Integrated Farming Systems for Nutrient Recycling and Food Security

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Soil, water and associated plants and animals, together constitute an important part of our natural resource endowment. Land provides food, fuel, fodder, shelter besides supporting secondary, other economic activities and life supporting systems. It is, therefore, that the land has been preserved continuously in a manner so that life can be supported externally on earth, without the fear of extinction. Similarly, water is also vitally linked with sustenance of life. The pressure on land resources, already severe has been aggravated by an indiscriminate expansion of cultivation on marginal lands which are better used for pastures, trees or other uses. As a result, problems of soil erosion, deforestation and land degradation have grown in dimension and become more difficult to tackle.

Hill agriculture is confined to Indian Himalayas which spread through 14 states in Western and Eastern regions and cover about 16 per cent of the geographical area and 4 per cent of the total population of the country. Physiographically, the Himalayan zone could be divided into 3 distinct sub zones of high Himalayas (> 3000m), middle Himalayas (900 - 3000 m) and lower Himalayas (< 900 m). The Indian Himalayan Region (IHR) is spread between 21°57' – 37 ° 5'N latitudes and 72 ° 40' – 97 ° 25'E longitudes. It has an area of 5,31,250km^2 spread over 12 states and constitutes about 16.16% of India's total geographical area. This great chain of mountains in Indian territory extends all along the northern border of the country from the eastern border of Pakistan on the west to the frontiers of Myanmar in the east for about 2,500 km with an average width of 240 km. Orographically the Himalayan mountain system is divided into Greater Himalaya (*Himadri*) - area above the main central thrust consisting of snow-clad peaks, glaciers, and ranges of majestic mountains; Lesser Himalaya (*Himanchal*) - separated from the *Himadri* by the 'main central thrust' in the north and by the 'main boundary thrust' in the south, consisting of high mountains cut into deep ravines and precipitous defiles; and the Sub-Himalayan tract (*Sivalik*) - the foot-hill belt of the region - consisting of latest geological formation of loose boulders and soil. The Kashmir Himalaya occupies a geographical location between latitudes 32 ° 17' - 37 ° 5'N and longitudes 72 ° 40' - 80 ° 30'E, with a total area of 2,22,236km^2. The region lies at a strategic position in India with its borders touching Afghanistan in the north-west, Pakistan in the west, and China/Tibet in the north. Almost the whole of the Kashmir Himalaya is covered by a series of parallel mountain chains running in NW-SE direction. The region has three prominent thrusts, *viz*., Murre, Panjal and Zaskar thrusts. The whole region can be differentiated into four broad groups *viz*., Karakoram, Ladakh, Zaskar and Pir Panjal, and these huge mountain ranges are separated by deep gorges forming the valleys of the Shyok, Indus, and Jhelum rivers, respectively. The Himachal Himalaya lies between the latitudes 30 ° 23' – 33 ° 13'N and longitudes 75 ° 43' – 79 ° 4'E with a total area covering 55,673km^2. The state of Himachal Pradesh lies to the south of Kashmir. The state is bound in the east by Tibet (China), Garhwal region of Uttar Pradesh in the south-east, Punjab in the south-west, and in the south by Haryana. The region presents an intricate mosaic of mountain ranges, hills, and valleys and is known for its natural beauty. The Dhauladhar range in its supreme majesty overlooks the Kangra valley, while the Pir Panjal, the Great Himalaya and the Zaskar ranges stand guard over

