

# CLIMATE CHANGE AND SUSTAINABILITY OF AGRODIVERSITY IN TRADITIONAL FARMING OF THE SIKKIM HIMALAYA

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## ABSTRACT

Climate change impact at the global level has become a major concern today and Sikkim Himalaya is no exception. In the regional context, climate change has contributed to unpredictable or erratic rainfall pattern, drying up of local springs and streams, species migration to higher elevations, shift of sowing and harvesting period of crops, emergence of invasive species and incidence of diseases/pests in crops as well as in fodder species. Building resilience in both human and ecological systems to an optimum level is the best possible way to adapt to climatic variation. This study has identified the primary challenges of mountain farmers for ensuing adaptive capacity and water security in the agriculture systems. High levels of impact from climatic change was recorded for paddy, maize, wheat, oil seeds, cardamom, ginger, drinking water sources and springs and fodder trees. A total of 9 types of rains (*jhari*) and 12 traditional landuse practices are studied which have undergone changes due to climatic change impacts in the area. Innovative coping mechanisms developed by local farmers against emergence of diseases and pests, invasive alien species, untimely shift of crop sowing and harvesting season, rapidly declining productivity, climatic variability etc. are detailed. Pastoralists are now resorting to an alternate strategy for making the best use of their land and herds. There is a need to develop a comprehensive master plan for strategically planning conservation, addressing poverty and food security in the wake of climate change impacts.

**KEYWORDS:** *Sikkim Himalayan traditional agriculture, Climate change impacts, Agroforestry systems, Adaptive capacity, Human well being*



Agropastoralism in Muguthang (4000-4800 m), North Sikkim



Drying up of mountain springs due to environmental change poses a serious threat to rural water security

The Third Assessment Report of the Intergovernmental Panel on Climate Change has reported the projected rise in temperature (1.4 °C by 2020 and 3.8 °C by 2080s) and precipitation (3% by 2020 and 11% by 2080) over the Indian region resulting into flash floods, droughts, cyclones and forest fires (IPCC 2001; Shukla et al. 2002; Rupa Kumar and Ashrit 2001). Arora et al. (2005) have reported that in the north Indian floodplains the seasonal temperature has increased by 0.94 °C per 100 years for the post monsoon season and by 1.1 °C per 100 years for the winter season. Adaptation is critical over the last century as climate change can cause adverse impacts on agriculture sector and adaptation can reduce the vulnerabilities (Swaminathan 2002). Mirza and Dixit (1997) in their analysis found the climate change along the major river systems in India - the Ganges and Brahmaputra basin is likely to change river flows and cause draught, floods and sedimentation. Rainfall variation and increasing temperatures has been reported in Nepal (Shrestha et al. 1999). Such events are inextricably going to change the type and magnitude of ecosystem services and impact largely the rural people and their agriculture. Scientific evidence indicates strongly that global climate change is indeed taking place and will have practical ramifications on local ecosystems (IPCC 2007).

However, little is known about the vulnerability of mountain ecosystems to climate change particularly the Himalayan region. A comprehensive report developed by International Centre for Integrated Mountain Development clearly mentions that the Eastern Himalayas are experiencing widespread warming of generally 0.01 to 0.04 °C per year (Sharma et al. 2009). The dynamic Sikkim Himalayan agriculture is being impacted due to increasing uncertainty. Only about 12% of the total land area of Sikkim (7096 sq km) is cultivable between the vertical elevation gradients from tropical (300 m) to the Trans-Himalayan region (5000 m), where about 65% of the total population of 6,07,688 (Census 2011) depend on agriculture for their livelihood. The mountain farmers are facing numerous unpredictable scenarios related to global warming and climate change. Apart from the already existing drivers of change such as social, political, economic and environmental affecting the life and livelihoods of the mountain communities, the global climate variability is an additional factor which is directly affecting and multiplying the impact of other drivers of change (ICIMOD 2010). However, in-depth information on impacts of climate change is lacking for the Sikkim Himalaya and long term research studies are yet to be taken up.

This chapter outlines the basic elements of agrodiversity, ecosystem services and traditional land use types of the traditional farming system of Sikkim Himalaya. Further farmer's perceptions and observations on climate change and its effect on the traditional farming are discussed. A few indicators of the impacts of climate change on agrodiversity systems, adaptive measures initiated by the farmers and the growing challenges of rural livelihoods are also discussed.

### **Agrodiversity elements in the Sikkim Himalayas**

The Sikkim Himalayan traditional agriculture system encompasses variations of agro-ecological zones that cover a range of ecosystem diversity extending between 300 m to 5000 m asl within 88°00'10" to 88°56'06" N longitude and 27°03'34" to 28°06'10" E latitude. It is a part of the Eastern Himalayas – a globally significant biodiversity hotspot and houses a range of agro-biodiversity. The tropical zone (>500 m) mostly follows rice cultivation system in terraces and along the river valleys. Above this are large cardamom-based and farm-based traditional agroforestry in the subtropical to warm temperate zones (600-2500 m), subsistence farming in the cool temperate and lower alpine zones (2500-4000 m) and the Trans-Himalayan nomadic agro-pastoral to pastoral systems in the Tibetan plateau (4000-5000 m) of Thangu, Muguthang, Lhonak valley and

Yumesamdong-Lhasar-Tso Lhamo valley. The information of the case studies presented here is based on the argo-ecological range between 300-5000 m. The Sikkim Himalaya falls in the Indian monsoon region and has three main seasons: winter (November-February), pre-monsoon (March-May) and monsoon (June-October). The mean monthly maximum temperature varies from 22° C to sub-zero in the lower subtropical agro-climatic zone to the Trans-Himalayan zone.

The agrodiversity in mountain systems faces marginality, inaccessibility and fragility to sustain its resilience. The traditional system of agrodiversity management practices as described by Stocking (2002) represent adaptation mechanisms developed by mountain communities to adapt to the changing climatic variables over time (Table 1). The four elements of management systems sustained by Sikkim Himalayan farmers have promoted sustainable production as a result of their agro-ecological knowledge base.

**Table 1:** The four elements of agrodiversity. Modified from Stocking (2002)

Sl. No.	Agrodiversity categories	Description
1	Biophysical diversity	Traditional mountain farms are endowed with diversity of natural environment, including the natural resource base required for production. It also refers to the natural resilience of the biophysical environment, soil characteristics, plant life, and other biota in the agro-ecosystems. The physical and chemical aspects of soil, hydrology, climate and the variability in these elements.
2	Management Diversity	This refers to the management methods of land, water systems, biota for crop and livestock production and the maintenance of soil fertility and structure. It also refers to the physical, biological and chemical methods of management of the agro-ecosystems
3	Agro-biodiversity	Mountain farmers grow a diversity of species and varieties, with emphasis on integrated farming with a combination of crop, plant and animals. It also includes a variety of species or biota that is indirectly useful to humans and managed within the system
4	Organizational diversity	This refers to how mountain farmers operate, manage and own their farms and the manner under which natural resource endowments are used from the source as per situation and time. This also includes agriculture labour, assets, reliance on off-farm employment, household size, farm size, farmer's institutions, share cropping, labour share, barter system etc.

