrobiodiversity, an important subset of biodiversity, is a major life support system of mountain communities. It provides food to the majority of earth's population and ensures their well-being (Wood et al., 2000; Rudebjer et al., 2009).

Biodiversity for food and agriculture (BFA), or agrobiodiversity, is an important component of biodiversity. It encompasses the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output (FAO, 2019). This includes domesticated plants and animals that are raised for food, milk, meat, etc. Kaplan and Thompson (2019) define agricultural biodiversity as "the variety and variability of animals, plants and microorganisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries." Species harvested from forest and water bodies, the wild relatives of domesticated species, and other wild species harvested for food and other products, are known as "associated biodiversity".

Agrobiodiversity of the HKH encompasses an enormous array of biological resources such as crops, livestock, wild and non-cultivated crops, and rangelands (Agnihotri and Palni, 2007; Pandey et al., 2016; Xu et al., 2019; Giri et al., 2020). Agroecosystem plays a key role in ensuring food and nutritional security of communities and maintaining genetic diversity on farms. It is estimated that about 60% of the world's agriculture (approximately 3 million ha) consists of traditional subsistence farming systems, which nurture a huge diversity of crops and species (Wood et al., 2000; Jackson et al., 2005; Dorji, 2012). Agroecosystem thus contributes significantly to mountain livelihood. There is still opportunity to improve small-scale farming without affecting the diversity that farmers maintain (Rana et al., 2007; Aryal et al., 2009; Benayas and Bullock, 2012).

Traditional agroecosystems in the Himalayan region are highly diverse. Crop farming, animal husbandry, and forests constitute complex and interlinked production systems in the region. The region is a reservoir of a large variety of crops and livestock genetic resources owing to high agroclimatic heterogeneity and sociocultural diversity (Hodgkin et al., 2006; Agnihotri and Palni, 2007; Galluzzi et al., 2010; Wang et al., 2020). Traditional home gardens also come under agroforestry as they bring different plant species together in a temporal and/or spatial succession and aid the conservation and management of mountain ecosystem (Sunwar et al., 2006; Negri, 2009; Galluzzi et al., 2010; Pala et al., 2019). Agroecosystem provides various ecosystem services that support humans and wildlife – provisioning (food, fibre, fuel), supporting (nutrient cycling, soil formation), regulating (climate, flooding, disease regulation, and water purification), and cultural services (aesthetic and recreational value) (Pascual and Perrings, 2007; Kandel et al., 2018). However, there is not enough data on the contribution of ecosystem goods and services.

Ecosystem goods and services are important to human beings. However, a number of crops, local livestock breeds in particular, are rapidly eroding from their important habitats (Bisht et al., 2007; Chaudhary et al., 2016, 2017). Many genetic resources are on the verge of extinction and many others have already disappeared. Mountain communities are facing numerous unpredictable scenarios related to both climatic and non-climatic changes (Wangda, 2008; Chaudhary et al., 2011). At the same time agricultural intensification relies on a few crops and excessive use of agrochemicals and external water and energy inputs, which has negative impact on biological diversity (Schmidt et al., 2010; Adhikari et al., 2017).

Climate change is a major challenge of our time and its impacts on agrobiodiversity are apparent in high-altitude environments, especially among economically disadvantaged rural mountain communities (Chaudhary and Aryal, 2009; Sharma et al., 2009; Chaudhary et al., 2011; Phuntsho et al., 2012). There is an urgent need to study the impacts of climate change on agrobiodiversity and its consequences for food security. It is imperative to understand local peoples' perceptions of climate change as well as generate scientific data to inform policy makers about the effects of climate change.

The Kangchenjunga Landscape (KL), which covers parts of western Bhutan, Sikkim and parts of northern West Bengal in India and eastern Nepal, has rich agrobiodiversity. The wide array of agricultural resources in the KL sustains the lives and livelihoods of its diverse communities. However, the wealth of agrobiodiversity in the landscape is increasingly threatened by natural and anthropogenic pressures. The status of the KL's agrobiodiversity and its importance for mountain communities has not been documented properly. This paper attempts to fill this gap and provide a comprehensive analysis of agrobiodiversity in the landscape.

1.1 Objective of the study

To document the current status of agrobiodiversity in the KL including crop varieties and landraces, and livestock/animal breeds and wild species

To study threats and opportunities related to agrobiodiversity in the KL and their impact on the livelihood of local communities

To identify key areas requiring intervention for the conservation of agrobiodiversity in the KL

KEY MESSAGE

Around 16% of the Kangchenjunga landscape is under cultivation. This accounts for 5% of the landscape area in Bhutan, 18% in India, and 25% in Nepal.

SECTION II

Methods

This paper is based on a review of published and grey literature as well as data from ICIMOD's Regional Database System.

2.1 Study area

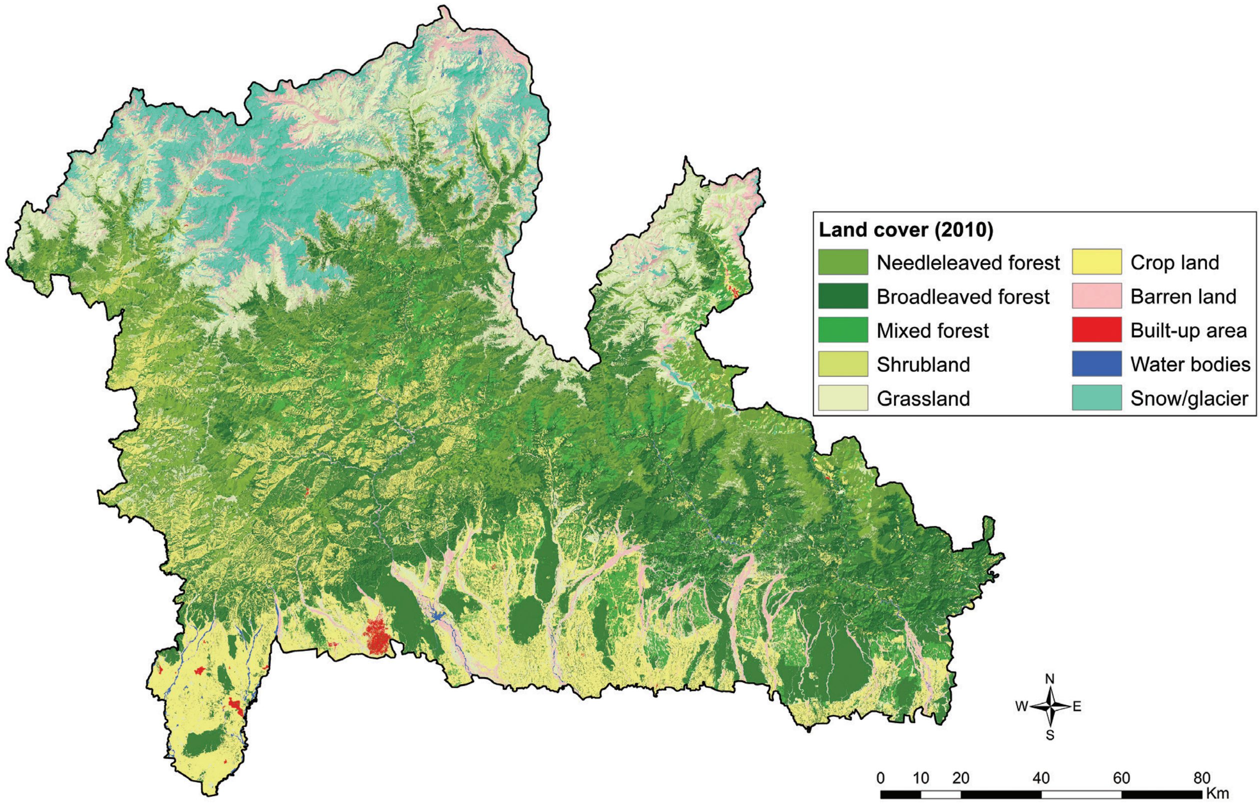
The Kangchenjunga Landscape (KL) is a transboundary complex that covers parts of eastern Nepal (21%), Sikkim and parts of northern West Bengal in India (56%) and western and south-western Bhutan (23%). It has an area of 25,086 km^2 (Figure 1). The landscape is situated between latitudes of 26°21'40.49" to 28°7'51.25" North and longitudes of 87°30'30.67" to 90°24'31.18" East (Chettri et al., 2009; ICIMOD et al., 2017a). The landscape climbs up from the lowlands of Nepal and India, to the mid-hills area, to the third highest peak in the world (Mount Kangchenjunga) with an elevation ranging from 40 m to 8,586 m above sea level (ICIMOD et al., 2017a).

The KL is a 'Himalayan biodiversity hotspot' housing a significant portion of the world's biodiversity. It includes various climate zones such as tropical, subtropical, warm temperate, cool temperate, subalpine and alpine (Sharma et al., 2007; Kandel et al., 2016). The landscape has 19 protected areas, 22 Important Bird and Biodiversity Areas (IBAs), one UNESCO World Heritage Site (Khangchendzonga National Park), and one Ramsar Site (Mai Pokhari, Ilam, Nepal) (Pandey et al., 2019, Kandel et al., 2019).

The landscape is home to about 7.2 million people, some of whom belong to minority ethnic groups such as the Lepcha community of Sikkim and Darjeeling (India), eastern Nepal and Bhutan, the Walungpa of Taplejung, Nepal, and the Lhop Doya community of the Amo Chhu Valley in Bhutan (Chettri et al., 2009; ICIMOD et al., 2017b). These communities have rich traditional knowledge of the use and management of biodiversity.

Agriculture is the main source of livelihood for the majority (over 90%) of people in the landscape (Chaudhary et al., 2015; ICIMOD et al., 2017b).

FIGURE 1 THE KANGCHENJUNGA LANDSCAPE IS SPREAD ACROSS PARTS OF SOUTH-WESTERN BHUTAN, SIKKIM AND PARTS OF NORTHERN WEST BENGAL IN INDIA, AND EASTERN NEPAL.



Through innovation and experimentation carried out over generations, farmers and herders have established a variety of land use systems for nurturing a rich diversity of plants and animals, both wild and domesticated (Sharma et al., 2016). Around 16.7% of the landscape is under cultivation. This accounts 5.5% of the landscape area in Bhutan, 18.1% in India and 25.9% in Nepal (ICIMOD et al., 2017a and b). Most farmers in the landscape practice subsistence agriculture, integrating crops, livestock and forest resources (ICIMOD et al., 2017b). Such mixed crop-livestock-forest based farming allows them to maintain agrobiodiversity on their farms, which in turn builds their resilience to climate change.

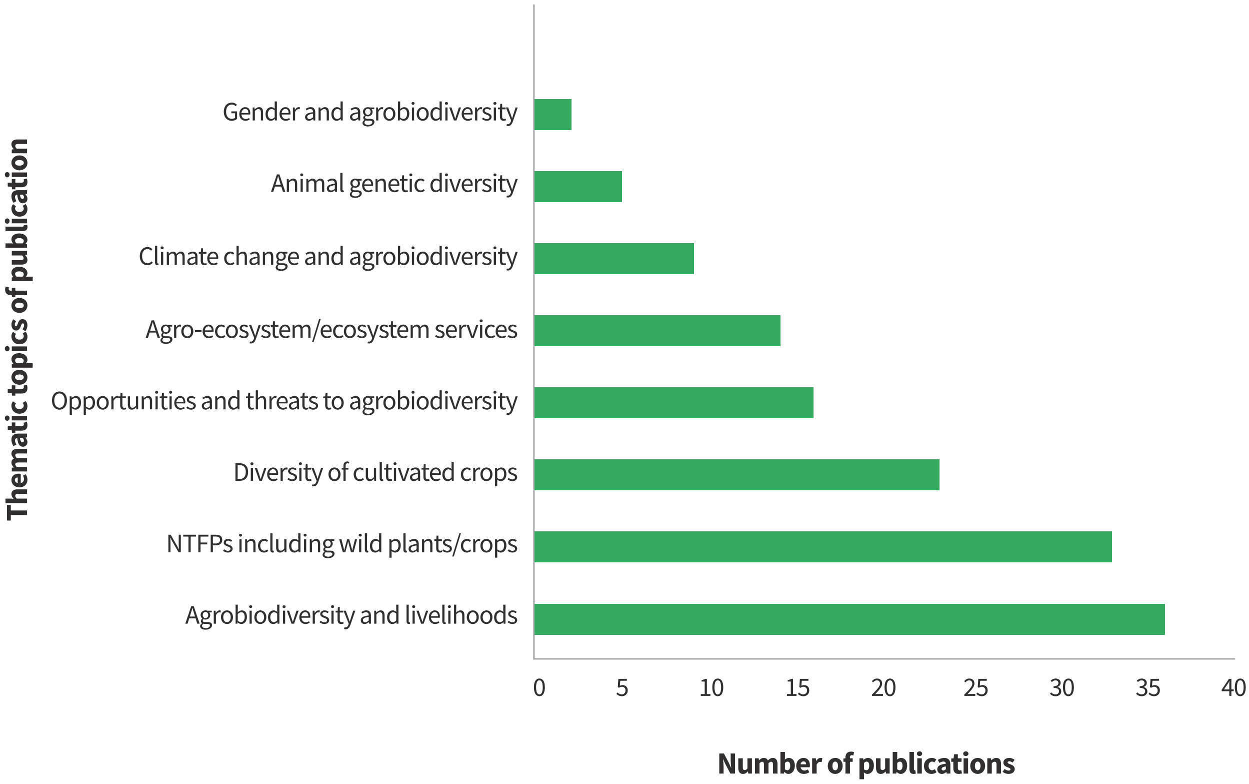
2.2 Criteria for literature review and data collection

This paper is based on a review of published and grey literature as well as data from ICIMOD's Regional Database System. For literature search, we used Google Scholar using key words such as agrobiodiversity, biodiversity, biodiversity richness, agroecosystem, ecosystem services, crop and livestock diversity, crop/plant diversity, animal genetic diversity, climate change and agrobiodiversity, NTFPs, traditional knowledge on agrobiodiversity, wild and underutilized crop diversity, wild plants, semi-domesticated plants, local landraces, local cultivars, traditional agriculture, mountain farming system, traditional crops, gender and agrobiodiversity, issues and challenges on agrobiodiversity. Our sources included journal articles, book chapters, working papers, government reports, reports by ICIMOD and its partners, and published and unpublished reports by other organizations that have been working in the area. Initially we obtained a total of 250 relevant studies. A total of 138 publications that were most relevant to the KL and the HKH region were taken up for analysis. The majority (34) of the sources were focused on the Kangchenjunga Landscape and the HKH region, 41 on KL-India, 28 on KL-Nepal, 17 on KL-Bhutan, and 18 on areas beyond the region. Publications that dealt with areas outside the region were reviewed in order to gain a comparative perspective on the landscape.

The second step was to divide the sources into broad thematic categories. From among the 22 search items, we came up with eight broad topics related to agrobiodiversity (Figure 2). These themes were later used to analyse the current status of agrobiodiversity and related threats and opportunities in the landscape.

As a third step, we analysed data on the Kangchenjunga Landscape available in ICIMOD's Regional Database System (RDS): http://rds.icimod.org/

FIGURE 2 **THEMATIC CATEGORIES FOR LITERATURE ON AGROBIODIVERSITY**



KEY MESSAGE

Agroforestry is an integral component of traditional agriculture and farming systems in the rural areas of the landscape. Agroforestry species have multiple uses – as food (fruits, vegetables), medicine, fodder, bedding material for livestock, mulching materials, fuelwood, timber, fibre and so on.