Chamba, Lahaul-Spiti, Kullu and Kinnaur respectively. The Uttar Pradesh Himalaya popularly known as Uttarakhand is geographically located between latitudes 29 ^{o} 5' – 31 ^{o} 25'N and longitudes 77 ^{o} 45' – 81 ^{o} E covering an area of 51,124km^{2}. The Tons River separates the region from Himachal Pradesh in the north-west, while Kali separates it from Nepal in the east. Starting from the foot hills in the south the region extends upto the snow-clad peaks of the *Himadri*, marking the Indo-Tibetan boundary. The region being situated centrally in the long sweep of the Himalaya forms a transitional zone between the per-humid eastern and the dry to sub-humid western Himalaya. The region comprises of two administrative units, Garhwal (north-west portion) and Kumaon (south-east portion). The Eastern Himalayan region lies between the latitudes 26 ^{o} 40' - 29 ^{o} 30'N and longitudes 88 ^{o} 5' – 97 ^{o} 5'E and covers a total area of 93,988km^{2} comprising Arunachal Pradesh, Sikkim and Darjeeling hills of West Bengal with 83,743, 7,096 and 3,149 km^{2} of area respectively. In the north, the *Himadri* marks the international boundary with Tibet, which corresponds with the internationally accepted, well-known McMohan Line in the north-east. The Singalila range separates the region from Nepal in the west, while the Burma ranges of the Assam valley mark the eastern and southern boundary of the region. The Kingdom of Bhutan located between the Tibetan plateau and Assam-Bengal plains of India, separates Sikkim and Darjeeling hills from Arunachal Pradesh. The eastern boundary of the kingdom is Arunachal Pradesh while it is separated from Sikkim Himalaya by the Chumbi valley in the west. Purvanchal Himalaya is the eastern extension of the concealed Peninsular Block of Shillong Plateau. This block merges in the Tertiary ranges of the Purvanchal Himalaya, which belongs to the great Arakan consisting of tightly packed parallel ridges and valleys. The Purvanchal Himalaya lies between the latitudes 21 ^{o} 5' - 28 ^{o} 23'N and longitudes 91 ^{o} 13' - 97 ^{o} 25'E, covering a total area of 108,229km^{2} comprising Assam Hills (15,322km^{2}), Manipur (22,327 km^{2}), Meghalaya (22,429km^{2}), Mizoram (21, 081km^{2}), Nagaland (16,579km^{2}), and Tripura (10,491km^{2}). The region is extended in NE-SW direction touching the Tirap district of Arunachal Pradesh in the north-east and Chitagong Hill Tracts of Bangladesh in the south-west while the Assam valley is the northern boundary. The region lies at a strategic position in North-East India having international boundary both in the east and the west with Myanmar and Bangladesh respectively. The constraints of hill farming are manifolds and as such noted hereunder.

- Undulating topography, small fragmented and scattered land holdings, with very limited use of inputs
- Due to the slopes, soils are prone to erosion, which is aggravated by heavy migratory grazing leading to soil degradation.
- The land is inaccessible, and infrastructure, communications and mobility are obstructed by different physical, climate, biological and socioeconomic factors.
- Despite sufficient water resources, irrigation facilities are meager, and most agriculture depends on rainfall.
- Improved technology has largely remained confined to irrigated areas and commercial crops.
- Shortage of energy and labour, especially women and children, which constituted 75-80 per cent of family labour, due to their engagement in other activities.
- Natural hazards like intense rainstorms, hailstorms, floods, epidemic diseases, insects and an erratic monsoon.
- In some regions monkey, wild pigs, stray animals and birds are menace to crops.

- Reducing areas of cultivable land due to house construction, and land use for non-agricultural purposes

Mountain ecosystems are generally fragile. Biophysical characteristics of mountain areas combined with inappropriate land use can lead to major and often irreversible environmental damage. In terms of agricultural production, mountains have a low carrying capacity and the exploitation of natural resources is limited. The delicate human life-support system which has evolved over centuries is highly vulnerable if subjected to increased external pressure. Inaccessibility is due to the particular terrain in mountain areas. It is a primary cause of the physical isolation of mountain people. Steep slopes and harsh conditions challenge mobility. The establishment and maintenance of infrastructure is difficult and expensive. Therefore, transport costs to mountain areas are higher. This reduces the ability to trade and affects the supply, availability and price of agriculture inputs, such as seeds, fertilizers or pesticides, which are needed for food production. It also reduces the availability of affordable foods other than those that can be obtained locally, and limits income generation opportunities, thereby undermining household food security. As noted earlier, inaccessibility also reduces access to social services, negatively affecting the health and education standards of mountain communities. Marginality is the outcome of both fragility and inaccessibility but is also closely associated with historical and political processes. This is as true in the Appalachia of the United States as it is in the Hindu Kush Himalaya or the Andes. While the reasons which led to this marginalization may be long forgotten, the cultural gap remains and is strongly embedded in language and traditional practices. Marginality leads to the separation of mountain people from mainstream economies and greater dependence on the natural resources available in mountains, with clear implications for the ecological balance of the natural resource base. Lack of understanding of mountain communities by government institutions has led to inappropriate decision-making and under-estimation of indigenous knowledge, experience and economic systems. As a result mountain people often have had to adapt their livelihoods to policies, laws and interventions that further compromised their access to food and productive resources undermined their knowledge system and social organization and marginalized them further. Food consumption patterns are one of the main characteristics of local cultures: they reflect local food availability but also people's knowledge and perceptions, traditions and social organization. While this is clearly the case everywhere in the world, it is particularly true of marginalized mountain communities which have been less exposed to external influences and in particular "modern" or "scientific" information. It is important to keep fragility, inaccessibility and marginality in mind when trying to understand the causes of food insecurity/malnutrition in mountain areas.

