SUSTAINABLE LAND USE PLANNING FOR THE SIKKIM HIMALAYAS – PERSPECTIVES AND OPTIONS

Patiram [*1], R. K. Avasthe [2] and S. B. S. Bhadauria [3]
ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Sikkim - 737 102
[2] Sr. Programme Officer, WWF-India, Sikkim Field Office, Gangtok – 737 102
[3] C F & Nodal Officer (FCA), Department of Forest, Government of Sikkim, Deorali, Gangtok, Sikkim - 737 102

Introduction

The environment of which land is a vital component, acts as a highly sensitive system to provide the means of sustainability to all forms of life. The Agenda 21 of Chapter 10 of the United Nations Conference on Environment and Development (UNCED), held at Rio de Janeiro in 1992, focused attention on planning and management of land resources, to make management economically and environmentally sustainable and socio-economically acceptable. Soil and land degradation are perhaps more important and less spectacular but widespread. Several writers have attributed the end of Mesopotamian Civilization as a result of salinization of Greek and Mayas and others to soil erosion (Hillel, 1991).

There are many definitions of sustainability and are equally plentiful (Greenland, 1994), but the definition given by FAO (1991) is most relevant. It states that "a system which involves the management and conservation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in agriculture, forestry and fisheries sector) conserve land, water, plant and animal genetic resources, and it is economically viable and socially acceptable". Land use systems require constant monitoring and adaptation to maintain food security, minimize deforestation, conservation of biological diversity, reduction of green house gas emissions, protection of environments and enhancement of health and safety of human occupation to the changing social, economic and natural environments. Even we may change our pattern of consumption, land use practices and energy use to safeguard the environments. The sustainable land utilization of hills involves the management and conservation of natural resources (land, water and forest) to maintain the quality of environments for favour of the present and future households and communities' needs.

The beautiful tiny Himalayan state, Sikkim provides the snow capped mountain peaks, glaciers, transverse river valleys, cascading streams and rivers, lakes, floral and faunal diversity and richness within its narrow rugged mountainous terrain of roughly 64 km wide and 112 km long distances. Such biogeographical region is unique and unparallel, perhaps nowhere else in a similar situation on the earth. Terraced cultivated fields interspersed with streams along with bamboo and tree groves are the traditional hill agriculture confined to the elevations of 2000m. The high intensity of rainfall on steep hill slopes causes extensive soil erosion and landslides during rainy season. The increasing demographic pressure is resulting indiscriminate exploitation of precious natural land resources leading devastating ecological imbalances threatening their own means of survival through degradation of not only land but also biodiversity rich zone. Therefore, an attempt has been made to suggest land utilization for sustainable hill so as to increase the land productivity and restoration of soil degradation and increase the quality of environments to preserve the natural beauty for our present and future generations.

Geography and geology

Sikkim is located between 27^{o} 46' and 28^{o} 7' 48" North latitude and between 88^{o} 0' 5" and 88^{o} 55' 25" East longitude in the eastern Himalaya, bounded between three international borders of China, Bhutan and Nepal on the north, east and west sides, respectively and southern boundary by

---

* *Present address*:
[1] ICAR Research Complex for NEH Region, Umroi Road, Barapani, Shillong, Meghalaya – 793 103
[2] Senior Scientist, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim - 737 102

Darjeeling district of West Bengal State. Sikkim with geographical area of 7096 km^2 is surrounded almost on all sides by steep mountain walls except in south it is open by Teesta river and high mountains of north are always covered under perpetual snow cover. Teesta and Rangeet are the major rivers, which originate from the glaciers and drain the water of the state. The altitudes vary from 300m to 8586m and on the basis of physiography, the whole state can be divided into 6 physiographic zones; summits and ridges; side slope of hills, narrow valley, cliff and precipitous slope, zone of glacial drift and perpetual snow cover (Anonymous 1992a).

The entire state is a young mountain system with highly folded and faulted rock strata at many places. The Daling group of rock is found in the central part of Sikkim and composed of phyllites, schists, slates and quartzites. The northern central part of West Sikkim chiefly made up of Darjeeling gneiss. The gneiss of South Sikkim is highly micaceous and frequently passes into mica-schists. The younger Gondwana contains sandstone, shale, and carbonaceous shale with occasional thin coal bands.

Climate and vegetation

Climatically, Sikkim experiences variable temperature with scorching summer at the foothills to freezing chills in winter on high mountains. Rainfall occurs throughout the year and state as a whole gets 80-90% of the annual rainfall (except around 65% in north-east) during monsoon (May to September) (Anonymous, 1991). The mean annual rainfall varies from 840 to 5000mm with heavy precipitation of snow on the higher reaches and the Greater Himalayas.

All the botanical zones from tropical to alpine are found in Sikkim due to its geographical position, climate and altitude. The vegetation of Sikkim has been distinguished into 6 forest zones based on altitudes (Khoshoo, 1992). They are:

1. Tropical Evergreen Forests (up to 900m)
2. Sub-tropical Forests (900-1800m)
3. Temperate Forests (1800-2700m)
4. Sub-alpine Forests (2700-3500m)
5. Alpine vegetation (3500-4500m)
6. Alpine deserts (> 4500m)

Sikkim is renowned for its Rhododendrons, and orchids and for high altitude Primulas, Meconopsis and Blue poppies. This state is veritable storehouse of medicinal and economically important plants.