SECTION III

Findings

According to a modest estimate, approximately 330 species of agricultural crops are found in the Kangchenjunga landscape; these include cereals, oil seeds, pulses, vegetables, tuber crops and fruits.

3.1 Status of agrobiodiversity in the KL

About 26% of the publications (n=36) focus on broad themes related to agrobiodiversity. The landscape houses 5,204 plant species, 242 species of animal (mammals and amphibians) and 618 species of bird. KL-India has the highest recorded number of species, followed by Nepal and Bhutan (see Figure 3). Among the plant species recorded so far in the landscape, 97% (5,056 species) occur in India, followed by 43% in Nepal (2,230 species), and 8% in Bhutan (427).

Among the 5,204 species of plants in the KL, the majority belongs to angiosperms (5,181) and only 23 species belong to gymnosperms. Angiosperms include different species of orchids, rhododendrons, agricultural crop species, NTFPs, including wild edibles and medicinal plants. Within angiosperm species, there are 3,866 dicots and 1,315 monocots (see Table 1). In the KL, 216 flowering plant families have been recorded. These include Orchidaceae (704 species), Fabaceae (308 species), Asteraceae (255 species), Poaceae (233 species), and Rubiaceae (147 species).

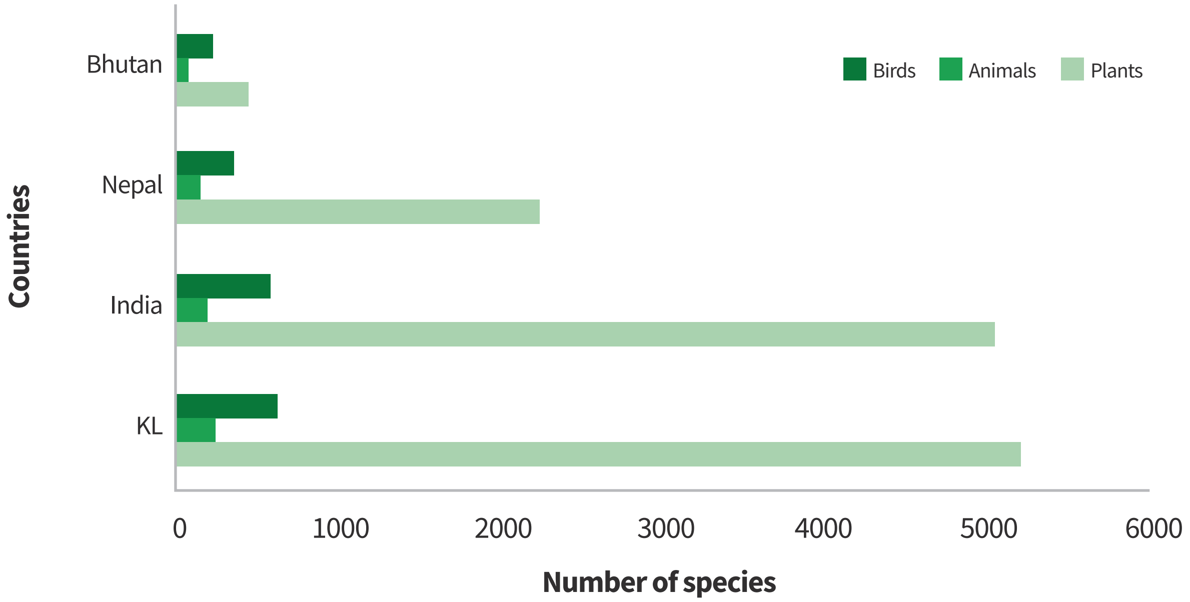
Among the total animal species (242) in the KL, 79% (28 families with 190 species) are mammals and 21%

TABLE 1 PLANT DIVERSITY IN THE KANGCHENJUNGA LANDSCAPE

Plant groups	Family	Genus	Species
Dicotyledons	179	1,181	3,866
Monocotyledons	31	357	1,315
Gymnosperms	6	16	23
Total	**216**	**1,554**	**5,204**

Source: ICIMOD/RDS (2020); Kandel et al., (2019)

FIGURE 3 AGROBIODIVERSITY IN THE KANGCHENJUNGA LANDSCAPE



Source: ICIMOD/RDS (2020); Kandel et al., (2018).

(8 families with 52 species) are amphibians. The most diverse families are Rhanidae (28 species), followed by Vespertilionidae (27 species) and Hystericidae (18 species). Out of the total 618 species of bird, the richest family is Muscicapidae (83 species), followed by Sylviidae (66 species) and Accipitridae (35 species).

3.2 Diversity of cultivated crops

The diverse crops found in the KL are a source of food, nutrition and income for the local communities. About 16% of the publications (n=23) we reviewed are focused on cultivated crop diversity (see Figure 2). According to a modest estimate, approximately 330 species of agricultural crops are found in the landscape; these include cereals, oil seeds, pulses, vegetables, tuber crops, fruits, etc. (ICIMOD, RDS 2020). Among the three countries that share the landscape, KL-India has the highest variety of agricultural crops with around 235 species, followed by KL-Nepal (159 species) and KL-Bhutan (about 52 species). A study by Rahman and Karuppaiyan (2011) in Sikkim, India documented about 178 cultivars/ local landraces from 69 crops. Rice landraces have the greatest genetic diversity (43) followed by maize (26). Important cereals, vegetables, fruits and cash crops grown in the landscape are presented in Table 2.

Traditional agriculture is the mainstay of communities in the landscape. Major cereal crops range from rice and maize to highland barley, wheat and millets. Broadleaf mustard, radish, taro, cauliflower and cabbage are the common vegetable crops grown and consumed by households. Black cardamom is the most popular cash crop and contributes significantly to household income in the landscape (Sharma et al., 2009, 2002a&b). Tea and yacon are also listed as cash crops grown by farming communities in the landscape.

Traditional crops have become very popular among urban consumers. These include barley, buckwheat, finger millet, amaranth and some high-mountain varieties of rice, beans and pulses. Because of their unique taste and health benefits, these crops are called 'super foods' or 'future smart crops'. Given their growing popularity, these crops have great potential for improving the income of mountain communities.

Major crops (cereals, pseudo cereals, legumes/pulses, vegetables, spices, root crops and fruits) found in the KL are presented in Annex I. The list of available crops and varieties and genetic diversity may change as further studies are carried out.

3.3 Non-timber forest products and multipurpose agroforestry species

A huge diversity of NTFPs are collected, used and marketed by the local people in the landscape (Rinchen, 1996; Nawang, 1996; Sherpa, 2001; Oli and Nepal, 2003; Maity et al., 2004; Singh and Sundriyal, 2005; Chettri et

TABLE 2 COMMONLY GROWN CROPS IN THE LANDSCAPE

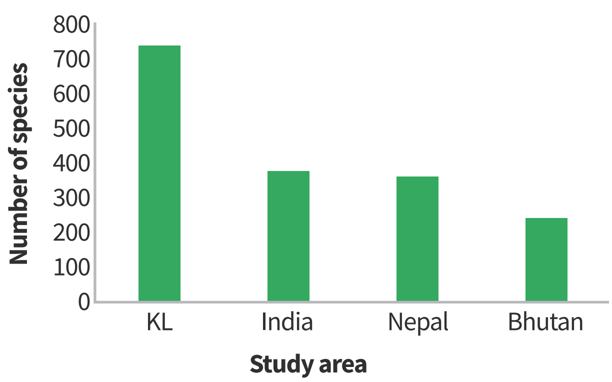
Cereals and pseudocereals	Vegetables	Fruits	Cash crops
Rice (*Oryza sativa* L.)	Broadleaf mustard (*Brassica juncea* [L.] Czem.)	Walnut (*Juglans regia* L.)	Large cardamom (*Amomum subulatum* Roxb.)
Maize (*Zea mays* L.)	Radish (*Raphanus sativus* L.)	Orange (*Citrus reticulata* Blanco)	Tea (*Camellia sinensis* [L.] Kuntze)
Wheat (*Triticum aestivum* L.)	Taro (*Colocasia esculenta* [L.] Schott.)	Pear (*Pyrus communis* L.)	Ginger (*Zingiber officinale* Rosc.)
Barley (*Hordeum vulgare* L.)	Carrot (*Daucus carota* L.)	Banana (*Musa paradisiaca* L.)	Mandarin orange (*Citrus reticulata* Blanco.)
Finger millet (*Eleusine coracana* Gaertn.)	Potato (*Solanum tuberosum* L.)	Plum (*Prunus domestica* L.)	Potato (*Solanum tuberosum* L.)
Buckwheat (*Fagopyrum esculentum* Moench.)	Brinjal/eggplant (*Solanum melongena* L.)	Peach (*Prunus persica* [L.] Batsch)	Chillies (*Capsicum annuum* L.)
Proso millet (*Panicum miliaceum* L.)	Cauliflower (*Brassica oleracea* var. *botrytis* L.)	Bayberry (*Myrica esculenta* [Buch. Ham. ex D. Don.])	Chiraita (*Swertia chirayita* [Roxb. ex Fleming] H. Karst.)
Foxtail millet (*Setaria italica* [L.] Beauvois)	Cabbage (*Brassica oleracea* var. capitata L.)	Indian gooseberry (*Phyllanthus emblica* L.)	Areca nut (*Areca catechu* L.)
Amaranth (*Amaranthus caudatus* L.)	Tomato (*Lycopersicum esculentum* L.)	Chestnut (*Castanopsis indica* [Roxb.] Mig.)	Turmeric (*Curcuma longa* L.)
	Spinach (*Spinacia oleracea* L.)	Passion fruit (*Passiflora edulis* Sims)	Dalle khursani (*Capsicum annuum* L.)
	Pea (*Pisum sativum* L.)		Yacon (*Smallanthus sonchifolius* [Poepp. & Endl.] H. Rob.)
	Pumpkin (*Cucurbita maxima* L.)		
	Chayote (*Sechium edule* [Jacq.] Sw.)		
	Ash gourd (*Benincasa hispida* [Thunb.ex Murray])		

Source: Katwal, (2013); Aryal et al., (2010); Regmi, (2008); Rahman and Karuppaiyan, (2011); Choden, (2008)

al., 2005c; Chhetri et al., 2005; Pradhan and Badola, 2008; Koirala, 2008; Bharati and Sharma, 2010; Pal and Palit, 2011; Uprety et al., 2016; O'Neill et al., 2017). Uprety et al., (2016) documented 739 species of NTFPs from the Kangchenjunga Landscape (see Figure 4).

In the present study, NTFPs include all the wild and uncultivated edible plants, medicinal plants, fungi, lichens and mushrooms used by the local people. They recorded 24 uses of these species in the landscape, the most common uses being food, nutrition, medicine, and tradition/cultural and cash income. The study showed that the diversity of NTFPs in India (377 species) and Nepal (363 species) and their uses are similar. Majority of the NTFPs are angiosperms with 705 taxa, followed by gymnosperms (10), pteridophytes (17), fungi (3),

FIGURE 4 DIVERSITY OF NON-TIMBER FOREST PRODUCTS IN THE KANGCHENJUNGA LANDSCAPE



Source: Uprety et al., (2016)

lichens (2), bryophytes (1) and algae (1). The most commonly used species belong to the Asteraceae (56 species) family, followed by Fabaceae (41), Lamiaceae (27), Rubiaceae (24) and Poaceae (23).

NTFPs found in the Kangchenjunga Landscape have rich potential for trade. However information on the marketing of such species is limited. In KL-India about 40 species are sold in the local market in small quantities. In KL-Nepal 15 species are commercially traded within and outside the country. In Bhutan there is very limited information on the local trade of NTFPs.

Species such as *Aconitum heterophyllum, Bergenia ligulata, Bergenia ciliata, Heracleum nepalense, Heracleum wallichii, Litsea citrata, Oroxylum indicum, Swertia chirayita* are commonly available and sold in the local market in Sikkim. Species such as *Piper longum, Dactylorhiza hatagirea, Rubia cordifolia* are even exported to other states of India. Commonly traded NTFPs from KL-Nepal are: *Dactylorhiza hatagirea, Fritillaria cirrhosa, Neopicrorhiza scrophulariiflora, lichens*, and *Taxus wallichiana*. Species such as *Daphne bholua, Edgerworthia gardnerii, Rhododendron anthopogon, Rubia cordifolia, Swertia chirayita, Valeriana jatamansi*, and *Zanthoxylum* species are legally traded in many parts of India and the process involves getting the government's approval for their cultivation and collection. Despite their huge importance, a number of NTFPs from the Kangchenjunga Landscape are now on the IUCN List of Threatened Species. In Nepal, the government has identified 30 herb species as national priority herbs, and out of them 26 herb species are found in KL-Nepal. Some of the threatened species are *Nardostachys grandiflora, Neopicrorhiza scrophulariiflora, Rauvolfia serpentina*.

The study showed that illegal collection and unregulated harvesting of economically important NTFPs and the lack of a legal transboundary trade facility are major constraints for long-term management of these species in the landscape. Sustainable harvesting practices, value chain development at the local and national level, and legal marketing of these resources are necessary for diversifying opportunities for income generation and livelihood improvement in the landscape.

Local communities in the KL have for generations been using wild and uncultivated edible plants (Sundriyal and Sundriyal, 2001 and 2003; Matsushima et al., 2006; Subba, 2009; Aryal et al., 2010; Ghimeray et al., 2010; Matsushima et al., 2012; Tamang et al., 2013; Chavhan, 2017). Some of the commonly used wild edibles are presented in Annex II. Chavhan (2017) recorded 124 wild and uncultivated plant species belonging to 100 genera of 61 families which are used as food in West Sikkim in KL-India. This list includes 44 herbs, 10 shrubs, 54 trees and 16 climbers. Moraceae, Fagaceae and Dioscoriaceae have the highest proportion of edible wild species. Some of the commonly used fruit species are *Actinidia callosa, Aegle marmelos*, and *Agapetes serpens*. Subba (2009) recorded 193 species of wild plants that are used as food, medicine, or fodder in KL-India. Chimeray et al. (2010) has listed 74 species used by local people in Ilam district of Nepal. Species such as *Nasturtium officinale, Urtica dioica, Ficus lacor, Chenopodium album, Dioscorea deltoidea, Dioscorea bulbifera*, and *Dendrocalamus hamiltonii* are used throughout the year, mainly as vegetables.

Wild edible plants are part of the Bhutanese diet; however, consumption of wild plants is on the wane. Matsushima et al. (2006) documented a total of 98 edible plant species in Bhutan; among these 30 species were wild species.

Agroforestry is an integral component of traditional agriculture/farming system in the rural areas of the KL. Agroforestry species have multiple uses such as food (fruits, vegetables), medicines, fodder, bedding material for livestock, mulching materials, fuelwood, timber, fibre and so on (Oli, 2003; Pant et al., 2012; Sharma et al., 2016; O'Neill et al., 2017; Bhattarai, 2018). Important multipurpose agroforestry trees found in the KL are listed in Annex III.

3.4 Animal genetic diversity

So far 242 animal species have been recorded (190 mammals and 52 amphibians) in the KL, which include domestic, wildlife and amphibians (see Figure 5). Data disaggregated by country shows that the highest number of mammals was recorded in KL-India (171) followed by KL-Nepal (95). Similarly, KL-India has more amphibians (50 species) compared with KL-Nepal (37 species). In Bhutan 58 species of amphibians were recorded countrywide; however specific data on KL-Bhutan is not available.