Food security

Food security is defined by access to sufficient and affordable food; it can relate to a single household or to the global population. The first Millennium Development Goal (MDG) falls short of food security aspirations in seeking only to reduce by half the proportion of the world's population experiencing hunger. Furthermore, governments signing the Millennium Declaration were overriding a tougher commitment made just 4 years earlier at the World Food Summit of 1996 which applied the same target to the *number* of people. The first of two benchmarks for measuring progress is the "minimum dietary energy requirement" for each person as stipulated by the UN Food and Agriculture Organization (FAO). This naturally

varies by age and sex so that a weighted average is calculated for each country based on its population profile; typically this average is just below 2,000 kilocalories per day. Despite the political commitment to reduce world hunger, the number of people lacking access to this minimum diet has risen from 824 million in the baseline year 1990 to 963 million in 2008. A further 750 million are assessed to be at risk. Only one third of developing countries have succeeded in reducing hunger during this period. Even on the less demanding MDG basis, hunger has fallen only from 20 per cent to 17 per cent of the population of developing countries. Prospects for achieving the 2015 Goal will be further diminished by the impact of the current economic crisis on poorer countries; the FAO has already warned that its latest figures may be conservative. Sub-Saharan Africa and South Asia are the regions most affected. There are 15 countries in Africa where the incidence of hunger exceeds 35% of the population. Almost half of all young children in India are underweight. Malnutrition impairs the ability to learn or to work and reduces resistance to disease, these problems increasing in severity with the shortfall from the minimum dietary requirement. Hunger is therefore a cause as well as a consequence of poverty. Children's health and cognitive development are especially sensitive, to the extent that the majority of child mortality is attributed to malnutrition. The second MDG indicator is therefore the proportion of children under five years who are underweight in relation to their age. This figure has reduced only from 32 per cent to 27 per cent in the period 1990-2006.

Poverty is widespread in rural areas of India particularly in the Himalayas, which is caused by marginalization, deprivation and exclusion of certain section of communities, and characterized by the food deficit and malnutrition, inaccessibility to health and education, inability to participate local governance, and vulnerability to insecurities. Rural livelihoods are also prone to dispossession phenomenon. Organizing and empowering the communities, institutionalization, training, education & extension, research, and technical/market support are the principal strategies to improve the livelihoods and food security of poor families. Loss of genetic diversity coupled with inequity in the society rapidly imperils the native landraces and overall sustainability of the agriculture systems in both Western and Eastern Himalayas.

This primacy of market economics over the last 20-30 years, often imposed on developing countries by international financial institutions, is arguably the major cause of current food insecurity. The micro-profile of agriculture - there are 450 million farms of less than 2 hectares in developing countries – has been deemed unsuitable for investment. The proportion of foreign aid allocated to agriculture has fallen from 18 per cent in 1979 to less than 3 per cent. African governments have therefore struggled to meet their 2003 Maputo Declaration commitment which called for 10% of national budgets to be dedicated to agriculture by 2008. Whilst overall population growth creates pressure on food security, it is secondary to the failure of equitable distribution and consumption. Since 1961 world production of food has outpaced population growth. Feeding over a third of the world's grain production to animals is the more significant indicator. As 7 kg of grain is required to produce 1kg of beef, there is an argument that meat production on this scale impedes the goal of global food security. Projections that demand for food will double by 2050 far outpace estimated population growth of about 40 per cent in that period.

In the eastern Himalayas, there is a food grain deficit of 24 per cent, deficit in meat (45 per cent), egg (87 per cent) and fish (48 per cent). Food grain availability in eastern Himalayas undergoes variability from 186 to 83 kg/annum (fig. 1).