Land Use

The land use pattern of Sikkim is strongly influenced by the elevation, climate and mountainous terrain, especially in the field of agriculture and forestry. Forest is the main land use in the state and nearly 40% (reserve + private) of the geographical area is under varying forest densities cover followed by alpine barren land, snow and glaciers (Table 1). The cultivated land is approximately 11% of the total geographical area (776.74km^2) and is confined to altitude less than 2000m. Around 70% of the cultivated land (541.44ha) is terraced/semi-terraced and remaining is under fallow/scrub.

Land degradation

Degraded lands include those lands whose condition has deteriorated to such an extent that it can not be put to any productive use as such, except current follows due to various constraints. The degraded lands of Sikkim mainly have resulted due to over exploitation of forest for fuel, timber and fodder, improper land use practices and infrastructure development. Theng (1991) in his review essay - Soil Science in the Tropics - the next 75 years' addressed three soil related issues: forest resources and deforestation; degradation of soil resources and soil management as integral parts of sustainable land management. Soil erosion is one of the major causes of soil degradation on steeply sloping lands devoid of vegetative cover and often subjected to landslides or landslips during rainy season (May to September). The total degraded land through erosion was estimated 3.8 lakh hectares, which reduced to 1.54 lakh hectares up to 1989-90, as a result of suitable conservation measures (Anonymous, 1992b). The conservation measures are not keeping pace everywhere with land degradation due to heavy rainfall. The geological make up of surface as well as underlying rocks influence land degradation to a great extent on slopy lands. The north, eastern and western portions of state are made up of hard massive gneiss, which is comparatively more resistant to the weathering thus, denudation. Central and southern phyllites and schists are highly susceptible to weathering and prone to erosion and landslides.

Lachen chu (Teesta) and Lachung chu originate at an elevation of about 5800m in North Sikkim and both join at Chungthang and give the major Teesta River, which drops to about 200m at Rangpo covering a total distance of 175km. The water of Teesta River is sky blue in colour upto Chungthang, further turns greyish and intensity increases as river moves southwards. The suspended sediment inflow of this river measured at Chungthang and Dikchu by the Central Water Commission (Government of India) is given in Table 2 for the mean of the data collected 10 and 14 years, respectively. It is evident that, the sedimentation of river water at Chungthang just down stream of the confluence of Lachen Chu and Lachung Chu was found to be between 0.119 (February) and 24.042 ham (July), 50 km downward at Dikchu was between 0.482 and 148.353 ham and sedimentation rate increased tremendously. It is also evident that the coarse fraction increased as the river moved downward towards Singtam. The average annual suspended sediment inflow at Chungthang, 79.087 ham appears to be quite low. The further increase of sedimentation load at Dikchu (497.156 ham) is the result of unstable banks on either side of Teesta that experience major landslides during the monsoon period and more than 94% of the total annual suspended sediment inflow occurred during the same period.

Soil degradation by erosion is often non-reversible, particularly where a top fertile soil is replaced by a compact acid sub-soil, through adverse changes in physical, chemical and biological properties. The rate of soil degradation by different processes is generally increased by using land for whatever it is not capable of and unsuitable methods of soil and crop management. Consequently, soil degradation sets in resulting in widespread occurrence of sheet and gully erosion, and ultimately encroachment by Seeru (*Imperata cylindrica*) on highly eroded land. The net cultivated which was 64,927 in 1976-77 increased 78,321 in 1980-81 and decreased to 63,254 in 1980-91 is the indicator of land degradation in Sikkim by increasing culturable wasteland (Anonymous 1996). The resource poor farmers and landless labourer were forced to cultivate lands during 1977-1980 that were too steep, too shallow, rocky and stony and by the methods that were ecologically unfriendly. Soil erosion even occurs on gradual terraces, non-cultivable land grazing land and in settlements. The construction and operation of roadways, urbanization and other infrastructure development activities cause disturbances of soil, vegetation, slope inclination and drainage patterns create further potential for accelerated erosion and increased sediment yield. Land slides adversely effect utility services such as roads, power generation, reservoirs, human settlements, trade, tourism and other developmental and economic activities parameters effecting on-site slope processes. These processes not only affect the land/soil but also cause loss of bio-diversity including base resource itself, and human life.

Restoration of land degradation

The thermodynamics of soil system suggest that it is easier to degrade soil than to restore it, and degradation occurs at a far more rapid rate than reclamation. Understanding the processes, factors and causes of land degradation is a basic prerequisite towards successful restoration of the productivity of degraded lands. Knowing the category of soil degradation is an important stage to restore the soil quality and its productivity by preventing soil erosion, promoting high biological activity, increasing soil organic matter content and increasing rooting depth of plants. There are two approaches that have been used to reclaim degraded soils and intensify agricultural production from areas already under cultivation.