3.4.1 Diversity of domestic animals

Livestock is an integral part of the farming system in the KL. Livestock are used as emergency capital, and they provide nutrition (milk, meat and eggs), soil nutrients (manure, urine and decaying carcasses), energy (draught power, transportation and fuel), animal fibre (wool, pashmina and hair), and carcass by-products (bone, hide and skin). Over 90% of farm households in the landscape rear animals such as cattle, buffaloes, goats, sheep, pigs, yaks, horses, mules, dogs, domestic fowls, ducks/geese and pigeons (Wilson, 1997; Dorji et al., 2003; Ning et al., 2016a&b; Sharma et al., 2016; ICIMOD et al., 2017b). A list of domestic animals that are commonly reared in the landscape is presented in Annex IV. The number and type of livestock/farm animals vary according to agro-ecozones. At higher elevations of Haa in KL-Bhutan, Sikkim in KL-India, and Taplejung and Panchthar districts in KL-Nepal, villagers raise/rear yak and crossbreeds of yaks and cows. In lower elevations of the landscape, most people rear cows, buffaloes, goats, sheep, pigs, and poultry.

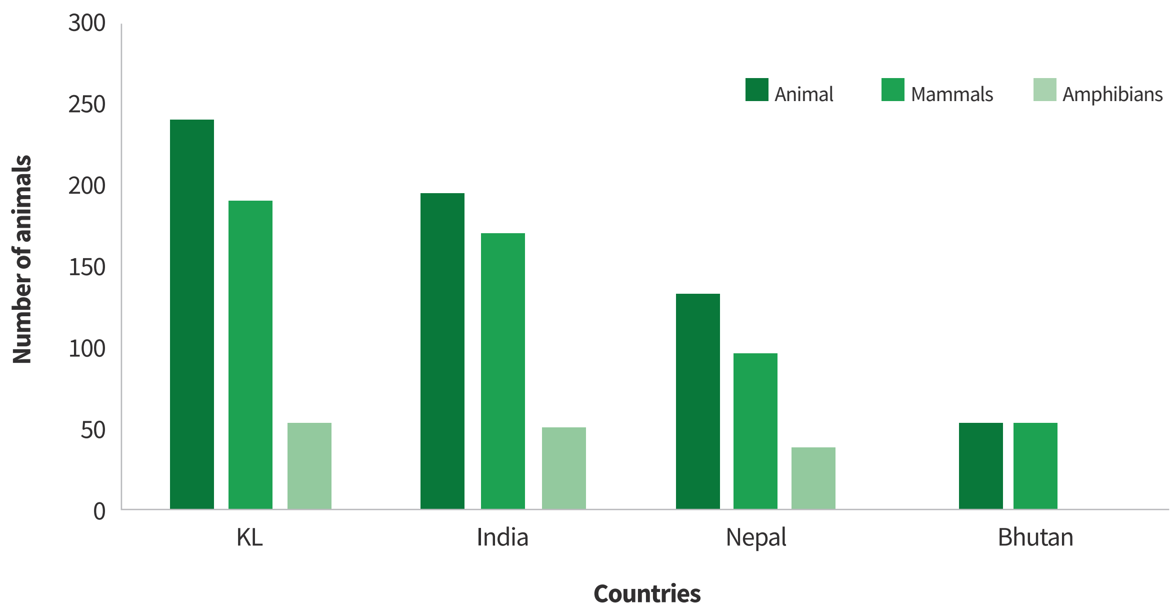
In KL-India (Sikkim Himalaya), mixed crop-livestock farming is a key element of traditional agriculture. Over 80% of mountain farmers in Sikkim own livestock and earn supplementary income from nutrient-rich animal products (Sharma et al., 2016). KL-India hosts a rich variety of livestock including different breeds of pig, goat, cow, sheep, rabbit, and poultry. Local breeds of cows such as *Pahadey gai* and *Siri gai* and local breeds of goats such as *Sigari bakhra* are on the verge of disappearance in KL-India.

Wilson (1997) reported 17 species of livestock including cattle, buffalo, pigs, goat, sheep, chicken, horses, ponies and donkey in KL-Nepal. In KL-Nepal roughly 70% of rural households keep some type of livestock – cattle, buffalo, goat, pig, horse, mule, poultry, ducks, dzo, etc.

In KL-Bhutan, yak and cattle are the major domesticated animals in the upper Himalaya region of Haa and Paro, while cattle, buffaloes, goats, pigs and poultry are common in the lower areas such as Samtse. Yak is a flagship species reared above 3,000 masl and an important source of livelihood for people in Haa and Paro dzongkhags (Dorji et al., 2000). Traditionally, some communities from Haa and Paro also practice transhumance, moving from higher to lower elevations and vice versa while taking their cattle to graze in different locations depending on the season.

Livestock's capacity to provide various products (meat, milk, wool, etc.) depends on how people manage them. Due to commercialization of livestock, there is a growing trend of replacing local breeds with improved ones. Modern breeds of cow, goat, and poultry that are suited for the high levels of input-output of industrial agriculture are displacing the diversity of indigenous livestock breeds. Our study found that there are very few (only five publications) studies on animal genetic diversity and their contribution to livelihood support. There has been no genetic evaluation of many traditional local breeds.

FIGURE 5 ANIMAL GENETIC DIVERSITY IN THE KANGCHENJUNGA LANDSCAPE



Source: ICIMOD/RDS (2020); Subba et al., (2017).

3.4.2 Diversity of wild animals used for food

Very few wild animals are hunted for food and there is limited information on it. Hunting is an illegal activity in much of the landscape. A study by Subba (2009) found that 79 species of big and small wild animals are hunted for food and nutrition in Sikkim. They include 13 species of grasshopper and other insects, 4 species of crab, 14 species of fish, 8 species of frog, 30 species of bird and 10 species of mammal which the locals normally collect/hunt from forests, streams, rivers and rivulets and their own cardamom fields at Hee and Hee Patel villages in West Sikkim. In Papung and Tankhu of KL-Nepal, people hunted wildlife such as barking deer (*Muntiacus muntjac*) and Himalayan goral (*Naemorhedus goral*) in the past, though it has completely stopped now (Shrestha et al., 2016). It is reported that species such as wild boar are sometimes killed in retaliation against crop depredation in the landscape.

3.4.3 Diversity of aquatic species

Studies on the diversity of aquatic species in the landscape are scarce. In KL-India, about 48 species of inland and cold water fishes were reported by Rahman and Karuppaiyan (2011). According to their study, the most common local fishes in Sikkim are *Schizothoraichthys plagiostomus, Schizothoraichthys esocinus, Danio rerio, Puntius sarana, Amphipnous cuchia, Tor tor, Labeo angra*, and *Labeo gorrius*. In KL-Nepal, Chaudhary et al., (2015) have documented 44 species of fish. Among them, *Tor putitora* falls under the vulnerable category and *Labeo coeruleus* and *Semiplotus semiplotus* are in the susceptible category of the National Red Data Book. The most common species found in KL Nepal is *Psilorhynchoides pseudecheneis*, which is endemic to the area. Similarly, *Barilius shacra, Barilius bendelisis, Barilius barila* and *Schizothoraichthys labiatus* are some of the common species found in KL Nepal (Chaudhary et al., 2015; Limbu et al., 2018). A total of 91 species of fish have been recorded in Bhutan; however the exact number of species found in the KL part of Bhutan is yet to be recorded systematically (Gurung et al., 2013; Rai et al., 2008). Indigenous fish species found in KL-Bhutan include Himalayan trout (*Barilius* spp.) and mahseer (*Tor tor*), which is listed as a protected species in the Forest and Nature Conservation Act 1995. Catching and harvesting fish is a common practice in KL-India and KL-Nepal; however, in KL-Bhutan, there are restrictions on killing/harvesting fish from nature or the river. Still, consumption of dried fish is very common in Bhutan. In addition to fish, a great variety of shrimps, gastropods and bivalves are found in the lakes, wetlands, ponds and streams of the KL.

3.4.4 Diversity of pollinators

The Kangchenjunga Landscape hosts a great diversity of pollinators such as insects (bees, butterflies, flies, moths, etc.), birds, mammals, etc. They play an important role in pollination and gene flow among vegetable crops, pulses, fruit trees, cash crops, and agroforestry/forest species crops and other natural flora occurring in the landscape (Singh et al., 2011; Gaira et al., 2014 and 2016). Among insect pollinators, bees – honeybees, bumblebees, stingless bees (*Hymenoptera*), butterflies and moths (*Lepidoptera*) and hover flies/syrphid flies (*Diptera*) are the most common and efficient pollinators (Sharma et al., 2016). Among bees, five species of honeybee, one species of stingless bee, two species of bumblebee are commonly seen pollinating various crops (Sharma et al., 2016). Bumblebee species – *Bombus haemorrhoidalis* and *B. breviceps* were reported to be the most efficient pollinators of black cardamom flowers in the landscape (Gaira et al., 2016; Sharma et al., 2016). Other common pollinators found in the landscape are leaf cutter bees (*Megachile lanata*), hover fly (*Episyrphus balteatus*), hawk moth (*Macroglossum stellatarum*), and crimson sunbird (*Aethopyga siparaja*), which are effective pollinators for black cardamom and other farm fruits and crops.

The agroecosystem of the landscape has great potential for pollinator species of birds and butterflies. Birds and butterflies are considered bio-indicators and used as surrogate taxa to predict the health of an ecosystem. Nearly 50% of the total 1,400 butterflies recorded in the Indian subcontinent by Haribal (2000) are found in the KL, particularly in Sikkim. Acharya and Chettri (2012) have recorded 689 species of butterflies, 1,500 species of moth, and 574 species of bird (45% of the total bird species found in the Indian subcontinent) in Sikkim.

Honeybee species naturally found in the landscape include *Apis cerana, Apis dorsata, Apis florea* (called Kathyauree in Nepali), *Apis laboriosa* and the stingless honeybee, *Trigona* (*Putka* in Nepali). Among these, farmers keep only *Apis cerana* and *Trigona* in hives for honey while other species occur in the wild. The European honeybee *Apis mellifera* has been introduced and managed for commercial honey production. The landscape is rich in bee floral diversity necessary to support honeybees and other pollinators. *Leucosceptrum canum* (known as *bhusure* in Nepali or *ghurpis* in the local language), *Eurya accuminata* (wild osmanthus), *Englehardtia spicata* (mauwa), and *Prunus cerasoides* (wild cherry) are the main sources of honey depending on the season. Other prominent bee forage sources available in the KL include *Albizia chinensis. Bauhinia purpurea, Berberis angulosa, Bombax ceiba, Castanopsis indica, Neolamarckia cadamba, Prunus persica, Pyrus communis, Pyrus pashia, Rubus ellipticus, Saurauia napaulensis, Schima wallichii, Shorea robusta,* and *Zea mays*.

3.5 Threats to agrobiodiversity conservation and maintenance in the KL

The KL exhibits rich agrobiodiversity. However, in recent years the wealth of traditional crops and varieties/landraces and indigenous breeds of livestock has been gradually declining. A large number of plant species are eroding from their habitat or growing environment (Regmi, 2008; Aryal et al., 2010; Rahman and Karuppaiyan, 2011; Katwal et al., 2015; Chaudhary et al., 2015; Sharma et al., 2016). Both natural and anthropogenic induced pressures on agrobiodiversity loss are reported by the local people and published sources. Broadly, these drivers could be (i) environmental (climate change, land use land cover change, invasive and alien species etc.); (ii) social (demographic change, urbanization, rural development, etc.); iii) economic (global market, tourism, wildlife trade, hydropower etc.); (iv) cultural (erosion of culture, taboos, loss of traditional knowledge system, customary practices etc.); and (v) governance & institutions (see Table 3).

A study by Katwal et al., (2015) revealed a 28.6% loss of traditional varieties of six major cereal crops in Bhutan. The loss ranged from 14% for millet to 43% for barley, which is quite alarming. Even among major crops like paddy, wheat, maize and potatoes, a few varieties promoted by agricultural extension agencies have led to a decline in diversity, as reported by farmers (Chaudhary et al., 2015; Sharma et al., 2016).

Access to road has surprisingly led to decreased agricultural activity and agrobiodiversity in many villages. With improved access to road, people are relying more on market supply of cereal crops and vegetables. Further, the younger generation is not enthusiastic to work in the fields.

Climate change impacts such as fluctuating weather and unreliable monsoon have led to a rise in local temperature and increased the frequency of drought, flood, frost and hailstorm. This has given rise to new pests and diseases in both crops and livestock, affecting agrobiodiversity in the landscape.

Human-wildlife conflict has made it highly challenging for the locals to continue their agricultural activity. Crop and livestock depredation by Asiatic black bear, wild boars, monkeys and porcupines are reported regularly in the hills and mountain areas of the landscape. Farming communities in the landscape see this as a serious threat to agrobiodiversity in the KL (Chaudhary et al., 2015; Katwal et al., 2015; ICIMOD, 2019).

Increased outmigration has led to labour shortage in rural areas. Farmland in many parts of the landscape lie fallow as a result. This has contributed to a gradual decline in the diversity of local crops and landraces.

In recent years, climate induced and other changes in the landscape have altered the composition of forest and grassland species, leading to a shortage of fodder and grass necessary for maintaining the number and diversity of livestock. Forest degradation and replanting of pines has reduced the availability of fodder, while invasive species such as *Eupatorium odoratum, E. adenophorum, Ageratum houstonianum, Erigeron karvinskianus, Galinasoga parviflora, Erichthites valarianiifolia, Argemone mexicana* and *Parthenium hysterophorus*, etc. have encroached on grassland and forest floor.

In addition, climate change may hamper pollination services as it changes plant components and alters plant-pollinator interactions (Klein et al., 2007). In KL-India, several cross-pollinated crops depend on pollination services. There is a need to promote effective pollination through agroforestry based diversified farming. For example, black cardamom agroforestry offers foraging resources to wild bees (pollinators) throughout the year.

3.6 Opportunities for agrobiodiversity conservation

Amid the various threats mentioned above, there are ample opportunities for improving agrobiodiversity in the KL. One possibility is to revitalize traditional crops and native livestock, contributing to both nutrition security and ecosystem resilience. Adapting a variety

TABLE 3 KEY THREATS TO AGROBIODIVERSITY LOSS

Key threats to agrobiodiversity loss	Nature of loss
Environmental: Climate change, land use land cover change, invasive and alien species are major factors behind the loss of agrobiodiversity.	Increase in temperature, drought, diseases and pests result in the loss of crop and livestock breeds Climate change alters phenology and productivity, and increases incidence of diseases. Land use change affects microclimate and nutrient availability, leading to loss of local land races Invasive species colonize and eliminate local and traditional variety
Social: Increasing population, urbanization and rural development has led to a loss of agrobiodiversity	Demographic changes have led to land fragmentation Infrastructure development has allowed market forces to make inroads into rural areas and replace subsistence crops with market-oriented cash crops The education system fails to encourage the younger generation to pursue farming as a career
Economic: Global market forces, improved crop varieties, tourism, and wildlife trade have gradually eroded subsistence farming in the mountains	A wide diversity of traditional crops are replaced due to mono-cropping system Displacement of indigenous landraces and indigenous livestock breeds Declining interest in agriculture and livestock farming Shortage of labour for farm activities Abandonment of agricultural fields Change in cropping pattern due to comparative economic advantage Access to the road and market has made fast food easily available, resulting in a loss of traditional crops and food recipes Crop and livestock depredation is discouraging farmers Poaching and illegal trade of flora and fauna puts additional pressure on gene pools
Cultural: Changes in traditional practices and food habits have adversely affected agrobiodiversity	Erosion of traditional food culture and the desire to maximize profits through cash crop monocultures such as maize Traditional knowledge is disappearing; it is not getting transferred to younger generations.
Governance and institutions: A stronger governance structure is needed for effective management of natural resources	Old customs and traditions for managing agrobiodiversity are vanishing. Extension agencies do not give priority to preserving local and traditional varieties Government agencies prioritize economic prosperity over preservation of local varieties Field gene bank/community seed bankpractices are not properly managed

Source: Aryal et al., (2010); Rahman and Karuppaiyan, (2011); Katwal, (2013); Katwal et al., (2015); Chaudhary et al., (2015); Sharma et al., (2016).

of genetic materials in diverse agro-ecological condition could help in identifying suitable varieties and breeds for enhanced production. Local varieties and breeds likely have greater ability to adapt to the changing climate. A systematic survey of the entire landscape could be done to prevent further erosion of traditional varieties/species/breeds. More detailed analyses of agrobiodiversity in selected sites would help in identifying potential sites for in-situ conservation of crop genetic resources.

