OPPORTUNITIES AND CHALLENGES OF THE GLOBALLY IMPORTANT TRADITIONAL AGRICULTURE HERITAGE SYSTEMS OF THE SIKKIM HIMALAYA

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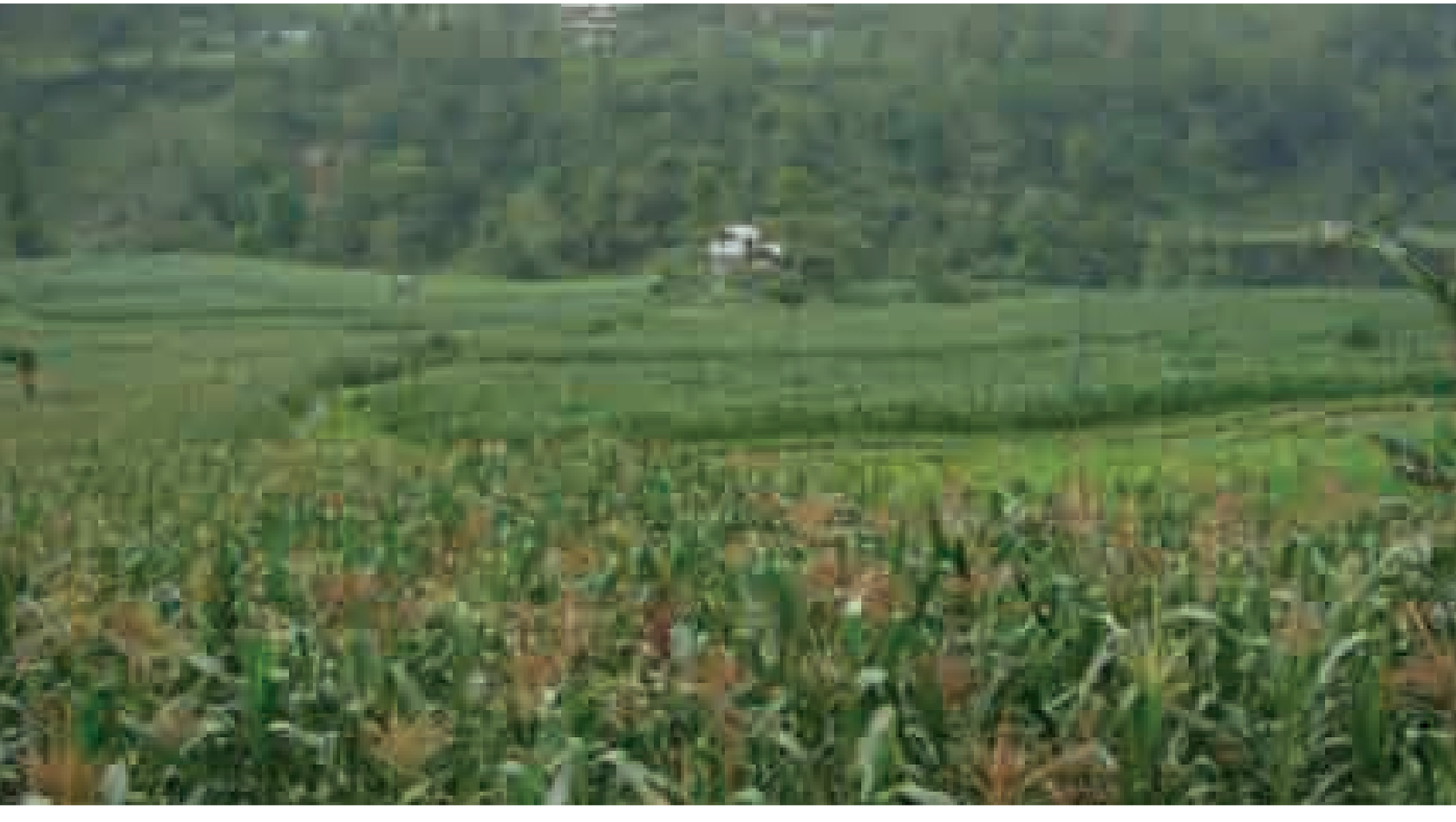
ABSTRACT

The existing agroforestry practices in the Traditional Farming Systems (TFS) have gained wider attention in the international agreements and among academicians and policy makers for their multifunctional role and dynamics of ecosystem services. The Convention on Biological Diversity has advocated an ecosystem approach while Intergovernmental Panel on Climate Change (IPCC) emphasizes agroforestry to reduce emissions and enhance sinks of greenhouse gases. The multifunctional Sikkim Himalayan TFS are examples from the Eastern Himalayas that support ecosystem services and livelihood to mountain communities. They are considered to be adaptive to the climate change situations and serve as efficient means to carbon sinks. Due to the remarkable significance of TFS in the mountain ecosystem, environment and livelihood, the Sikkim Himalayan Agriculture Systems has been considered as an associate site under FAOs Globally Important Ingenious Agriculture Heritage (GIAHS) Programme. With climate change rapidly impacting both ecosystems and services in the mountainous region, the sustainability of dynamic Himalayan TFS is now facing new challenges and vulnerabilities. The adaptive TFS offer opportunities for sustainable management of natural resources from a unit land use type to a landscape level land use stages and support socio-ecological and socioeconomic benefits. The TFS needs to be further strengthened through research and development to achieve the goals of sustainable development.

KEYWORDS: *Sikkim Himalayan Agriculture, Traditional Farming Systems, Agroecological Diversity, Climate Change; Resilience, Livelihood*



Maize a staple food in subtropical agroclimatic zones

Women sell agriculture products and earn cash

INTRODUCTION

The management of upland cultivated and non-cultivated systems in the Eastern Himalayas by growing multipurpose trees and species and intercropping understorey crops and fruits, livestock raising and protection of adjacent forests for variety of services is an adaptive century-old indigenous practice of the mountain communities. Such practices, recently been defined as agroforestry, is now a collective name for land use system and technologies involving trees combined with crops and/or animals on the same land management unit (Nair, 1993; Tamale *et al*., 1995; Ibrahim and Sinclair, 2005). The environmental services that agroforestry practices in Traditional Farming Systems (TFS) can provide, and especially their potential contribution to the conservation of biodiversity, have recently attracted wider attention among the conservation scientists (Mcneely and Scroth, 2006). The Intergovernmental Panel for Climate Change (IPCC, 2007) has cited agroforestry as one of the options to reduce emissions and enhance sinks of green house gases. The IPCC Land Use Change and Forestry Report (2001) concluded that transformation of degraded agriculture land to agroforestry has far greater potential to sequester carbon than any other land use change. The ecosystems approach which is a strategy for the integrated management of land, water and living resources that presents conservation and sustainable use in the equitable way, has been emphasized by the Convention on Biological Diversity (CBD) during the Seventh Conference of the Parties (COP Decision VII/11, 2004). The Global community is now known to act on both mitigation and adaptation, and agroforestry has great potential to leverage these synergistically (World Agroforestry Center, 2006).

Most of the TFS in the Sikkim Himalayas are at the subsistence level evolved through trial and error practices of farmers to meet their needs of food, fiber, fodder, fuelwood, medicine and timber. Characterized by substantial diversity and high degree of self-reliance (Semwal and Maikhuri 1996; Ramakrishnan *et al*., 1994; Nautiyal *et al*., 2003; Sharma and Liang 2006; Sharma *et al*. 2006; Sharma *et al*., 2009), TFS promote low cost sustainable development in ecosystems, protect and conserve ecological systems, and improve economic efficiency of the farming community, while climate change has induced negative impacts. The International Centre for Integrated Mountain Development (ICIMOD) has recommended a holistic approach such as REDD^{+} (Reduced Emission from Deforestation and Degradation), enhanced REDD $^{++}$, or AFOLU (Agriculture, Forestry and other Land use) for adaptation and mitigation of climate change (ICIMOD 2009).

However, in-depth research on socio-ecological and socio-economic perspectives of TFS is lacking and available literature is limited. This chapter is designed to discuss the structure and organizational diversity of the human managed agroecosystems, ecosystem services and opportunities, functional roles of adaptive practices, dynamics of management diversity; and some indicators of climate change impacts observed over the years.