1. Engineering approaches
2. Ecological approaches

Engineering approaches

Engineering approaches are used in cases of extreme degradation, where other approaches are not possible or slow. Contour ridges, check dams and bench terraces involve high cost of construction and maintenance, which poor farmers cannot afford to invest. Ecological measures are more effective when used in combination with engineering techniques. By adopting terracing and protected waterways, the steep slope could be cultivated safely and profitably. Any small damages in terraces should be immediately repaired before it becomes worse. Many terrace areas have failed not because of design or construction, but owing to negligence in protection and maintenance. The terrace risers can be planted with local grasses to protect the soil loss and produce forage for cattle. The terrace outlets are well protected either sod-forming grasses or using a piece of rock or brick to form a check. Fords culverts and bridges are needed in large enough for crossing small streams, sediment, debris etc. to remove the water before it has a chance to concentrate and cause erosion. Slope stabilization includes re-vegetation and other engineering measures to control surface erosion on road cut and fill slope and waste and borrow areas. During construction of road, to avoid mass movement of soil, the best way is to place the culverts to the natural stream channel as closely as possible. Wattling and staking is a combination of mechanical stabilization and re-vegetation on road fill banks and similar areas of base slopes for building new roads in the hilly terrain. It helps to reduce the run-off and its velocity, barrier or buffer strip for controlling soil and conservation of moisture for stake growth.

Ecological approaches

The ecological approaches involve the manipulation of inherent soil processes to check the soil degradation. Practical method of controlling water erosion require that a cover be maintained over the soil at all times to break the erosive force of the rain. Farmers, foresters and pastoralists are users of land for production and sustained output of plant materials year after year depends on maintaining the quality and quantity of soil as a rooting medium and supporting the dynamics of the biological self renewed capacity of soil (Shaxson 1981). The objective of conservation is to work out how to satisfy people's aesthetic and physical needs from the land without harming or destroying its capacity to go on satisfying those needs in the future (Shaxson *et al.*, 1989). The ecological approaches to restore land degradation includes following objectives:

i) to stabilize slopes and control of sedimentation in the stream,
ii) to establish dense and diverse vegetative cover to provide ecological stability to the site and act as soil amendments,
iii) to ensure nutrient cycling and enrichment of soil,
iv) to fulfill fuel, fodder and other requirements of local people, and
v) to enhance the ameliorative value of the site.

The main ecological approaches are described in brief for the sustainability of land.

Landscape stabilization

Before restoration of degraded lands, the stabilization of landscape against erosion or slope failure is essential. It can be done through the grading of slopes before surface treatment and re-vegetation or cut-off-ditches with a variety of terraces. With an effective vegetation cover, the establishment of plants may control gradients without supplemental mechanical measures in protecting the landscape against water erosion. Catastrophic events (such as land slides) cannot be altogether prevented, but management action can be implemented to reduce the frequency of events by preventing human occupation, economic development therein and planting of deep-rooted trees and/or shrubs on steep slopes.

Maintenance of soil fertility for crop productivity

The most serious effect of soil erosion results loss of most fertile top soil and exposure of infertile acid subsoil, decrease of plant available water capacity, degradation of soil structure, non uniform removal of soil surface and ultimately decrease of economic return on production. Soil conservation not only includes control of erosion, but also recognizes equally the importance of soil fertility maintenance. The management practices include the maintenance of soil fertility, soil quality and productivity. Almost 50% soil of the state has pH less than 5.5, where growth of the plant roots are restricted resulting low productivity due to aluminum toxicity. The field experiments conducted on acid soils gave the maximum yield of maize, wheat and soybean, when limestone rates were 1-2.5 equivalent of exchangeable aluminum and soil pH raised around 5.5 (Patiram *et al.*, 1991). A ready reckoner for quick appraisal of lime requirement to the acid soils of Sikkim is suggested to raise the pH 5.5 (Patiram, 1991). The limestone rates based on exchangeable aluminum cannot become popular in the hilly terrain of state, because here inputs are carried on the head to the distant fields. The field experiments on acid soils, gave the encouraging results that this problem can be overcome by furrow application of small doses of limestone (250 kg/ha) every year to achieve optimum productivity than a relatively higher dose once in three to four years (Patiram, 1994).

Organic matter in one form (cattle manure) or other is used in Sikkim to replenish the soil fertility for sustainable land management in maintaining soil quality through its effect on soil structure, water-holding capacity and nutrient supply. For low input system it is the only provider of nutrients and protection against nutrient loss. In general, organic matter is needed for the amendment of severely degraded land where conditions are limiting to establish the vegetative cover. The addition of organic matter to acid soil reduces the soluble and exchangeable aluminum temporarily by forming complexes with organic matter to provide favourable environments for plant growth in addition to improve the physical, chemical and biological properties of soil (Patiram, 1996).