#### **WHY DO NATIVE FARMERS CONSERVE AGRODIVERSITY?**

The management of agrodiversity by the indigenous communities is for a variety of reasons. The land use types, land use stages, aspect, soil fertility, availability of water and shade trees etc. are essential variables which an indigenous farmer considers while cultivating a diversity of traditional landraces in the farm for food security. The diversity of land use types and land use stages is related to drought-tolerant varieties, disease-tolerant varieties, crop residue (for farm animals), market potential, agronomic productivity, taste and also for customs and rituals.

Sikkim Himalaya is unique owing to elevation gradients forming different agro-climatic zones at short distances. Thus, nature has bestowed conducive environments for agrodiversity, which is supported by cultural diversity

of communities practicing customs, traditions, rituals and Traditional Ecological Knowledge Systems (TEKS). The diversity of landscape, land-use stages and specific land use category at temporal and spatial scales has provided opportunities to manage agro-biodiversity and intrinsic human-nature relationship. The agrodiversity is an assemblage of high value mountain niche products, medicinal plants, agroforestry systems, integrated watersheds, springs and local water sources and the *Beyuls* in the cultural landscapes in the region (Table 2).

**Table 2:** Dominant land use stages and their attributes in traditional farming in sub-tropical to temperate agro-climatic belt of Sikkim Himalaya

Land Units	Traditional land-use classification	Attributes of practices
Khet System (wet rice)	<i>Pakho khet</i>	Slope >30°, terraced rice fields, trees grown on the terraces, terrace fall is frequent during rainy season
	<i>Byanshi</i>	<i>Thang</i> or flat paddy fields, along Teesta and Rangpo river, nutrient rich soil, good productivity
	<i>Sim/kholyang</i>	Water seepage round the year, also the source of potable water
	<i>Bagarrey</i>	Paddy fields along the river banks, <i>pango</i> (clay soil), fertile
	<i>Birauto</i>	Newly terraced field, soil conservation structures that are sometimes the test lands for new crops or the crops that are not suited for other land use types
Bari (dry land)	<i>Tar bari</i>	Flat dry field, rain-fed, for growing maize, wheat, vegetables, oil seeds, millets and buckwheat etc. These are mostly fertile terraced plots and are highly productive.
	<i>Kothe bari</i>	Field within the home-garden for many crops and vegetables, horticultural crops, banana etc., annual and inter-cropping done. Home gardens house traditional and cultural crops, medicinal plants, or preferred sacred species
	<i>Pakho bari</i>	Steep hill slopes are converted into cultivable, productive but narrow terraces, fodder grasses, fodder trees, other multipurpose agroforestry species, pulses and banana etc. are grown
	<i>Bhasmey/Khoria</i>	This is the remnant of shifting cultivation, scrublands, slash and burn in the sloping land, pulses, horse gram are grown
	<i>Siru bari</i>	<i>Imperata</i> sp. (for roof thatching) and trees are grown
	<i>Alaninchi bari</i>	Large cardamom plantations under the mixed tree species, support fuel, fodder and timber apart from economic return from cardamom
Niji Jungle (private forests)	<i>Bans-ghari+jungle</i>	Indigenous farmers conserved agroforests/forests at the edge of the farmland that functions as protective lands. Bamboo groves and other agro-forestry species grown



Grazing regimes are reducing due to impacts of climate change

### **Agrodiversity goods and services**

The Traditional Agro-ecosystems (TAs) provide a number of goods and services that are of vital importance for the functioning of biosphere. The ecosystems goods and services in the mountain environments have provided opportunities to mountain communities and are in high demand for the low-land population, as they provide pristine natural landscape for recreation and freshwater for a variety of uses. The TAs provide the basis for the delivery of tangible benefits such as food, water, air etc. to the mountain societies. These services are divided into four categories (Hassan et al. 2005), viz.,

1. *Supporting services*: The TAs are responsible for primary and secondary production and agro-biodiversity which is necessary for sustaining the goods and services that mountain societies need and enjoy from these ecosystems for their well being.
2. *Provisioning services*: The TAs provide agriculture products such as food (crops, roots, tubers, seeds, nuts, fruits, fodder, spices, etc), fiber (wood, textiles) and medicinal and aromatic plants.
3. *Regulating services*: The TAs and forest ecosystems are critically important for carbon sequestration, water and climate regulation, protection from natural hazards such as floods, landslides, avalanches etc, water and air regulation and disease and pest regulation.
4. *Cultural services*: The TAs in the Sikkim Himalayan Sacred Landscape is the centre of spiritual, cultural and aesthetic importance. Traditional mountain societies conserve, preserve and protect these ecosystems for the present and future generations.

The range of ecosystem services differ at spatial scales while strengthening resilience can overcome climate uncertainties and enhance adaptive capacity thus reducing the vulnerabilities from local to regional level (Table 3).

**Table 3:** Range of ecosystem services bestowed by Traditional Agroecosystems in spatial scales. Modified after Kremen (2005)

Ecosystem Services	Spatial scale		
	Farm Level (local)	Sikkim Himalaya (landscape)	Himalaya (regional)
Net Primary Production			
Food production, NTFPs, Lesser known/Underutilized crops, medicinal plants etc.			
Timber, fuel wood, litter			
Disease and pest control			
Pollination and seed dispersal			
Soil fertility maintenance and enrichment			
Control of soil degradation, stabilization and erosion control			
Fresh/clean water			
Flood control and flood mitigation			
Fresh/clean air			
Carbon sink, carbon sequestration in diverse land use systems			
Biodiversity (hot-spot)			
Sacred landscape (aesthetic/cultural/spiritual value)			

### TEMPERATURE AS AN INDICATOR

The India Meteorological Department (IMD) records reveal that between 1958 and 2005, there were slight changes in the climate of Gangtok. The maximum temperature has been falling by 0.3 °C per decade, and the minimum temperature has been rising by 0.2 °C per decade. The annual rainfall has been increasing by 49.6 mm per decade (Seetharam 2008; Anon. 2008). Our interaction and subsequent interview with farmers and herders revealed that they are experiencing warmer summer months in recent times. They informed that temperature rise has caused vertical shift of some horticultural crops and those grown earlier in the lower altitudes can be grown at higher altitudes now.