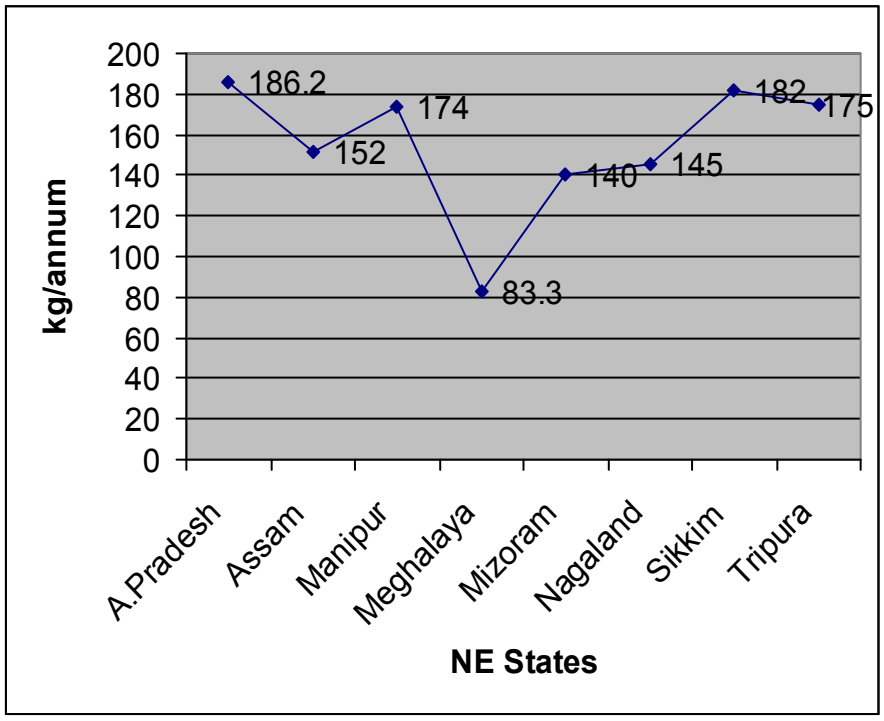


Fig.1. Food grain availability in Eastern Himalayas

The demand for food grain in India is expected to reach a level of 423 million tones and 301 million tones in 2025 using 250 kg and 200 kg food requirement /annum, respectively.

Table 1. Demand (million tonnes) for food grain

India	**2011**	**2021**	**2025**
High	315	385	423
Low	247	286	301
High- 250 kg/annum, Low- 200 kg/annum			

Integrated farming systems –concepts

The concepts of integrated farming systems (IFS) lie in watershed technology which was initiated in 1949 by Damodar valley Corporation through rural development programmes including afforestation, pasture, shelter belt plantations and sand dune stabilization. Actually, watershed management is of major concern in agricultural development considering the whole gamut of soil, water and associated plants/animals in the natural resource endowment. It takes into account of the land providing food, fodder, fuel, shelter besides supporting related economic activities and life supporting systems. In an integrated manner, it reflects awareness for ameliorative measures to check soil erosion, improve moisture retention capacity and natural fertility status of soils**.** The components of IFS to achieve the self sufficiency in food are of many dimensions as noted hereunder.

- Crops (Cereals/pulses/oilseeds).

- Vegetables.
- Fruit crops (Tropical/subtropical/temperate fruits).
- Spices/plantation crops.
- Livestock based systems.
- Fishery components.
- Agro forestry.

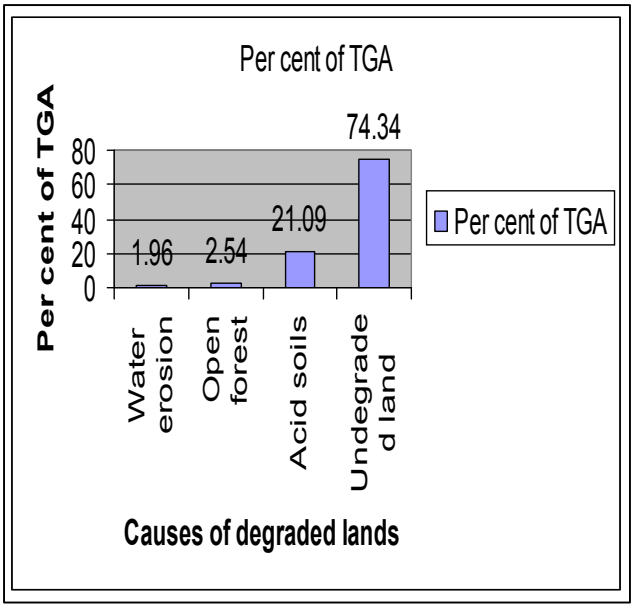
Land degradation

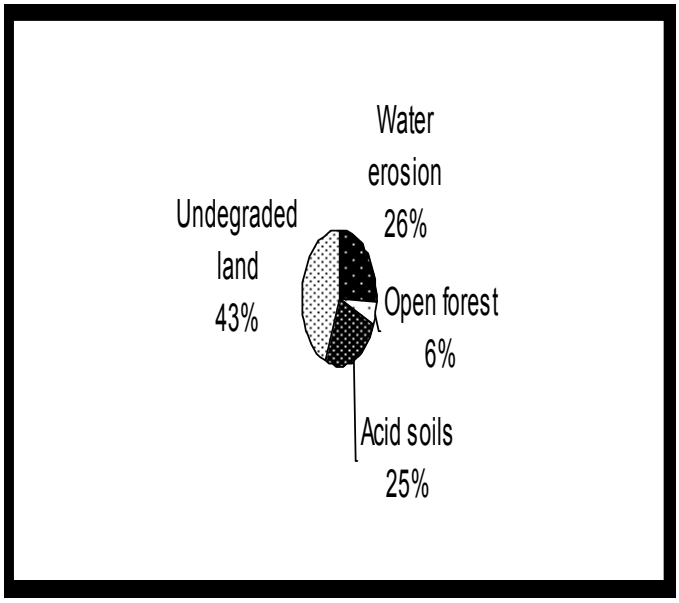
Land degradation is a major threat to our food and environmental security and in the Himalayan region, water erosion, acid soils , open forest (< 40 per cent canopy) and shifting cultivation are the main problems leading to severe erosion (> 20 t soil/ha/yr). Mining / Industrial waste lands and water logged / marshy lands are also existing in this region. Soils of the Himalayan region generally belong to Alfisols, Entisols, Inceptisols and Ultisols. The loss in productivity is closely linked with the magnitude in soil erosion. The soil erosion is quite high in soils in Siwalik Hills (> 80 t/ha) and shifting cultivation area in the north east (> 40 t/ha).