Soil fertility remains at an optimum level if regular doses of manure and fertilizers are added to it and soil pH adjusted to 5.5 to eliminate the aluminum toxicity. Multiple cropping, inter-cropping, relay cropping, inclusion of legumes in rotation, strip cropping etc. ensure better crop productivity, besides maintaining soil fertility. The optimization of the plant nutrient management for the productivity of agricultural systems should be conceived according to the system mobilizing natural resources in order to sustainably increase farmers' output. Plant nutrients in crop residues, litter from forests, cattle manure and domestic-waste composts comprise the working capital of plant nutrients because farmers can transfer and allocate those nutrient sources to a particular crop (e.g. ginger) in a crop rotation and to a particular plot (e.g. vegetables). The legumes in farming systems are essential to ensure and sustain agriculture with a moderate level of agricultural output. The integrated plant nutrient system (IPNS) promotes to increase the efficiency of applied chemical fertilizers by adopting the best time, method and source of application and utilizing sources other than chemical fertilizers such as organic manure, bio-fertilizers etc. to meet part of the nutrient needs of crops and cropping system (Prasad, 1997). IPNS is a step in the direction of sustainable agricultural development through necessary modification of the conventional technology to improve soil health. Efforts are needed for its adaptability at farmers level, because in most of the cases in Sikkim farmers have the availability of organic manure.

Afforestation and Agroforestry

Forests, hydrologically and from the erosion control point of view, provide more protection due to closed system as long as they are maintained as forestlands. Even after cutting, re-growth of vegetation quickly restores any hydrological or erosion impacts to pre-harvest level, at least in the more humid zone. Open/degraded forestland + forest blank + scrubs in reserve forest and alpine scrub occupy 38% of the geographical area (2709km^2) (Anonymous, 1994). In order to restore these areas an integrated approach is needed through afforestation to change the unpleasant look into pleasant view of the site. Restoration or afforestation makes the unproductive lands to productive by minimizing erosion and rebuilding of nutrient budget. In the initial stage severely eroded lands, require complete forest cover of local origin coupled with protection from grazing. The local perennial tall tufted grass species amliso (*Thysanolaena agrostis*) can reclaim and protect the degraded land, terrace risers, water ways, land between trees, and vulnerable points, provides fodder to animals in winter and spikes for brooms.

Appropriate agro-forestry systems have the potential to check soil erosion, maintain soil organic matters and physical characteristics, augment nitrogen buildup through nitrogen fixing trees and promote efficient nutrient cycling. In Sikkim, agro-forestry is an integral part of the farming system, where trees are integrated extensively with crop and livestock production. Large cardamom with shade trees on hill slopes unsuitable for crop production is ecologically sustainable. The combination of trees, grasses, herbs and shrubs along with large cardamom plantation arrest the flow of water, reduce the risk of soil erosion and water pollution hazards. Besides this, fodder trees are extensively grown around the settlement, roadsides, on field bunds and small patches of land among the terraces serve as a lean fodder to animals. Bamboo thickets along the drainage channels on steep slope, grasses on terrace risers and on marginal land stabilize the soil against degradation and gives production from land occupied. The multistory homestead gardening and mandarin (*Citrus reticulata* Blanco) based cropping system possess the inherent capacity to arrest land denudation. All the existing systems optimize the positive interaction among components (trees/shrubs and crops/animals) to obtain a more diversified and/or more sustainable production from the available resources and physical environments that is possible under socio-economic conditions. The variation of climate due to altitude further provide ample scope for growing a variety of agricultural crops, multipurpose tree species and fruits of tropical to temperate climates in Sikkim for the effective utilization of land under agro-forestry for its sustainability.

Proper land use planning

The land use planning is the systematic assessment of physical, social and economic factors in such a way so as to encourage and assist land users in selecting options that increase their productivity with sustainability and meet the needs of society (FAO, 1993). The planning decisions may not always be scientific because of conflicts among sectoral interests, government policies and the priorities of landowners. Therefore, planning decisions for implementation should be based on compromisation among several interests without risking the principles of land capability, sustainability and environmental security for agriculture, forests, horticulture, grasslands, urban development, mining, infrastructure facilities, recreation and others. Suitable planning of land use with reference to the nature of land and needs of the community would provide maximum returns of optimum land resources.

The planning of area development can be best tackled on a natural drainage unit called 'watersheds' with a view to develop resources in such a manner so as to get maximum benefits to the people by maintaining ecological balance through continued long-term efforts and commitments for example maintenance of infra-structure, protection and judicious use of land, water and forest resources to meet the continued demands, etc. In order to implement the land use planning at catchment for the hilly terrain of Sikkim should be based on following objectives:

1. Optimization of production from agriculture, forests, plantation (large cardamom), mixed farming systems and others on a sustained yield basis for self-sufficiency in basic needs.
2. Control of land degradation to their primary production potential.
3. Development of wasteland for profitable bio-mass production.
4. Exploitation of important mineral resources with proper planning for rehabilitation of mined areas.
5. Efficient utilization of perennial water resources by reducing run-off and sedimentation.
6. Provide the security for food, fodder, fibre, fuel, timber etc.
7. Protection of scenic beauty, natural vegetation, wildlife and birds of montane region for appreciation to next generation.
8. The modification of indigenous knowledge based on latest technical know-how by inter-generational wisdom of local inhabitants of the region through native means to suit their conditions.

