

LAND HUSBANDRY FOR RESTORATION OF DEGRADATION IN NORTH EASTERN HILLS

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INTRODUCTION

Land is the basis of life support systems, through production of biomass to provide food, fodder, fibre, fuel, timber, and other biotic materials for human uses, either directly or through animal husbandry including aquaculture and inland and coastal fishery. Land use is a kind of permanent or cyclic human interaction to satisfy the human needs, either material or spiritual or both from the complex of natural and artificial resources for the development. Present conditions of land in many areas of northeastern hills are the result of a combination of both its natural and genesis and human influences, which are still active. The human influences such as agriculture in Apatani plateau of Arunachal Pradesh, building of terraces for wheat cultivation by Monpas tribes of Arunachal Pradesh, terraced wet-rice cultivation by Angamis and Chakesang of Kohima district of Nagaland, and terraced agriculture in Sikkim hills may be the result of positive human action. The prevalence of shifting cultivation (*jhum*) is the result of human negligence or lack of knowledge and foresight that resulted severely eroded hills without good vegetation. The concept of land husbandry is more acceptable to farmers to manage and improve the present use of land for production purposes on sustainable basis. Sustainable land management is an emerging concept, which seeks to assure the inter-generational equity of the land. Eswaran (1992) defined sustainable land management as "*a system of technologies that aims to integrate ecological and socioeconomic principles in the management of land for agricultural and other uses to achieve inter-generational equity*". In the northeastern hills (NEH) region, the farmer's immediate concern is crop yield improvement, diversity of crops, and enhancement of basic income to meet the individual needs. The basic social concept of sustainable management of land is based on balance among the different segments of the society as well as a balance between individual and institutional values. The land of this region is suffering from various kinds of land degradation as a result of different activities to meet the increasing demand of population for comfortable and luxury life. In this paper an attempt has been made to identify and quantify the land resources for sustainable land husbandry of the fragile and degraded mountain and hills of northeast hills of India.

GEOGRAPHY AND GEOLOGY

The North Eastern Hills (NEH) zone starts from Singalila range and covers all the seven sister states as well as Sikkim and Darjeeling hills of West Bengal. It lies between 21.50° and 29.50° N and 85.5° - 97.5° E, representing a distinct agroclimatic area of our country. The great Himalayan range includes Sikkim, Darjeeling hills and eastern most border of Arunachal Pradesh. The north-eastern ranges, the spurs of great Himalayas, has two major sections- the Mishmi hills of Arunachal Pradesh and Patkai ranges run to the east and south of Assam along the Indo-Burma border. They are known under different names in different parts of Assam (Karbi Anglong and North Cachar hill districts), Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura and are collectively called *Purvachal* (*Purva*, east and *achal*, mountain). The Meghalaya plateau is really an eastward extension of the massive block of peninsular India to the east of the great gap of Achaean terrain. Assam is surrounded by all hill states (excepting Sikkim). This region is surrounded by the international boundaries of China, Nepal, Bhutan, Bangladesh and Myanmar. Among the hill states of northeast, Arunachal Pradesh has the maximum geographical area and Sikkim has the least, and both possess the continental climatic zones in this region. The northeastern geographical hill area

comprises 75.3% (2,02,212 km²) of the total area of 2,74,942 km² of northeastern region of our country (Table 1).

Table 1: Area and population of northeastern hill states-2001*

State	Geographical area (km ²)	Total population	Decadal growth rate (%)	Density (persons/km ²)
Arunachal Pradesh	83,743	1,091,117	26.21	13
Manipur	22,327	2,388,634	30.02	107
Meghalaya	22,429	2,306,069	29.94	103
Mizoram	21,081	8,91058	29.18	43
Nagaland	16,579	1,998.636	64.41	120
Sikkim	7,096	540,493	32.98	76
Tripura	10,486	3,191,168	15.74	304
Total, NEH states	1,83,741	1,23,97,975	23.05	67
India	32,87,300	1,027,015,247	21.35	312
% Population of India	5.59	1.207	-	-

* Data for Assam & W.B. hills not available

Morphologically northeastern hills are marked by the development of a series of ridges and valleys, terraces, scraps, several geomorphologic or planar surfaces at different elevations (15 to 5000 m and above), etc. The North Eastern Hills Region has developed *in-situ* on different types of rocks of geological ages starting from Paleozoic to recent formation. The old rocks are inter-layered with tertiary and quaternary formations. Disang, Barail, Surma, Tipam and Duptila series represent the rock formation in Nagaland, Manipur, Mizoram and Tripura. Both Jaintia and Disang series are overlain by very thin thick Barail series, which is of considerable economic importance as it contains thick seams of coal. Manipur valley soils have developed from the transported material formed from shale. The North Eastern and Western portion of Sikkim is made up of hard massive gneiss rocks, and the gneiss of south Sikkim is highly micaceous, muscovite and biotic being present. The Himalayas rivers (Sikkim and Arunachal Pradesh) originate from the snow-clad mountains and alive hills in other states and primarily constitute Brahmaputra drainage basin.