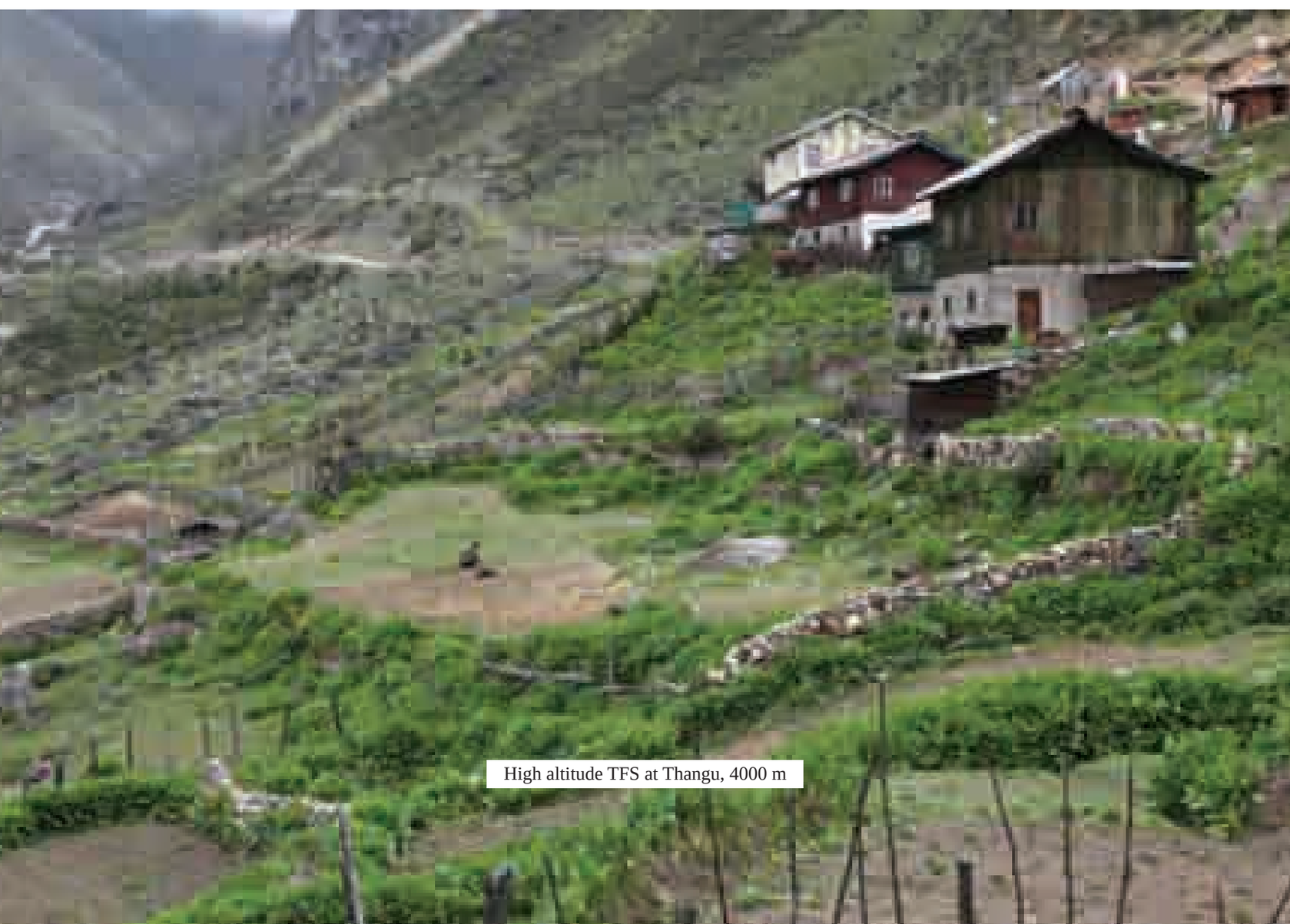
AGRO-ECOLOGICAL DIVERSITY OF TFS

The Sikkim Himalayan TFS encompasses variations of agro-ecological zones covering a range of ecosystem diversity extending between 300 and 6000 m asl. The subtropical zones (300 m above) houses terrace rice cultivation systems and farm based agroforestry. Above this are cardamom-based and farm-based TFS in the subtropical to warm temperate zones (600–2500 m), extreme 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 Plateaus (4000–5500 m). The TFS are based on biophysical and management diversities, socio-ecological and socio-economical conditions, traditional knowledge systems, land use types and the land use stages and their functional roles.

Trans-Himalayan Agro-Pastoralism

Agro-pastoralism in Trans-Himalayan cold deserts of Lhonak Valley, Muguthang, Thangu Tso Lhamo and Lashar Valley above 4000 m in North Sikkim has been a part of human life support system over several centuries. The nomadic *Dokpas* (Tibetan pastoralists) are guardians of Trans-Himalayan ecosystems, a unique example of how people survive in such drought and cold-stricken landscapes through mobile livestock production systems. They herd yaks, dzos (cow-yak hybrid), sheep and goats (pasmina type) in the plateaus and meadows. Adapting to the harsh climatic conditions over several centuries, *Dzumsa* (traditional institution in North Sikkim) and the *Dokpas* have indigenously regulated and managed the grazing regimes of the Greater Himalaya, transition zones and in the Trans-Himalayan meadows. The *Dzumsa* specifies dates of movement of herds from one location to another as per the lunar calendar which is applicable to all herders round the year. *Dzumsa* strongly controls the rotational grazing for rangeland resource management and regeneration. Irregular herding or shifting of livestock from one pasture to another, other than the specified dates is unlawful, resulting in fines levied by the *Dzumsa*. Grazing regimes are chosen for the next move depending upon the forage availability pasture area, number of grazing animals, snow fall events and appropriate seasons.

Presently, 23 families of the *Dokpas* manage about 90% of yak population, and the wool, meat, cheese, fat (*tsilu*) of yak and sheep, and other products fetch good income. After 1975, through intriguing challenges and pressures, the *Dokpas* are restricted to a limited patch of the vast Tso Lhamo, Lhonak and Lashar Plateaus. Earlier, herders had open cross border movements from these valleys into Tibet and back through *Nyima La* or *Naku La* pass. Over the last two decades, the new generations of the herders have started migrating to cities for better education and employment. This has resulted in labour shortage for grazing. Therefore, the owners of yaks and sheep in the recent years have started employing paid herders.



High altitude TFS at Thangu, 4000 m

Nomadic Dokpa grazers in Trans-Himalayan Sikkim

Slope-land Traditional Farming Systems

Below the Trans-Himalayan agro-ecosystem (Phadamchen-Kupup, Lachen, Lachung, Dzongu, Thangu and Thegu area) between 3000 and 4300 m, the communities mostly *Lepchas, Bhutias* and *Sherpas* practice subsistence farming by cultivating a variety of crops and fruits such as barley, wheat, potato, cabbage, apple, maize, peas, beans, peach, and medicinal plants. The agricultural tools, farm implements and techniques, cultivation methodology, farm raised animals; local crops, irrigation system etc. are traditional innovations. Since time immemorial, grazing of cattle is a part of their culture and livelihood. The traditional homestead products such as blankets, rugs and carpets made from the wool of high altitude sheep are rare marketable items apart from animal products such as skin, meat, cheese, butter etc. Seabuckthorn (*Hippophae tibetiana*), and *Yarsa Guenboob* (*Coedyceps sinensis)* are potential high value products that plough back substantial income to the communities. They conserve in situ germplasm of valuable medicinal plants e.g. *Nardostachys jatamansi,* several species of *Aconites, Picrorhiza kurroa, Ephedra gerardiana, Mandragora* sp., *Gentians, Cordyceps sinensis* and many others. Local people collect mushrooms, tubers and edible NTFPs from the wild for household consumption and often sell them in the nearby markets.

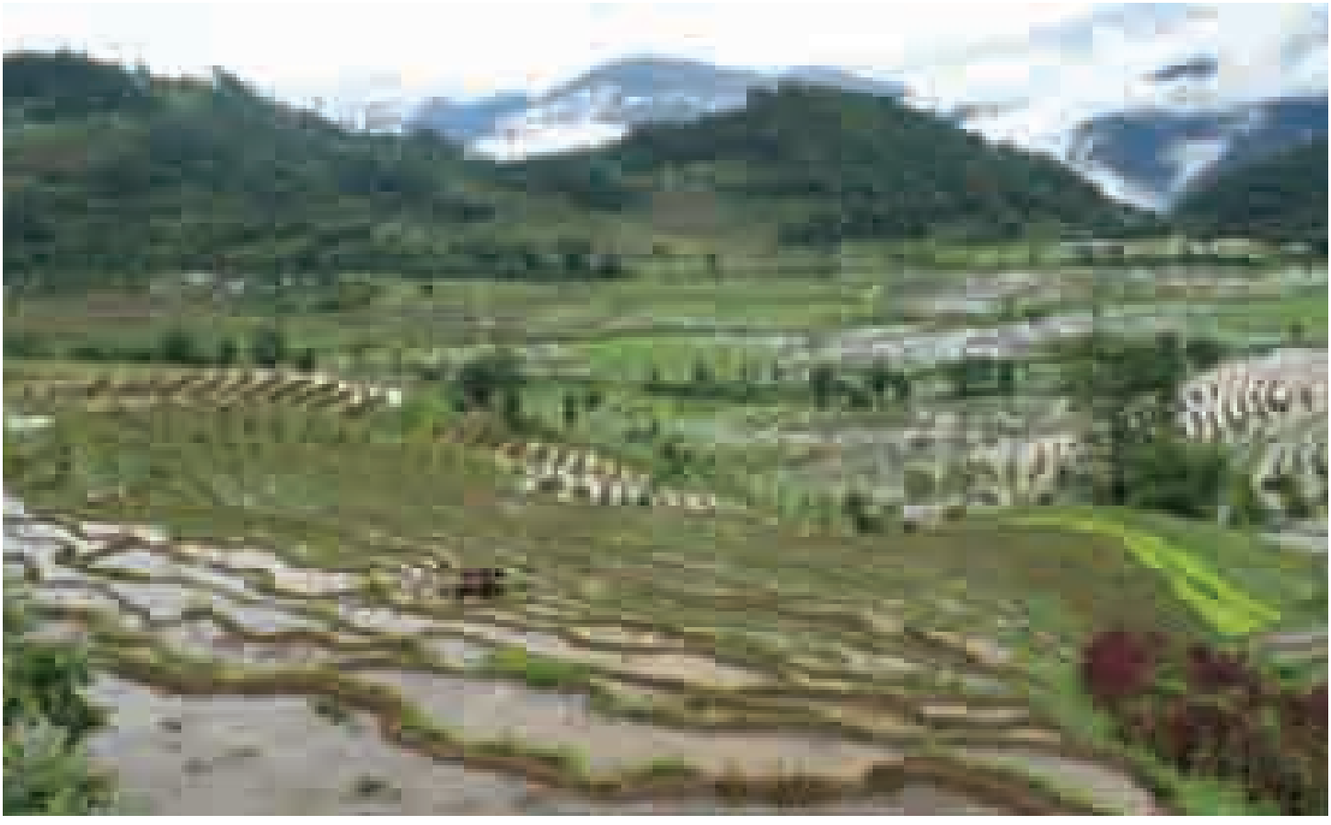
The lower agro-ecological zone (300-2500 m) consists of a wide range of indigenous production systems, that includes the terraced and valley rice cultivation, locally called the *Khet* agroforestry systems such as alder-cardamom (*alainchi-bari*) or farm-trees-mandarin (*suntola-bari*) agroforestry, *Sukha-bari*, *Pakho-bari* system, and forest-based agroforestry system (Table 1). These systems have traditional irrigation practices, management regimes, diversified cropping systems, crops diversity including medicinal plants, wild edibles, a large number of underutilized/lesser-

known crops, semi-domesticated crops and their wild relatives. Livestock are mostly stall-fed due to limited grazing pasture. In an indigenous system, land parcels of a unit household are classified into different sections for growing agroforestry, terraces for growing crops and for resource allocation and utilization.