### FARMER'S PERCEPTION ON IMPACT OF CLIMATE CHANGE

The Sikkim Himalayan region encompasses a diversity of climatic conditions from tropical in the lower elevations to alpine and Trans Himalayan in the high altitudes, which are the regions of complex topography. The hydrological system is largely governed by the South Asian Monsoon, while the relationship between the timing and quantum of monsoon rainfall across the altitudinal variation is less understood. Due to its orographic

effects, the temporal and spatial precipitation dynamics in the Sikkim Himalaya needs detailed studies, and the hydro-meteorological data is available for only two locations for about four decades does not show “cause and effect” scenario. Only about 12,643 ha of land is irrigated while 52,265 ha is un-irrigated, barren and grassland. Traditional agriculture is dependent on the specific micro-climatic variations in the localised ecosystems, and thus climate change has major implications on agriculture and adaptation.

### ***Trans-Himalayan agro-pastoralism and sub-alpine agriculture***

The Trans-Himalayan (4000-5000 m) agropastoralism is characterized by yak, sheep, goat or horse grazing. The socio-cultural life of the indigenous communities immensely contributes to the socio-ecological adaptability to changing climatic conditions. The climate change impacts in the Trans-Himalayan areas are being felt with a shift in snowfall events. The nomadic herders are experiencing increased summer temperatures with decline in snowfall. Elderly farmers remarked that 20-30 years ago at Thangu (3900 m), snowfall events used to be continuous for a week to 15 days. In the last 10 years, dramatic changes have been observed at Thangu where snowfall events have become untimely and occasional snowfall takes place that lasts for one to two days only. Herders recount that more than 3 m of snowfall was natural at Thangu, Bamzey and Dambochey (4000-4700 m) around 20-30 years ago. In the last 5-8 years (2000-2010) the total snowfall in these areas has declined by almost 40%. About 15 years ago, in Thangu area, first snowfall was observed normally by the end of October. Now snowfall begins only by the first or second week of November showing a shift by 15-20 days. Unusual and untimely snowfall has severely impacted the life and livelihood of the Dokpas (high altitude pastoralists). This has significantly impacted the fodder productivity for livestock. Rangeland degradation, frequent landslides/mudslides, flooding, avalanches during winter and reduction of pastures is commonly observed in the Trans-Himalayan and alpine areas. These unusual natural events are a threat to yaks, goats and sheep and also to herders.

Similarly, seasonal shift of snowfall events and untimely snowfall has severely impacted the Trans-Himalayan subsistence agriculture. The Dokpas are nomadic herders who move with their herds every season depending upon the availability of grazing pastures. In Muguthang (5000 m) and in the Lhonak valley, they are gradually shifting to a sedentary lifestyle. Diversification of agriculture crops (medicinal plants, oil seeds, potato) and permanent settlements are now observed at Muguthang. During 1995-96 there was a serious outbreak of disease and heavy snowfall that killed a large number of sheep. After this event, sheep rearing is now completely abandoned in Lhonak Valley by the *Dzumsa* of Lachen. The gradual and sometimes sudden shift of seasonal events has caused serious problems to the rotational grazing of livestock in alpine and Trans-Himalayan plateaus. The *Dzumsa* of Lachung and Lachen in North Sikkim is a strong customary and traditional institution of local governance that has been securing the high altitude areas including the Trans-Himalayan Tibetan Plateaus from all externalities and eventualities.

The local people have observed that species are migrating with rise in altitude in Sikkim. The National Biodiversity strategy and Action Plan (NBSAP 2002) for Sikkim has reported that mosquitoes are appearing in the temperate region while house crows have spread in Lachung where they were uncommon earlier. Similar reports have been published in Tibet where changes in climate along with land use had impacts on ecosystems and human health (Xu et al. 2008).

### ***Temperate and sub-tropical agroclimatic zones***

The Sikkim Himalayan agriculture systems exhibit an ecosystem diversity which is dependent on micro-climatic and biophysical factors in exceptionally fragile and varying topography. Climate change events observed and recorded here have given rise to mudslides in terrace risers (in *khet* and *bari* systems) and productivity decline of crops (e.g., cardamom, ginger, orange, paddy, maize, wheat and buckwheat etc.) resulting in emerging food insecurity in the mountain region (mainly to those farmers living in highly inaccessible areas). Farmers



remarked that the sowing of maize in the sub-tropical zone has shifted by 15-20 days, while sowing at temperate zones remains the same. Similarly, the harvest of maize remains the same in the sub-tropical zone while harvest time has shortened by 15-20 days in the temperate zone. Information on temperature rise and untimely rainfall and its impact on agriculture have been reported by the farmers of the Sikkim Himalaya. Ecosystem services trade-off is a matter of concern due to land use change.

## ECOLOGICAL KNOWLEDGE ON RAINFALL EVENTS

Local communities of Sumbuk-Kartikey, Aho-Yangthang, Sumik Linzey and Linkey-Tareythang Gram Panchayats revealed that there are local names assigned to rainfall patterns called *Jhari* (continuous rain for two to several days). Previously *Titey Jhari*, the rain that continues for about a week during the flowering time of Titeypati (*Artemisia vulgaris*) was very common. Such *Jharis* are important for rain-fed agriculture (Table 4).

**Table 4:** Traditional Ecological Knowledge associated rainfall patterns

Sl. No.	Name of the <i>Jhari</i>	Knowledge associated to rains
1	Titey <i>Jhari</i>	This rain continues for about a week during the flowering time of Titeypati ( <i>Artemisia vulgaris</i> )
2	Naurathey <i>Jhari</i>	Rain that continues for a few days during <i>Navaratha</i> before <i>Dusshera</i> festival. This time is called <i>dhan pasauney bela</i> (paddy about to flower) and requires plenty of water. Farmers believe that after this rain, paddy flowering takes place indicating a good production
3	Sisney <i>Jhari</i>	This rain appears during the flowering time of nettle plant Sisnu ( <i>Urtica dioica</i> ). This plant is an indicator species.
4	Bhadaurey <i>Jhari</i>	Farmers expect rain after the paddy is shown during June-July ( <i>Ashad</i> and <i>Shravana</i> ). They also need rain during <i>Bhadau</i> (15 July-15 August) which would recharge the perennial springs and seasonal springs for continuous irrigation of the paddy fields
5	Sauney <i>Jhari</i>	Extended rainfall event during <i>Shravana</i> (period between 15 June-15 July) during sowing of paddy in subtropical to lower temperate region
6	Makurey <i>Jhari</i>	During <i>Shravana</i> , when the spiders start constructing their webs everywhere in the agriculture and forest areas, indigenous people believe that it is a sign of a few days of rainfall
7	Bagareni <i>Jhari</i>	The high altitude bird species mostly those inhabiting the riverine forests gradually start migrating to the warmer subtropical belt, thus farmers understand that that is a sign of Bagareni <i>Jhari</i>
8	Kartikey <i>Jhari</i>	Short rains during <i>Kartik</i> month of the lunar calendar in October. Some of the traditional varieties of crops require rains
9	Sohrasaradey <i>Jhari</i>	Rainfall events about one month before the <i>Dusshera</i> festival

At the face of receding glaciers in Sikkim, the lake outburst events may occur. One such event took place in June 2007 due to outburst of a lake in North Sikkim which washed away the seabuckthorn (an economically important Nitrogen fixer) along the Lachen Chu. Unpredictable flooding has been an emerging risk to mountain farmers inhabiting along the river belt.

