Life-Sustaining Plants of the Himalayas

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Foreword

The agricultural production in the Himalayas had been under constraints over the centuries. These constraints were vagaries of weather, soil pH, soil fertility, severe incidences of insect-pests and disease epidemics. Frequent spells of food shortages had, therefore, necessitated the search for alternate food sources by the inhabitants. As a consequence, a large number of wild edible plant species, which may be consumed as roots, tubers, bulbs, corms; leafy shoots, leaves, tender tops; flower buds, flowers; unripe and ripe fruits; seeds and nuts etc., are available in sizeable quantities from natural habitats. Now of course with ease in access to different parts of the country, the consumption of these species is on the decline because of the availability of major food cereals. Moreover these species are becoming scarce due to disturbed habitats; these may not be palatable and usually require some kind of processing. Because of these and other reasons people consuming these plants have started to pay less attention to ensure their conservation for posterity.

These plants known variously as lesser-known, under-utilized, under-exploited, wild edibles, ethnobotanical, ethnomedicinal plants, are likely to have commercial potential in the years to come. The need of the hour is their immediate bioprospecting so as not to get deprived of their patenting rights to someone elsewhere in the world. These plant species have a high potential for exploitation as a source of new medicine or as a source of some rare vitamins, minerals, specific essential amino acids or fatty acids. So there is ample scope to serve the world with new class of nutraceuticals. The impressive diversity of wild edibles in the Himalayas offers vast scope to the bio-based industries. This group

Preface

The book on life-sustaining plants of the Himalayas began with the idea of writing survival botany during my tenure in north-eastern region. I started collecting relevant information and photographs. Later on, when I was back in Shimla to work in the western Himalaya, I continued the work here and decided to cover whole of the Himalayas. There was a strong realisation that the present narrowed food base of humanity has added several problems such as malnutrition, food shortage, and neglect of species which at one time had human patronage. The vast reservoirs (*c.* 3000 species), which were being consumed in the past, had been phased out because of their difficult processing before use, palatability and access. However in this endeavour there was a knowledge gap that these numerous plant species served the humanity in several ways. These had lessened the burden on the main food plant species, supplemented the human diet with rare and deficient vitamins, minerals, essential amino acids of protein diet as well as essential fatty acids lacking fat constituent of man's diet. Besides, these plant species which are collected from their natural habitats are free from any chemical pollutants and also provide the chemical constituents which have disease-curing effects. Consequently in many instances of disease manifestation the presence of these medicinal constituents did not allow its onset.

Since times immemorial Ayurveda had advocated the use of herbal medicines grown in the Himalayas from quality view point. This is true even today when pollution of herbal medicines has acquired a serious dimension. The Himalayas have a vast diversity of medicinal plants because of existence of a very wide range of ecological, agro-ecological, geo-physiographic conditions in the Himalayas. For instance there are large altitudinal variations,

areas with high rainfall to cold arid deserts, soils of many types, river basins, fertile valleys with hot climate, snow-bound mountains etc. The Himalayas provide suitable habitats for the occurrence of a wide array of medicinal and wild edible plant species. The interesting fact is that majority of wild edible plant species, being consumed by man in the length and breadth of the Himalayas and its extension known as north-eastern region, are found abundantly in forests, around cultivated areas, near water sources and near snow-bound areas. And some of them happen to be well-known medicinal plants as well.

The traditional knowledge given in this book will be of immense use to researchers, industrial people, social scientists and students of genetic resources. A majority of plant species still await chemical, nutritional, pharmaceutical and nutraceutical investigations.