Lachung apple, North Sikkim

Terrace Rice Cultivation Systems

The ancient *Demazong vis-a-vis* Sikkim, characterized the valley rice cultivation system along the river banks on flat lands traditionally called *Thang* (e.g. *Tarey-thang-byansi, Pi-thang-byansi*) and along the typically terraced slopes in the lower hills, which contribute to the large genetic pool of paddy. Some of the dryland paddy varieties (*Ghyya-dhan, Takmari, Bhuindhan, Marshi* etc.) have disappeared largely from the system while the irrigated rice varieties still cultivated (*Attey, Timmurey, Krishnabhog, Bachhi, Nuniya, Mansaro, Baghey-tulashi, Kataka, Champasari, Sikrey, Taprey* etc.) are adapted to agro-ecological zones between 300 and 1800 m. Traditional varieties of rice e.g. *Krishnabhog, Nuniya* and *Kataka* are famous for their aroma, medicinal importance and fine quality grain as good as Indian basmati rice (Sharma and Liang, 2006). Farmers grow a variety of pulses and beans along the raised bunds and terrace edges. After rice, farmers grow maize, wheat, buckwheat, oil seeds, vegetables etc. during winter. Between the terraced open rice fields, along the slopes, are cardamom-based and forest-based agroforestry systems. The landscape mosaic consisting of open cropped compartments surrounded by multifunctional agroforestry is characteristic of unique agro-ecosystem management. The system in addition supports water conservation and flood control, provides nutrient and biomass to the farm and homestead.



Valley rice cultivation at Sang-Martam, East Sikkim

AGROFORESTRY PRACTICES IN TFS

Farm-based Agroforestry

The farm-based agroforestry practices are primarily agrisilvicultural systems (home gardens, traditional beekeeping and livestock), multipurpose trees on terrace edges, terraces for growing a variety of traditional and underutilized/lesser known crops as nutrient/protein banks (Table 2). This type of agroforestry also comprises of multilayer tree gardens with fruit crops where trees act as wind breaks and function as protective belts to the terrace risers along the edges of the crop production slopes called *sukha-bari* or terrace paddy fields. In addition, hedgerows of *Thysanolaena agrostis* and other ground grasses are grown for fodder and for supporting the terraces.

In the farm-based agroforestry, farmers manage multipurpose tree species for fodder, fuel woodlots and timber, and for a variety of other direct and indirect uses within and around the cultivated land. Trees on the terrace risers are grown for soil conservation, while farmers practice intercropping under tree canopies. Management of fodder tree is important for livestock production and also for a variety of reasons.

The farm-based agroforestry is an important land-use system for sustaining the agricultural practices in slope lands, recycling of organic dry matter for soil fertility maintenance, resource utilization, and improvement of the agro-ecosystem functions and services. Farmers regularly convert wastelands/degraded lands or abandoned lands into agroforestry.

Farm Forest-based Agroforestry

The farm forest-based agroforestry practices are agro-silvopastoral/agro-silvocultural systems comprising a diversity of multipurpose tree species required for local construction and repairs, fuelwood, fodder for stall-fed livestock, bamboo groves, and pasture areas for seasonal grazing within the marginal landholdings (Table 2). The forest-based practices of agroforestry are developed as support land. Horticultural crops are mainly grown in this

system. This system supplies nutrients and organic matter to the farm. Farmers often collect minor forest products such as fruits, fibers, medicinal plants, tubers, other wild vegetables. In the last 10 years, most of the barren slope lands have been converted into broom grass plantations (*amliso-bari*) under multipurpose tree species to overcome shortage of fodder.

Bamboos are multipurpose plants (28 species found in Sikkim)

High Value Crop-based Traditional Agroforestry

High value crop-based agroforestry practice comprises of large cardamom (*Amomum subulatum*) based (called *alainchi-bari)* and mandarin orange (*Citrus reticulata*) based (called *suntola-bagan)* practices comprising of a diversity of tree species. About 70% of the cardamom-based agororestry practices are under N_2-fixing Himalayan alder (*Alnus nepalensis*) while 30% are under the mixed-tree agroforestry species. The cultivation area of large cardamom had increased by 2.3 times in the past 20 years until 2000. Since early 2000, the plantation area declined almost by 50%. Interventions on development of efficient, environment friendly and low cost curing kiln, value addition to the produce at site and forward and backward linkages to the system for obtaining good outputs have met with only limited success and need to be strengthened.

High value large cardamom agroforestry

Another prominent socio-economically important agroforestry is mandarin orange based farming. N_2-fixing *Albizia* species is extensively grown with agroforestry trees in the terraced croplands. Such farming involves a number of multilayer fruit species, and mixed intercropping of maize, pulses, beans, ginger, buckwheat, finger millet, pulses, oilseeds, taro and yam. Mandarin orange and ginger are potential cash crops of Sikkim after large cardamom. Mandarin orange is a high value, comparatively less labour intensive farming. Diversity of crops and other associate tree species are maintained in the system for other subsistence requirements and benefits. However, the system is considered as highly nutrient exhaustive compared to the cardamom-based system.

The interacting components and flow of services in a unit mountain farming system in Sikkim is presented in Figure 1.

Finger millet, a poor person's food

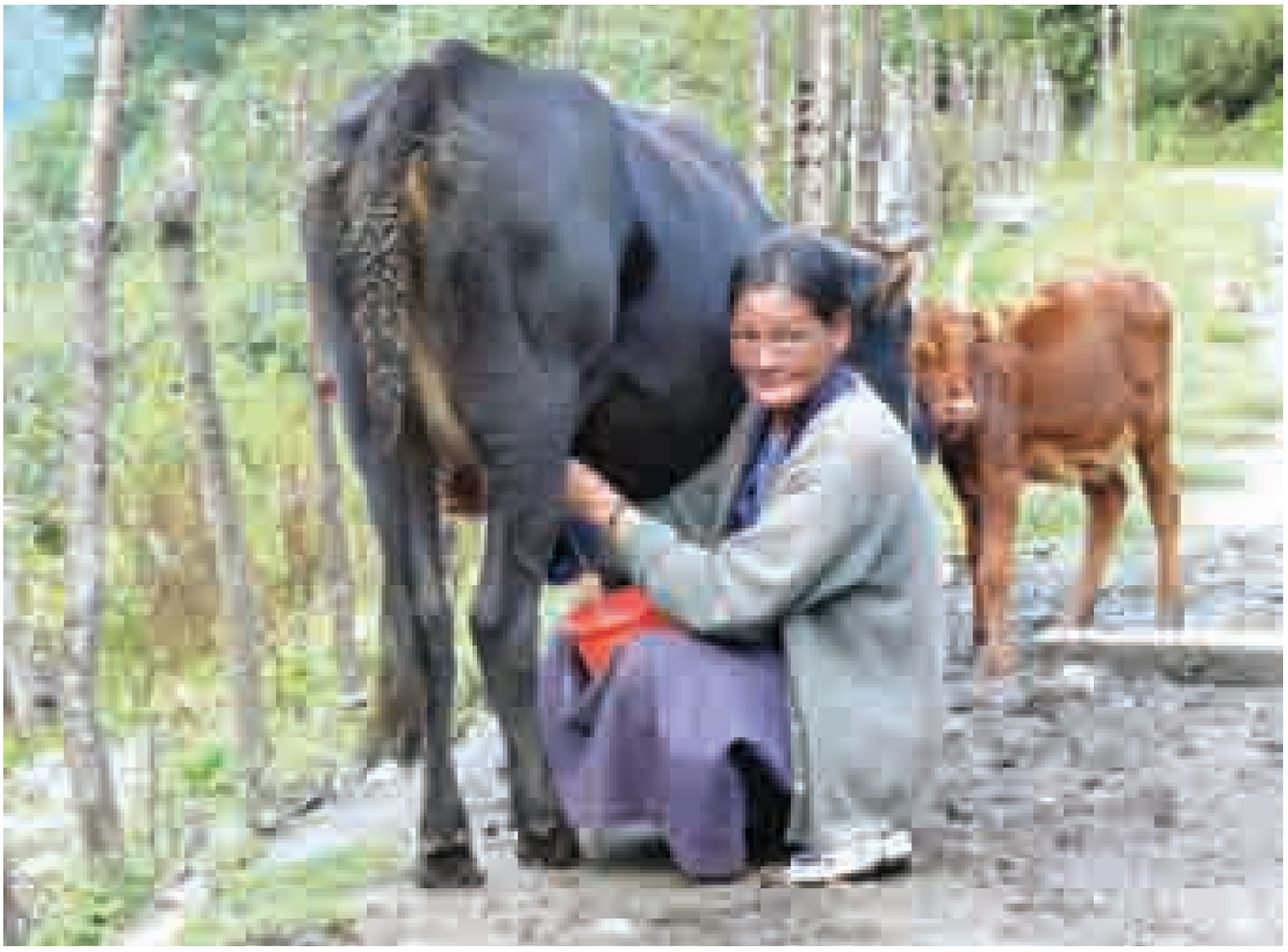
Agrobiodiversity in TFS

The unique mountainous terrain of the Sikkim Himalaya consist of varied physiographic factors and topography that allow location specific microclimatic conditions giving rise to a range of ecosystem diversity rich in agrobiodiversity. The challenging mountain physical specificities have resulted in vulnerability, at the same time such biophysical features of diversified landscapes in short distances allow conducive environment for genetic variations and landraces with sustained natural resource management. Sikkim Himalayan region is a reservoir of gene pool of several unique crops, land races and their wild relatives. The indigenous ethnic communities contribute to agrobiodiversity with various farming systems, with a matrix of agricultural crops. The majority of the inter-cropping such as cardamom, mandarin-based intercropping, ginger-maize, paddy-soybean, pulses-turmeric, maize-potato and vegetable crops are practiced as understorey crops. The strategies for conservation of agrobiodiversity are specific to different ethnic communities. The management of local agrodiversity includes conservation of species and varieties with emphasis on crops and livestock for manure. Thus, agrobiodiversity would reduce risks, increase production and enhance income. Indigenous women are the custodians of traditional knowledge (TK) in the TFS. The blending of traditional wisdom to frontier knowledge (bio-technology, information technology and space technology) would greatly contribute to sustainable agriculture development.