The farmers of the Sikkim Himalaya have lost the comparative advantage of large cardamom; the production of this commercial traditional crop has declined drastically in the last 10 years. The total cultivation area of large cardamom was 26,700 ha in Sikkim and around 3,300 in Darjeeling until 2000 (Sharma 2004; Srinivasa 2006), which has reduced significantly now. In the Ilam area of Nepal, large cardamom in the last 10 years is growing in 2300-2500 m, having climbed up by 200 m in more than a decade. Farmers here reported that cardamom in high altitudes is growing well with no signs of diseases, while the low altitude plantations have severely declined. Similarly, *Alnus nepalensis* that was growing up to 2300 m is now showing up above 2500 m in Lachen and Lachung valleys of North Sikkim which is also observed in Ilam of Nepal. The extreme climatic conditions such as long dry spells, emergence of viral diseases such as *Chirkey*, *Furkey* and fungal disease *Colletotrichum* blight have contributed to the decline in large cardamom plantations and their productivity. The *Colletotrichum* disease appears at the advent of pre-monsoon showers (April-May) and progresses rapidly during the rainy season (June-August). The affected area becomes necrotic and dries up. This disease is causing severe plantation loss since last 10 years (Spices Board 2008). Most of the commonly found cultivars of cardamom are susceptible to this disease.

Similarly, Sikkim mandarin orange has declined both in terms of productivity and plantation area. In the 1990s, emergence of new diseases were observed in almost all citrus growing areas of Sikkim. Some of these diseases and pests are citrus dieback (drying of twigs from the tip/gradual degeneration), root/foot rot, powdery mildew, scab, sooty mould, red rust, nematodes, vascular-borne disease caused by Tristeza virus, colonization of ants in the citrus twigs and roots etc. The average decline of yield is 3.5 times less compared to the yield 10 years ago. The climate change events such as erratic rainfall and their impacts like poor yield and high incidence of pest and diseases have also been observed by the coffee growers in Chickmagalur district of Karnataka (Chandrasekharan 2009). Similarly, Miguel and Padoch (2009) have reported that as a consequence of climate change, higher and longer flood durations have been observed in the estuarine floodplains of Brazilian state of Amapa with significant impact to smallholders who plant crops and practice traditional agriculture.

### ***Multipurpose agroforestry species***

Due to untimely rainfall, fodder production has reduced with stunted growth of branches. This is followed by emergence of pests eating up the green foliage of trees (Table 1). The impact of climate change due to untimely precipitation is visible on the phenology of fodder species of both subtropical and temperate agro-climatic zones. One highly preferred fodder tree *Ficus lacor* (locally called *Rato Kabro*, *Seto Kabro*) is displaying budding and growing foliage in November, while the natural season of new foliage emergence is February end.

Farmers have observed the colonization of invasive species such as *Chromolina adenophorum*, *Eupatorium odoratum*, *Bidens biternata*, *Artemisia nilgirica*, *Lantana camara*, *Ageratum conyzoides*, *Cestrum aurantiacum*, *C. fasciculatum*, and *Galingosa parviflora* causing problems in the farmlands, forests, traditional agroforestry systems, fallow lands, croplands and wetlands. These invasive species are fast colonizing and have spread from sub-tropical to temperate agro-climatic region causing productivity decline. The spread of *Artemisia nilgirica*, *Bidens biternata*, *Eupatorium adenophorum*, *E. odoratum* etc. has resulted in a decline of grasses, thatch grass, firewood, timber etc. Also lack of adequate food resources in the nearby forest areas has caused wild animals to invade croplands. In the croplands, clearing invasive species involves labour input for land preparation for cultivation and management. Sikkimese farmers have observed crop-environment relations and associated changes at different intensities and have evaluated potential risks and uncertainties (Table 5).



Manuring by tying the cattle in agricultural fields is a common farming practise during winter



Nomadic Dokpa herders in the Trans-himalayas follow rotational grazing and forage production for the lean season