Promotion, conservation and judicial use of agrobiodiversity is necessary for sustained food production. It is important to assess the status of agricultural biodiversity and associated trends, the underlying causes of change, and knowledge of management practices; identify adaptive management techniques, practices and policies; build capacity, increase awareness and promote responsible action; and mainstream national plans and strategies for agrobiodiversity conservation and management (Chettri et al., 2008b; Chettri et al., 2010). We need transboundary networking and regional cooperation to be able to carry out these efforts.

The landscape offers great opportunities for working with mountain women for the conservation and management of local agrobiodiversity. Strategic engagement with women is very important as they are the custodians of agricultural biodiversity and play a crucial role in conservation and maintenance of agrobiodiversity (Aryal et al., 2010; Bhattarai et al., 2015; Sharma et al., 2016; Goodrich, 2020). Women play a considerable role in agrobiodiversity management, seed selection, preservation, exchange, cultivation and decision-making at the farm level. As repositories of knowledge, women have helped enrich crop diversity and build the resilience of traditional and local food systems (Sharma et al., 2016). Their knowledge of quality attributes of landraces and of the uses of medicinal, herbal and aromatic plants has been crucial for sustaining the use of these species at the farm level.

There is great potential for transboundary collaboration and exchange of information, technology and traditional knowledge among the member countries at the local, national and regional level. Seed and genetic materials are being exchanged informally at the local level, which suggests possibilities for joint research on common crops/livestock. There is opportunity for establishing a regional gene bank and facilitating exchange of germplasm for bona fide uses.

Given its spectacular views and important tourist destinations, the landscape has great potential for regional tourism. There are opportunities for developing culinary tourism and promoting unique products from the landscape, e.g., Kangchenjunga cardamom tea.

Increasing restrictions on grazing (mostly by community forest user groups) has impact on animal husbandry in the landscape. While grazing restrictions are important for forest conservation, they can prevent livestock from getting fodder. In Nepal, forest offices are trying to address this situation by planting fodder crops. Fodder plantation has also helped restore degraded private land/agroecosystems.

Efforts could be made to harvest rainwater and wastewater for irrigation purposes, especially in the dry areas of the landscape. A successful example is the ‘Dhara Vikas’ initiative in KL-India (Sikkim) which helped revive drying springs/streams and lakes.

Improved management of land, soil and water can help communities to cope with adverse climatic conditions, and maintain crop diversity.

There is great potential for the development and promotion of organic agriculture in the landscape. Organic agriculture that recognizes the importance of traditional farming systems can benefit mountain farmers in the landscape. An increasing number of small farmers have adopted bio-composting or vermi-composting non-traditional methods for improving the nutrient content and water-holding capacity of soil in their fields (Sharma et al., 2016; Gaira et al., 2019). Both traditional and innovative farm techniques can strengthen the resilience of local food systems.

The landscape offers rich possibilities for promoting pastoralism and agropastoralism. It is the main source of livelihood of indigenous communities in the alpine and Trans-Himalayan region. The key features of pastoralism – rotational grazing, traditional management of resources, and conflict resolution – promote community ownership and environmental stewardship and sustainability.

Pollinators can help improve production in organic farming. It is therefore important to ensure their year-round availability, particularly in winter season (Pandey et al., 2019). A clear policy on inclusion of crop-pollinator interactions and ecology (management of ecological processes) is essential. A comprehensive calendar of non-crop foraging resources needs to be developed, with special emphasis on high-value species like *B. ciliata*, which could benefit the community in multiple ways (Pandey et al., 2019).

In recent years traditional crops (amaranth, buckwheat, finger millet, and barley) have become popular in the high-end niche market of India and Nepal. This has opened up possibilities for developing agro enterprises to generate income for mountain communities. Wild and non-cultivated plants hold great potential for alleviating hunger, malnutrition and poverty. These plants are climate resilient, nutrition rich and easy to cultivate, and can be developed as site-specific staple food commodities. They could be diversified and exported by linking farmers to markets.

Agrobiodiversity gives farmers opportunities/options to manage climate risks. Climate smart agriculture relies on agrobiodiversity at three different levels – genetic, species, and ecosystem – to enhance productivity, adaptability and resilience. It entails the promotion of agroforestry system/species, development and dissemination of stress tolerant varieties, and introduction of early maturing varieties.

KEY MESSAGE

Agrobiodiversity has been recognized as a major contributor to food and nutritional security, household-level health care and income security of the billions of people across the globe. However, we are yet to assess the value of agrobiodiversity in the KL.

SECTION IV

Discussion

Transboundary collaboration and coordination are needed for the conservation and management of agrobiodiversity in the region.

In this working paper, we have reviewed publications relevant to agrobiodiversity, particularly key components of agrobiodiversity such as: a) cultivated crop diversity, b) NTFPs including wild and non-cultivated plants, and c) animal genetic diversity. We discussed agrobiodiversity and the present state of knowledge, its sociocultural, ecological and economic significance to mountain communities, threats to agrobiodiversity, and opportunities and strategies for conservation and management of agrobiodiversity in the Kangchenjunga Landscape.

Agrobiodiversity (particularly plants – cultivated and wild, animals – domesticated and wild, and birds) plays a major role in ensuring life support systems and provides food, medicines, fibres and other essentials to about 7 million people who live in the KL. Agrobiodiversity has been recognized as a major contributor to food and nutritional security, household-level health care and income security of the billions of people across the globe (Bantawa and Rai, 2009; Badola and Pradhan, 2013; Baldinelli, 2014; Panmei et al., 2016; Ong and Kim, 2017; Aryal et al., 2018; Diaz et al., 2018; FAO, 2019). However, we are yet to assess the value of agrobiodiversity in the KL.

Our review recorded 5,204 plant species, along with 242 species of animal and 618 species of bird from the landscape. Among them about 750 species of plants (both cultivated and wild) have been used for various purposes by the local people of the KL. Human beings have long been using plant species for food, medicines, fibre and so on. Many communities continue to depend on plant resources for daily survival and livelihood. They have traditional knowledge and skills for utilizing agrodiversity (Maestre et al., 2012; Wangyal, 2012; Parajuli, 2013; Konsam et al., 2016; Singh et al., 2016; Aryal et al., 2018; FAO, 2019). A number of animals, particularly domestic animals and a few wild mammalians, also contribute significantly to local livelihood in the KL. These animals are an integral part of the mountain farming system. However, compared to plants (those which are cultivated), animals –mammals, birds, fish, amphibians, and reptiles, and a wide range of invertebrates – have received less priority in research and development programmes of both government and non-government organizations (Kandel et al., 2016; Uprety et al., 2016).

Despite their importance to human beings, various crops and varieties, livestock breeds, birds and wildlife are rapidly disappearing from their habitats (Bisht et al., 2007; Shakya and Joshi, 2008; Ugyen and Olsen, 2008; Pal and Palit, 2011; Acharya and Chhetri, 2012; Adhikari et al., 2017; Aryal et al., 2017; Joshi et al., 2017). Many genetic resources are on the verge of extinction while a large number of them have already disappeared before they could be fully utlized. Furthermore, agricultural intensification that relies on a handful of crops, accompanied by excessive dependence on agrochemicals and external water and energy inputs, has negative impact on biological diversity (Schmidt et al., 2010; Adhikari et al., 2017). The decline of agrobiodiversity in the landscape can be attributed to both natural and anthropogenic drivers. Some of the drivers our study identified are – introduction of modern and uniform crop/plant varieties as well as new improved livestock breeds; large-scale migration for employment; destruction of habitat and development of road and infrastructures; changing food habit and attitudes, particularly among the youth; the desire to maximize profit through cash crop monocultures such as cardamom and tea; human-wildlife conflict; and climate change. Previous studies in and outside the region identified similar factors behind decreasing agrobiodiversity (Aase et al., 2009; Chaudhary and Aryal, 2009; Chettri et al., 2010; Verma et al., 2010; Chaudhary et al., 2011; Chettri et al., 2012; Baldinelli, 2014; Bhattarai et al, 2015; Aryal et al., 2017, 2018; Dendup, 2018; ICIMOD, 2019; FAO, 2019). On the other hand, knowledge about climate and non-climatic changes and their impact on food and nutritional security and genetic resources management in the region has not been well documented (Aase et al., 2009; Chaudhary et al., 2011; Kumar, 2012).

One of the serious issues in the landscape is human-wildlife conflict (Naha et al, 2019, 2020). The landscape has witnessed a number of cases of crop and livestock depredation due to wildlife. This has affected the livelihood and well-being of locals. Crop and livestock depredation by Asiatic black bears, wild boars, monkeys, peafowl and porcupines are reported regularly in the hills and mountain areas of the landscape. Farming communities see this as a major cause for the decline of on-farm agrobiodiversity (Chaudhary et al., 2015; Katwal et al., 2015; ICIMOD, 2019). Wild animals like monkeys, wild boars and porcupines, and birds such as parrots and peafowl are the major crop pests in the landscape. The respective governments and authorities should come up with integrated schemes for resolving human-wildlife conflict. However, within the landscape, there is a mismatch between policies of KL countries; one country prioritizes conservation over the livelihood needs of local communities, whereas another country seeks to integrate conservation and livelihood needs. Transboundary collaboration and coordination are needed for the conservation and management of agrobiodiversity in the KL (Chettri et al., 2007; Chettri et al., 2008b; ICIMOD et al., 2017a; ICIMOD, 2019).

Traditional crops/varieties, NTFPs and livestock breeds which are tolerant to fluctuating environmental conditions and have different qualities (storability, cooking quality, taste) and disease/pest resistant traits can play a key role in maintaining agrobiodiversity (Vernooy and Song, 2004; Ghimiray, 2005; Sthapit et al., 2008; Regmi et al., 2009; Frison et al., 2011; Ajani et al., 2013; Paudel et al., 2016; Ghimire et al., 2018; Alemu et al., 2019). However we lack data and information on such attributes of the particular crops/plants, breeds which is also a leading cause of loss of agrobiodiversity. Hence it is important to conduct a comprehensive assessment of the loss of agrobiodiversity, identify key causes of agrobiodiversity loss and its impact on food security, nutrition and overall livelihoods of the communities. In-depth knowledge and understanding of such factors is necessary for identifying solutions to address these issues. Finally, there is a need to improve cooperation (research, extension and education) among Bhutan, India and Nepal for effective conservation and management of agrobiodiversity in the landscape.

KEY MESSAGE

Long-term management of agrobiodiversity is constrained by several knowledge gaps. We have analysed those gaps and come up with a way forward that involves investments in research, capacity enhancement, policy support, and regional cooperation.

SECTION V

Conclusions and way forward

Despite challenges, there are emerging opportunities to conserve and sustainably use agrobiodiversity in the KL.

The Kangchenjunga Landscape is a storehouse of agricultural biodiversity. Agrobiodiversity provides food, medicines, fibres and other essentials to about 7 million people who inhabit the landscape. Over the years the process of globalization has posed a grave threat to agrobiodiversity worldwide including the KL. Monocultures and cash crops-based farming, and introduction of modern and uniform high-yielding hybrids are taking over the mixed farming system and traditional varieties and land races. Agricultural lands are being used for non-agricultural purposes such as infrastructure development. Due to changing food preferences and attitudes of consumers, cultural erosion, lack of interest in agriculture among youth, and migration for employment, fields lie abandoned or neglected. Decline in agrobiodiversity narrows down the food choices of mountain communities and affects their food and nutrition security as well as their ability to cope with changes.

Despite challenges, there are emerging opportunities to improve agrobiodiversity in the KL. It is important to conserve and protect farming systems and practices that sustain agrobiodiversity for the welfare of current and future generations. Traditional practices in agrobiodiversity management can enhance the capacity of farmers to adapt to climate change and cope with adversity.

As discussed above, long-term management of agrobiodiversity is constrained by several knowledge gaps. We have analysed those gaps and come up with a way forward. Our recommendations are divided into three broad categories (research, capacity enhancement and policy support):

Investment in research

Enhance scientific understanding of types of land use/land cover, the variety of farming cultures, agriculture management practices, and socioeconomic, ecological and cultural dynamics of agrobiodiversity in different agro-ecozones in the KL.

Document the rich traditional knowledge of the diversity of crop varieties/landraces, livestock, neglected, underused and wild plant species and their management and uses. The knowledge gap needs to be filled to reduce the erosion of agrobiodiversity and exploit its full benefits.

Conduct research on the role of pollinators, their management and their impact on crop productivity and other multiple ways in which they help build the resilience of farm communities

Carry out an assessment of the loss of agrobiodiversity, identify key drivers of the loss and its impact on food and nutritional security and overall livelihood of communities. In-depth knowledge and understanding of such factors is necessary for identifying solutions.

Capacity enhancement

Build the capacity of farmers and their organizations to develop and promote enterprises through value addition, quality assurance, and marketing of mountain agro products.

Strengthen the local, regional and national information and communication system for the maintenance and use of agrobiodiversity. The information needs of different stakeholders, especially policy makers and rural communities, should be assessed, and programmes should be developed to address such needs.

Enhance farmers' access to information, financial resources and technology related to agrobiodiversity management and development of market-oriented agrobiodiversity products.

Link farmers and their organizations to buyers to ensure that their products find an adequate market and they receive a fair price for their products. Farmers' organizations/cooperatives can also be supported to establish market outlets to promote and sell mountain agrobiodiversity products.

Policy support

Incorporate agrobiodiversity conservation in existing policies, strategies and plans for conservation and development, and ensure effective implementation of existing policies.

Emphasize in situ conservation of landraces of traditional varieties; ex situ conservation of base collections in field gene banks; in vitro storage and cryopreservation of important germplasm; and characterization of indigenous livestock and poultry resources, which might have adaptive and disease resistance genes.

Support the agriculture, horticulture, and animal husbandry departments to form biodiversity management committees to promote community-based biodiversity management and community-based biodiversity registration. Garner appropriate technical and financial support for community seed banks and community-led plant or animal breeding.

Promote underutilized and neglected crops and wild species to enhance food, nutrition and income security of mountain communities in the landscape. Identify promising species and develop ways to promote their conservation and sustainable management.

Develop and promote organic farming with a special focus on pollinators and giving due recognition to the importance of integrated production systems such as home gardens.

Provide incentives to farmers to maintain agroecosystems and agrobiodiversity on their farms.