Maize diversity in Sikkim

Indigenous Traditional Knowledge Systems (ITKS)

The traditional/cultural knowledge of the mountain societies is the inherent identity that is embedded within each ethnic community, which is very unique and diverse in all respects for TFS management and conservation. It is reflected in their cultivation system, ethnobiology, and health and nutrition management. The ITEK associated to GRs wealth has become the centre of attraction for national and international pharmaceutical companies and an immediate concern of Intellectual Property Rights. Institutional mechanisms need to be developed to regulate and protect access to GRs/TK and benefit sharing arising from the commercialization of these resources. In 2008, the Society for Better Environment, a local NGO based in Sikkim, initiated the formation of Biodiversity Management Committees for documentation of GRs and associated TK in Peoples Biodiversity Register. The documentation would help register knowledge-base, prevent biopiracy and promote bioprospecting.

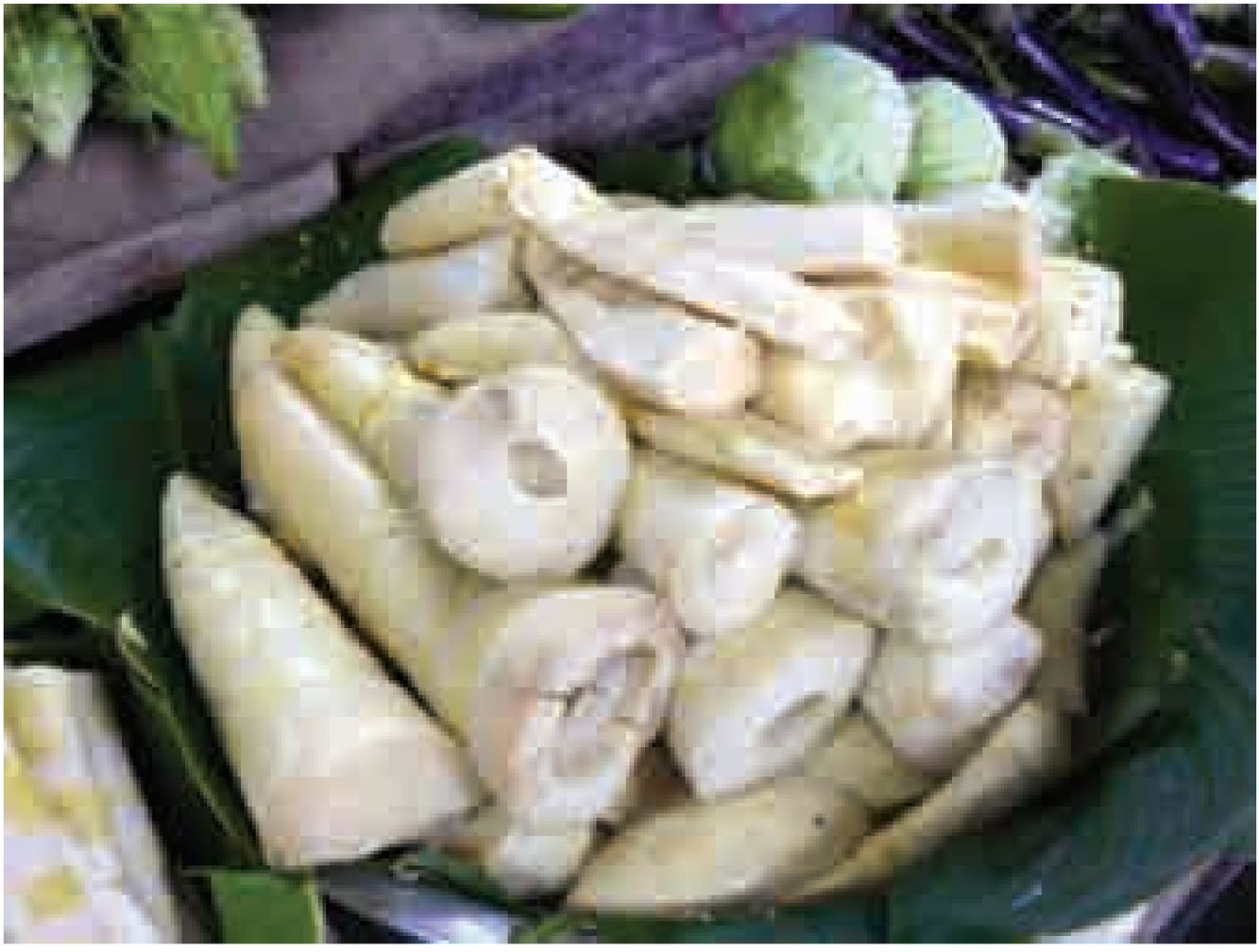


Livestock is a source of income and manure in TFS

Ethnic Food Products in TFS

The existence of rich agrobiodiversity is due to diversity in cultural and traditional food habits of ethnic communities. Cultivation of crop varieties and ethnic food habits of the mountain societies is embedded in their cultures, traditions and customary rituals. Indigenous communities conserve landraces of domesticated crops, wild relatives and underutilized crops for traditional and cultural rituals and festivals. For instance, the *Newar* festivals include the *Kokkti-Purney* or *Kwanti Purnima* and the *Rakhi Purnima*. On the day of *Rakhi-Purnima*, Newars prepare a special soup of newly germinated pulses known as *Kwathi* or *Kokti*. It is prepared out of nine types of pulses such as a mixture of beans (*Ghew simi, Singtamey simi, Mantulall simi, Rajmah*), Mung (*Kalodal, Panhelidal*), Field Peas (*Matar/Kerau*), Horse gram (*Gahat*), Ricebean (*Masyam*), Soybean (*Bhatmash*), Cowpea (*Tuneybori),* Gram (*Chana dal*) and lentil *(Musuridal*). Similarly, other communities have different traditional food recipes that are prepared on rituals. The communities thus protect GRs of pulses and crops grown in the Himalayas. The Sikkim Himalayas is one of the best examples of local communities managing cultural agrobiodiversity.

Communities enjoy fermented products and local beverages (such as *Janrn, Rakshi, Bhati-Janrn* etc. prepared from finger millet, cana, rice) throughout the year. These products are primarily used to perform rituals called *pitri puja, kul puja, Toksok-fingma, Himtongsing/Sitongsing* (traditional rituals of ethnic Limboos) and the like by the different local communities as per their culture or religion. The fermented products, such as *Gundruk* (from leaves of mustard, cabbage, radish, taro), *Sinki* (from raddish), *Kinema* (soyabean product), *Khalpi* (pickles from cucumber), *Tamako- achar* (pickle from bamboo shoots) and a lot more have health benefits as appetizer and fast-food supplement during the lean season, and also support cash incomes for the households. Tamang (2009) has reported 29 types of fermented foods, 9 types of alcoholic beverages, and 85 types of traditional non-fermented foods of different ethnic communities of Sikkim Himalayas.



Bamboo shoot is a food and a source of income

FUNCTIONAL ROLE AND SERVICES OF TFS: AN ECOLOGICAL PERSPECTIVE

Biodiversity, Wildlife Habitat and Protected Area (PA) Corridor, Landscape

The Khangchendzonga Landscape houses biodiversity of global significance; the unique ecosystems provide services and outputs what has been recently described as provisioning, regulating, and supporting the well being by the Millennium Ecosystem Assessment (2005). Schematic representation and categorization of the services and flow of resources and functions in the TFS in a mountain ecosystem is given in Figure 2. Sikkim Himalaya is a part of the 34 globally significant biodiversity hot-spots and endemism in the Himalayas (CI, 2005). Sikkim, Assam and other northeast states of India, appear to be distinct in floral and faunal assemblages because they form a gateway between Southeast Asia and South Asia after the tectonic plate collision some 10–65 million years ago, which resulted in the formation of the Himalaya (Mani, 1974; Gupta, 2001). It forms the meeting ground of Indo-Malayan and Indo-Chinese biogeographical realms as well as Himalayan and Peninsular Indian elements which has resulted in rich biodiversity both wild and in cultivated landscapes. The conservation of biodiversity-rich land spaces, forests, agroforestry systems, rivers and rivulets, hills and the valleys are attached to the rich culture of the communities deeply rooted and interwoven over several centuries. Landscapes form the functional unit for biological and ecological processes, since biodiversity and ecological services are normally delivered by landscape functions.

Apart from conservation of a large number of important wildlife species, traditional agroforestry in the TFS have directly contributed to biodiversity through *in situ* conservation of diversity of tree species, lower canopy shrubs,

understorey vegetation, minor forest products and medicinal plants. Thus, TFS is a close loop system where human needs are fulfilled from within the system and reduces anthropogenic pressure to the adjacent forests. They provide suitable habitat for wild animal species that tolerate disturbance to a certain level on the farmland and large patches of agroforestry at a landscape level to support movement of these species and function as corridors (Sharma and Chettri, 2007). The agroforestry practices in the cultivated systems between the PA network in the Sikkim Himalayan region serve as a biological corridor for the movement of wild animals designated as flagship species in the wider spaces along the Himalayas within India, and across borders towards Bhutan in the east, Tibetan Autonomous Region of China in the north and Nepal in the west. Agricultural landscapes allow gene flow of globally threatened and biologically restricted species and retain the biological connectivity of the discrete biological units (Sharma and Chettri, 2007).