**Table 5:** Agricultural crops and indicators of change

Crops	Indicators of change
Cereals and pulses	Several traditional varieties of rice disappeared such as <i>Punaro</i> , <i>Kanchi Attey</i> , <i>Kagey Tulasi</i> , <i>Thulo Attey</i> , <i>Ghaiyya Dhan</i> , <i>Sanu Tulashi</i> , <i>Seto Tulashi</i> , <i>Thulo Marshi</i> , <i>Tauli Dhan</i> , <i>Baghey Tulashi</i> . The roots are infected by termites when the rice is in fruiting stage.
Large cardamom	Spread of fungal disease <i>Colletotrichum</i> blight and viral diseases commonly called <i>chirkey</i> and <i>furkey</i> since early eighties have drastically reduced the production (60 %) and plantation area (almost 50 %).
Ginger	The biggest challenge for ginger cultivation has been to control the soil borne diseases, soft rot, dry rot, bacterial wilt and so on. At the same time production of enough manure, manpower for cultivation and marketing at the time when market fetches high price are other challenges.
Chayote	Shrinking leaves, blights etc has been observed in the last five years.
Broom grass	Broom grass is a multipurpose agroforestry species in the mountain farming system all along the Himalayas. In the last 10 years, this grass is infested with yellowing of leaves and leaf blight. During winter especially after October the broom grass bushes develop this disease and dry up making the fodder un-palatable to farm animals.
Orange	Recently, the productivity has declined owing to diseased trees where potential fruit bearing potency is lost. In addition to this, the old plantations have lost the vigor and majority of them are affected by viral and other disease infestations.
Fodder species	In the recent years, farmers have witnessed that tree fodder production has significantly declined. One of the reasons is pests eating up the leaves before they mature for harvesting especially during the lean season. Some of these preferred trees are <i>Artocarpus lakoocha</i> (Badar), <i>Ficus cunia</i> (Khasreto), <i>Ficus benghalensis</i> (Pate Bar), <i>Ficus roxburghi</i> (Nibaro), <i>Ficus lacor</i> (Kabro), <i>Ficus semicordata</i> (Khanew), <i>Ficus hispida</i> (Khasreto), <i>Morus alba</i> (Kimbo), <i>Bauhinia</i> sp. (Koiralo), <i>Ficus hirta</i> (Khasre Khanew), <i>Ficus clavata</i> (Lute Khanew), <i>Bauhinia purpurea</i> (Tanki), <i>Litsea monopetala</i> (Kutmero), <i>Saurauia roxburghi</i> (Auley Gogun), <i>Osbeckia chinensis</i> (Chuletro), <i>Ficus nemoralis</i> (Dudilo), <i>Saurauia fasciculata</i> (Gogun), <i>S. griffithi</i> (Tatey Gogun), <i>S. napaulensis</i> (Gogun), <i>S. punduana</i> (Auley Gogun).
Common grass fodder declining	With the colonisation of invasive species, the common fodder species such as <i>Digitaria sanguinalis</i> (Ghogey Bansa), <i>Paspalum conjugatum</i> (Chitre Bansa), <i>Panicum repens</i> (Phurkey), <i>Thysanolaena agrostis</i> (Amliso) are declining.
Emergence of weeds in cultivated farms	Some of the common weeds of maize are <i>Eleusine indica</i> , <i>Setaria glauca</i> etc. Similarly, common weeds of paddy are <i>Cyperus eragrotis</i> , <i>Hydrocotyle nepalensis</i> , <i>Paspalum paspoides</i> , <i>Echinochloa crusgalli</i> , <i>Echinochloa colonum</i> , <i>Cyperus rotundus</i> , <i>Cynodon dactylon</i> , <i>Ageratum conyzoides</i> etc. The common weeds of wheat are <i>Chenopodium album</i> , <i>Amaranthus</i> sp., <i>Cynodon dactylon</i> , <i>Polygonum capitata</i> etc. The most common weeds are <i>Echinochloa crusgalli</i> , <i>Echinochloa colonum</i> , <i>Cyperus rotandus</i> , <i>Cynodon dactylon</i> , <i>Ageratum conyzoides</i> etc. Potato and mustard are common winter crops. They are mostly infested by common weeds such as <i>Polygonum capitata</i> , <i>Cyperus rotandus</i> , <i>Cyperus iria</i> , <i>Cynodon dactylon</i> , <i>Drymaria cordata</i> , <i>Spilanthus paniculata</i> , <i>Sida rhombifolia</i> , <i>Gnaphalium officinale</i> etc.



Cultivation of broom grass a multi-purpose plant is increasing



Springs are the immediate sources of drinking water in rural areas.  
These water sources are disappearing rapidly

A total of 15 Participatory Rural Appraisal (PRA) exercises were conducted in 12 Gram Panchayat Units of North, East, South, and West Sikkim from subtropical to warm temperate agro-climatic zones for identifying and ranking of vulnerable traditional crops due to climate change impacts over the last 30 years. This was done through pair-wise ranking with stakeholders such as farmers, older people of 60-80 year age groups, women groups, Self Help Groups (SHGs) and general public. The local crops considered for pair-wise ranking were rice, maize, finger millet, potato, pulses, beans/cow-pea, leafy vegetables/radish, and cabbage. Of all these, it was found that rice is the most vulnerable followed by maize both of which are staple crops for the marginal farmers of the Sikkim Himalayas. Similarly, among the high value cash crops, large cardamom is the most vulnerable followed by ginger and broom grass in the traditional farming systems.

In recent years, large scale colonization of unpalatable species has been observed by the farmers in the temperate zone. In the open meadows on one side of Jaubari area along the Singalila range colonization of unpalatable species such as *Gnaphalium* sp. has been significantly increasing, while on the other side the entire area is now covered by a single unpalatable species *Iris* sp. The ground floral diversity has severely declined. Some naturalized exotics such as *Ageratum houstonianum*, *Erigeron karvinskianus*, *Galinasoga parviflora*, *Erichthites valarianiifolia* and *Gleolaria maxicana* have been observed to colonize profusely.

### ***Soil and water resources***

The availability of water is the key factor in maintaining agricultural and livestock productivity in the integrated farming systems in mountain areas. However, field observation and farmers experiences over the years predict untimely and unprecedented rainfall with longer winter droughts. Consequently, these changes have resulted in reduced soil moisture for crops (e.g. large cardamom) and higher competition for water resources among users.

## CRITICAL ISSUES OF TAs

The Sikkim Himalayan agro-ecosystems are experiencing different levels of climatic variation over several decades in the form of erratic rainfall/snowfall events, prolonged dry spells or droughts, warmer winters, unpredictable monsoon, disappearance of local springs, emergence of new diseases and pests in crops/fodder trees etc., and these changes are expected to persist in future. Such events are posing potential future risks such as growing food and livelihood insecurity, dependence on cash based income, increased drudgery, degradation of plantations of large cardamom and mandarin orange, crop failure, scarcity of water for drinking and irrigation, migration of farm labour and increased workload to elderly people and women and increasing health problems etc. However, traditional farmers are building up the adaptive capacity of these ecosystems through their ecological knowledge systems. An example is large cardamom in the traditional agro-forestry system is in a declining phase over the last 10 years while cultivation of broom grass, fodder tees, medicinal plants and ginger cultivation is taking over. The agro-ecosystems are subjected to anthropogenic pressures such as rapid land use change (development activities such as road construction and establishment of industries etc), introduction of exotic crop varieties (High yielding varieties/hybrids of rice, maize, wheat, pulses, fruits such as kiwi, medicinal plants such as Korean ginseng, etc.) thus increasing the fragmentation and degradation of the natural habitat of the indigenous species. Thus, such human induced pressures are resulting in progressive loss of agro-biodiversity. Land races of rice, maize, pulses, finger millet, yams and pumpkin are rapidly disappearing due to climate change impacts.

The Sikkim Himalaya has enormous concentration of endemic biodiversity. These endemic elements will experience greater hardships in countering the onslaught of climatic changes. Human observations over the last 30-40 years have revealed that there is shifting of species over their agro-climatic range from lower to higher. One example is large cardamom growing up to 2200 m is now growing in 2500 m. The implications of change in the Sikkim Himalayan agriculture system is indicated in Table 6.