The climate of Arunachal Pradesh and Sikkim varies from sub-tropical to extreme alpine type and in other states, almost limited to subtropical to temperate. The major part of this region receives annual rainfall from 2000-4000 mm. The hill slopes facing south-western monsoon currents receive large amounts of rainfall than the enclosed valleys. All the botanical zones from tropical to alpine are found in these states due to its geographical situation, climate and altitude. These states are veritable storehouse of medicinal and economically important plants. Arunachal Pradesh and Sikkim are renowned for its Rhododendrons and orchids and for high altitude Primulas, Meconopsis and Blue poppies.

LAND USE

Through out the last millennium, a continued process of observation and innovation is maintained by the hill communities to evolve their economic activities and management strategies, primarily under conditions of undulated topographies, inaccessibility and isolation, and requirement to optimize production in the face of both risks and resources. Therefore, land use of NEH is the result of techniques and customs by different ethnic groups before their migrations as well as of their later adaptation to the location specific nature of soils and landscapes of settlement. The land use pattern of NEH region 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 these states (Table 2) and they are under varying forest cover densities followed by alpine barren land, snow and glaciers. Excepting Sikkim and Tripura, all states had the forest cover above 70% of their respective geographical area. However, reserve forest area is below 60% of the reported area in most of the states except Arunachal

Pradesh and Mizoram (above 70%). The net cultivated area varied widely from 3.37% (Arunachal Pradesh) to 26.41% (Tripura) and is approximately 6.8% of the total reported area of the states (Table 2).

Table 2: Land use pattern of northeastern hill states ('000 ha) (State of Forest Report 1999)^a

Land use	Arunachal Pradesh	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura
1.Geog. area	8374	2233	2243	2108	1658	710	1049
2.Reporting area	5495	2211	2241	2109	1538	710	1059
3. Forest	5154 (93.79)	602 (27.23)	935 (41.72)	1598 (75.77)	863 (56.11)	257 (36.20)	606 (57.77)
4.Misc. tree, crops & groves	44 (0.80)	24 (0.09)	159 (7.09)	0	129 (8.39)	5 (0.70)	27 (2.57)
5.Not available for cultivation	48 (0.87)	1445 (65.36)	244 (10.89)	65 (3.08)	61 (3.97)	270 (38.02)	133 (12.68)
6.Permanent pasture and grazing land	N*	N**	0	0	0	69 (9.72)	0
7.Culturable waste land	N*	N**	473 (21.11)	174 (8.25)	70 (4.55)	1 (0.14)	1 (0.10)
8.Fallow land except current fallow	36 (0.66)	0	165 (7.36)	163 (7.73)	85 (5.53)	9 (1.27)	1 (0.10)
9.Current fallow	28 (0.51)	0	69 (3.08)	0	105 (6.83)	4 (0.56)	5 (0.38)
10. Net sown area	185 (3.37)	140 (6.33)	216 (9.64)	109 (5.17)	225 (14.63)	95 (13.38)	277 (26.41)

N* and N** included misc. tree crops and groves and non-agricultural uses, respectively; () indicates percentage.

^a Data for hill region of W.B. & Assam is not available.

LAND DEGRADATION

Degraded lands are those land, whose conditions has deteriorated to such an extent that it can not be put to any productive use, except current fallow, due to various constraints. Soil degradation is the reverse of soil health, resulting persistent decrease of soil potential productivity and loss of environmental regulatory capacity. The land has been degraded mainly due to over exploitation of forest for fuel, timber and fodder, shifting cultivation, improper land use practices, infrastructure development, land tenure systems of different ethnic tribes, and mining activities without proper changes in land management. In NEH, there are high percentage of area under wasteland due to shifting cultivation (*Jhum*) in Nagaland, Assam hills, Manipur, Meghalaya and Mizoram. In Sikkim and Darjeeling hills land degradation is caused by deforestation (Table 3). Land degradation occurs mainly due to human interference of the ecosystem not only to meet their actual demands but their greediness to achieve luxuriant livelihood by exploiting the nature's gifts. The existing community/private land system has been excessively exploited for survival and realization of short-term objective without taking care of soil health. The major cropland areas of hill agriculture are eroding faster than natural processes and have been significantly degraded. Visual and morphological observations in the field caused by degradation can be recognized by:

1. Loss of top soil,
2. Water erosion as indicated by rills, gullies, stones on the exposed soil surface, exposed roots, and uneven topsoil,
3. Terrain deformation/mass movement,

4. Acidification, and biological and chemical degradation as indicated by poor growth of crops,
5. Physical degradation (crusting, hard pan, poor physical condition and water logging of foot hill lands), and
6. Field domination by unproductive grassy vegetation/weeds.