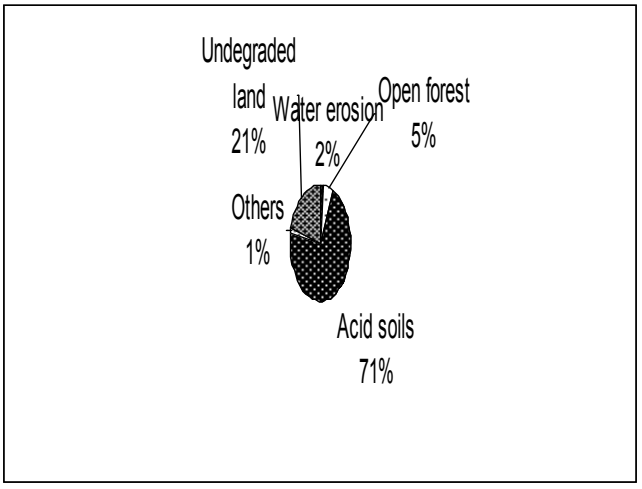
Table 2. Loss in productivity (per cent) under different degree of soil erosion

Degree of erosion	**Annual erosion (t/ha)**	**Loss in**	**Productivity (per cent)**
		Alluvial Soils	Red Soils
None to very slight	<5	None	<10
Slight	5-10	<5	10-25
Moderate	11-20	5-10	26-50
Strong	21-40	11-25	>50
Severe	>40	26-50	?

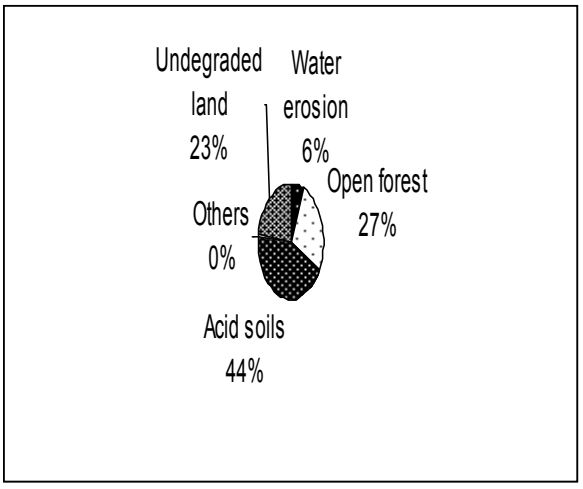
Soil degradation in the different areas in the Himalayan region is depicted below.