**Table 6:** Implication of change in the Sikkim Himalayan agriculture system

Indicators	Implications of change
Land-use/Land tenure system	<ul style="list-style-type: none"> <li>• Skewed distribution of operational land holding among the farmers in Sikkim</li> <li>• Resources divided</li> <li>• Per capita land holding declined drastically</li> <li>• Farmer's looking for off-farm employment</li> </ul>
High Value Horticultural Crops	<ul style="list-style-type: none"> <li>• Technology Missions emphasize more on horticultural crops</li> <li>• Small farmers do not take up due to limited landholding</li> <li>• There is a lack of emphasis on alternative and under-utilized crops, value addition and market their potential</li> </ul>
High Yielding Varieties (HYVs)	<ul style="list-style-type: none"> <li>• Introduction of HYVs</li> <li>• Introduction of hybrid varieties</li> </ul>
National Biodiversity Strategy and Action Plan	<ul style="list-style-type: none"> <li>• Agro-biodiversity is not recognized as one of the prominent components of biodiversity conservation</li> <li>• Food security and sufficiency is possible only through improvement in agro-biodiversity management</li> </ul>

## ADAPTIVE STRATEGIES TO MEDIATE CLIMATE CHANGE RISKS

Sikkim Himalayan-agriculture is an adaptive management system that offers economically valuable crop varieties and multipurpose plant species in agro-ecologically sound productive zones. The diverse indigenous communities house traditional ecological knowledge in adapting, monitoring and responding to ecosystem resilience and services.

### *Trans-Himalayan agro-pastoralism*

Under several threats and challenges of harsh and extreme environmental situation, the nomadic herders have developed a complex system of management and land use. This involves rotational grazing, sharing of grazing lands, seasonal movements of animals, forage production for lean season etc. This ensures that during the fallow period, the grazing land will have enough natural regeneration and biomass production. This is an indigenous conservation and management approach followed by the nomadic herders for sustainable management of the grazing pastures. The alpine and Trans-Himalayan pastures in the entire Yumesamdong-Lhasar-Tso Lhamo-Lhonak landscape continue to be traditionally utilized for resource use through grazing and associated activities.

Of late, the prevailing threats are seasonal variability, rapid reduction of grazing pastures, herd animals being predated upon by Tibetan wolf, snow leopard and feral dogs, landmines and winter forage shortage. The *Dzumsa* has ensured strong adaptive strategy in high altitude agro-pastoralism such as timing of farming, rotational grazing, movement of animals and fodder production for the lean season. Similarly, herders have started fodder production in their farms especially for the severe winter months. The *Dzumsa* has designed a coping strategy by regulating the number of herd animals, sharing of grazing pastures for a pre-determined period of time and diversification of agriculture crops. In the last 10 years, ecotourism promotion has gradually gained momentum as a supplement to the existing livelihood for the communities of Lachung and Lachen.

The traditional farmers in the Sikkim Himalayan region have been designing and reconstructing the land use attributes for maintaining agrodiversity systems (Table 7).



Broom grass is a socio-economically important and ecologically adaptive agroforestry species. It is getting increasingly infested by *rankey* (leaf blight and yellowing) disease



**Table 7:** Climate change adaptation measures for sustainable agriculture to manage climate and weather risks in the Sikkim Himalaya

Traditional Farming Systems	Attributes of the agrodiversity systems
Trans-Himalayan agro-pastoralism (4000-5000 m)	<ul style="list-style-type: none"> <li>• Yak, sheep and goat grazing</li> <li>• Rotational grazing; sharing of grazing lands and their use, seasonal moments of animals, forage production for lean season</li> <li>• Growing potato, cabbage, leafy vegetables, barley, medicinal and aromatic plants at Lhonak valley (Muguthang area), Dambuchey-Bamzey area, Thangu and Yumesamdong area in North Sikkim</li> <li>• A variety of animal products (alpine cheese, yak butter, meat, wool and traditional carpets)</li> </ul>
Traditional agriculture Systems (300-4000 m)	<p><b><i>Diversity of crops and associated species</i></b></p> <ul style="list-style-type: none"> <li>• large number of landraces of rice, maize, buckwheat, beans, pulses, finger millets, yams, tubers and ginger are grown in rotation</li> <li>• inter-cropping (mandarin-based, ginger-maize, paddy-soybean, pulses-turmeric, maize-potato and vegetable crops are practiced as under-storey crops)</li> <li>• Incorporation and cultivation of high value cash crops e.g. large cardamom, mandarin orange, ginger and potato in the different agro-ecological zones under integrated farming</li> <li>• Green manure and nitrogen-fixing species (<i>Alnus nepalensis</i>, <i>Albizia</i> sp., <i>Erythrina</i> sp., Seabuckthorn)</li> </ul>
	<p><b><i>Agro-forestry systems</i></b></p> <ul style="list-style-type: none"> <li>• Diversification of agro-forestry systems such as farm based agro-forestry (Agro-silvi-animal systems), farm-forest-based agro-forestry (Agro-silviculture systems) and high value cash crop based agro-forestry (Agri-horti-silviculture systems) such as large cardamom, mandarin orange, ginger and other under-storey crops cultivation</li> <li>• Agro-forestry will ensure multiple production options and services</li> </ul>
Land resource management	<p><b><i>Organizational and management diversity</i></b></p> <ul style="list-style-type: none"> <li>• Most of the mountain cultivated land is under diverse agro-forestry systems to reduce soil erosion and ensure substantial production</li> <li>• Terrace-based agriculture</li> <li>• Multipurpose tree growing on terrace edges</li> <li>• Farmers are establishing shelter-belts at the edges of the agriculture farms for maintaining water table to reduce negative impacts of drought</li> <li>• Conservation tillage with raised bunds at the terrace edges to prevent run-offs and wash outs during excessive rains</li> </ul>
Water resource management	<ul style="list-style-type: none"> <li>• Seepages and ponds are managed to ensure water retention and protection within the farm-based agro-forestry for potable water and water for irrigation</li> <li>• Plantation of water retaining species in and around the springs, developing the catchment</li> </ul>
Livestock management	<ul style="list-style-type: none"> <li>• In the recent years farmers have initiated stall feeding of farm animals</li> <li>• Winter feeding of farm animals in farm-fields to ensure farm nutrients and reduce labour costs for manure carriage from the sheds</li> <li>• Many farmers in the villages have started growing large number of fodder species (both tree fodder and under-storey grasses) on terraces</li> </ul>

### *Sub-alpine and temperate agro-climatic belts*

One of the adaptive approaches initiated by the farmers is to introduce late maturing crop varieties, whose sowing time and maturing time has shifted. This is done by bringing the crop from lower agro-climatic zones to higher agro-climatic situation and vice versa. Farmers have in the recent years, designed farm operation techniques to adjust cultivation timings of local crops, field preparation and field ploughing during favorable conditions for soil moisture conservation. This ensures improved irrigation efficiency to a number of crop varieties. The cropping adjustments to a diversity of crops at the farm level are inexpensive while introduction of scientific irrigation technologies is expensive to farmers.

In the traditional agro-forestry systems as many as 92 multipurpose species have been recorded which are commonly grown in the farmland (Sharma et al. 2006). These species contribute substantially to the household, the form of fodder, fuel-wood, timber and fruit while some of these have medicinal value as well. Many of these species are shade trees in agro-forestry systems. Based on the spatio-temporal dynamics, the farmers in Sikkim have evolved a traditional system to grow agriculture crops in their farms (Table 8).