In order to ensure optimum and proper utilization of land resources, State Land Use Board was constituted in 1984 to provide highest forum for policy, planning and coordination of all issues connected with healthy and scientific management of land resources. Board is also taking initiative to create public awareness for environmental protection through support mobilization. The National Watershed Development Project for Rainfed Areas (NWDPRA) is being implemented on micro-watershed basis (500-800ha) at 12 sites, covering total area of 7691 hectares through 4700 farming families being benefited during 8th Plan. During 9th Plan 30 new watersheds will be taken to implement the scheme with an area of 30,000 to 40,000 hectares. The department of Agriculture is implementing various programmes for watershed development with the aims and objectives of natural resource base development, sustainable farming systems, improving the standards of poor farmers and landless labourers and restoration of ecological balance. The forest department has taken to plant trees in the ecological fragile areas and located in the catchment of power projects and water supply schemes. Watersheds are also being treated under River Valley Projects in South and East districts and catchment area of Rangit hydroelectric project in South and West districts. Through Natural calamity scheme and other activities, priority is given to the treatment of landslide affected village holdings. Jhora (drainage) training works are carried out to prevent bank erosion and safe disposal of run-off in rainy season. Some slopy lands under watershed programmes with appropriate soil and water conservation practices have become quite productive taking into consideration economy and environmental risks. The preservation of natural ecosystems, scenic areas and wildlife habitat represent another dimension of many watershed projects. The preservation of some ecosystems, particularly those with threatened species, could be in the interest of ecology and society as a whole. In such instances, the importance of an ecosystem may not readily be evaluated on the basis of economics, but the expected benefits should be explicitly described in the appraisal. High quality water is usually associated with forested watershed that are well managed, having sparse human populations, few grazing animals and least soil erosion. According to established practice, climate, soil, land form, hydrology etc. of an area, the human intervention should be restricted to the choice of a crop, a livestock or a forest type.

Diversification

The research conducted in USA showed that less crop diversity can slow development resulting soil degradation, more losses to pests and adaptation of crops to pests by loosing resistant (Barneet *et al*., 1990). Diversification as a concept is based on agricultural organization developed over generations for future utilization. We are only reaffirming and transferring the advantage of this system, in the face of our changing times. Diversification improves the mobilization of the diverse resources and production conditions available on the farm while improving the use and productivity of available labour, capital and skills. The diversification of the crops in crop sequence is a proven way of upgrading the efficiency of plant nutrition management to explore the nutrient requirement from different soil layers. Most of the nutrients consumed by livestock are returned via manure for nutrient cycling to field crops. The tree component for feed, fruit, fuel and timber as a component of diversification is important for livestock, human needs and shade for some crops (tea and large cardamom). The association of perennial crops and annual crops with relay cropping creates basic changes of water and plant nutrient availability as compared to pure, perennial crops, this combination modifies crop cycles, the competition for light and water between species and the demand for plant nutrients. Diversification empowers small-scale farmers, increasing their technical know-how and decision making capacity and promoting adequate changes in land use, crop rotations, interaction between forestry, livestock systems and cropping systems in support of sustainable development and an important component of risk management. Thus, diversification is a key component for necessary and sustainable progress of agricultural production in order to meet the growing demand while the size of farms is decreasing regularly with time.

Alternate agriculture and holistic approach

Sustainable agriculture is based on ongoing production to maintain equilibrium with the changing demands of the growing population in order to prevent further degradation of the resource base and problems of nutrient removal. The alternative agriculture integrates and takes advantage of naturally occurring beneficial relationships, such as those between pest and predator, and natural process of nitrogen fixation instead of chemically intensive methods to reduce the harmful off farm effects of production practices. The technology should be planned keeping in mind that its main beneficiaries are non-commercial subsistence or resource poor farmers in order to obtain higher yields on a sustainable basis. The development and transfer of technology can be divided into those which focus on problems of adoption (location constraints and incentives at the level of individual farmers and communities) and those which relate more to the sustainability of the technology transfer, particularly regarding institutional and infra-structural weakness. Okigbo (1991) emphasized the need for a system engineering approach of sustainability within a holistic management framework rather than a compartmentalized thinking. The holistic approach is often refereed to examine totalities the research priorities developed over the years. Catizzone (1994) suggested 15 basic points in formulating a holistic approach for the understanding of those basic points essential both to identify problems on the technical and scientific level and to solve them by research. Swift *et al.* (1994) opined that the goal of sustainability of agriculture can be achieved through participatory research which involves the full participation of the farmers as a part of inter-disciplinary team to identify the research problems jointly which can be reorient research needs to achieve the desired results. The goal depends on creative and innovative conservation, restoration and production practices that provide farmers with economically viable and environmentally sound alternatives or options in their farming systems (Parr *et al*., 1990). It poses major research questions for both natural social scientists and a multi-disciplinary framework for sustainable land management has yet to be agreed. The problem of soil degradation therefore calls for a holistic and multi-disciplinary solution to sustainable land use system for Sikkim hill terrain which are given below in brief:

Horticulture

The wide agro-climatic variation of Sikkim from sub-tropical to alpine provides scope for growing a large number of fruits like mandarin (orange), guava, mango, banana, avocado, peach, plum, pear, apple etc., all kinds of vegetables and flowers like orchids, gladiolus, ornamental and house plants. The lands that are not suitable for seasonal crops and lying barren and unproductive could be covered with orchards to generate additional income for farmers without causing land degradation. The preliminary trials indicated that kiwi fruit (*Actinida* sp.) (Chinese goose berry) can be grown in the mid-altitude of the state. The hills between Melli and Namchi having low elevation and less rainfall, guava, aonla, pomegranate, mango, ber (*Zizyphus* sp.) etc. would be a profitable commodity, where failure of seasonal crop is a regular feature. Orange grown below 1500m is very much popular for its excellent quality, need orientation to promote the area and agro-techniques for production on sustained basis. Apple can come up well around 2500m with proper selection of planting material and disease control. The popular Rabi vegetables could be grown successfully at high hills above 2000m during summer. In some areas farmers have adopted this practice with the cooperation of Horticulture Department of the State Government through vegetable development programme. Sikkim is famous for orchids from sub-tropical to sub-alpine zone. To promote floriculture, three floriculture cooperative societies (Namchi, Turuk and Gangtok) have been established for the promotion of *Cymbidium* orchid and other commercial flowers.

Among the commercial crops large cardamom (70% of world) and ginger is well adopted into the farming system of Sikkim. Large cardamom plantation is economically viable and ecologically sustainable agro-forestry system despite low average yield (around 200kg dry capsule/ha) on steeply slopy lands. This system is a major source of cash to supplement subsistence farming and has considerable unrealized potential (Patiram *et al.,* 1996). The yield and sustainability of system can be increased considerably through maintaining optimum plant population '*chirkhe*' and '*furkey*' virus disease free high yielding cultivars, uprooting and burning/covering deep in soil diseased suckers, proper shade, curing techniques of capsules and marketing. The cultivation technique of ginger not only replenishes the nutrients removed but also has a positive effect on soil quality (Patiram *et al.* 1995). There is a need to select the ginger rhizome rot resistant variety to get higher yield for the economically poor farmers' cash crop that is the main constraint for production.

Livestock-based farming

Livestock forms an integral part of village life of Sikkim. The rearing of different species of animals (cattle, sheep and goat, yaks, pigs, poultry, etc.) is done for draught, milk and meat purposes and these animals also provide manure to meet the crops requirement of nutrients. The government is also providing the necessary inputs through its various departmental schemes for the development of livestock. The production of dairy cattle on small land holdings in the rural area in conjunction with primary agriculture production creates employment and contributes substantially to domestic income and obtaining better utilization of farm resources. Rabbits and goats are the possible alternative to pig production by making available food scraps, crop by-products as well low quality forages for meat production without competing with human food. In Sikkim plenty of grasses are available during the monsoon periods and scarcity only occurs in winter (November to March). Cultivation of fodder crops on agricultural lands is impractical due to constraints of land availability and other inputs. Here number of natural feed resources (tree leaves, grasses, shrubs and vines) is available. The only practical alternative is available to encourage the propagation and planting of fodder tree species and grasses on village waste and marginal lands, community grazing lands, out scrub between and around the farm boundary etc. under different afforestation programme for their lopping of leaves to meet the feed requirement during lean period. The leaf of some fodder trees is almost as nutritious as that of leguminous fodder crops and offers an added advantage of producing fuel wood as a by-product. Leguminous fodder trees (*Albizia* sp; *Alnus nepalensis*, and others) enrich the site through nitrogen fixation, which helps in effective soil and water conservation.

Development in pre-urban areas

Urbanization in Sikkim after 1975 is proceeding at a rate that is without historical precedent. Urban development is very beneficial for the overall development.

- agricultural products need stimulate supra-regional marketing;
- supply of rural areas with higher quality goods and services;
- infrastructure necessary for the development of local resources to increase the agricultural productivity;
- job for rural sector migrants for the preservation of ecological viability.

However, the development of cities are facing environmental problems within their boundaries and surrounding rural areas. These are: (a) city expansion on agriculture land and on slopy hills-ecologically not suitable; (b) use of stones for building materials through quarrying; (c) mass movement of soil during monsoon; (d) disposal of solid waste and land disposal of sewage water and effluents; (e) water pollution from agricultural chemicals as a result of intensive agriculture and horticulture and (f) conflicts between recreation, farmers and natural resource departments. All these problems require systems oriented research approach to identify the problems on the technical and scientific level. The development of cities has no limits, the technical personnel should not ignore the many existing interaction between urban rural areas.

Development of sustainable hill farming

The indigenous farming systems developed for the hill agriculture of Sikkim were also conservative. The increasing population pressure without modifying the system has resulted in a number of areas, serious soil degradation problems. The design of farming system is the need of hour that would permit continuous sustainable production and the same time well adapted to the requirements of farming community. Sound soil conservation and soil management practices should be an integral part of such farming system, to suit the specific location conditions of the varying elevations of Sikkim hills. The research on different farming systems for hills of north-eastern region is in progress since 1983 at ICAR Research Complex for NEH Region, Barapani, Meghalaya to assess the environmental impact of systems and their sustainability on steep slopes (Prasad, 1990). The eight years results revealed cropping system/livestock was economically viable and integration of livestock in the farming systems enhanced the income, provided manure for soil health and family labour utilization. In economic terms, there is great potential for the development of commercial production of tree and perennial crops (large cardamom, tea, coffee, black pepper etc.) on the slopes of tropical hills for export market.