Highlight the importance (and potential for use) of local plant, animal and fungi species along with the traditional and indigenous knowledge related to their use in school and college curriculums.

Regional cooperation

Facilitate exchange of information, research, technology and traditional knowledge among the member countries at the local, national and regional level.

Develop agro-based products specific to the landscape and create a regional brand.

Develop culinary tourism to promote the unique traditional foods of each country in the KL.

Strengthen regional cooperation to protect indigenous and local knowledge, skills and ways of life.

Encourage joint research to establish a regional gene bank and facilitate exchange of germplasm for bona fide uses.

References

Aase, T. H., Chaudhary, R. P., & Vetaas, O. R. (2010). Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya. *Area, 42*(2), 228–238. https://doi.org/https://doi.org/10.1111/j.1475–4762.2009.00911.x

Acharya, B. K., & Chettri, B. (2012). Effect of climate change on birds, herpetofauna and butterflies in Sikkim Himalaya: a preliminary investigation. In M. L. Arrawatia, &. S. Tambe (Eds.), *Climate change in Sikkim: patterns, impacts and initiatives* (pp. 141–160). *Gangtok: Information and Public Relations Department*.

Adhikari, L., Hussain, A., & Rasul, G. (2017). Tapping the potential of neglected and underutilized food crops for sustainable nutrition security in the mountains of Pakistan. *Sustainability, 9*(2), 291. https://www.mdpi.com/2071–1050/9/2/291

Agnihotri, R. K., & Palni, L. M. S. (2007). On-farm conservation of landraces of rice (Oryza Sativa L.) through cultivation in the Kumaun region of Indian Central Himalaya. *Journal of Mountain Science, 4*(4), 354–360. https://doi.org/10.1007/s11629–007–0354–3

Alemu, S., Alemu, M., Asfaw, Z., Woldu, Z., & Fenta, B. A. (2019). Cowpea (Vigna unguiculata (L.) Walp., Fabaceae) landrace (local farmers' varieties) diversity and ethnobotany in Southwestern and Eastern parts of Ethiopia. *African Journal of Agricultural Research, 14*(24), 1029–1041. https://doi.org/10.5897/AJAR2018.13641

Ajani E. N., Mgbenka, R. N., & Okeke, M. N. (2013). Use of Indigenous Knowledge as a Strategy for Climate Change Adaptation among Farmers in sub-Saharan Africa: Implications for Policy. *Asian Journal of Agricultural Extension, Economics & Sociology, 2*(1): 23–40. 10.9734/AJAEES/2013/1856

Antonelli, A., Kissling, W. D., Flantua, S. G. A., Bermúdez, M. A., Mulch, A., Muellner-Riehl, A. N., Kreft, H., Linder, H. P., Badgley, C., Fjeldså, J., Fritz, S. A., Rahbek, C., Herman, F., Hooghiemstra, H. & Hoorn, C. (2018). Geological and climatic influences on mountain biodiversity. *Nature Geoscience, 11*(10), 718–725. https://doi.org/10.1038/s41561–018–0236–z

Aryal, K. P., Berg, A, & Ogle, B. (2009). Uncultivated Plants and Livelihood Support- A Case Study from the Chepang People of Nepal. *Ethnobotany Research and Applications,* 7, 409–422.

Aryal, K. P., Kerkhoff, E. E., Maskey, N., & Sherchan, R. (2010). *Shifting Cultivation in the Sacred Himalayan Landscape: A Case Study in the Kangchenjunga Conservation Area*. WWF Nepal.

Aryal, K., Poudel, S., Chaudary, R. P., Chettri, N., Ning, W., Shaoliang, Y., & Kotru, R. (2017). Conservation and management practices of traditional crop genetic diversity by the farmers: a case from Kailash Sacred Landscape, Nepal. *Journal of Agriculture and Environment, 18*, 15–28.

Aryal, K. P., Poudel, S., Chaudhary, R. P., Chettri, N., Chaudhary, P., Ning, W., & Kotru, R. (2018). Diversity and use of wild and non-cultivated edible plants in the Western Himalaya. *Journal of Ethnobiology and Ethnomedicine, 14*(1), 10.

Badola, H. K., & Pradhan, B. K. (2013). Plants used in healthcare practices by Limboo tribe in South-West of Khangchendzonga Biosphere Reserve, Sikkim. *Indian J Traditional Knowledge, 12*(3), 355–369.

Baldinelli, G. M. (2014). Agrobiodiversity conservation as a coping strategy: Adapting to climate change in the Northern highlands of Bolivia. *Consilience: The Journal of Sustainable Development, 11*(1), 153–166.

Bantawa, P., & Rai, R. (2009). Studies on ethnomedicinal plants used by traditional practitioners, Jhankri, Bijuwa and Phedangma in Darjeeling Himalaya. *Natural Product Radiance, 8*(5), 537–541.

Benayas, J. M. R., & Bullock, J. M. (2012). Restoration of biodiversity and ecosystem services on agricultural land. *Ecosystems, 15*(6), 883–899. https://doi.org/10.1007/s10021–012–9552–0

Bharati, K. A., & Sharma B. L. (2010). Plants used as ethnoveterinary medicines in Sikkim Himalayas. *Ethnobotany Research and Applications, 10*, 339–356.

Bhattarai, K. R. (2018). Plants of Mai Pokhari Botanical Garden and Adjoining Areas, East Nepal. *Journal of Plant Resources, 16*(1), 46.

Bhattarai, B., Beilin, R., & Ford, R. (2015). Gender, agrobiodiversity, and climate change: A study of adaptation practices in the Nepal Himalayas. *World Development, 70,* 122–132. https://doi.org/10.1016/j.worlddev.2015.01.003

Bisht, I. S., Mehta, P. S., & Bhandari, D. C. (2007). Traditional crop diversity and its conservation on-farm for sustainable agricultural production in Kumaon Himalaya of Uttaranchal state: a case study. *Genetic Resources and Crop Evolution, 54*(2), 345–357. https://doi.org/10.1007/s10722–005–5562–5

Chaudhary, R. P., Uprety, Y., Joshi, S., Shrestha, K., Basnet, K., Basnet, G., Shrestha, K. R., Bhatta, K. P., Acharya, K. P., & Chettri, N. (2015). Kangchenjunga Landscape Nepal: from conservation and development perspectives. MoFSC, RECAST, & ICIMOD.

Chaudhary, P., Rai, S., Wangdi, S., Mao, A., Rehman, N., Chettri, S. and Bawa, K. S. (2011). Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape. *Current Science*, *101*(4), 504–513.

Chaudhary, P., & Aryal, K. (2009). Global warming in Nepal: challenges and policy imperatives. *Journal of Forest and Livelihood, 8,* 4–13.

Chaudhary, S., Tshering, D., Phuntsho, T., Uddin, K., Shakya, B., & Chettri, N. (2017). Impact of land cover change on a mountain ecosystem and its services: case study from the Phobjikha valley, Bhutan. *Ecosystem Health and Sustainability, 3*(9), 1393314.

Chaudhary, S., Chettri, N., Uddin, K., Khatri, T. B., Dhakal, M., Bajracharya, B., & Ning, W. (2016). Implications of land cover change on ecosystems services and people's dependency: A case study from the Koshi Tappu Wildlife Reserve, Nepal. *Ecological Complexity*, *28*, 200–211.

Chavhan, A. (2017). Traditional Use of wild plants for food in West Sikkim, India. *International Journal of Life Sciences, 5*(4), 730–741.

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., … & Oli, K. P. (2010). Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change. ICIMOD.

Chettri, N., Sharma, E., & Lama, S. D. (2005). Non-timber forest produces utilization, distribution and status in a trekking corridor of Sikkim, India. *Lyonia 81,* 93–108.

Chettri, N., Shakya, B., Lepcha, R., Chettri, R., Rai, K. R., & Sharma, E. (2012). Understanding the linkages: Climate change and biodiversity in the Kanchenjunga landscape. In M. L. Arrawatia, &. S. Tambe (Eds.), *Climate change in Sikkim: patterns, impacts and initiatives* (pp. 161–178). *Gangtok: Information and Public Relations Department*.

Chhetri, D. R., Basnet, D., Chiu, P. F., Kalikotay, S., Chhetri, G., & Parajuli, S. (2005). Current status of ethnomedicinal plants in the Darjeeling Himalaya. *Current Science, 89*(2), 264–268.

Chettri, N., Shakya, B., & Sharma, E. (2008). *Biodiversity conservation in the Kangchenjunga landscape*. ICIMOD.

Chettri, N., Thapa, R., Shakya, B. (2007). Participatory conservation planning in Kangchenjunga transboundary biodiversity conservation landscape. *Tropical Ecology, 48*(2), 163–176.

Choden, S. (2008). Socioeconomic Analysis of the Toorsa Strict Nature Reserve and Jigme Dorji National Park Conservation Corridor in Bhutan. In N. Chettri, B. Shakya, & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp.111–116). ICIMOD.

Ghimeray, A. K., Sharma, P., Chimire, B., Lamsal, K., Ghimire, B., & Cho, D. H. (2010). Wild edible flowering plants of the Lllam Hills (Eastern Nepal) and their mode of Use by the Local community. *Korean Journal of Plant Taxonomy, 40*(1), 74–77.

Dendup, T. (2018). Agricultural transformation in bhutan: From peasants to entrepreneurial farmers. *Asian Journal of Agricultural Extension, Economics & Sociology*, 1–8.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., van Oudenhoven, A. P. E., van der Plaat, F., Schröter, M., Lavorel, S., … Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*(6373), 270 LP–272. https://doi.org/10.1126/science.aap8826

Dimitrov, D., Nogues-Bravo, D., & Scharff, N. (2012). Why do tropical mountains support exceptionally high biodiversity? The Eastern Arc Mountains and the drivers of Saintpaulia diversity. *PLOS One, 7*(11), e48908. https://doi.org/10.1371/journal.pone.0048908

Dorji, T., Hanotte, O., Arbenz, M., Rege, J. E. O., & Roder, W. (2003). Genetic Diversity of Indigenous Cattle Populations in Bhutan: Implications for Conservation. Asian Australian *Journal of Animal Sciences 16,* 946–951.

Dorji, T., Goddard, M., Perkins, J., Robinson, N., & Roder, W. (2000). Genetic diversity in Bhutanese yak (Bos grunniens) populations using microsatellite markers. In H. Jianlin, C. Richard, O. Hanotte, C. McVeigh, & Rege J. E. O. (Eds.), *Yak production in central Asian highlands. Proceedings of the third international congress on yak held in Lhasa, P.R. China, 4–9 September 2000* (pp. 197–201). International Livestock Research Institute (ILRI)

Dorji, Y. (2012). Women's roles in wild yam, conservation, management and use in Bhutan. In: M. Khadka, R. Verma (Eds.), *Gender and biodiversity management in the Greater Himalayas* (pp. 25–27). ICIMOD.

FAO. (2019). *The State of the World's Biodiversity for Food and Agriculture*. FAO Commission on Genetic Resources for Food and Agriculture Assessments.

Frison, E. A., Cherfas, J., & Hodgkin, T. (2011). Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability, 3*(1), 238–253.

Gillison, A. N. (2012). *Biodiversity in Bhutan: A preliminary synthesis*. Center for Biodiversity Management. http://biodiversity. bt/biodiv/content/documents/document.

Gaira, K. S., Singh, K. K., & Rawal, R. S. (2014). Socio-economic evaluation of best practices and management needs for promoting sustained pollination in large cardamom crop (*Amumum subulatum* Roxb.) in Sikkim Himalaya. In *International Symposium on Conservation and management of pollinators for sustainable agriculture and ecosystem service*s. National Agriculture Science centre.

Gaira, K. S., Rawal, R. S., & Singh, K. K. (2016). Variations in pollinator density and impacts on large cardamom (*Amomum subulatum* Roxb.) crop yield in Sikkim Himalaya, India. *Journal of Asia-Pacific Biodiversity*, 9(1), 17–21.

Gaira K.S., Lepcha N., Chettri S.K., Sharma K., Pandey A., Joshi R. & Chettri N. (2019). *Technical Manual: Promoting Low-Cost Organic Farming Techniques in Khangchendzonga Landscape-India*. GBPNIHESD

Galluzzi, G., Eyzaguirre, P., & Negri, V. (2010). Home gardens: Neglected hotspots of agro-biodiversity and cultural diversity. *Biodiversity and Conservation*, 19(13), 3635–3654.

Ghimiray, M. (2005). Plant Genetic Resources in SAARC Countries: Their Conservation and Management. Bhutan Chapter, Renewable Natural Resources Centre, Wangdue Phodrang.

Ghimire, Y., Rana, R., Ale, S., Poudel, I., & Tamang, B. (2018). Use of agrobiodiversity and crop management practices for climate change adaptation in high hill agriculture of Nepal. *Journal of Agriculture and Environment*, 18, 6–14.

Giri, K., Mishra, G., Rawat, M., Pandey, S., Bhattacharyya, R., Bora, N., & Rai, J. P. N. (2020). Traditional Farming Systems and Agro-biodiversity in Eastern Himalayan Region of India. In *Microbiological Advancements for Higher Altitude Agro-Ecosystems & Sustainability* (pp. 71–89). Singapore.

Goodrich, C. G. (nd) Ethnic communities and agrobiodiversity conservation in the eastern Himalayas.https://www.researchgate.net/profile/Chanda_Goodrich2/publication/267716042_ETHNIC_COMMUNITIES_AND_AGROBIODIVERSITY_CONSERVATION_IN_THE_EASTERN_HIMALAYAS_BULLET/links/555c544f08ae6aea08173b08.pdf

Gurung, D. B., Dorjii, S., Tsheringi, U., & Wangyal, J. T. (2013). An annotated checklist of fishes from Bhutan. *Journal of Threatened Taxa, 5*(14), 4880–4886.

Haribal, M. (2000). *The Butterflies of Sikkim Himalaya and their natural history*. Natraj Publishers.

Hodgkin, T., Rana, R., Tuxill, J., Didier, B., Subedi, A., Mar, I., Karamura, R., Valdivia, R., Colledo, L., Latournerie, I., Sadiki, M., Sawadogo, M., Brown, AHD. & Jarvis D. (2006). Seed systems and crop genetic diversity in agro ecosystems. In D. Jarvis, C. Padoch, & D. Cooper (Eds.), *Managing Biodiversity in agricultural ecosystems*. IPGRI, & Columbia University Press.

ICIMOD/RDS. (2020). http://rds.icimod.org. ICIMOD.

ICIMOD, WCD, GBPNIHESD, & RECAST, (2017a). *Kangchenjunga Landscape conservation and development strategy and regional cooperation framework*. Working Paper 2017/2. ICIMOD.

ICIMOD, WCD, GBPNIHESD, & RECAST, (2017b). *Kangchenjunga Landscape Conservation and Development Initiative feasibility assessment report—regional synthesis.* ICIMOD working paper 2017/9. ICIMOD.

ICIMOD. (2019). Converting conflicts to consensus: A road map for mitigating human–wildlife conflict in the Kangchenjunga Landscape. Technical report. ICIMOD.

Jackson, L., Bawa, K., Pascual, U., & Perrings, C. (2005). Agrobiodiversity: a new science agenda for biodiversity in support of sustainable agroecosystems. DIVERSITAS report, 4. DIVERSITAS.

Joshi, B. K., Acharya, A. K., Gauchan, D., & Chaudhary, P. (2017). *The State of Nepal's Biodiversity for Food and Agriculture*. MoAD.