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Ecology and Physiography of the Himalayas

Introduction

Some hundred million years ago, the land-mass consisted of a single continent called Pangaea. Sometime later this continent developed to east to west running crack containing formation of two continents and the sea entered the widening crack. The two continents were named Angara land to the north and Gondwana land to the south, and the sea formed was called as Tethys Sea. A large number of rivers flowed from both the continents to the Tethys Sea bringing with them huge amounts of sand, stone etc. which caused sagging in the sea. Very heavy weights of sedimentary deposits due to formation of sagging trench in the sea bottom resulted into very high stresses and strains on the earth's crust. As a consequence to this, about 50 million years before, the Angara land started moving towards south giving birth to the folded high-rise of sedimentary beds of sea bottom followed by a great volcanic activity in Gondwana land. All this happened in spasms at the birth of the Himalayas, confining Tethys Sea to the north-west and the north of the central Himalayan axis, and cracks developed in Gondwana land drifting apart to form various continents such as Africa, Australia, South and North America. This spasmodic movement continued about 8 cm per year over a long period and is still continuing resulting in the rise and formation of the Himalayas. The structure of the Himalayas

became extremely complex owing to three upheavals, that is southward pushes and development of further cracks in the folds along their axis. As the Himalayas rose higher and higher, the eroding action of rain, wind and snow exposed the buried granites and gneisses forming very high peaks.

The high peaks in the Himalayas remain covered with snow throughout the year. The formation of the Himalayas have conferred unique distinction to the Indian subcontinent. The subcontinent has several benefits from the Himalayas. It is the abode of spiritual giants, great benefactor to the spiritual aspirants, protector of India from the icy chill blowing from northern arctic region as well as rare incursions from the invaders. The great rivers originating from the snowy Himalayan peaks are perennial and supply irrigation water to field crops, drinking water to big cities and bring with them fertile soil enriching flooded plains every year during rainy season. It has really contributed everything precious to India's heritage. It has been a source of inspiration to poets, artists and writers since times immemorial. Its landscape beauty and peace thrills every visitor. A large number of pilgrims visit the shrines of Kedarnath, Badrinath, Parsuram Kund, Amarnath, Gangotri, Yamunotri, Pashupatinath, Jwalaji, Naina Devi, Vaishno Devi, etc. every year. There are many spots of excellent scenic beauty and tourist destinations in the hills. These are Valley of Flowers, Khajjiar, Pahalgam, Gulmarg, Nainital, Mukteshwar, Shimla, Kullu, Manali, Dharmshala, Dalhousie, Mussoorie, Darjeeling, Gangtok, Shillong etc. There are also attractions for trekkers in Lahaul-Spiti, Leh-Ladakh, Rohtang, Baspa, Zemu etc.

The higher reaches of the Himalayas remain snow-covered perpetually. The snowline, the line where the snow remains almost throughout the year, is roughly 5000 metres above the mean sea level. This area is the cradle for miraculous medicinal plants. The area grows grasses credited to be highly invigorating to milch cattle. The Gujjar inhabiting these high reaches rear cattle and make *ghee* to sell in the nearby plains. Snowfall is common in western Himalaya at a height of 1600 to 1700 metres whereas it is uncommon even at a height of 2000 metres in the eastern Himalaya. Himalayan rivers, being perennial, have been a great blessing for generation of hydroelectric power.

Besides the above, the Himalayas are rain-maker and hosts vast biodiversity resources. Many minerals are also found. It has tremendous potential for growing temperate and subtropical crops, fruits and vegetables especially off-season vegetables. Cultivation of tea, flowers and medicinal and aromatic plants have large scope. Non-traditional edible plants throw new challenges to utilize huge potential to feed and better nourish the growing population of this subcontinent.

The snowline areas or higher reaches could be an excellent place to preserve our heritage of plant genetic wealth with zero power failure risks and under total safety to other man-made hazards. Still there are areas in the Himalayas which are the least disturbed, environment health-bracing and free of any hazards.

The Himalayan wall starts from near Gwadar on the Makran coast in the west to the Mizo hills in the east. The total length is about 5000 kilometres and of this from western wing of Baluchistan to trans-Sindhu upto the bend of Nanga Parbat is 1500 kilometres. The central Himalaya is 2500 kilometres and the eastern wing from Namcha Barwa to Mizo hills is about 1000 kilometres. The striking feature of the Himalayas is its altitudinal variation. The average altitude of the western wing is 2000 metres, 6000 metres in the central area and 1500 metres in the eastern wing. The highest peak (8848 metres) is in the central Himalaya and is known as Mount Everest or Sagarmatha or Chomo-lung-ma. In cross section, the Himalayas include outer Himalaya or Shivalik ranges (low-lying foothills having 1000 metres mean altitude and 10 to 60 kilometres width); middle Himalaya about 60 to 80 km wide and with 3500 m in average altitude; the great Himalayan range of about 120 to 140 km width and the trans-Himalayan range of about 40 km width which encompasses Leh, Ladakh, Lahaul, Spiti and the Tibetan Plateau.