Infrastructure development

The development of roads, power plants, schools, hospitals, and commercial centres are the basic need of the people for all round development. Large number of landslides occurs during rainy season particularly with the construction of large numbers of roads to meet the internal demands as well as defence. During road construction steep rocky hill slopes interspersed with more weathered rock or truncated weathering profiles, which is subjected to down slope movement by wash and creep, frequently disturbing the social and economic activities of the state. For the proper functioning of road, the long-term benefits of effective conservation can be realized with the coordinated approach of geologist, civil engineer, soil scientist, forester, geographer etc. in the initial period of the way of the road selection. The second requirement is to use hydroelectric power resources properly without inflicting serious human or environmental damage. A series of small projects, meeting the needs of the people and medium industries, offer Sikkim the best way to develop in a sustainable manner.

Artisan manpower development

In Sikkim, traditional handicrafts represent the physical manifestation of tradition, whose value transcends the economic and on the other hand, they hold the potential to create a vibrant rural economy. The Sikkim traditional crafts, which include beautifully hand-woven carpets, rugs and blankets and former is a combination of attractive rich colours and also quite popular in foreign countries. There are also available Lepcha weaver bag, shawls, and jackets and delicately hand carved beautiful tables (choktsis), stools and screens of typical Sikkimese styles are manufactured by Bhutias. The different species of bamboo are used for baskets, mats, wine vessels, cooking utensils, house building, furniture, shoots as vegetables, water vessels etc. Institutional support has been instrumental in the revival and revitalization of traditional crafts through education, training and financial support. The indigenous handicrafts and handloom along with other rural development initiative would not only generate jobs, but also keep alive the land resources, its biodiversity for protection.

Eco-tourism

Sikkim has the congenial environments of tourism; they are rafting rivers, deep gorges, snow-clad peaks, alpine pastures, hot springs, trekking routes, yak safari, rhododendrons, undisturbed forests, monasteries etc. and friendly, hospitable multi-coloured people. Within a matter of hours one can move from the sub-tropical heat of the lower valleys to the cold of the rugged mountain slopes up to perpetual snow. At higher elevations above 2000m eco-tourism is the other way to meet the people's needs through alternative employment opportunities leaving the land in natural way to maintain the beauty of Sikkim. Sikkim government is providing facilities for the attraction of tourists in the state. Attention is needed to develop the moral duty of trekkers and tourists to make the environment pollution free to bury raw garbage (waste paper, card board, baskets, plastic wrapping and cup, water bottle, aluminum can etc.) or burn the inflammable items. Proper care is needed to check the burning of rhododendrons and junipers as firewood. There should be strict legislation for tourists to admire the beauty of nature's gifts not to be uprooted or collect the colourful flowering herbs and medicinal plants of the alpine region.

Table 1. Area of forest cover and land use (Anonymous 1994)

Particulars	Area (km^2)	% Geographical area
1. Cultivated land	776.74	10.95
2. Forest cover	2847.81	40.13
Forest blank, scrub in Reserve forest and alpine scrub	836.59	11.79
4. Alpine pasture	433.00	6.10
5. Alpine barren and Snow/glaciers	2051.93	28.92
6. Built-up area	3.52	0.05
Others (water bodies, dry river bed, land slide/rock outcrop)	146.41	2.06
Grand Total	7096.00	100.00

Suggestions for sustainable land use

1. Multidisciplinary approach for identification of priorities to research and adoption of technologies for better utilization of land, maintenance of soil fertility and rehabilitation of degraded lands.
2. Behaviour of land systems in relation to various types of land use by human societies in Sikkim hills effecting soil forming processes, degradation and problems of product quality.
3. Involvement of local population in identifying the problems of land resource, degradation, constraints and opportunities to change land use through research, extension and training for solution to their future generation's survival.
4. Survey and complete inventory of the landscape, crop and non-crop plants, forests, wild animals, fish, domesticated animals, catchment areas etc. for the holistic approach to check the habitat degradation including soil.
5. Recognition of people who produce land resources to create interest for soil building.
6. Development of eco-tourism as an alternative employment opportunity at higher elevation where land use and farming systems cannot provide quality of life and standard of living.
7. Identification of alternative means of achieving objectives of production as well as conservation in relation to questions of timing, scale, location and technology choice.

Table 2. Average monthly suspended silt load in Teesta

Months	Chungthang (ham)	Dikchu (ham)
January	0.187	0.494
February	0.119	0.482

March	0.344	1.497
April	0.853	11.820
May	4.058	36.665
June	20.323	92.375
July	24.042	148.353
August	15.720	132.256
September	8.410	61.425
October	2.056	10.000
November	0.725	1.540
December	2.239	1.184

ham= hectare meter

Table 3. Physiography of Sikkim

Physiographical unit	% Area
1. Summit and ridge	4.50
2. Escarpments	5.76
3. Very steeply sloping (70%)	19.02
4. Steeply sloping (33-50%)	33.49
5. Moderately steep sloping (15-30%)	2.21
6. Valleys	1.22
7. Cliff and precipitous slope	12.20
8. Glacial drifts/moraines/boulders	3.59
9. Perpetual snow	14.01

References

Anonymous 1981. *Report of High Level Team for Land Use Plan of Sikkim*, Govt. of India, Planning Commission, New Delhi

Anonymous 1992a. *Soils of Sikkim for Land Use Planning*. National Bureau of Soil Survey and Land Use Planning, Nagpur.