Kandel, P., Thapa, I., Chettri, N., Pradhan, R., & Sharma, E. (2018). Birds of the Kangchenjunga Landscape, the Eastern Himalaya: status, threats and implications for conservation. *Avian Research, 9*(1), 9.

Kandel, P., Chettri, N., Chaudhary, R. P., Badola, H. K., Gaira, K. S., Wangchuk, S., Bidha, N., Uprety, Y., & Sharma, E. (2019). Plant diversity of the Kangchenjunga Landscape, Eastern Himalayas. *Plant Diversity, 41*(3), 153–165. https://doi.org/https://doi.org/10.1016/j.pld.2019.04.006

Kandel, P., Gurung, J., Chettri, N., Ning, W., & Sharma, E. (2016). Biodiversity research trends and gap analysis from a transboundary landscape, Eastern Himalayas. *Journal of Asia-Pacific Biodiversity, 9*(1), 1–10.

Kandel, P., Tshering, D., Uddin, K., Lhamtshok, T., Aryal, K., Karki, S., Sharma, B., & Chettri, N. (2018). Understanding social–ecological interdependence using ecosystem services perspective in Bhutan, *Eastern Himalayas. Ecosphere, 9*(2), e02121. https://doi.org/https://doi.org/10.1002/ecs2.2121

Kaplan, D. M., & Thompson, P. B. (Eds.). (2019). *Encyclopedia of food and agricultural ethics*. Springer Netherlands.

Katwal, T. (2013). Multiple cropping in Bhutanese agriculture-present status and opportunities. In *Regional Consultative Meeting on Popularizing Multiple Cropping Innovations as a Means to raise Productivity and Farm Income in SAARC Countries*. Srilanka.

Katwal, T. B., Dorji, S., Dorji, R., Tshering, L., Ghimiray, M., Chhetri, G. B., Dorji, T. Y., & Tamang, A. M. (2015). Community Perspectives on the On-Farm Diversity of Six Major Cereals and Climate Change in Bhutan. *Agriculture, 5*(1), 2–16. https://www.mdpi.com/2077–0472/5/1/2

Koirala, M. (2008). Non-timber forest products as alternative livelihood options in the Transborder villages of Eastern Nepal. In N. Chettri., B. Shakya., & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp. 105–110). ICIMOD.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences, 274*(1608), 303–313. https://doi.org/doi:10.1098/rspb.2006.3721

Konsam, S., Thongam, B., & Handique, A. K. (2016). Assessment of wild leafy vegetables traditionally consumed by the ethnic communities of Manipur, northeast India. *Journal of Ethnobiology and Ethnomedicine, 12*(1), 9. https://doi.org/10.1186/s13002–016–0080–4

Kumar, P. (2012). Assessment of impact of climate change on Rhododendrons in Sikkim Himalayas using Maxent modelling: limitations and challenges. *Biodiversity and Conservation, 21*(5), 1251–1266. https://doi.org/10.1007/s10531–012–0279–1

Limbu, J. H., Acharya, G. S., & Shrestha, O. H. (2018). A brief report on ichthyofaunal diversity of Dewmai khola of Ilam district, Nepal. *Journal of Natural History Museum, 30*, 312–317.

Matsushima, K., Nemoto, K., Nakashima, N., Dema, D., Thapa, L., Watanabe, A., Maegawa, F., Baba, T., & Matsushita, G. (2006). Report of investigation for wild edible plants and their traditional knowledge in Bhutan. *Journal of the Faculty of Agriculture, Shinshu University, 42*(1/2), 37–46.

Matsushima, K., Minami, M. & Nemoto K. (2012). Use and conservation of wild plants of Bhutan. *J Faculty Agricult Shinshu University, 48*(1–2), 75–83.

Maestre, F. T., Quero, J. L., Gotelli, N. J., Escudero, A., Ochoa, V., Delgado-Baquerizo, M., García-Gómez, M., Bowker, M. A., Soliveres, S., Escolar, C., García-Palacios, P., Berdugo, M., Valencia, E., Gozalo, B., Gallardo, A., Aguilera, L., Arredondo, T., Blones, J., Boeken, B., ... Zaady, E. (2012). Plant species richness and ecosystem multifunctionality in global drylands. *Science, 335*(6065), 214 LP–218. https://doi.org/10.1126/science.1215442

Maity, D., Pradhan, N. & Chauhan, A. S. (2004). Folk uses of some medicinal plants from North Sikkim. *Indian Journal of Traditional Knowledge* 3(1), 72–9.

Naha, D., Sathyakumar, S., Dash, S., Chettri, A., & Rawat, G. S. (2019). Assessment and prediction of spatial patterns of human-elephant conflicts in changing land cover scenarios of a human-dominated landscape in North Bengal. *PLOS One, 14*(2), e0210580. https://doi.org/10.1371/journal.pone.0210580

Naha, D., Dash, S. K., Chettri, A., Roy, A., & Sathyakumar, S. (2020). Elephants in the neighborhood: patterns of crop-raiding by Asian elephants within a fragmented landscape of Eastern India. *PeerJ, 8*, e9399

Nawang, R. (1996) Medicinal plants. In *Non-wood forest products of Bhutan*, (pp. 13–20). FAO.

Negri, V. (2009). Possible incentives to home garden maintenance: comparing possibilities and raising awareness among farmers. In *Proceedings of a workshop on crop genetic resources in European home gardens* (pp. 72–80). Bioversity International.

Ning, W., Shaoliang, Y., Joshi, S., & Bisht, N., (Eds.). (2016a). *Yak on the move: transboundary challenges and opportunities for yak raising in a changing Hindu Kush Himalayan region.* ICIMOD.

Ning, W., Oli, K. P., Gilani, H., Joshi, S., & Bisht, N. (2016b). Yak raising challenges: transboundary issues in far eastern Nepal. In W. Ning, Y. Shaoliang, S. Joshi, & N. Bisht (Eds.). (2016a). *Yak on the move: transboundary challenges and opportunities for yak raising in a changing Hindu Kush Himalayan region* (pp. 53–64). ICIMOD.

Oli, B. R. (2003). Ethno-medicinal uses of plants among the Limbus of Hellock area of Tapethok VDC, Taplejung, Nepal. *Botanica Orientalis 3,* 112–115.

Oli, B. R., & Nepal, B. K. (2003). *NTFPs from Kangchenjunga Conservation Area: Aspects of Trade and Market Opportunities*. WWF Nepal Program, 72. WWF Nepal.

O'Neill, A. R., Badola, H. K., Dhyani, P. P., & Rana, S. K. (2017). Integrating ethnobiological knowledge into biodiversity conservation in the Eastern Himalayas. *Journal of Ethnobiology and Ethnomedicine, 13*(1), 21.

Ong, H. G., & Kim, Y.D. (2017). The role of wild edible plants in household food security among transitioning hunter-gatherers: evidence from the Philippines. *Food Security, 9*(1), 11–24. https://doi.org/10.1007/s12571–016–0630–6

Pal, S.,& Palit, D. (2011). Traditional knowledge and bioresource utilization among Lepcha in North Sikkim. *NeBIO, 2*(1), 13–7.

Pala, N. A., Sarkar, B. C., Shukla, G., Chettri, N., Deb, S., Bhat, J. A., & Chakravarty, S. (2019). Floristic composition and utilization of ethnomedicinal plant species in home gardens of the Eastern Himalaya. *Journal of Ethnobiology and Ethnomedicine, 15*(1), 14.

Pandey, A., Badola, H. K., Rai, S., & Singh, S. P. (2018). Timberline structure and woody taxa regeneration towards treeline along latitudinal gradients in Khangchendzonga National Park, Eastern Himalaya. *PLOS One, 13*(11), e0207762. https://doi.org/10.1371/journal.pone.0207762

Pandey, A., Joshi, R. K., & Negi, B. K. (2019). Winter season bloomer Hairy Bergenia *Bergenia ciliata* (Haw.) Sternb.(Saxifragales: Saxifragaceae), an important winter forage for diverse insect groups. *Journal of Threatened Taxa, 11*(7), 13937–13940. https://doi.org/10.11609/jott.4268.11.7.13937–13940

Pascual, U., & Perrings, C. (2007). Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes. *Agriculture, Ecosystems & Environment, 121*(3), 256–268. https://doi.org/10.1016/j.agee.2006.12.025

Parajuli, R. R. (2013). Indigenous Knowledge on Medicinal Plants: Maipokhari,Maimajhuwa and Mabu VDCs of Ilam District, Eastern Nepal. *J Dept Plant Resour Nepal*, 35, 50–58.

Paudel, M., Joshi, B., & Ghimire, K. (2016). Management status of agricultural plant genetic resources in Nepal. *Agronomy Journal of Nepal, 4*, 75–91.

Pant, K. P., Rasul, G., Chettri, N., Rai, K. R., & Sharma, E. (2012). *Value of forest ecosystem services: a quantitative estimation from the Kangchenjunga landscape in eastern Nepal.* Working Paper 2012/5. ICIMOD.

Panmei, R., Gajurel, P., & Singh, B. (2016). Ethnobotany and nutritional values of some selected wild edible plants used by Rongmei tribe of Manipur Northeast India. *Internat J Appl Biol Pharmaceut Technol, 7*(4), 1–9.

Phuntsho, K., Chettri, N., & Oli, K. P. (2012). *Mainstreaming community-based conservation in a transboundary mountain landscape–Lessons from Kangchenjunga*. International Centre for Integrated Mountain Development (ICIMOD).

Pradhan, B. K., & Badola, H. K. (2008). Ethnomedicinal plant use by Lepcha tribe of Dzongu valley, bordering Khangchendzonga Biosphere Reserve, in north Sikkim, India. *Journal of Ethnobiology and Ethnomedicine, 4*(1), 22.

Pradhan, S., & Tamang, J. P. (2015). Ethnobiology of wild leafy vegetables of Sikkim.

Rahbek, C., Borregaard, M. K., Antonelli, A., Colwell, R. K., Holt, B. G., Nogues-Bravo, D., Rasmussen, C. M. Ø., Richardson, K., Rosing, M. T., Whittaker, R. J., & Fjeldså, J. (2019). Building mountain biodiversity: Geological and evolutionary processes. *Science, 365*(6458), 1114–1119. https://doi.org/10.1126/science.aax0151

Rahman, H., & Karuppaiyan, R. (2011). Agrobiodiversity of Sikkim. Climate Change in Sikkim: Patern, Impact and Initiatives. M. L. Arrawatia, & S. Tambe (Eds.), *Department of Information and Public Relations* (pp. 403–428). Government of Sikkim.

Rai, D. S., Tshering, K., Gyeltshen, K., Norbu, N., Sherub, N. R., & Wangchuk, S. (2008). Biodiversity of Toorsa Strict nature Reserve–Jigme Dorji national Park proposed conservation corridor, western Bhutan. In N. Chettri, B. Shakya, & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp. 39–56). ICIMOD.

Rana, L. N. (2008). Biodiversity Status in the Potential Conservation Corridors of the Kangchenjunga Landscape: a Distribution Model of Flagship and Indicator Species. In N. Chettri, B. Shakya, & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp. 31–38). ICIMOD.

Rana, R. B., Garforth, C. J., Sthapit, B. R., Subedi, A., Chaudhary, P., & Jarvis, D. I. (2007). On-farm management of rice genetic diversity: understanding farmers' knowledge on rice ecosystems and varietal deployment. *Plant Genetic Resources Newsletter, 152*, 58–64.

Regmi, P. P. (2008). Landscape elements and agricultural issues in the border villages of eastern Nepal. In N. Chettri, B. Shakya, & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp. 83–89). ICIMOD.

Regmi, B. R., Thapa, L., Suwal, R., Khadka, S., Sharma, G. B., & Tamang, B. B. (2009). Agro-biodiversity management: an opportunity for mainstreaming community-based adaptation to climate change. *Journal of Forest and Livelihood*, *8* (1), 111–121

Rinchen, D. (1996). Bamboo, cane, wild banana, fibre, floss and brooms. In *Non-wood forest products of Bhutan* (pp. 13–20). FAO.

Rudebjer, P., Van Schagen, B., Chakeredza, S., & Kamau, H. (Eds). (2009). Learning agrobiodiversity: options for universities in Sub-Saharan Africa. Proceedings of a regional workshop, Nairobi, Kenya, 21–23 January 2009. Bioversity International

Schmidt, M., Lam, N. T., Hoanh, M. T., & Padulosi, S. (2010). Promoting neglected and underutilised tuberous plant species in Vietnam. In R. Haas, M. Canavari, B. Slee, C. Tong, & B. Anurugsa (Eds.), *Organic and quality food marketing in Asia and Europe* (pp. 183–193). Wageningen Academic Publishers.

Singh, H. B., & Sundriyal, R. C. (2005). Composition, economic use, and nutrient contents of alpine vegetation in the Khangchendzonga Biosphere Reserve, Sikkim Himalaya, India. *Arctic, Antarctic, and Alpine Research, 37*(4), 591–601. https://doi.org/10.1657/1523–0430(2005)037[0591:CEUANC]2.0.CO;2

Shakya, B., & Joshi, R. M. (2008). Protected Areas and Biodiversity Conservation in the Hindu Kush-Himalayan Region with Special Reference to the Kangchenjunga Landscape. In N. Chettri, B. Shakya, & E. Sharma (Eds.), *Biodiversity conservation in the Kangchenjunga landscape,* (pp.13–20). ICIMOD.

Singh, R. K., Singh, A., & Pandey, C. B. (2014). Agro-biodiversity in rice–wheat-based agroecosystems of eastern Uttar Pradesh, India: implications for conservation and sustainable management. *International Journal of Sustainable Development & World Ecology, 21*(1), 46–59. https://doi.org/10.1080/13504509.2013.869272

Singh, B., Sultan, P., Hassan, Q. P., Gairola, S., & Bedi, Y. S. (2016). Ethnobotany, traditional knowledge, and diversity of wild edible plants and fungi: a case study in the Bandipora District of Kashmir Himalaya, India. *Journal of Herbs, Spices & Medicinal Plants*, 22(3), 247–278. https://doi.org/10.1080/10496475.2016.1193833

Sharma, E., Chettri, N., Gurung, J., & Shakya, B (2007) Landscape approach in biodiversity conservation: A regional cooperation framework for implementation of the Convention on Biological Diversity in Kangchenjunga Landscape. ICIMOD.

Sharma, E., Chettri, N., & Oli, K. P. (2010). Mountain biodiversity conservation and management: a paradigm shift in policies and practices in the Hindu Kush-Himalayas. *Ecological Research, 25*(5), 909–923. https://doi.org/10.1007/s11284–010–0747–6

Sharma, E., Chettri, N., Tsering, K., Shrestha, A.B., Jing, F., Mool, P., & Eriksson, M. (2009). Climate change impacts and vulnerability in the eastern Himalayas. ICIMOD.

Sharma, G., Uma, P., Sharma, E., Golam, R., & Awasthe, R. (2016). *Agrobiodiversity in the Sikkim Himalaya: sociocultural significance, status, practices, and challenges*. Working Paper (2016/5). ICIMOD.

Sharma, G., Sharma, R., & Sharma, E. (2009). Traditional knowledge systems in large cardamom farming: biophysical and management diversity in Indian mountainous regions. *Indian Journal of Traditional Knowledge 8*(1), 17–22.

Sharma, G., Sharma, E., Sharma, R., & Singh, K.K. (2002a). Performance of an age series of Alnus-large cardamom plantations in the Sikkim Himalayas: Productivity, energetics and efficiencies. *Annals of Botany,* 89, 261–272.