In strict sense, the Himalayan mountain wall stretches from Baluchistan to Far East in Burma through West Pakistan, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Nepal, Sikkim, Darjeeling (W.B.), Bhutan, Arunachal Pradesh, Assam, Nagaland, Meghalaya, Manipur, Tripura and Mizoram. It may be convenient to divide the Himalayas of Indian subcontinent into three divisions:

temperate forest type, sub-alpine forests and the alpine pasture and scrubs.

The recent time is facing changes in human psychology, living style, communication system etc. and as a consequence, the ecological conditions have become very fragile. The forest vegetation is depleting very fast threatening extinction of many valuable genetic resources hosted in the region.

Agro-Ecological System

The agro-ecological system is essentially concerned with basic human needs of food, fodder, fuel, fibre, medicinal and timber plants. The underlying principle should be the sustainable production of these goods and services. The system has evolved in such a way that the local physical resources of water, land and vegetation have been oriented for sustainable production. The western Himalaya region has a mild summer and cool to cold winter. The mean annual rainfall varies from 831 to 1602 mm (Uttarakhand 831 mm, Himachal Pradesh 1602 mm and J&K 994 mm), which exceeds potential evapotranspiration during most of the year. Moisture availability is for 150 to 210 days in a year. In recent years, there has been excessive deforestation in this region and is coupled with a high degree of soil erosion. The crops cultivated include wheat, barley, maize, paddy, buckwheat, grain amaranth, grain chenopod, mandua (finger millet), kangani (foxtail), mung, mash, kultha, raungi (cowpea), rajmah, bhatta (soybean), oilseed, brassica, linseed, sesame (til), *Perilla* (Bhanjira), and a wide range of vegetables such as cucurbits, bhindi, baingan, potato, *Colocasia* (arbi, kachalu), onion, garlic etc.

Agriculture is on permanent settlement and is done on terraced fields on the hill slopes. The slope is of a wide range. Some trees such as *Grewia optiva* (bihul) semal, *Morus* spp. (hut), *Albizia* spp. *Acacia* spp., *Bauhinia* spp. (kachnar), *Dalbergia sisoo* (shisam), fig trees (*Ficus* spp.) are allowed to grow in cultivated fields. These serve the purposes of fodder, fuel and timber.

Natural Resources

The Himalayas are potentially rich in a great variety of resources which still await exploitation. These include hydroelectricity,

minerals, medicinal plants, grasslands, forests, agriculture and horticulture.

The altitudes beyond 5000 metres in the Himalayas mainly consist of perpetual ice and rocks. However there are valleys or grassy areas where sheep, goats, and cross-breeds of yak graze during summer months. These areas also grow valuable scented and medicinal plants such as dhoop (Chamba), kuth (Lahaul-Spiti), mamiri (Uttarakhand), rattanjot (Yamunotri area). Excellent grasslands occur between 4000 and 5000 metres, where the cold is too much for trees to grow. Many semi-nomadic tribes (e.g. Gujjars and Gaddis of J&K and Himachal) rear flocks of sheep, goats, cows, buffalo and horses on these grasslands. Their major income source is wool, pashmina and *ghee* or milk. These areas could be profitably used for dairy industry on the lines of Switzerland.

Agriculture is mainly sustainable in nature and crop yields are low because of employing age-old traditional methods. The crops grown at high altitudes are barley, wheat, buckwheat ('phapara' and 'ogal'), chenopod, potato, grain amaranth. At still lower altitudes (below 2000 metres) farmers cultivate wheat, maize, paddy, minor millets, and a number of vegetables are also grown. The vegetables such as peas, cauliflower, cabbage, capsicum and tomato are grown on commercial scale and are marketed to the plains.