Wild biodiversity and traditional agroforestry, in the Eastern Himalayas are continuous landscape elements which are characterized by proximate interaction between natural systems and human dimensions.

Protective Functions

In a Himalayan watershed land use system, overland flow, soil and nutrient losses are very high (about 72%) from open agriculture (cropped) fields, while cardamom-based and other agroforestry systems conserved more soil and nutrients under the traditional practices. Traditional interventions such as the use of multipurpose species e.g. broom grass and trees upon terrace risers, use of N_2-fixing trees *Albizia*, *Alnus* and *Erythrina* for maintenance of soil fertility on rain-fed slopes and plantation of horticulture trees have reduced the soil loss by 22% which is quite substantial in steep slopes. Soil and water conservation values in cardamom and broom grass based agroforestry were higher suggesting greater conservation potential for extensive large scale land use change from forestry to agriculture (Sharma *et al*., 2001). The adoption of sustainable TFS has helped to reduce deforestation thereby minimizing pressure on forests and biodiversity due to human intervention. The diversity of agroforestry practices in the TFS close to reserve forests, protected areas and along the riparian habitats constitutes a continuous buffer thereby protecting the biodiversity and forests. The agroforestry systems surrounding the open cropped area act as windbreaks and considerably reduce soil degradation and landslide events.

Watershed Functions: Carbon Sequestration and Climate Change

The majority of micro-watersheds in the cultivated systems are dominated by agriculture and agroforestry land use. Agroforestry trees in TFS play a major role in sequestering carbon. Carbon stocks from different components like crop, tree, litter and soil were analyzed for cardamom-based agroforestry and the rainfed agroforestry with *Albizia*, *Alnus* and mix forest-tree species as shade trees. It was found that *Alnus*-cardamom system had 3.5 times more atmospheric carbon fixed compared to rainfed agriculture (Rai and Sharma, 2004). Promotion of techniques that are familiar to small farmers such as crop rotation, cutting back chemical fertilizers through the use of composts can act as an important sink for atmospheric CO_2 storing it below the soil surface (Altieri, 2008). The total stand C stock in a Himalayan watershed measuring an area of 3,014 ha was 624×10^3 Mg while total carbon stock in 1 m depth soil was 456×10^3 Mg. The total carbon stocks when compared in the cardamom based agroforestry showed highest stocks in the *Alnus*-cardamom stands followed by forest-cardamom and *Albizia*-cardamom stands. However, as a whole, the system under the nitrogen fixing *Alnus* showed higher carbon stocks compared to the other systems (Rai and Sharma 2004). The belowground biomass carbon in agroforestry stands also contributed more to total carbon storage (Sharma *et al.*, 1997). The adaptive traditional agroforestry sequesters carbon, contributes in regulating climate change and also reduces global warming (Rai and Sharma, 2004; Sharma *et al*., 2008). Using traditional agroforestry model as carbon sinks and by designing a suitable carbon trading system, the Kyoto Protocol provides a new source of financial support for protection and management of biological diversity. Development of such a mechanism could be a potential source of income to the vulnerable smallholder farmers in the Eastern Himalayas.

Sacred/Cultural Landscapes and Aesthetic Values

The Khangchendzonga landscape, culturally described as *Beyul* (the hidden land) and *Ters* (the hidden treasure) is linked to diversity of resources and ecological functions (GIAHS 2009; Sharma *et al*., 2009). The diversity of sacred landscapes extend from Sikkim on both sides along the Himalayas and has been referred to as *Beyul-Khempalung* and *Dema-Dzong* (the valley of rice) for Sikkim. The traditional conservation wisdom is based on intrinsic realization of paramount single entity consisting of the plants, animals, humans and the abiotic natural components. The Himalayan region is also described as *Ney Pemathang* or *Shangrila* (the hidden paradise on earth), and is worshipped in various religious-traditional festivals such as *Pang-Lhab-Sol* (mother deity Khangchendzonga) and *Tendon-Lho-Rum-Faat* (Tendong Hill). The concept of sacred landscapes and human-nature interrelationship has long been illustrated in the holy *Neysol* of Buddhism.

Human managed natural systems are a part of the whole sacred landscapes consisting of traditional communities, agriculture systems and cultural diversity which has been considered for the GIAHS Sikkim Himalayan Agriculture proposal. Through a joint effort of Government of Sikkim, United Nations University, Tokyo and International Centre for Integrated Mountain Development (ICIMOD), the Sikkim Himalaya traditional agriculture has been recognized by FAO as an associate system of the GIAHS initiative. The sacred landscapes in the Ganga River System of the Central Himalaya, *Dema-Dzong* valley of the Eastern Himalayas, and the sacred mountains such as Holy Hills of the Dai tribe of Xishuangbanna in Yunnan Province of China (Ramakrishnan, 2000) are all examples of biodiversity conservation and natural resource management based on ITEKS.

Over the last two decades, Sikkim has established itself as a recommended destination for contemporary tourists. The scenic beauty, rich biodiversity, friendly people and rich culture is attracting tourists from all over the world. The multi-ethnic groups residing in the area with diverse traditional knowledge blended with culture and religions provide an added attraction to the nature tourists (Sharma E. *et al*., 2008). Conceptualised and inspired from Sikkim Biodiversity and Ecotourism Project (Sharma E. *et al*., 2002), Sikkim is taking a lead role in diversifying and enhancing ecotourism by promoting 'home stays'. The TFS from the lower elevations to the forest ecosystems and alpine meadows provide ideal aesthetic values for tourism business.

SOCIAL PERSPECTIVE

Human Well-being

The TFS provides economic and social well-being to the communities. The high value cash crops are of paramount importance for fetching economically sound monetary benefits to the smallholder farmers for health care, education and social activities while the farm-based agroforestry provide essential products for subsistence needs such as food and nutrition. Apart from scenic and aesthetic beauty and recreational opportunities, the mountain ecosystems are the main reserves of water systems for both agriculture and portable water. Agroforestry practices are the constant source of non-timber forest products, underutilized crops, clean air and water, which assist in improving the quality of life of the mountain communities.

The diversity of TFS are managed through organizational diversity that includes the diversity in the manner in which the farms are operated, owned and managed and the use of resource endowments from different sources in a traditional way. The management of such multifunctional TFS and domestication of useful species, livestock, food, air, water and material for shelter have contributed to the well-being of the smallholders and their society as the products of these systems are crafting the local and international markets.

Climate Change Indicators in TFS

In addition to emerging market forces already active, impacts of climate change have caused tremendous vulnerabilities to humans and their managed agroecosystems. Such impacts have posed threats to the socio-ecological and socio-economic resilience of the agroecosystems. A general trend of climate change indicators are summarized in the

Mandarin orange, a high value cash crop found in the mid and low hills

following paragraphs. However, empirical research should be carried out to support the development of strategic policy to mitigate the growing impacts through multidimensional approaches and recognize the adaptability and resilience of the TFS in the Himalayan landscapes.

Trans-Himalayan and Sub-alpine Agroclimatic Zones

In high altitude areas (4000 - 5500 m) grazing symbolically integrates with the socio-cultural life of the indigenous communities and contributes to socio-ecological adaptability to changing climatic conditions. The climate change impacts in the Trans-Himalayan areas have been felt in the last 10 years with the shift of snowfall events and time. The herders have realized the increased summer temperatures followed by decline in snowfall. Elderly farmers remarked that 20 years ago at Thangu (4000 m), snow fall events use to last for a week to 15 days. In the last five years dramatic changes have been felt at Thangu, snowfall events are untimely and occasional that last only for one to two days. Herders recount that more than 10 feet snowfall was natural at Thangu, Bamzey and Dambochey (4000-4700 m) 15-20 years ago which has declined by almost 40%. Rangeland degradation, frequent landslides / mudslides, flooding, avalanches during winter, reduction of pastures are commonly observed in the Trans-Himalayan and alpine areas. These unusual natural events are threats to the nomadic agropastoral community.

Similarly, untimely and seasonal shift of snowfall events have also affected the Trans-Himalayan agropastoralism. As a consequence the *Dokpas*, who depend upon the availability of grazing pastures mostly in Muguthang (5000 m) and Lhonak valley (4500 m), have gradually shifted to a sedentary lifestyle. Diversification of agriculture crops and permanent establishments are observed at Muguthang. During 1995 - 96, outbreak of a serious disease and heavy snowfall killed a large number of sheep. As a result sheep rearing was completely abandoned in Lhonak Valley by *Dzumsa*.

A few reports are available on species migration to higher altitudes. The National Biodiversity Strategy and Action Plan (NBSAP, 2002) for Sikkim has reported that mosquitoes are appearing in Lhonak Valley well above 5000 m while

house crows have spread to Lachung which is an uncommon sight. Similar observations were reported from Tibet Autonomous Region of China where changes in climate along with land use have impacted ecosystems and human health (Xu, *et al.*, 2008). The large cardamom and ginger are gradually migrating to the temperate agro-ecological zones in the TFS.

Temperate and Sub-Tropical Agroclimatic Zones

The climate change events observed and recorded over the years in the TFS revealed that frequent mudslides in terrace risers (in *khet* and *bari* systems), productivity decline of crops (e.g. cardamom, ginger, orange, rice, maize, wheat, buckwheat etc.), emergence of diseases and pests etc. have resulted in emerging food insecurity in the mountain region (mainly to those farmers living in highly inaccessible areas). Farmers revealed that the sowing time of maize at the sub-tropical zone has been delayed by 15-20 days while it remains the same in temperate zone. The harvest time of maize remains the same in the sub-tropical zone while it has shortened by 15-20 days in the temperate zone.