Sharma, G., Sharma, E., Sharma., R, Singh, K. K. (2002b). Performance of an age series of Alnus-large cardamom plantations in the Sikkim Himalayas: Nutrient dynamics. *Annals of Botany, 89*(3), 273–282. https://doi.org/10.1093/aob/mcf036

Sherpa, S. (2001). *The high altitude ethnobotany of the Walung people of Walangchung Gola, Kanchanjunja Conservation Area, east Nepal* [Master's thesis, Central Department of Botany, Tribhuvan University].

Shrestha, K. K., Basnet, K., Bhandari, P., & Gurung, M. B. (2016). *Biodiversity assessment of the Mewa River valley (Papung Corridor), Kangchenjunga Landscape, Taplejung, East Nepal*. ICIMOD.

Singh, K. K., Gaira, K. S., & Rai, L. K. (2011). Agricultural scenario vis-à-vis the pollinator elements of the Sikkim Himlayan Region. In M. L. Arrawatia, & S. Tambe (Eds.), *Biodiversity of Sikkim-exploring ad conserving a global hotspot* (pp. 429–446). Department of Information and Public Relations, Government of Sikkim

Sthapit, B., Rana, R., Eyzaguirre, P., & Jarvis, D. (2008). The value of plant genetic diversity to resource-poor farmers in Nepal and Vietnam. *International journal of agricultural sustainability, 6*(2), 148–166.

Subba, J. R. (2009). Indigenous knowledge on bio-resources management for livelihood of the people of Sikkim. *Indian Journal of Traditional Knowledge, 8*(1), 56–64.

Subba, B., Aravind, N. A., & Ravikanth, G. (2017). Amphibians of the Sikkim Himalaya, India: an annotated checklist. *Check List, 13*(1), 2033.

Sundriyal, M., & Sundriyal, D. C. (2001). Wild edible plants of the Sikkim Himalaya: Nutritive values of selected species. *Economic Botany, 55*(3), 377. https://doi.org/10.1007/BF02866561

Sundriyal, M., & Sundriyal, R. (2003). Underutilized edible plants of the Sikkim Himalaya: Need for domestication. *Current Science*, 731–736.

Sunwar, S., Thornstrom C.G., Subedi, A., & Bystrom, M. (2006). Home gardens in western Nepal: opportunities and challenges for on-farm management of agrobiodiversity. Biodiver Conserv 15:4211–4238

Tamang, D. K., Dhakal, D., Gurung, S., Sharma, N., & Shrestha, D. (2013). Bamboo diversity, distribution pattern and its uses in Sikkim (India) Himalaya. *International Journal of Scientific and Research Publications, 3*(2), 1–6.

Thomas, M. B. (2017). *Medicinal Plants of Bhutan-a preliminary checklist*. Serbithang. http://bhutanbiodiversity.net/checklists/checklist.php?cl=1&proj=&dynclid=0

Ugyen P. W., & Olsen, A. (2008). Vulnerable medicinal plants and the risk factors for their sustainable use in Bhutan. *J Bhutan Stud, 19*, 66–90.

Uprety, Y., Poudel, R. C., Gurung, J., Chettri, N., & Chaudhary, R. P. (2016). Traditional use and management of NTFPs in Kangchenjunga Landscape: implications for conservation and livelihoods. *Journal of ethnobiology and ethnomedicine, 12*(1), 19.

Vernooy, R.,& Song, Y. (2004). New approaches to supporting the agricultural biodiversity important for sustainable rural livelihoods. *International Journal of Agricultural Sustainability, 2*(1), 55–66. https://doi.org/10.1080/14735903.2004.9684567

Verma, N., Rana, M. K., Negi, K. S., Kumar, G., Bhat, K. V., Park, Y. J., & Bisht, I. S. (2010). Assessment of genetic diversity in Indian Perilla [Perilla frutescens (L.) Britton] landraces using STMS markers. *Indian Journal of Biotechnology, 9,* 43–49.

Wang, M. S., Thakur, M., Peng, M. S., Jiang, Y., Frantz, L. A. F., Li, M., ... & Suwannapoom, C. (2020). 863 genomes reveal the origin and domestication of chicken. *Cell Research*, 1–9.

Wangyal, J. T. (2012). Ethnobotanical knowledge of local communities of Bumdeling wildlife sanctuary, Trashiyangtse, Bhutan. I*ndian Journal Traditional Knowledge, 11*, 447–452.

Wangda, P. (2008). Preservation of agro-biodiversity landscape in a typical rural Bhutan. In *Biocultural Diversity – Applied Projects from different Parts of the World. Proceedings of the Meeting on Preservation of Biocultural Diversity – a Global Issue, May 6–8, 2008, BOKU, Vienna* (pp. 156–163).

Wilson, R. T. (1997). Animal genetic resources and domestic animal diversity in Nepal. *Biodiversity & Conservation, 6*(2), 233–251.

Wood, S., Sebastian, K., & Scherr, S. J. (2000). Pilot Analysis of Global Ecosystems: Agroecosystems. International Food Policy Research Institute and World Resources Institute

Xu, J., Badola, R., Chettri, N., Chaudhary, R. P., Zomer, R., Pokhrel, B., Hussain, S. A., Pradhan, S., & Pradhan, R. (2019). Sustaining Biodiversity and Ecosystem Services in the Hindu Kush Himalaya. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People* (pp. 127–165). Springer International Publishing. https://doi.org/10.1007/978–3–319–92288–1_5

Annexes

Annex I: Commonly available agricultural crops in the KL

Crops	Scientific name
CEREALS	
Rice	*Oryza sativa* L.
Wheat	*Triticum aestivum* L.
Maize	*Zea mays* L.
Finger millet	*Eleusine coracana* (L.) Garetn.
Foxtail millet	*Setaria italica* (L.) Beauvois
Proso millet	*Panicum miliaceum* (L.)
Barley	*Hordeum vulgare* L.
Oat	*Avena sativa* L.
Pearl millet	*Pennisetum glaucum* (L.) R.Br.
Sorghum	*Sorghum bicolor* (L.) Moench
Job's tear	*Coix lacryma*-jobi L.
PSEUDO CEREALS	
Buckwheat	*Fagopyrum esculentum* Moench. *F. tataricum* (L.) Gaertn.
Grain amaranths	*Amaranthus caudatus* L. *A. hypochondriacus* L.
Quinoa	*Chenopodium quinoa* Willd.
LEGUMES/PULSES	
Soybean	*Glycine max* (L.) Merr.
Common French bean	*Phaseolus vulgaris* L.
Black gram	*Vigna mungo* (L.) Hepper
Mung dal	*Vigna radiata* (L.) R. Wilczek
Rice bean	*Vigna umbellata* (Thunb.) Ohwi & H.Ohashi
Butter bean	*Phaseolus lunatus* L.
Horse bean	*Vicia faba* L.
Pigeon pea	*Cajanus cajan* (L.) Millsp.
Pea	*Pisum sativum* L.

Crops	Scientific name
VEGETABLES	
Cauliflower	*Brassica oleracea* var. *botrytis* L.
Potato	*Solanum tuberosum* L.
Tomato	*Lycopersicon esculentum* Mill.
Broadleaf mustard	*Brassica juncea* (L.) Czem.
Field mustard	*Brassica campestris* L.
Field Pumpkin	*Cucurbita pepo* L.
Wild Chilli Pepper	*Capsicum frutescens* L. var. *grossum* (L.) L.H. Bailey
Brinjal	*Solanum melongena* L.
Spinach	*Spinacia oleracea* L.
Carrot	*Daucus carota* L.
Onion	*Allium cepa* L.
Broccoli	*Brassica oleracea* L. var. *italica* Plenck
Bottle gourd	*Lagenaria siceraria* (Molina) Standl.
Ash gourd	*Benincasa hispida* (Thunb.) Cogn.
Autumn and winter squashes	*Cucurbita maxima* Duchesne
Bitter gourd	*Momordica charantia* L.
Cucumber	*Cucumis sativus* L.
Sponge gourd	*Luffa acutangula* (L.) Roxb.
Sweet gourd	*Momordica cochinchinensis* (Lour.) Spreng.
Snake gourd	*Trichosanthes anguina* L.
Chenopodium	*Chenopodium album* L.
Water cress	*Nasturtium officinale* W.T. Aiton
Nettle plant	*Urtica dioica* L.
Nakima	*Tupistra nutans* Wall. ex Lindl.
Celery	*Apium graveolens* L.
Poison berry	*Solanum anguivi* Lam.

Crops	Scientific name
Jack fruit	*Artocarpus heterophyllus* Lam.
Amaranthus	*Amaranthus viridis* L.
Drumstick	*Moringa oleifera* Lam.
Black mustard	*Brassica juncea* (L.) Czern.
Garden cress	*Lepidium sativum* L.
Radish	*Raphanus sativus* L.
Lady's finger	*Abelmoschus esculentus* (L.) Moench
SPICES	
Black cardamom	*Amomum subulatum* Roxb.
Cumin	*Cuminum cyminum* L.
Nepal Pepper	*Zanthoxylum armatum* DC.
Perilla	*Perilla frutescens* (L.) Britt.
Sesame	*Sesamum indicum* L.
Ginger	*Zingiber officinale* Roscoe
Turmeric	*Curcuma longa* L.
Black pepper	*Piper nigrum* L.
Cinnamom	*Cinnamomum zeylanicum* Blume
Mountain pepper	*Litsea cubeba* (Lour.) Pers.
Hemp	*Cannabis sativa* L.
Coriander	*Coriandrum sativum* L.
Fennel	*Foeniculum vulgare* Mill.
Garlic	*Allium sativum* L.
Mint	*Mentha piperita* L.
Niger	*Guizotia abyssinica* (L.f.) Cass.
Fenufreek	*Trigonella foenum-graecum* L.
ROOT CROPS	
Yams	*Dioscorea alata* L.
Sweet potato	*Ipomoea batatas* (L.) Lam.
Tapioca	*Manihot esculenta* Crantz
Elephant's foot yam	*Amorphophallus paeoniifolius* (Dennst.) Nicolson
Chayote	*Sechium edule* (Jacq.) Sw.
Taro or cocoyam	*Colocasia esculenta* (L.) Schott
Palmate leaved yam	*Dioscorea pentaphylla* L.

Crops	Scientific name
FRUITS	
Banana	*Musa paradisiaca* L.
Nutgall	*Rhus chinensis* Mill.
Guava	*Psidium guajava* L.
Plum	*Prunus domestica* L.
Custard apple	*Annona squamosa* L.
Apple	*Malus domestica* (Sucknow) Borkh.
Peach	*Prunus persica* (L.) Batsch
Passion fruit	*Passiflora edulis* Sims
Citrus	*Citrus mammosa* Michel
Monkey Jack	*Artocarpus lakoocha* Roxb.
Mango	*Mangifera indica* L.
Litchi	*Litchi chinensis* Sonn.
Areca nut	*Areca catechu* L.
Hog plum	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill
Indian crab-apple	*Docynia indica* (Wall.) Decne.
Indian gooseberry	*Phyllanthus emblica* L.
Papaya	*Carica papaya* L.
Pear	*Pyrus communis* L.
Wood apple	*Aegle marmelos* (L.) Correa
Grape	*Vitis vinifera* L. var. *candicans* (Engelm. ex A.Gray) Kuntze
Indian hog plum	*Spondias pinnata* (L.f.) Kurz
Himalayan walnut	*Juglans regia* L.
Tejbal	*Zanthoxylum rhetsa* (Roxb.) DC.
Pomegranate	*Punica granatum* L.
Avocado	*Persea americana* Mill.
Pineapple	*Ananas comosus* (Schult. &Schult.f.) Mez
Common persimmon	*Diospyros virginiana* L.
Indian butter tree	*Diploknema butyracea* (Roxb.) H.J. Lam
Chestnut	*Castanopsis hystrix* Miq.
Mandarin orange	*Citrus reticulata* Blanco

Source: Sharma et al., (2016); Katwal, (2013); Aryal et al., (2010); Regmi, (2008); Rahman and Karuppaiyan, (2011); Choden, (2008)

Annex II: Commonly available wild edibles in the KL

Common English name	Scientific name	Use value	Part used
Bamboo shoot	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	V	Ts
Cane/rattan	*Calamus tenuis* Roxb.	V, F	Ts, F
Wild mushrooms	*Agaricus arvensis* Schaeff	V	Fb
Wild onion	*Allium wallichii* Kunth	V	Bu
Nakima	*Tupistra nutans* Wall. ex Lindl.	V	In
Asparagus	*Asparagus racemosus* Willd.	V	Ys
Water cress	*Nasturtium officinale* W.T.Aiton	V	L, Ts
Orange day-lily	*Hemerocallis fulva* (L.) L.	V	F, L,S,
Nettle Plant	*Urtica dioica* L.	V, M	Ts
Himalayan nettle	*Girardinia diversifolia* (Link) Friis	V	In
Knotweed/bistort, smartweed	*Aconogonum molle* D. Don	V	Ys
Pig weed	*Amaranthus viridis* L.	V, M	Yl
Goose foot	*Chenopodium album* L.	V	Yl,Ts
Asuro	*Adhatoda vasica* Nees	V	Fl
Mint	*Mentha suaveolens* Ehrh.	C	L
Bay leaf	*Cinnamomum tamala* (Buch.-Ham.) T. Nees & C.H.Eberm	Sp, M, I	L
Chest nut	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	N	N
Sichuan pepper	*Zanthoxylum armatum* DC.	Sp	F
Barberry	*Berberis aristata* DC.	F, M	
Yartsa gunbu	*Ophiocordyceps sinensis* (Berk.) G.H. Sung et al.,	I, M	WP
Bayberry	*Myrica esculenta* Buch.-Ham. ex D.Don	F	B
Raspberry	*Rubus ellipticus* Sm.	F	F
Yam	*Dioscorea deltoidea* Wall. ex Griseb.	V	Rt
Spicebush	*Lindera neesiana* (Wall. ex Nees) Kurz	F	F
Sea buckthorn	*Hippophae tibetana* Schltdl	F	B
Mountain ebony or orchid tree	*Bauhinia variegata* L.	V	Fl, Bu, SO
Common knotweed	*Polygonum arenastrum* Boreau subsp. *boreale* (Lange) Karlsson	V	L, Ys
Indian butter tree	*Diploknema butyracea* (Roxb.) H.J.Lam	F	F, N
Fig	*Ficus auriculata* Lour and *Ficus carica* L.	F	F
Edible fern	*Diplazium esculentum* (Retz.) Sw. *Dryopteris cochleata* (D.Don) C. Chr	V	Yf
Walnut	*Juglans regia* L.	F	F
Sword fern	*Nephrolepsis cordifolia* (L.) C. Presl	M	F
Rhododendron	*Rhododendron arboreum* Sm.	M,O	Fl
Indian gooseberry	*Phylanthus emblica* L.	M, Sp	F
Black plum	*Syzygium esculenta* Buch.-Ham. ex D.Don	F, M	F

Use value: V= Vegetable, F=Fruit, M=Medicine; Sp=Spice; In=Income; O=Ornamental

Parts Used: Ts =Tender Shoots, Fl= Flower, F =Fruits, Yf =Young fronds, L =Leaves, Rt= Root tubers, B= Berries, Bu= Buds, SO= Seed Oils, N=Nector, Fb = Fruiting bodies, Bul =Bulb, In= Inflorescence, Ys = Young shoots, Ts = Tender Stem, Yl= Young leaf, WP= Whole plant

Sources: Sundriyal & Sundriyal, (2001 and 2003); Aryal et al., (2010); Tamang et al., (2013); Sharma et al., (2016); Uprety et al., (2016); Thomas, (2017).