The Himalayas are highly suitable for the cultivation of a variety of temperate fruits and nuts. Commercially grown fruits are apples, pear, apricot, plum cherries, peach, dry grapes, oranges, pineapple. Among the nuts which are commercially grown are almond (J&K), hazelnut (Thangi), chilgoza (Pangi, Kinnaur, H.P.), chestnut (north-eastern region) and walnut (J&K and H.P.).

The forests occur up to 3500 metres and are important for hill economy. They are great source of timber, medicines, fruits and other commercial value products (pine resin). Lower altitudes grow excellent quality tea (Palampur, H.P.)

Meagre work has been done on exploration and exploitation of mineral wealth of the Himalayas. Copper is known to occur in Almora (Uttarakhand).

The western Himalaya have rich genetic diversity for species of the genera of *Pyrus, Prunus, Sorbus, Ribes, Rubus, Hordeum, Elymus, Eremopyrum, Avena, Aegilops, Allium, Lepidium, Carum, Linum, Cicer, Cucumis, Chenpodium* and *Vicia.*

Central Himalaya (Nepal)

Physiography

The middle part of the Himalayan mountains are supposed to be limited to Nepal and spread from about 80° to 88° E longitude. On the western border it begins from the Nampa (6750 m) and Api (7132 m) peaks and ends at Kanchenjunga in the east. The river Kali forms its western boundary and Mechi river forms its eastern boundary. The topography of Nepal can be divided into eight longitudinal belts as follows:

a) Trans-Himalayan belt—Biggest portion lies in Manang Bhot.
b) Snowy peaks of the Great Himalaya.
c) The midland hills and valleys lying between the Great Himalaya and the Mahabharat Lekh, which is less rugged.
d) Mahabharat Lekh—Is middle of Nepal which represents a continuous range running from west to east.
e) Bhitri Madesh—Represents longitudinal valleys such as Kamla, Naryani, Dang, Rapti, Chitawan etc.
f) Churia-Muria—Are towards south of Bhitri Madesh, i.e. Shivaliks which in Nepal is called Churia-Muria hills.
g) Bhabar lands—South of Churia-Muria.
h) Tarai forests.

Nepal has three important river valleys. These are:

1. The Ghagra valley occupies western Nepal, having other rivers such as Karnali, Seti, Bhari.
2. The Gandak valley is formed by the Kali or Krishna, Gandaki and tributaries such as Marsiandi and Trisuli.
3. The Kosi valley is mainly formed by snow-fed Sun Kosi, Arun and Tamur which together form the Sapta Kosi or Kosi. The other rivers are Indrawati, Bhota Kosi, Dudh Kosi. Kathmandu is a small circular valley of Bhagmati river and once was a lake which is evidenced by the presence of old

lake deposits as terraces all round the valley. The central part represents the intermediary climatic condition between those found in the western and the eastern parts.

A variety of races inhabit the country. In the north and east live the Bhotias and the Tamangs. In the western part, live the Magars, the Kiratis, the Gurungs and the Sunwars. The Newars inhabit in central Nepal. In the Tarai belt are found the Dhimals and the Tharus.

The great Himalaya in Nepal is about 25 to 30 km wide. Many of the tallest peaks are situated in this region. Some of the important ones are Mount Everest (Sagarmatha in Nepali, 8814 m), Kanchenjunga (8598 m), Dhaulagiri (8167 m), Gauri Shankar (7145 m) etc. There are about 240 high peaks in Nepal Himalaya which have altitude more than 6500 m.

Natural Vegetation

According Polunin and Stainton (1986), in the central Himalaya (Nepal) some 6500 plant species are known to occur. Flora is subtropical in deep valleys and lower foothills of Nepal. This is also the cultivated and much inhabited area. Flora is also richer towards the wetter eastern parts of Nepal. Beyond the subtropical zone lies the temperate zone which goes right upto the treeline. The treeline lies about 4000 m except in the west where it lies about 300 m lower. The areas beyond are covered by thick rich shrub flora. The alpine zone begins from the treeline and extends upwards to reach the snowline. The alpine provides excellent grazing areas on lower heights whereas the upper parts contain flora adapted to extreme cold and high moisture stress. Many endemic species are found there in small areas at various locations. About 40 percent of land is under forest cover in the country.