Buckwheat, a traditional crop

In the Ilam area of Nepal, large cardamom growing below 2200 m has climbed up by 200 m in more than a decade and is now growing upto 2500 m. Farmers reported that cardamom in high altitudes is performing well with no signs of diseases while plantations have severely declined at lower altitudes. *Alnus nepalensis* earlier growing upto 2200 m is now ascending above 2500 m. The extreme climatic conditions such as long dry spells, emergence of viral diseases such as *Chirkey*, *Furkey* and fungal disease *Colletotrichum* blight (Spices Board, 2008; Annual report 2009) have contributed to large reductions in the plantation area and decline in productivity.

Similarly, mandarin orange in Sikkim has declined both in terms of productivity and plantation area. Since 1990s, emergence of new diseases (citrus dieback, root/foot rot, powdery mildew, scab, shooty mould, anthracnose, red rust,

nematodes, vascular-borne disease caused by Tristeza virus, colonization of ants in the citrus twigs and roots etc.) have been observed in almost all citrus growing areas of Sikkim. The average decline of yield is 3.5 times lower compared to 10 years ago. The climate change events such as erratic rainfall, and high incidence of pests and diseases have been observed widely in the TFS.

Multipurpose Agroforestry Species

Farmers harvest fodder tree branches/twigs during winter season to supplement the animal feed. Due to untimely rainfall the tree fodder production has been reduced with stunted growth of branches. This is followed by wide emergence of pests eating up the green foliage of some of the fodder trees. Untimely precipitation has also impacted the phenology of tree species.

Farmers reported that invasive alien species such as *Chromolina adenophorum*, *Eupatorium odoratum*, *Bidens biternata*, *Artemisia nilgirica*, *Lantana camara*, *Ageratum conyzoides*, *Cestrum auranticum*, *C. fasciculatum*, and *Galingosa parviflora* have caused serious problems in the farmlands, forests, traditional agroforestry systems, fallow lands, croplands and wetlands. These invasive species are fast colonizing and spread from sub-tropical to temperate agro-climatic region causing productivity decline in the last 10 years. Rapid spread of these alien species has resulted in a reduction in production of fodder grasses, thatch grass and firewood.

Coping of Climate Change

Unpredictable weather patterns believed to be an indicator of climate change has influenced resources in the TFS with negative consequences on the system and people. In addition, an irreversible loss of diverse indigenous plant resources and narrowing down of the genetic pool of resources has been recorded in the Himalayan region. Therefore, the conservation and management of diversity occurring in the TFS is utmost necessary as it acts as a source of climate resilience for community's food and livelihood security, given the rapid climate induced changes in the region. With the rapid and unplanned social and economic development occurring in the region combined with anthropogenic and climate change induced factors, the greatest challenge now is to maintain biological and socio-cultural diversity in these ecosystems along with economic development. Most of the ecologists and conservationists in the Himalayas and worldwide are concerned about conservation and management of biodiversity in a manner which is sustainable and addresses the needs of communities (Shengji, 1998).

Addressing climate change and conservation issues at landscape, ecosystem and species level cannot be a possibility without an integrated and evidence based research and knowledge focusing on both social and ecological perspective. Few studies have been carried out in Sikkim to understand TFS from socio-economic, livelihood and vulnerability perspective. Ecosystem-based adaptation activities such as conservation of agrobiodiversity, establishment of diverse agroforestry, conservation and restoration of forests and sustainable management of uplands and floodplains have been emphasized by the technical report 41 of Convention on Biological Diversity (SCBD 2009). As highlighted in a study by ICIMOD, opportunities should be explored for marginal farmers of the Eastern Himalayan states through proposed holistic landscape approach (such as REDD$^{+,}$ REDD^{++} or AFLOU) and "good carbon governance" for carbon financing (ICIMOD, 2009).

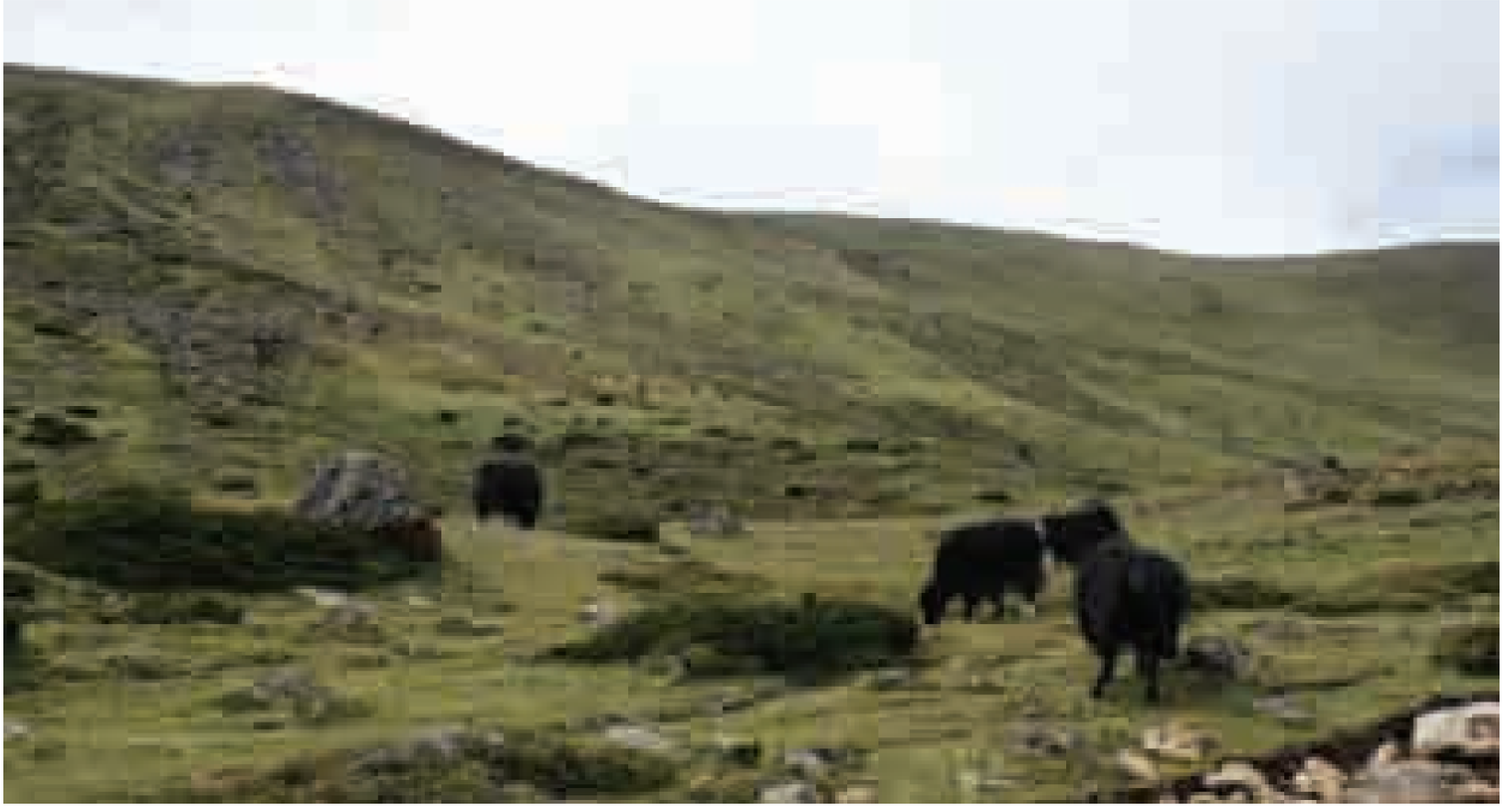
Policy and Development Relevance

Since 2008, under the Technology Mission of the Government of India for development of horticulture, the Sikkim Government has initiated Mini Mission I, II, III, and IV with the aim to provide technology support, enhance horticulture production, and create post harvest technology and infrastructure (Annual Report, 2009). This mission also supports market promotion, Research and Development, and human resource development. The government has promoted organic agriculture for greater economic returns while declaring the Sikkim as the first organic state in India. Similarly, the Rashtriya Krishi Vikash Yojana (RVKY) is an additional central assistance to Sikkim initiated since 2007 to achieve the goal of 4% growth in agriculture sector. The Government of Sikkim has initiated Poverty Free Mission in 2010 to completely eliminate poverty by 2013 (RMDD, 2010).

The northeastern Himalayan states of India can take the advantage of the post-WTO Indian legislation pertaining to agriculture such as the Indian *sui generis* legislation Protection of Plant Variety and Farmer's Rights Act, 2001, The Geographical Indications of Goods (Registration and Protection) Act, 1999, and the Patent (Second Amendment) Act, 2002. Similarly, for protection, conservation and access and benefit sharing arising from genetic resources and associated TK the umbrella legislation The Biodiversity Act 2002 should be appropriately analyzed and made user friendly for mountain states. In the context of changing global policy on trade and commerce valuable bio-resources, access, equitable benefit sharing, appropriate policies on promotion and conservation of traditional agriculture for sustainable utilization demand regulation through appropriate mechanism is critical and challenging.