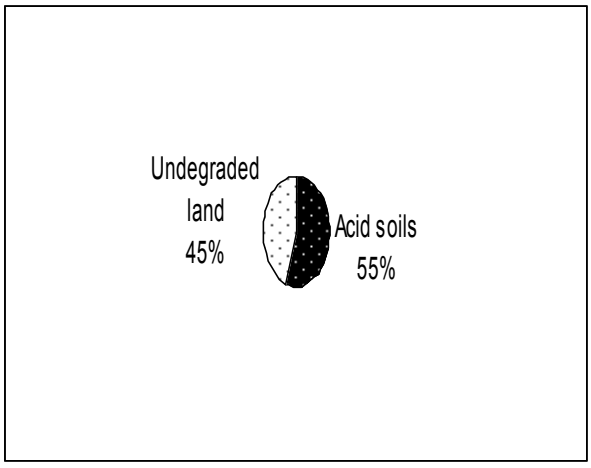




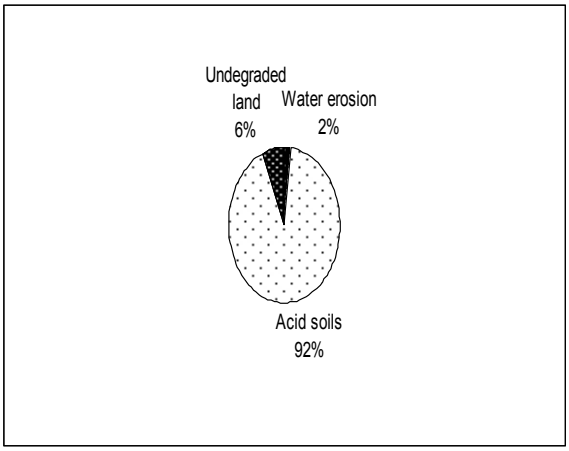
Manipur



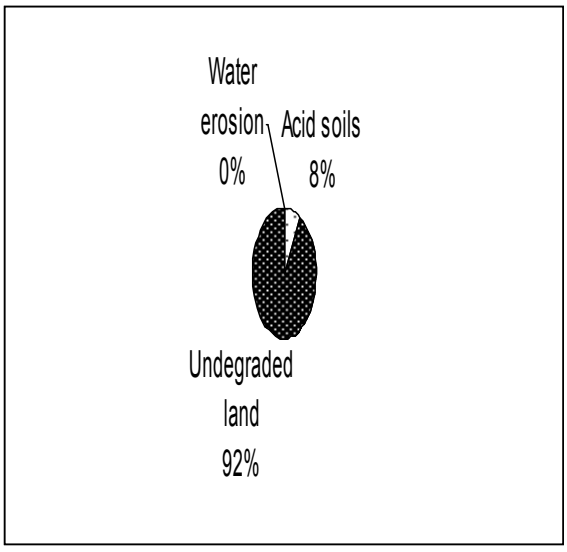
Meghalya



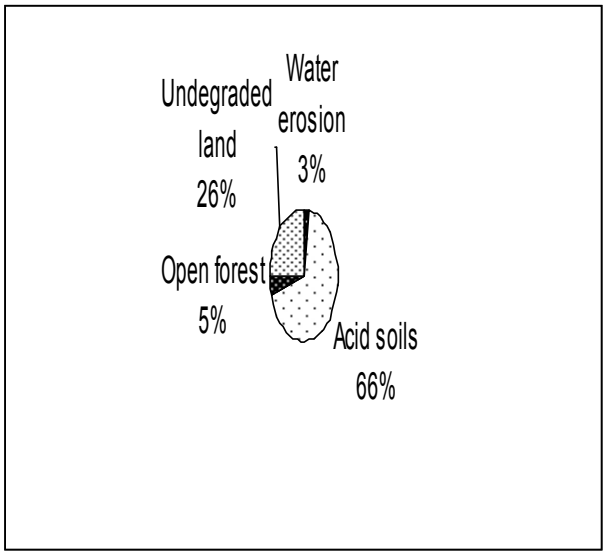
Mizoram



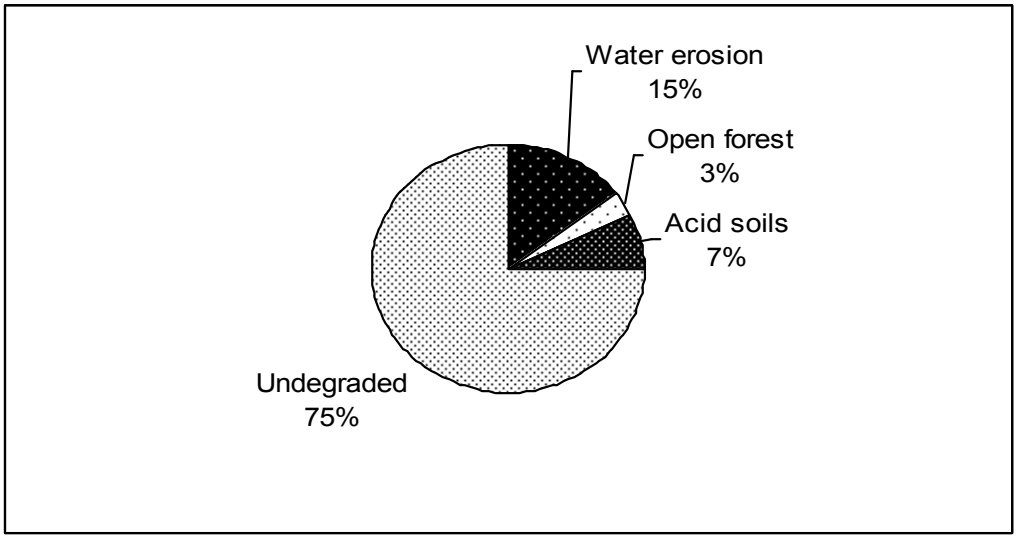
Nagaland



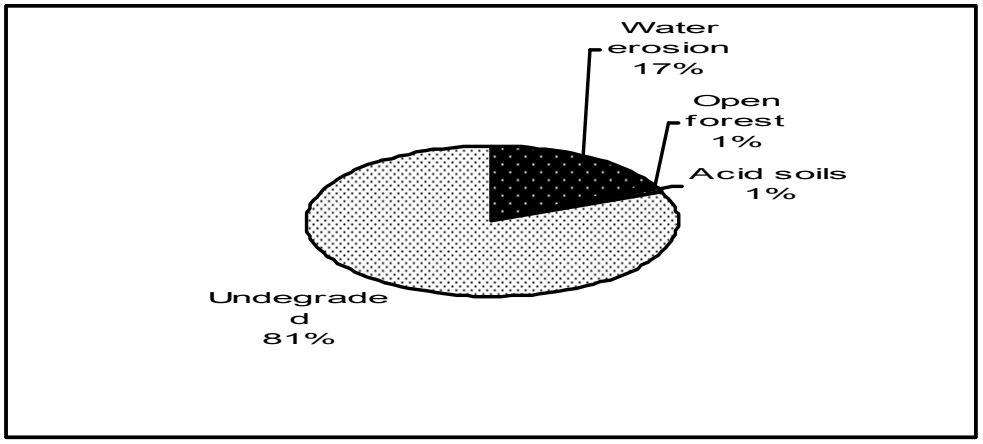
Sikkim



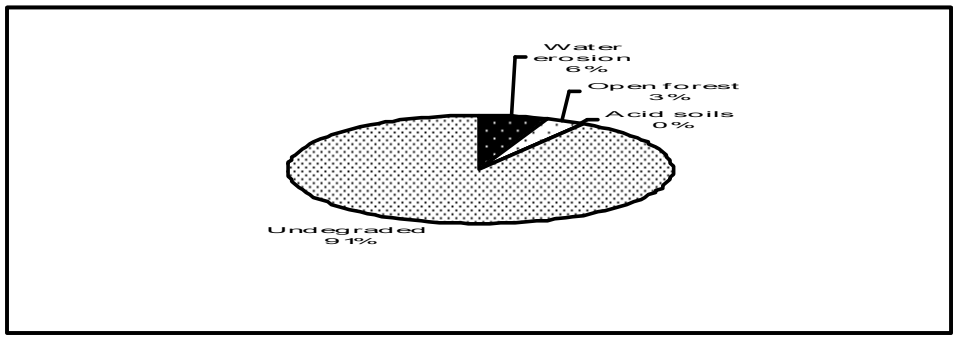
Tripura



Uttarkhand



Himachal Pradesh



Jammu & Kashmir

Land degradation in both eastern and western Himalayas is caused by soil acidity coupled with water erosion, but the soil acidity is predominant in eastern Himalayas.

Land capability classification

There are eight classes under land capability and land from Class I to Class IV can be utilized for arable land development. But the land under the class V to Class VIII is for non arable land development. Soil depth, permeability, Slope per cent, Soil erosion, gullies can be considered for determining the land capability classification which can guide to have the land use options. So, class I and II can be brought under agriculture and vegetable land use, Class III for horticulture and plantation crops and Class IV to VII for forestry with interventions of agricultural crops according to suitability.

Soil erosion – control measures

There are various ways through which soil erosion could be brought under control, viz., mechanical, mixed farmimg and biological. Mechanical ways of soil control measures are contour cultivation, bund in mild slopes. Graded bund, bench terrace and gully control. .Use of mulch, intercroppin and stripcropping are very common for soil erosion control. Use of pineapple, arhar, cowpea, various trees/shrubs can be successfully utilized as vegetative barrier for control of soil erosion.