Climatic Conditions

The climate of Nepal in predominantly cold due to snow-clad mountains and rivers flowing from there. Summers are quite pleasant but winters are shivering cold. The average annual rainfall is about 150 cm. Characteristically, Nepal's climate is mid-average of eastern and western Himalaya.

Natural Resources

The agriculture is practiced on around 16 percent of land area and about 60 percent population is dependent on agriculture. A large number of minerals such as iron ore, copper, graphite, mica, gold, gypsum etc. occur abundantly, though they still remain under-exploited. Medicinal herbs occur in plenty.

Agro-Ecology

Agriculture is practiced both in plain valleys as well as on hill slopes in terraced fields. Main food crop is rice. However maize, buckwheat, amaranth, chenopod, wheat also form part of cereal diet, besides small millets. Other important crops are sugarcane, tobacco, tea, cotton, jute, cardamom, banana, pineapple and oranges. Potato cultivation is widespread. *Bassia latifolia* (chiura) grows wild and its seeds are a good source of fat to the most people in Nepal.

Small industries are the ancient feature and still predominate. They manufacture jute rope, baskets, cloth, woolen garments etc. Famous cities and towns include Kathmandu (capital), Viratnagar, Birganj, Lumbini, Simra, Nepalganj, Bhairba, Naraingarh, Pokhra, Amlekhganj, Bhatgaon etc.

Eastern Himalaya

Physiography

It comprises of the Himalaya which spreads into Sikkim, Darjeeling and Arunachal Pradesh. The eastern Himalaya further extends its ranges and hills run into Assam (Mikir) hills, Nagaland hills, Manipur, Meghalaya, Tripura and Mizoram. The latter is collectively called as north-eastern hills region. The climate in the eastern and north-eastern Himalaya can be broadly recognized as follows:

a) Below 800 metres represents warm tropical
b) Between 800 and 1200 metres it is warm subtropical
c) Between 1200 and 2400 metres it is cool temperate
d) Between 2400 and 3600 metres it is cold temperate
e) Above 3600 metres it is arctic.

Climatic Conditions

In contrast the eastern parts have more rain and less snowfall. The snowline is higher in the east. The average annual temperature is 10-14°C and total annual rainfall is 84 mm at Leh (Ladakh) which is at 3522 metres height. At Shimla (2130 metres) the average annual temperature is 13-15°C and total annual rainfall is 1982 mm. The third hill station is Darjeeling in the eastern Himalaya and is located at the same altitude as Shimla. However its average annual temperature is 15.4°C which is higher than Shimla and annual rainfall is 3077 mm. Ziro in Arunachal is located at an altitude of about 2200 metres with an average temperature of 29°C and annual rainfall of 2292 mm. Cherrapunjee which is in the north-eastern hills has average monthly temperature of 17°C, annual rainfall is 11,420 mm and altitude of 1310 metres.

Natural Vegetation

The eastern Himalaya has always been considered as a distinct phytogeographical region. The natural vegetal cover (about 4000 species) includes extensive stems of pines, rhododendrons and beaches etc. The reasons for this great biological diversity in comparatively small area are many. Major causes for this biodiversity include diverse eco-system, seismic zone, high rainfall and influence of flora of Myanmar (Burma), China etc. The frequent earthquakes produce strong vibrations which may cause mutagenic variations in the plant species. All the factors mentioned above have greatly contributed to the varied and rich forest types as well as cultivated diversity, which account for a great floristic diversity. The major forest types that occur in eastern and north-eastern Himalaya are:

1. Tropical evergreen or semi evergreen forests
2. Tropical deciduous forests (below 1000 metres)
3. Subtropical broad-leaved forests (1000-2000 metres)
4. Subtropical pine forests (1500-1800 metres)
5. Temperate forests (1800-3000 metres): These have predominant species such as *Rhododendron* species, *Quercus* species, *Castanopsis* species, *Pyrus* species. The 'sacred grove' of Shillong plateau also represents this type of forests.