Anonymous 1992b. *Indian Agriculture in Brief.* Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Anonymous 1994. *Forest Cover Mapping Through Digital Image Proceeding of Indian Remote Sensing Satellite Data with Special Reference to Sikkim*. Forest Department, Government of Sikkim and Regional Remote Sensing Service Centre, Kharagpur.

Anonymous 1996. *Sikkim State Annual Plan* 1996-97. Planning and Development Department Government of Sikkim, Gangtok.

Barrett, G.W., Rodenhouse, N. and Bohlen, P.J. 1990. Role of Sustainable Agriculture in Rural Landscapes. In: *Sustainable Agricultural Systems*, (Eds.) C.A. Edwards, R. Lal, P. Madden, R.H.Miller and G. House, pp. 624-636. Soil and Water Conservation Society, Ankeny, Iowa.

Catizzone, M. 1994. Soil Science Research in Developing countries: Towards a Holistic Approach. In: *Soil Science and Sustainable Land Management in the Tropics*, (Eds.) J.K. Syers and D.L. Rimmer, pp. 268 - 274. CAB International, Wallingford, U.K.

FAO 1991. *The den Bosch Declaration and Agenda for Action on Sustainable Agriculture and Rural Development*. Report of the Conference, FAO, Rome.

FAO 1993. *Guidelines for Land Use Planning*. FAO Development Series 1, Rome.

Greenland, D. J. 1994. *Soil Science and Sustainable Land Management. In: Soil Science and Sustainable Land Management in the Tropics*, (Eds.) J.K. Syers and D.L. Rimmer, pp. 1 - 15. CAB International, Wallingford, U.K.

Hillel, D. 1991. *Out of Earth* . University of California Press, Berkeley, California.

Khoshoo, T. N. 1992. *Plant Diversity in the Himalaya*: *Conservation and Utilization*. G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal.

Okigbo, B.N. 1991. *Development of Sustainable Agricultural Production systems in Africa*. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Patiram, Rai, R. N. and Singh, K.P. 1991. Application of dolomitic limestone enhances crop yields in the acidic soils of Sikkim. *Indian Farming 41 (1): 18 -20.*

Patiram 1991. Liming of acid soils and crop production in Sikkim. *J. Hill Res. 4(1) 6 - 12.*

Patria 1994. Furrow application of lime is economical to rectify the acid soils of Sikkim. *Indian Farming 44 (5): 21.*

Patiram, Upadhyaya, R.C. and Singh, L.N. 1995. An appraisal of ginger (*Zingiber officinale Rosc.*) production in Sikkim, *India. J. Spices and Aromatic Crops 4(2): 111 -118.*

Patiram, Bhadauria, S.B.S. and Upadhyaya, R.C. 1996. Agroforestry practices in hill farming of Sikkim. *Indian Forester 122 (7): 624 - 630.*

Patiram 1996. Effect of limestone and farmyard manure on crop yields and soil acidity on an acid Inceptisol in Sikkim, India. *Trop. Agr.* (*Trinidad*): *73(3): 238 - 241.*

Parr, J.F., Papendie, R.I., Youngberg, T.C. and Meyer, R.E. 1990. Sustainable Agriculture in the United States. In: *Sustainable Agricultural Systems,* (Eds.) C.A. Edwards, R. Lal, P. Madden, R. H. Miller and G. House, pp. 50 - 67. Soil and Water Conservation Society, Ankey, Iowa.

Prasad, R. N. 1990. *Farming System Research Project*. ICAR Research Complex for NEH Region, Barapani, Meghalaya.

Prasad, R. 1997. Integrated plant nutrition supply system - agronomic perspective. *Proc. Intern. Workshop on Integrated Plant Nutrition System*, Bhubaneswar (March 10 - 12, 1997): *40 - 49.*

Shaxson, T.F. 1981. Developing Concept of Land Husbandry for the Tropics. In: *Soil Conservation, Problems and Prospects*, (Eds.) R.P.C. Morgans. Pp. 351-302. John Wiley and Sons, Chichaester, England.

Shaxson, T.F., Hudson, N.W., Sanders, Dwi. Roose, F. and Moldenhauer, W.C. 1989. *Land Husbandry: A Framework for Soil and Water Conservation.* Soil and Water Conservation Society, Ankeys Iowa.

Swift, M.J., Dvorak, K.A., Mulongoy, K., Musoko, M., Sanginga, N. and Tian, G. 1994. The Role of Soil Organisms in the Sustainability of Tropical Cropping Systems. In: *Soil Science and Sustainable Land Management in the Tropics* (Eds.) J.K. Syres and D.L., Rimmer, pp. 155 - 172. CAB International Wallingford, UK.

Theng, B.K.G. 1991. Soil Science in the tropics - the next 75 years. *Soil Sci. 151 (1): 76 - 90.*