Agricultural crops in IFS

Under integrated farming systems, attempt should be made to increase the cropping intensity from the existing monocrops in the Himalayan region to double or triple cropping. Land under the class II /III are to earmark for growing cereal based cropping systems in order to ensure the food security to the people. Introduction of vegetables in the cropping sequence becomes more remunerative as observed from the cropping systems as studied in Tripura.

Table 3. Economics of cropping systems adopted in IFS in Tripura

Cropping sequence	**Benefit/cost ratio**
Maize -carrot	3.06
Maize -cabbage	2.82
Upland rice - cabbage	2.28
Moong –radish -frenchbean	2.70
Upland rice-french bean—capsicum	2.76
Indian bean – radish -carrot	1.98
Bhindi-cabbage	1.86

Considering the local need of the people, suitable oilseeds or pulses should be grown in the cereal based cropping systems and in the soils where organic matter is in depleted state, supply of organic sources for nutrient recycling may be ensured.

Sloppy land – utilization

Under hill farming, sloppy land is one of the major constraints encountered for effective implementation of IFS and the following are options of land utilization in the sloppy areas. Here, attempt must taken to have a plausible control of soil erosion either through mechanical ways or by adopting biological barriers.

- **Fruit crops** (15-30 per cent slope)

Pineapple, jackfruit, banana, guava, litchi, lemon, citrus, musambi, plum, pear, apple etc.

- **Forest Trees** (> 30 per centslope)

Teak, gulmohar, *Michelia champaca*, pine, *Alnus nepalensis*, *Schima wallichii*, *Albizzia* spp., *Parkia roxburghii*, *Acacia* spp., *Bauhunia variegata* etc.