Annex III: Agroforestry tree species and their uses in the KL

Scientific name	Family	Distribution (masl)	Uses
Abies spectabilis (D.Don) Mirb.	Pinaceae	1700-4600	Timber
Acer campbellii Hook.f. & Thomson ex Hiern	Aceraceae	900-1900	Timber, poles for houses, fodder, fruit for medicines
Acer oblongum Wall. ex DC.	Aceraceae	1000-3000	Timber, poles for houses, fodder
Aegle marmelos (L.) Correa	Rutaceae	300-800	Fruits edible, medicinal uses
Albizia stipulata (DC.) Boivin	Fabaceae	300-1600	Timber, poles for houses, fodder, leaves for mulching and compost making, medicinal use
Albizia lebbeck (L.) Benth.	Fabaceae	300-1200	Timber, poles for houses, fodder, leaves for mulching and compost making, medicinal use
Albizia odoratissima (L.f.) Benth.	Fabaceae	300-1600	Timber, poles for houses, leaves for mulching and compost making, fodder, medicinal uses
Albizia procera (Roxb.) Benth.	Fabaceae	300-1300	Timber, poles for houses, fodder, leaves for mulching and compost making, medicinal use
Alnus nepalensis D. Don	Betulaceae	700-2200	Timber, leaves for mulching and compost making, fodder
Anthocephalus chinensis Walp.	Rubiaceae	300-1200	Timber, fodder, medicinal
Artocarpus heterophyllus Lam.	Moraceae	300-1500	Wood for making 'theki' (a vessel for storing milk fat), leaves for fodder, twigs for fuelwood, edible fruits, medicinal use
Artocarpus lackoocha Roxb.	Moraceae	300-1500	Timber, theki, fodder, fuelwood, wild edible fruits, fruit bark as medicine, plough handle
Bauhinia purpurea L.	Fabaceae	300-1500	Fodder, fuelwood, young flowers and flower buds for vegetables and pickle, bark for medicine
Bauhinia vahlii (Wight & Arn.) Benth.	Fabaceae	300-1500	Fodder, fuelwood, leaves for making plates, fruits for medicine
Bauhinia variegata L.	Fabaceae	300-1200	Leaves for mulching and compost making, fodder, flowers/ flower buds for vegetables, bark for medicinal use
Beilschmiedia roxburghiana Nees	Lauraceae	500-1700	Timber, fodder, medicinal use
Betula utilis D.Don	Betulaceae	1500-3600	Timber, poles for houses, leaves for mulching and compost making, fodder, fuelwood, baer and roots medicinal use
Bischofia javanica Blume	Phyllanthaceae	300-1500	Timber, fodder, fuelwood, medicinal
Bombax ceiba L.	Malvaceae	300-1100	Timber, fuelwood, fodder, medicinal
Brassiopsis hainla (Buch.-Ham.) Seem.	Araliaceae	300-1800	FW, FD, MMU (bark and young buds)
Callicarpa arborea Roxb.	Verbenaceae	300-1000	Yoke of plough, FD, FW, LC, MMU (bark)
Castanopsis hystrix Miq.	Fagaceae	1500-2400	Timber, poles for houses, leaves for mulcing and compost making, fodder, fuelwood, fruits edible
Castanopsis indica (Roxb. ex Lindl.) A.DC.	Fagaceae	300-1500	Timber, poles for houses, leaves for mulcing and compost making, fodder, fuelwood, fruits edible, bark used for medicine
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	1500-2300	Timber, poles for houses, leaves for mulcing and compost making, fodder, fuelwood, fruits edible
Celtis tetrandra Roxb.	Cannabaceae	300-1700	Minor household implements, beehives, fodder, fuelwood, fruits edible
Cinnamomum impressinervium Meisn.	Lauraceae	600-1800	Leaves as tea, leaves, bark, roots as medicine
Choerospondias axillaris (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	200-1100	Timber, poles for houses, fodder, fruits edible, medicinal
Citrus reticulata Blanco	Rutaceae	300-1300	Fruits edible, high-value crop

Scientific name	Family	Distribution (masl)	Uses
Diploknema butyracea (Roxb.) H.J.Lam	Sapotaceae	300-1400	Poles for house, wood for beehive making, poles for houses, fodder, fuelwood, fruits edible, bark medicinal, butter from seed
Duabanga grandiflora (Roxb. Ex DC.) Walp.	Sonnertaceae	300-1600	Timber, poles for houses, fodder, leaves for mulching and compost making
Edgeworthia gardneri (Wall.) Meisn.	Thymelaceae	1700-3000	Fiber for making ropes, lokta for making paper, bark also has medicinal use
Ehretia wallichiana Hook.f. & Thomson ex C.B.Clarke	Boraginaceae	700-2000	Fodder, fuelwood, leaves and bark has medicinal use
Elaeocarpus lanceolatus Blume	Elaeocarpaceae	900-1600	Fodder, fruits edible and have medicinal use
Endospermum chinense Benth.	Euphorbiaceae	500-1900	Fodder, fuelwood, bark and flowers have medicinal use
Erythrina arborescens Roxb.	Fabaceae	300-1700	Timber, poles for houses, fodder, fuelwood, leaves and bark have medicinal use
Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.		800-2200	Timber, poles for houses, fodder, fuelwood, leaves and bark have medicinal use
Ficus auriculata Lour.	Moraceae	500-1900	Fodder, fuelwood, fruits edible, and fruits, young leaves have medicinal use
Ficus benghalensis L.	Moraceae	300-1600	Timber, poles for houses, fodder, fuelwood, leaves for mulching and compost making, fruit edibles and have have medicinal use
Ficus cunia Buch.-Ham. ex Roxb.	Moraceae	300-1500	Fodder, fuelwood, fruit juice and leaves have medicinal value, fruits edible
Ficus cyrtophylla (Miq.) Miq.	Moraceae	300-1800	Fodder, fruit edible, also have medicinal use
Ficus elastica Roxb. ex Hornem.	Moraceae	300-1800	Timber, poles for houses, fodder, fuelwood, bark and sap have medicinal use
Ficus glaberrima Blume	Moraceae	300-1200	Poles for houses, fodder, fuelwood, bark, young leaves and fruits have medicinal use
Ficus glomerata Roxb.	Moraceae	300-1500	Fodder, fuelwood, fruits and leaves have medicinal use
Ficus hispida L.f.	Moraceae	300-1300	Fodder, fuelwood, fruits have medicinal use
Ficus hookeriana Corner	Moraceae	600-2000	Fodder, fuelwood, fruits edible and have medicinal use
Ficus infectoria Willd.	Moraceae	300-1500	Fodder, fuelwood, bark, leaves and flower have medicinal use
Ficus nemoralis Wall. Ex Miq.	Moraceae	1000-2000	Fodder, fuelwood, fruits edible
Ficus neriifolia Sm.	Moraceae	1000-2200	Fodder, fuelwood, fruits have medicinal use
Ficus semicordata Buch.-Ham. ex Sm. var. *montana* Amatya	Moraceae	300-1700	Fodder, fuelwood, fruits and bark have medicinal use
Garuga pinnata Roxb.	Burseraceae	300-1400	Timber, poles for houses, fodder, fuelwood, leaves for mulching and compost makin, bark and flowers have medicinal use
Glochidion acuminatum Mull.Arg.	Euphorbiaceae	700-2000	Timber, minor household implements, fodder, fuelwood, bark and flowers have medicinal use
Grewia optiva J.R.Drumm. ex Burret	Tiliaceae	700-1200	Fodder, fuelwood, fibre for making ropes
Gynocardia odorata R.Br.	Flacourtiaceae	300-1700	Oil is edible and used as medicine
Jambosa formosa (Wall.) G.Don	Myrtaceae	300-1300	Minor household implements, leaves for mulching and composting making, fodder, fuelwood, fruits are edible, bark and fruits have medicinal use
Juglans regia L.	Juglandaceae	900-1600	Timber, poles for houses, fodder, fruits edible, fruits, bark, leaves, and roots have medicinal use
Leucosceptrum canum Sm.	Lamiaceae	1400-2300	Fodder, fuelwood, bee forage, medicinal
Litsea polyantha Juss. Lodh	Lauraceae	300-1600	Fodder, fuelwood, bark has medicinal use

Scientific name	Family	Distribution (masl)	Uses
Lyonia ovalifolia (Wall.) Drude	Ericaceae	500-1800	Fodder, has medicinal use (it produces poisonous nectar)
Macaranga pustulata King ex Hook.f.	Euphorbiaceae	300-1600	Fodder, fuelwood, roots and bark have medicinal use
Mangifera indica L.	Anacardiaceae	300-1500	Fruit edible, high value crop, poles for houses, beehive making
Machilus odoratissima Nees in Wall	Lauraceae	300-1700	Timber, poles for houses, minor household implements, fodder, fruits edible, fruits and bark have medicinal use
Melia azedarach L.	Meliaceae	300-1800	Minor household implements, fuelwood, all plants parts have medicinal use
Michelia champaca (L.) Baill. ex Pierre	Magnoliaceae	1500-2300	Timber, fodder, bark, flowers and roots have medicinal use
Michelia excelsa (Blume) Kuntze	Magnoliaceae	1200-2200	Timber, household implements, fodder, flowers have medicinal use
Michelia velutina DC	Magnoliaceae	900-1800	Timber, household implements, fodder, flowers have medicinal use
Moringa oleifera Lam.	Moringaceae	300-900	Fodder, fruits and young leaves edible and used as vegetable, bark and roots have medicinal use
Morus alba (Engl.) Tiegh.	Moraceae	300-1200	Timber, poles for houses, wood for making beehives, minor household implements, fodder, fuelwood, fruits edible, bark and fruits have medicinal use
Morus macroura Miq.	Moraceae	300-1400	Timber, poles for houses, minor household implements, fodder, fuelwood, fruits edible, bark and fruits have medicinal use
Oroxylum indicum (L.) Kurz	Begoniaceae	300-1100	Fodder, flowers as vegetables, bark, roots and gnus have medicinal uses
Ostodes paniculata Blume	Euphorbiaceae	300-1200	Leaves for mulching and compost making, fodder, oil from fruits, has medicinal uses
Pandanus nepalensis H.St. John	Pandanaceae	300-1700	Fruits edible, have medicinal uses
Phyllanthus emblica L.	Euphorbiaceae	300-1500	Fodder, fruits edible, made into pickle, fruits and seeds have medicinal uses, rich source of vitamin C
Prunus cerasoides Buch.-Ham. ex D.Don	Rosaceae	300-2000	Poles for houses, fodder, fuelwood, bee forage, stem, bark
Prunus napaulensis (Ser.) Steud.	Rosaceae	300-1500	Fodder, fuelwood, fruits edible, have medicinal uses
Pterospermum acerifolium (L.) Willd.	Sterculaceae	300-1500	Minor household implements, fodder, fuelwood, roots have medicinal uses
Pyrus pashia Buch.-Ham. ex D.Don	Rosaceae	800-2200	Fodder, fuelwood, fruits edible and used in making fruit jam, have medicinal uses
Quercus fenestrata Roxb.	Fagaceae	800-2000	Timber, poles for houses, fodder, fuelwood, leaves for mulching and compost making, fruits edible and fruits have medicinal use
Quercus lamellosa Sm.	Fagaceae	1400-3000	Timber, poles for houses, fodder, fuelwood, fruits edible and have medicinal use
Quercus pachyphylla Kurz	Fagaceae	600-1900	Timber, poles for houses, fodder, fuelwood, fruits edible and fruits have medicinal use
Rhododendron arboreum Sm.	Ericaceae	1500-3300	Fodder, fuelwood, flowers used to prepare squash and wine, flowers also have medicinal uses
Rhus insignis (Fiori) Oliv.	Anacardiaceae	300-2000	Fodder, poisonous causes blisters, irritation
Rhus semialata Murray	Anacardiaceae	300-1900	Fodder, fruits boiled to make traditional sauce used as medicine
Saurauia roxburghii Wall.	Actinidiaceae	1200-1600	Fodder, fuelwood, fruit and bark have medicinal use
Schima wallichii (DC.) Korth.	Theaceae	300-2000	Timber, poles for houses, plough, fuelwood, bark juice has medicinal use
Spondias pinnata (L.f.) Kurz	Anacardiaceae	300-900	Fodder, fuelwood, edible, fruit and bark have medicinal uses

Scientific name	Family	Distribution (masl)	Uses
Stereospermum suaveolens (Roxb.) DC.	Bignoniaceae	300-800	Beehives, fodder, fuelwood, roots and flowers have medicinal uses
Symplocos racemosa Roxb.	Symplocaceae	1400-2000	Plough handles, fuelwood, bark has medicinal use
Symplocos theifolia D.Don	Symplocaceae	600-1800	Poles for houses, fuelwood, bark has medicinal use
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	300-1000	Timber, poles for houses, plough handles, fodder, fuelwood, fruit edible, fruits have medicinal use, used in Ayurvedic preparations
Terminalia chebula Retz.	Combretaceae	300-1000	Timber, poles for houses, plough handles, fodder, fuelwood, fruit edible, fruits have medicinal use, used in Ayurvedic preparations
Terminalia myriocarpa Van Heurck & Mull.Arg.	Combretaceae	300-1200	Timber, poles for houses, fodder, bark has medicinal use
Toona ciliata M. Roem.	Meliaceae	500-2500	Timber, poles for houses, minor household implements, fodder, fuelwood, bark and flowers have medicinal use
Viburnum erubescens Wall.	Viburnaceae	1400-2300	Plough handles, fodder, fuelwood, fruit edible, medicinal use

Source: Sharma et al., (2016); Chaudhary et al., (2015).

Annex IV: Farm animals in the KL and their uses

	Farm animal resource	
Common name	**Scientific name**	**Household/ farm use**
Cattle	*Bos taurus* and *Bos indicus*	Milk, cheese, draught power, procreation, manure
Buffalo	*Bubalus bubalis*	Milk, cheese, draught power, meat, skin, procreation, manure
Pig	*Sus scrofa domesticus*	Meat/ pork
Goat	*Capra hircus*	Milk, male goat for meat, manure, procreation, sacrifice
Sheep	*Ovis aries*	Wool, meat, manure, pack animal in high altiutudes, procreation
Yak	*Bos grunniens*	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Yuksam-Dzongri)
Phe-Yak	*Bos grunniens*	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Thangu-Muguthang)
Lho-Yak	*Bos grunniens*	Milk, cheese, butter, meat, fur, skin, procreation, pack animal in high altitudes (Yuksam-Dzongri)
Dzo (yak-cow/bull)	*Bos grunniens*	Pack animal in Yuksam-Dzongri trekking trail, meat
Chicken/domestic fowl	*Gallus domesticus*	Eggs, meat/ chicken
Horse and ponies	*Equus ferus caballus*	Transport
Donkeys	*Equus africanus asinus*	Pack animal
Mules	*Equus asinus Equus caballus*	Pack animal
Dog	*Canis lupus familiaris*	Guard household, livestock, crops
Cat	*Felis catus*	Control of pests, especially rodents
Ducks/ goose	*Anas platyrhyncos*	Eggs, meat
Pigeon	*Columba livia*	Religious purposes, meat

About ICIMOD

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 Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have 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-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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