Research and Development: A Policy Imperative

Given the vast biodiversity of the region and in each of the systems, diverse adaptive strategies have been a continuous practice of the mountain communities where both genders manage multiple roles and production systems for their daily survival. In all of these systems, communities have played a critical role in its conservation and maintenance simultaneously preserving the biological diversity occurring in it as a result of their traditional knowledge, spiritual/ cultural beliefs, conservation ethics and practices carried over since generations. Studies done worldwide reveal that woman play a very important role to maintain and sustain local-level ecosystems due to their vast knowledge of agriculture systems, biological and genetic resources of both plants and animals (Howard, 2001; Lambrou and Laub, 2010). In Sikkim Himalayas, women are primarily responsible for local level biodiversity. Homestead gardening and plots in vicinity to their households are considered as a female domain where they grow diverse plant species thus significantly responsible for conserving local level agrobiodiversity. The household mothers are generally the custodians of gene-banks of crop diversity who keep record of varieties/yields and preserve germplasm by growing them at heterogeneity of land parcels allotted for growing of landraces. However, gender dimension in the TFS has often been ignored by scientists and researchers studying plants or the systems thus leading to undermining of women's contribution who have been systematically marginalized in research and policy imperatives. Such needs attention. Further, market forces have placed high importance on systems and resources of global value thus ignoring women's critical role in the traditional and local level biodiversity and farming systems.



Trans Himalayan yak grazing in the alpine meadows

Sheep (*banpala*) grazing, a livelihood option for traditional communities

CONCLUSION

In the context of several externalities of the fast changing world, global policies and prospects, the TFS in the Sikkim Himalayas show successful examples of sustainable management of resources, goods and services they provide and climate change adaptation. The agricultural biodiversity has been central in sustaining the livelihood of the traditional communities. In socio-ecological and socio-cultural terms, TFS is a mixture of natural and man made adaptive ecosystems developed by mountain societies – an evolving dynamic landscape management system that supports human needs providing ecological/economical sustainability to both upstream and downstream communities. Large cardamom and mandarin are high value cash crops that are regular source of income to small farmers while traditional crops, underutilized and lesser known crops provide food security and nutrition to marginal farmers. The TFS has high potential to sequester carbon, retain biodiversity, support habitat to wildlife and above all it is considered as a self sufficient system. The system provides on-farm and off-farm employment opportunities such as resources, production, ecotourism and agro-tourism. The TFS plays a vital role in securing human well-being besides ecological and environmental sustainability. It supports and restores adaptability, ecological resilience and enhances ecosystem services to the region and the world at large and contributes to sustainable development. The mountain farmers have been applying the traditional technologies to adapt in the changing situations at temporal and spatial scales.

In the context of climate change, communities and gender roles in maintaining diverse genetic resources and traditional knowledge and skills related to biodiversity, occurring at species and ecosystem level needs to be valued and rigorously documented. There is a need to take up detailed studies on every aspect of TFS which will help in the formulation of inclusive participatory conservation policies and programs. This will help in mainstreaming the experiences in conservation and climate change adaptation to attain sustainable development in Sikkim.

Table 1. Indigenous system of household farm classification in TFS in the Sikkim Himalayas

Land Units	Traditional Classification	Attributes of practices
Ghar-ghyryan	Rachyan-ghuryan (Home garden)	The land parcel around a household, mainly allocated for growing seasonal vegetables (beans, leafy vegetables, squash, yams, colocasia, chillies, turmeric etc.), fruits (banana, guava, pear, plum, jack fruit etc.) and some traditional crops.
Khet	Pakho Khet (Terrace paddy field in a slopy land)	Terraced price fields of more 30° slope, ground fodder is grown along the high terrace raisers. The rice fields are mostly rain fed, irrigated subject to availability of water from the nearby streams and *jhoras* that appear only during rainy season. Crops grown are mostly rice, pulses, maize, and fodder trees for land stabilization as well as for fodder. Terrace-fall during rainy season is frequent causing excessive soil loss.
	Byansi (Flat paddy field)	Also called *Thang* are the flat lands along the river beds, mostly irrigated from the nearby streams. Rice, wheat, pulses at the bunds, buckwheat and maize are grown. Nutrient rich soil accumulates from up streams, very fertile and productivity is comparatively high. Some examples in Sikkim are Tareythang Byansi, Pithang Byansi, Tanak Byansi and Daramdin.
	Shim/Kholyang (Paddy field with a natural spring)	Rice fields with a spring source, water is also used for drinking during dry seasons. Such land does not require external irrigation facility. *Shim* is a source of drinking water for households, for grazing animals and also for wild animals. Water is also stored in small dug ponds. Farmers conserve such seepages by planting good tree species in their catchments.
	Bagarey (Paddy field at the bank of a river)	Rice fields at the river banks, full of *pango mato* (clay soil), farmers call it *malilo mato* (fertile soil) for crops. Productivity in Bagarey is high. Farmers cultivate rice, wheat, pulses, buckwheat and soybean.
	Birauto (Newly terraced paddy field)	Farmers keep on maintaining the farmland, repair and manage the slopes by terracing. The newly terraced rice field is called the Birauto.
Bari	Tar bari (Flat dry field)	A flat dry field, non-irrigated, meant for growing maize, vegetables, ginger, orange, wheat, barley, beans, pulses, oilseeds, millets, buckwheat etc. Tar bari is mainly rain-fed due to shortage of water.
	Kothe bari (Homestead garden)	Kothe-bari is a home garden of the household, farmers grow seasonal and off-season vegetables.
	Pakho bari (Slopy dry field)	This land consists of more than 30° slope. Terraced dry fields, farmers grow maize, millets, pulses etc. and grass fodder along the terraces. The land remains fallow during dry seasons. During winter farmer slash and burn as a management practice and cultivate pulses, tapioca and other lesser known crops.

Land Units	Traditional Classification	Attributes of practices
	Bhasmey/Khoria (Slopy land, slashed and burn for cultivation)	In sloppy fallow area farmer clear, slash and burn during the month of December-January to cultivate mixed landraces of pulses, horse gram or maize. After the crops are harvested the land remains fallow. The system cycle was once in two to three years, but now annually. This land supplies fodder, and litter for mulching. Such land parcels are unsuitable for terracing or other agriculture land use. Animals are grazed during winter.
	Siru bari (Dry field for growing thatch grass)	Dry infertile field allocated for Khar (*Imperata* sp. used for thatched roof), farmers grow timber, fodder and fuelwood tree species. Small farmers' use Khar for thatchi ng roofs of animal sheds.
	Alainchi bari (Large cardamom agroforestry)	Traditional agroforestry of large cardamom under *Alnus nepalensis* or mixed forest tree species.
Jungle (Forest Parcel)	Bans-ghari + Jungle	Bamboo groves and other fuelwood/timber species grown in a parcel of land. Such land would be infertile, dry either sloppy, or unsuitable for cultivation. Farmers loop branches of trees during November-February for green fodder and fuelwood and also as a management practice. Bans-ghari at the edge of the agriculture fields prevent landslides and soil loss and provide household requirements.

(Sharma et al., 2009)

Table 2. Major agroforestry practices under IFS in the Sikkim Himalaya

Agroforestry systems	Agroforestry practices
Agrosilvoanimal systems	***Farm-based Agroforestry :*** Multilayered vegetation structure with fodder species, shrubs and understorey crop based garden agroforestry, multiple intercropping in terraced productive zones and woody perennials and multipurpose species at the edges of the farm lands for soil erosion control, forming protective belts and windbreaks • Homegardens involving animal husbandry, traditional beekeeping, vegetable crops, protein banks, underutilized crops and lesser known crops • Trees and ground shrubs/herbs or other agroforestry species such as *Thysanolena* species for soil reclamation
Agrosilviculture systems	***Farm forest-based Agroforestry:*** Multipurpose trees species for fodder, fuel and timber and bamboo groves, and animal feed bank and for other productive needs • NTFPs and minor forest products, and medical plants or other plantation crops and pasture lands, water sources conservation • Soil conservation and reclamation
Agrihortisilvicultu re systems	***High value cash crop based agroforestry:*** 1. Cardamom-based agroforestry: *Alnus*-cardamom and Mix-tree-cardamom Ecologically adaptive and socially accepted multifunctional trees such as *Albizia* spp., *Alnus nepalensis* and mix tree agroforestry species and understorey commercial cash crop large cardamom • Ground fodder and NTFPS, medicinal plants • Trees, shrubs and ground grasses in soil conservation and reclamation 2. Mandarin orange-based agroforestry Multilayer arrangement of fruit orchard and fodder trees, intercropping of understorey traditional crops varieties, lesser known crops, protein banks, yams, taros etc. • Vegetable crops, traditional beekeeping, animal husbandry and trees for fodder in the appropriately designed homegardens • Mandarin orange trees, multipurpose trees and N_2-fixing *Albizzia* spp.

(Sharma G. unpublished)

Figure 1. Schematic model of interacting components in a Traditional Farming System

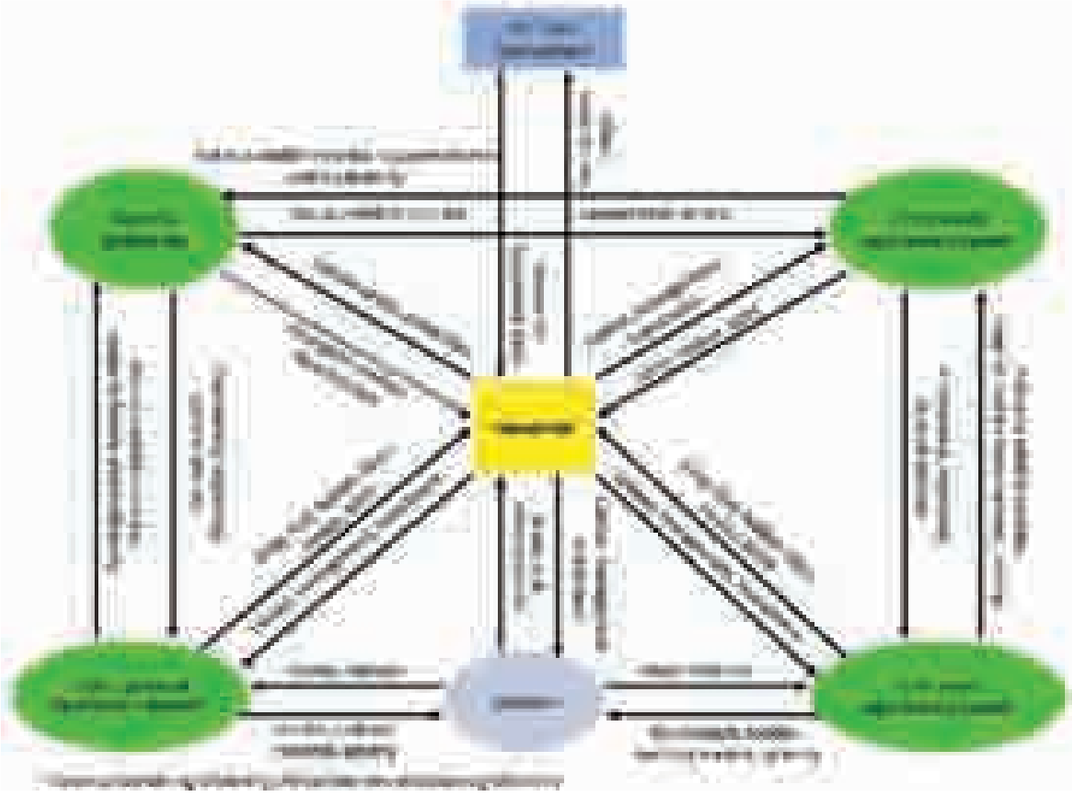


Figure 2. Schematic representation and categorization of services and flow of resources and functions in a Traditional Farming System in a mountain ecosystem (prepared based Millennium Ecosystem Assessment, 2005)