- **Plantation crops**

Arecanut, cashewnut, coconut

- **Spices**

Cardamon, black pepper

- **Tuber crops**

Elephant foot yam, dioscorea, colocasi etc**.**

- **Aromatic/Medicinal plants**

Patchouli, Black tulsi, Macuna , Asparagus

Agroforestry

Agroforestry in IFS supplies fuel wood, fodder, timber, fiber, resins, food/fruit crops, spices and on the other hand maintains the environmental protection. Multipurpose tree species (MPTs) suitable for humid subtropical region are *Acacia auriculiformis, Morus alba, Leucaena leucocephala, Dalbergia sissoo, Gliricidia maculata, Azadirachta indica, Michelia champaca, Eucalyptus hybrid, Tectona grandis, Gmelina arborea, Samania saman* and *Albizzia procera.* Field crops such as rice, groundnut and sesamum could be sustainable upto 3-4 years of tree planting. With the gradual increase in tree canopy, pineapple, turmeric, cowpea, lemon, patchouli and forage crops become viable as intercrops in agroforestry system.

Utilization of valley land

Valley land is the site where water harvesting structure could be made to store runoff water and $1/10^{th}$ of the area should be brought under water harvesting structure preferably in the lower reaches of the hills. The size of the water harvesting structure will be as follows

- Catchment area – 1 ha
- Yearly rainfall -2000 mm
- Accumulated rainwater -20,000 m^3
- Average runoff – 36 %
- Total runoff -7200 m^3
- Utilizable runoff – 2160 m^3
  During non monsoon period
- Size of water harvesting structure – 3000m^3 (40 m x 30m x 2.5m)

Animal and fishery components

In order to make the IFS more remunerative, it is a necessity to introduce the animal components particularly rural poultry, duckery, piggery in the systems. In an area having 1 ha of water harvesting structure, 40 pigs can be reared and 400-500 ducks can also be kept. The excreta obtained from the animals can be a source of fish in water harvesting structure where composite fish culture can be implemented. Improved method of fodder production may also be encouraged and as such cattle/goat can be reared. Net income from the agri-horti-duckery-fishery and agri-horti-piggery-fishery from the IFS conducted In Tripura was Rs 35,000/ and Rs 45,000/- ha/annum.

Nutrient cycling

Nutrient cycling is a matter of great concern so far as the nutrient supply for growing crops in IFS is considered. Animals reared in IFS can supply manure and vermicompost is also generally prepared from the crop residues available in IFS. Various tree leaves such as *Tephrosia candida*, *Gliricidia maculata*, *Indigoferra sp*., *Leucaenea leucocephala* can be successfully used for supplying the leaf biomass to maintain the soil fertility and moisture status.

Conclusion

Food security and nutrition are clearly core issues in sustainable mountain development but paradoxically are often ignored in mountain-related discussions and mountain development policies and projects. Nutrition surveys usually do not enquire or tell us what kind of households malnourished people come from and what constraints they face. There is no recognition of the wealth of knowledge and experience in communities which have survived for centuries in harsh and isolated environments, or of the similarities between them. Malnutrition leads to disease which in turn contributes to malnutrition: sickness leads to loss of appetite, such cycles need to be understood and can only be broken by ensuring that people have access to appropriate and sufficient food throughout the year. It is important to raise awareness at all levels of the implications of not making food security and nutrition a priority. Research, especially operational research, is needed to enable a fuller understanding of the living conditions of mountain people and their nutritional needs. Decision-makers, both within national governments and international donor agencies, must be equipped with the information and knowledge to develop appropriate policies to support mountain development. A dialogue must be established between mountain people and external stakeholders. Strengthening the capabilities of local communities and institutions is essential to this process. Nutrition education and training is important at both the community level and the technical level to orient people's decisions about production and purchasing, household resource management, food processing and preparation, and food practices, particularly those related to feeding children. While change is certainly needed, the recent evolution of the food and nutrition situation in mountain areas is alarming. There are, however, examples of positive changes in some areas. Mountain people could become a source of knowledge for each other if linkages can be established. By better understanding livelihoods, knowledge, experience and perceptions of mountain people and ensuring their full participation in relevant policy and project formulation, it may be possible to prevent destitution, malnutrition and social conflict. Over 52 per cent of total reporting area of Indian Himalayan region is covered by forests, which is much higher than the country's forest cover (over 20 per cent), followed by not available for cultivation (about 11.5 per cent). While the net sown area of the region is only 9.8 per cent in respect of the all-India figure (43.5 per cent) of total reporting area. So, integrated farming system approach involving crops both agricultural and horticultural ones, animal and fishery components could be viable options to arrest the problem of malnutrition and food insecurity in the mountain regions.