6. Sub-alpine forests (3500-4000 metres): Dominant species are *Abies* species, *Rhododendron hodgsonii, Rhododendron thomsonii, Salix* species, *Cotoneaster* species, *Berberis* species etc.
7. Alpine flora (4000-5000 metres): Have dominant species of *Primula* species, *Junipers, Rhododendron, Aconitum* etc.

Plant Genetic Resources

These varied forest types exhibit an enormous floristic diversity. There are large number of varieties and kinds of orchids, *Musa* species, *Bambusa* species, *Calamus* species (canes), medicinal plants, horticultural plants, wild germplasm of cultivated plants and even plant species of biological curiosities such as insect-eating pitcher plant. The diversity of this region is highlighted in the following few groups of plants.

Rice (*Oryza sativa*): Out of 22 species, 5 wild species with their different forms occur in the eastern and north-eastern Himalaya. These are *Oryza granulata, O. officinalis, O. rufipogon, O. meyeriana,* and *O. nivara* (Hore and Sharma, 1993). The varietal and landrace germplasm varies from 6730 to 8030 in the region (Sharma & Hore, 1988; Sharma et al., 1988).

Citrus germplasm: The region has a rich diversity of citrus germplasm. It includes 23 taxa with their 62 varieties or hybrids (Sharma et al., 2003).

Banana (*Musa* spp.): The eastern and north-eastern Himalaya has large diversity of wild banana species. Of the 42 species of *Musa*, 14 species have been found distributed in the eastern and north-eastern Himalaya (Hore and Sharma, 1992).

Yams (*Dioscorea* spp.): An impressive diversity of *Dioscorea* species and cultivated types occur in the region. There occur about 23 species of genus Dioscorea and about 240 germplasm accessions were collected from farmer fields and maintained at the NBPGR, Regional Station, Shillong (Sharma and Hore, 1993; Hore and Sharma, 1995).

Saccharum complex: The various genera and species related to sugarcane (*Saccharum officinarum*) are collectively known as *Saccharum* complex. Out of 27 Indian taxa, 19 taxa belonging to

the *Saccharum* complex have been found in north-eastern region (Hore and Sharma, 1995). These include 9 species of genus *Saccharum*, 3 species of *Erianthus*, 2 species of *Narenga*, 3 species of *Misanthus* and 2 species of *Sclerostachya*.

Orchids: The orchids are most fascinating among the ornamental plants. Among 1300 species of orchids that are found in India, the north-eastern India has about 700 species (Hore and Sharma, 1990).

Bamboos and Canes: More than 50 percent of the Indian bamboo and cane genetic resources occur in the north-eastern region. A total of 67 species of bamboos and 13 species of canes or even more have been reported so far (Sharma et al., 1992).

Wild relative of crop plants: Besides the above, a large number of wild species related to crops are also known to occur. Mention may be made of mango, *pyrus, prunus, piper,* cucurbits, *Digitaria crusiata* var. *escelenta, Moghania vestita, Tricosanthes, Coix lachryma-jobi, Atylosia curcuma, Zingiber, Perilla frutescens, Vigna umbellata.* It has been estimated that in India about 800 species are consumed as food plants (Singh and Arora, 1978), of these 300 species occur in eastern Himalayan alone. The eastern and north-eastern Himalaya have about 9000 species, of which 39 percent are reported to be endemic (Myers, 1988).

Agro-Ecosystems

Agro-ecosystem is a result of evolution of human culture. These have undergone many changes staring from food-gathering to food-producing and has affected the hydrological and geophysical cycles. The prevailing shifting cultivation has to be refined and made sustainable by scientific and technological inputs taking into account the indigenous knowledge developed over centuries by the inhabitants. The concept of agro-ecosystems aims to using land, water, domestic animal resource and vegetation for sustainable production and productivity.

The eastern and western Himalaya is comprised of three major agro-ecosystems viz. (i) hot humid to sub-humid alluvial deposit valley plains, (ii) warm pre-humid eco-region with brown and red soils, (iii) warm pre-humid eco-region with red and lateritic soils.