**Table 8:** Agriculture crops and cropping seasons along the altitudes (Sharma 2011 *Unpublished*)

Seasons	Crops/vegetables	Crops sown	Crops harvested
Winter	Wheat, Buckwheat, Mustard, Radish, Cabbage, Cauliflower, Potatoes, Peas, Tomatoes etc.	December-February	March-May
	Maize	March-April	June-July in lower altitudes August-September in higher altitudes
	Yams, Colocasia, Tapioca	March -April	December- March
	Chayote, other cucurbit crops (cucumber, pumpkin, gourds, etc.)	March-April	June-March
	Ginger, Turmeric	March-May	Anytime during November through March
Monsoon	Paddy, Pulses, Beans	June-July	October-December
	Finger-millet, Soybean	August	November-December
Off-season vegetables	Cabbage, Radish, Carrot, Cauliflower, Broccoli, Beans, Tomatoes etc.	Grown mostly in all the seasons at different altitudes	

### *Steep agriculture farmlands*

The upland farmers have developed protective belts along the edges of the terraces of their farmland using a number of multipurpose agro-forestry species such as *Schima wallichii*, *Engelhardtia spicata*, *Bridelia retusa*, *Bischofia javanica*, *Bombax ceiba*, *Rhus semialata*, *Castanopsis tribuloides*, *C. hystrix*, *C. indica*, *Ficus* sp., *Duabanga grandiflora*, *Erythrina arborescens*, *Gynocardia odorata*, *Juglans regia*, *Jambosa formosa*, *Litsea polyantha*, *Morus indica*, *Quercus* sp., *Terminalia chebula*, *Symplocus theifolia*, *Saurauia punduana*, *Toona ciliata*, *Betula cylindrostachys*, *Acer oblongum*, *Beilschmiedia roxburghiana*, *Cinnamomum impressinervium*, *Engelhardtia acerifolia*, *Ehretia wallichiana* etc. Lower hills of South district and some parts of West district



Farmers are the main sufferers due to climate change

of Sikkim fall in the rain shadow of the Darjeeling Hills. In the last ten years farmers have introduced nitrogen-fixing species (*Flemmingia* sp., *Indigofera* sp., *Erythrina* sp., *Gliricidia* sp., *Desmodium* sp., *Albizia* sp. *Alnus* sp.) and stabilised the steep farmlands by designing contour hedge-rows. Recently farmers have introduced permanent crops such as banana, Mandarin orange, plums, pears, guava, fodder species such as broom grass and trees with a variety of pulses and cereals as under-storey crops.

For soil fertility maintenance, farmers have introduced bio-composting, vermi-composting, production of farmyard manure, mulching and use of green manure. In the rain-shadow areas of South Sikkim, rain and roof water harvesting has been initiated. Bench terracing was a traditional practice often used by farmers practicing agriculture in the steep slopes. This has been revived recently to prevent runoff, soil stabilization from degradation, fertility maintenance and moisture retention.

Development of farm-based agro-forestry has a possibility to be an adaptive system for mitigating climate change impacts. Due to shortage of farm-labour, the farmers have developed farm-based agro-forestry for growing fodder and fuel-wood. The cultivation of *Swertia chirayita*, *Thysanolaena agrostis* and other multipurpose fodder species and medicinal plants under the *Alnus nepalensis* trees replacing large cardamom has been recently observed widely in several villages of Sikkim and also in villages of Ilam District of Eastern Nepal. This has supplemented the farmers with additional incomes while bringing back the ecological resilience of the system.

Applying several approaches and TEKS, Sikkim farmers routinely make land use and management decisions by adopting agro-forestry practices to overcome and manage climate and market variability. Thereby they create systems that are more resilient by choosing crop varieties which are resistant or resilient to drought or pests and

maintain the integrity despite stresses from internal and external factors. For example, farmers plant different crops (as observed in terrace rice cultivation) according to slope and aspect, or those cultivars that require less water in the terraces where irrigation is not available, some at the flat lands where water is available, and others at highly site-specific conditions. Maintenance of forests around the agricultural farmlands is a unique practice observed in the Sikkim Himalayan region. This has helped to conserve forests resources and to protect smaller water sources necessary for irrigation and drinking purposes. Water scarcity has been widely felt in the rain shadow areas of South Sikkim where the Rural Management and Development Department, Government of Sikkim has initiated the *Dhara Vikas Karyakram* (Spring-shed Programme) to artificially recharge the ground water by making staggered contour trenches and pits to revive springs, streams and lakes (Tambe 2009; RMDD 2009).

Until now we do not have a recorded data base for better understanding of current climate change impacts. The impacts of climate variability on the farm resources can be measured through farmer's perceptions as high, medium, low and negligible which can help support the designing of appropriate adaptation strategies and coping mechanisms (Table 9).

**Table 9:** Community perception of climate change in the Linkey-Tareythang and Sumbuk Gram Panchayat in Sikkim

Sl. No.	Agrodiversity	Perceived climate change impacts			
		High	Medium	Low	Negligible
1	Rice, maize, wheat and oil seeds				
2	Large cardamom				
3	Ginger				
4	Drinking water sources and springs				
5	Fodder trees				
6	Fruit crops				
7	Tubers/yams				
8	Pulses/beans				
9	Agro-forestry trees				
10	Broom grass				
11	Livestock				
12	Underutilized/Lesser known crops				
13	Medicinal plants in cultivated systems				
14	Finger millet and buckwheat				
15	Grass fodder for animals				

## VULNERABILITY AND CHALLENGES OF CLIMATE CHANGE

In an assessment of vulnerabilities in the Hindu Kush Himalayas, it is argued that the agro-ecosystems in the high altitudes of eastern Nepal, Sikkim Himalayas, Bhutan, Arunachal Pradesh and Tibetan Autonomous Region are highly vulnerable to climate change (Sharma and Tshering 2009). The subsistence farming of the Sikkim Himalayan agriculture is under threat. The communities are marginalized with low per capita land holdings (0.12 ha) (Subba 2006). The genetic diversity of the crop species with which the survival of

humankind is possible in the difficult mountainous region is vulnerable to climate change. The indicator of climate change in the fragile and marginalized mountains as noted earlier reveals the vulnerability of ecosystem services as a result of gradual loss of ecological resilience of the agro-ecosystems. In the wake of globalization, the traditional agriculture systems have been supplemented with newer and modern seeds and technologies leaving the adaptive system in transition. This has created a threat to sustainability of traditional agriculture and food security of the mountain societies in addition to the threat to biodiversity in both wild and cultivated landscapes. Technology and knowledge on adaptation and mitigation in the Sikkim Himalayan region are immediate concerns for developing an enabling and elaborate policy framework (Table 10).