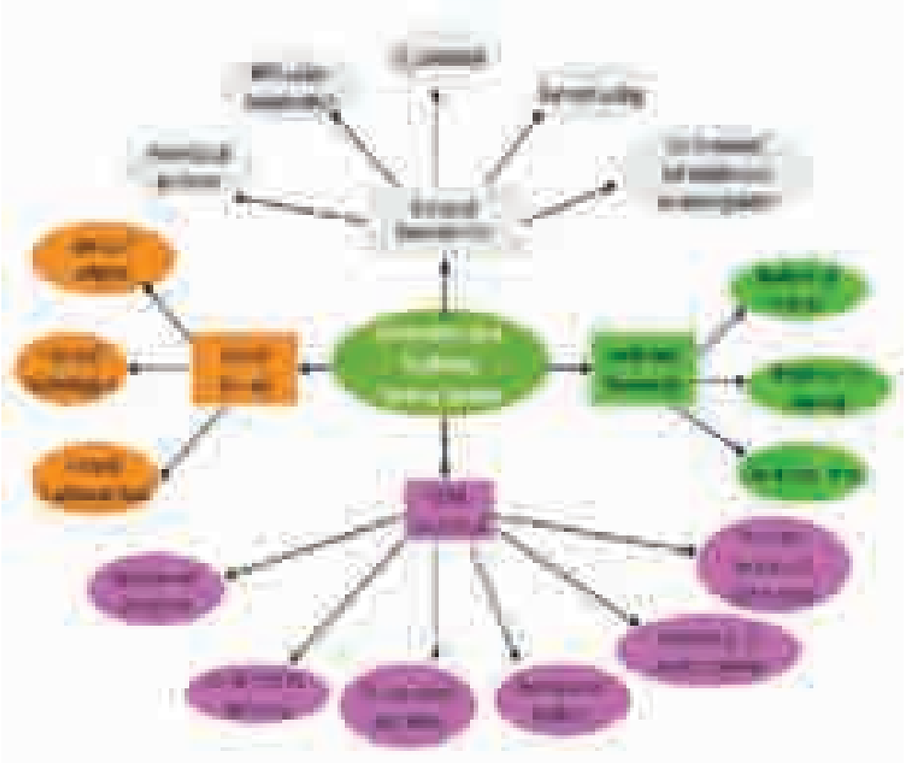
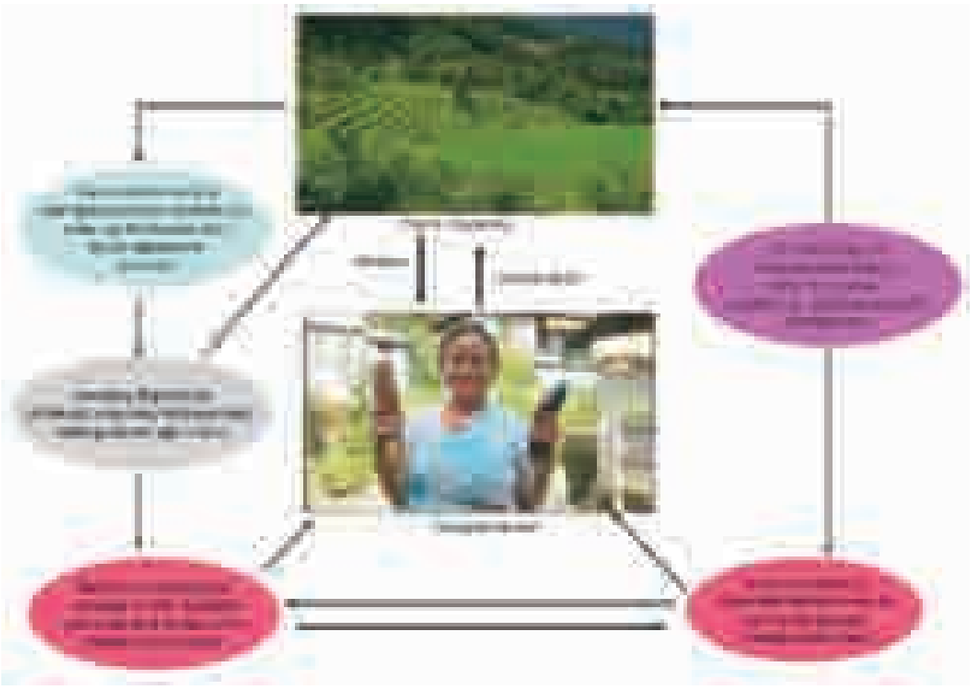


Figure 3. Indigenous farmers in transition in the Traditional Farming System



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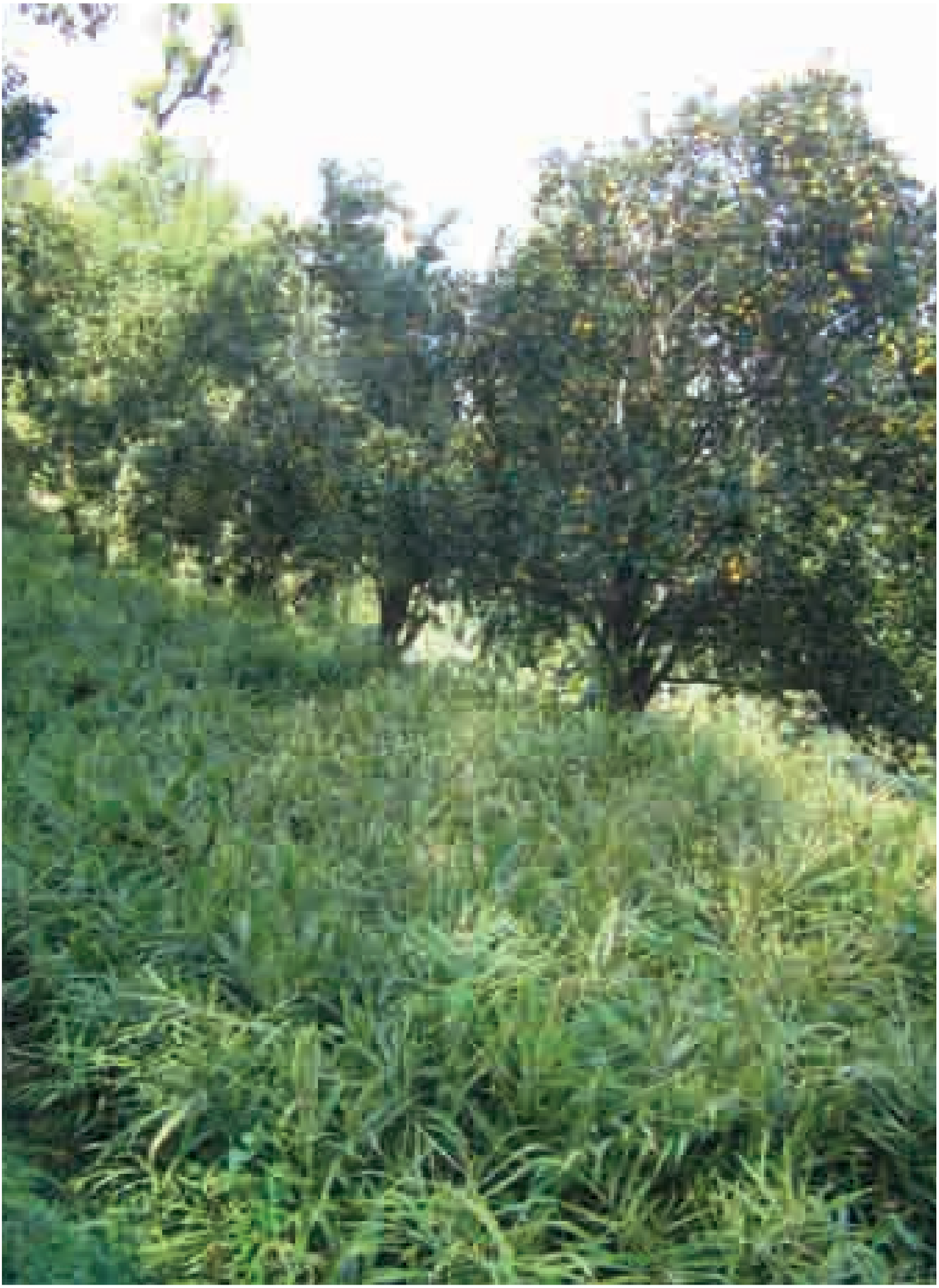

Mixed farming of Mandarin Orange with Ginger

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