Agro-eco Region

The alluvium derived soils of valleys are found in plains of Assam, Tripura and north Bengal adjoining to Darjeeling. It has natural vegetation comprising of tropical moist and dry deciduous forests. Because of high rainfall, the cropping system is rice-based. The main crops in the Kharif (summer and rainy season) are rice, jute, pulses (lentil, cowpea), oil seeds (til or sesame). In foothills plantation crops such as tea and horticultural crops like pineapple, coconut, citrus, banana, arecanut, pepper, red chillies are grown. Rice, jute, pulses and oilseed (mustard) are grown on residual soil moisture in Rabi season. The major agricultural constraints of this agro-ecosystem are: (i) flooding and waterlogging, (ii) excessive leaching of bases and nutrients resulting in low base status soils and soil acidity (causing fixation of soil phosphorus), (iii) high iron and aluminum toxicity in wetlands.

Warm Perhumid Agro-Ecosystem of Hills & Mountains

The eastern Himalaya agro-eco region is comprised of hills and mountains of West Bengal, northern Assam, Arunachal Pradesh and Sikkim states. The agro-climate of the region is characterized by warm summers and cool winters. The mean annual rainfall exceeds 2000 mm per annum. The area experiences short period of water stress during post-rainy period because of seasonal water deficit. The region has the longest period of 270 days for crop growing. The soils are shallow to moderately shallow, loamy and rich in organic matter. The natural vegetational cover consists of subtropical pine forests, temperate wet evergreen forests, sub-alpine forests etc. In general, Jhum (shifting) cultivation is the traditional farming system. Jhum (shifting) cultivation is practised with mixed cropping on sloppy lands at an interval of 3-4 years. In river valley plain lands intervened by hills and mountains, cultivation is practised on terraced lands, and potato, maize, millets and paddy are grown. Terraced fields are also used for cultivation of millets, upland paddy, *Coix lachryma-jobi*, beans etc. In lower valleys, rice, maize, millets, potato, sweet potato, mustard, sesame and pulses are grown under rainfed as well as irrigated conditions. In hilly areas, vegetables, plantation crops like tea, medicinal plants and horticultural crops such as pineapple, citrus

(oranges), apple, pear, peach, banana, coconut, arecanut are grown on terraces. Severe climatic conditions restrict the choice of crops. Poor fertility of soils and acidic conditions are major factors for low crop yields. In many areas frost in winters cause extensive damage to crop plants and reduce the crop growing period in certain years. High rainfall causes severe nutrient loss on sloppy land areas.

Warm Pre-humid Hilly Eco Region

In the north-eastern hills agro-ecosystem is constituted of hilly states of Nagaland, Manipur, Meghalaya, Mizoram, Assam, southern Tripura and Arunachal Pradesh. The agro-system is characterized by warm summers and cool winters. The mean annual rainfall varies from 2000 mm to 3000 mm. There is no water deficit except during the period of December to February and is 100 to 150 mm. There is a long crop growing shallow to deep, loamy red and lateritic yellow and red soils. These are strongly acidic. Jhum (shifting) is the traditional farming system. Rice is the crop and on hill terraces, millets, maize, potatoes, rice, jute are cultivated under rainfed conditions. Oilseeds (mustard), pulses (black gram, green gram, lentil, French bean-rajmah, cowpea) are cultivated as post-rainy season crops. Hill terraces are also used for plantation crops such as tea, coffee, coconut, arecanut, and horticultural crops like oranges, pineapple, pear, plum etc. Major constraints of this region are nutrient loss due to Jhum cultivation practice, low temperature in autumn and hill sloppy lands with marginal holdings.

The crop diversity is huge in the eastern and north-eastern region of the Himalaya. The vast agro-ecology diversity is responsible for this. The main food crops are: rice, millets (job's tear), *Eleusine coracana* (finger millet), *Setaria italica* (foxtail millet), *Panicum millaceum* (cheena) etc.; pulses (black gram, green gram, lentil, grain pea, cowpea, rice bean, rajmah etc.); oil seeds (brassica seeds, sesame etc.) and a very large number of vegetable plant species and their varieties evolved by farmers over the centuries of their co-existence. Large number of vegetable, medicinal, condiments and spices plant species are being grown in their back courtyards for their daily needs.

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