**Table 10:** Climate change facts and adaptive/mitigation measures needed to be ensured in the Sikkim Himalaya

<b>Adaptive /Mitigation measures</b>	<b>Benefits</b>
Climate change information: Early warning system for climatic conditions such as rainfall, hail storm, cold etc and risk management system in the Traditional Farming System Hydro-meteorological monitoring stations	Currently, communities lack such information system in the rural areas on climate change. Every year during the harvesting time of paddy, the retreating monsoon bring rain and cloudy weather causing crop damage during November-December. Information system can ensure suitable crop sowing and harvest time. Introduce and improve climate related weather forecasting system for rainfall, temperature, hail storm etc.
Introduction of scientific knowledge on adaptation measures in land use planning and infrastructure design	This will help farmers to scientifically manage the steep slopes and develop agro-forestry
Introduction of crop forecasting system and development and application of sustainable agriculture technologies	This will enable farmers to develop crop calendar, design and apply suitable cropping pattern, select appropriate crops, cultivate crops in appropriate cropping season and crop rotation.
Disaster preparedness on agriculture system, crop security through appropriate insurance policy, food security etc.	Appropriate training and capacity building on disaster preparedness in managing agriculture crops to ensure proper management and harvest and ensure loan repayment
Develop and test adaptive options	Identification of drought tolerant varieties, or disease resistant or tolerant varieties, improved irrigation systems and generate knowledge on impacts or vulnerability

Sustainability of “adaptive capacity” of the Sikkim Himalayan Agriculture system is emerging as one of the main challenges. The mountain farmers are applying traditional technologies for managing the dynamic mountain agriculture systems with adaptive practices to cope up with the growing consequences of climate change. Water security is the second challenge already faced by the mountain communities due to shortage of water for agriculture and drinking purposes. The long, dry winter spells have been a regular trend in recent years. The period between October 2008 and April 2009 was continuously dry with no rainfall and negligible snowfall in the alpine region in Sikkim. Field surveys at different places in Sikkim revealed that a large number of seasonal springs and local water ponds have dried. This long dry spell caused sharp decline of plantation areas of large cardamom. Other challenges include marketing and transportation and credit crises due to higher credit and operating costs to farms (Table 11).

**Table 11.** Impacts of vulnerability related events Agriculture Heritage Systems of Sikkim Himalaya

Vulnerabilities	Socio-economic and socio-ecological indicators
Climate change related disaster limits progress and productivity	Reduction of fixed assets, loss of production capacity and productivity, reduction of market access, landslides induced damage to transport, communication, energy/electricity, reduction of livelihood options to rural communities, low saving and physical capital and erosion of social capital
Development Versus Disaster	Weakly planned infrastructure and development or lack of strategic policies lead to unsuitable development practices in the mountainous region. The ecology and environment tend to degrade due to enormous anthropogenic pressure owing to a large number of development activities
Appropriate climate change adaptation and mitigating measures reduces risks to rural farmers	Local water sources such as springs and access to drinking water, food production, increased livelihoods options etc will increase people's resilience. Market expansion, value chain and value addition of local products and trade will reduce rural poverty. Investments and introduction of appropriate technology will ensure social security against vulnerability

### Policy priorities and initiatives

The Government of Sikkim has recently initiated the Indo-German climate change adaptation project (Tambe 2009). Sikkim is the first Himalayan state to go completely organic by 2015. The priority of the department in the agriculture sector in the Sikkim Himalayan Agriculture is to increase the per unit productivity which is low as compared to the regional and national averages. Thus, the major activity is to bridge this gap by area expansion under high yielding varieties (HYVs). The department implements a number of schemes including macro-management of agriculture through Integrated Crop Development Programmes (ICDP), Integrated Nutrient Management (INM), Natural Resource Management (NRM) and Rastriya Krishi Vikas Yojana (RKVY). The seeds of major traditional crops such as rice, wheat, maize, soybean and mustard are being increasingly replaced by HYVs thus causing disappearance of traditional landraces. At Daramdin, a major paddy growing area in West Sikkim, about 30 traditional landraces of rice have been all replaced by HYVs and only *Marsi* (traditional variety) is now cultivated.

To mitigate the crises caused by climate change and global warming, the Government of Sikkim has plans and policies to invest in irrigation, infrastructure, improved seeds and manure, agricultural research and development. Thus traditional subsistence farming is being replaced by rapid intensification which is not supported by appropriate changes in inputs or management strategies. The transformation of traditional land use systems coupled by conversion of agricultural land into non-agriculture sector (establishment of factories/ industries etc. in the farm-lands) has created pressure on agriculture biodiversity. It is reported that rapid intensification of traditional Himalayan agriculture using modern inputs and transformation into monocultures for economic benefits has resulted in a loss of agro-biodiversity (Xu 2009).

At present several developmental programs exist that need to be aligned with the agro-ecological functions for reducing climate change impacts. New technologies for farming, introduction of high yielding and hybrid seeds from outside, distribution of hybrid seeds, Effective Microorganism (EM) technology etc are benefiting in the short term and to a limited number of farmers. The mountain farmers are gradually losing their traditional crop varieties which are otherwise adapted to the mountain niches. They are becoming dependent on the seeds of crops brought from outside the mountain environments which are often non-adaptive due to a variety of reasons. Farmers of Sikkim have noted that introduced varieties perform well for one or two years and



Turmeric production is an alternative adaptive crop in areas where other crops are damaged by wild animals

lose their vigor after that. The traditional livelihood, indigenous and local plant varieties, landraces, lesser and underutilized traditional crop varieties and animal breeds are increasingly threatened by climate change impacts, rapid development activities and shortage of farm laborers.

## **CONCLUSION**

It is evident that the impacts of climate change has been witnessed in the Sikkim Himalayan agriculture systems. The mountain farmers have been applying traditional technologies to adapt to the changing situations at temporal and spatial scales. These mitigation measures need scientific and technical support through appropriate policies and investments. The farming systems play a key role in ecosystem functions and services in addition to conservation of biodiversity as they are situated between wider biodiversity landscapes and cultivated systems. In a situation where climate change is having increasingly high impacts, there is a need to strategize appropriate investment mechanism, with a holistic view to maintain soil fertility and water use efficiency in days to come. Therefore, this calls for development of a multi-disciplinary evaluation approach. Traditional farming systems need to be strengthened to achieve the goals of sustainable development and biodiversity conservation. The incremental benefits of Himalayan agriculture and ecosystem services bridge the linkage of upstream and downstream population and benefit human well being, in the form of goods and services to the present and future generations.



Large cardamom plantation has declined due to viral and fungal infestations.  
It is being replaced by broom grass planting under the same tree canopy

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