Table 3: Wasteland/degraded land in NEH (km²)

Degraded land	Arunachal Pradesh	Assam*	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura	West Bengal*
Land with and without scrub	3326.17	0	1.32	4190.63	0	1596.46	1073.11	286.87	14.40
Shifting cultivation	3088.08	8046.75	12014.06	2086.77	3761.25	5224.65	0	400.88	0
Degraded forest	1416.67	578.44	608.64	3612.11	310.45	1582.99	1060.57	588.18	44.60
Degraded pasture	2134.99	0	0	0	0	0	0	0	0.67
Total degraded land	8360.34	54.50	324.60	14.67	0	0	1435.90	0.11	10.92
% of total geog. area	18326.25	8679.69	12948.62	9904.38	4071.68	8404.10	3569.58	1276.03	69.62
Total geog. area	21.88	56.65	58.00	44.16	19.31	50.69	50.30	12.17	2.21
Total geog. area	83,743	15,322	22,327	22,429	21,081	16,579	7,096	10,486	3124

Source: Wasteland Atlas of India, 2000

* = North Cachar and Karbi Anglong districts of Assam and Darjeeling hill district of West Bengal.

** = Includes area of waterlogged, plantation, sand inland, mining, barren rocky, steep sloping and snow/glaciers.

The loss of top fertile soil from the hill agriculture has caused many farmers to abandon their traditionally cultivated lands and to move on to other marginal lands. The deterioration of soil quality/health is the joint result of the loss of soil fertility, biological degradation (decline of organic matter, biomass C, and decrease in activity and diversity of soil fauna), increase in erodibility and exposure of compact subsoil of poor physical-chemical properties.

The ecologically degraded lands include degraded forestlands, severely gullied and eroded lands, and areas affected by shifting cultivation. The second category of land degraded as a result of human activities consists of mined lands; waterlogged areas and industrial wastelands. 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). Landslides during monsoon adversely effect utility services such as roads, power generation, reservoirs, human settlements, trade, tourism and other developmental and economic activity parameters effecting on-site slope processes. This process not only affects the land/soil but also cause loss of bio-diversity including base resource itself, and human life.

Deforestation and removal of natural vegetation for *jhum*: The deterioration in the productivity of the mountain environment has now been defined as a function of vegetative cover of uncultivated land. As per government policy, two-thirds of the hills should be under forest cover to prevent land degradation for the stability of fragile hill ecosystem. All the hill

districts of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram and Nagaland had the forest cover more than 66% (Table 4). Forest ecosystems of hills are being threatened by a number of factors as follows:

- (a) Loss of forest lands to agriculture (mainly for shifting cultivation), industries, infrastructures and human settlements.
- (b) Loss of forestland due to multipurpose projects, construction of roads, transmission lines etc., quarrying and encroachments.
- (c) Degradation causes by illicit felling, lopping for fodder and fuel wood, overgrazing, removal of forest floor litter, forest fires, over felling, etc.
- (d) Population explosion and encroachment of forest land.

Table 4: Forest cover (km²) of northeastern hills states (State of Forest Report, 2001)

State	Geog. area	Forest cover	Dense forest	Open forest	Scrub	% Forest cover of Geog. area
Arunachal Pradesh	83,743	68,045	53,932	14,113	141	81.25
Manipur	22,327	16,926	5,710	11,216	190	75.81
Meghalaya	22,429	15,584	5,681	9,903	259	69.48
Mizoram	21,081	17,494	8,936	8,558	467	82.98
Nagaland	16,579	13,345	5,393	7,952	47	80.49
Sikkim	7,096	3,193	2,391	802	341	45.00
Tripura	10,486	7,065	3,463	3,602	44	67.38
Assam hills*	15,322	12,230	6,685	5,545	107	79.82
W.B. hill (Darjeeling)	3,149	2,196	1,417	779	0	69.74
NEH Total	202,212	156,078	93,608	62,470	1596	77.18
India	3,287,263	675,538	416,809	258,729	47,318	20.55
% of India	6.21	23.10	22.46	22.14	3.37	47.48

* Includes North Cachar and Karbi Anglong districts of Assam

The status of the change of the forest cover of northeastern region from 1987 to 2001 (Figure 1) shows that in most of the states where *Jhuming* is practiced the forest cover tended to decline. In Tripura forest cover has the tendency to increase after 1997. Shifting cultivation (*Jhum*) is the single largest factor for the loss of forest cover in this region (State of Forest Report, 1997). The loss of soil under shifting agriculture has been reported in the tune of 5 to 83 t/ha depending upon crops grown and slope of the land (Prasad *et al.*, 1986). The productivity of lands under shifting cultivation are directly dependent on the rest or fallow periods, during which such lands rebuild their store of organic matter, essential nutrient for remunerative agricultural yields predominantly stored in forest ecosystem rather than the soil.

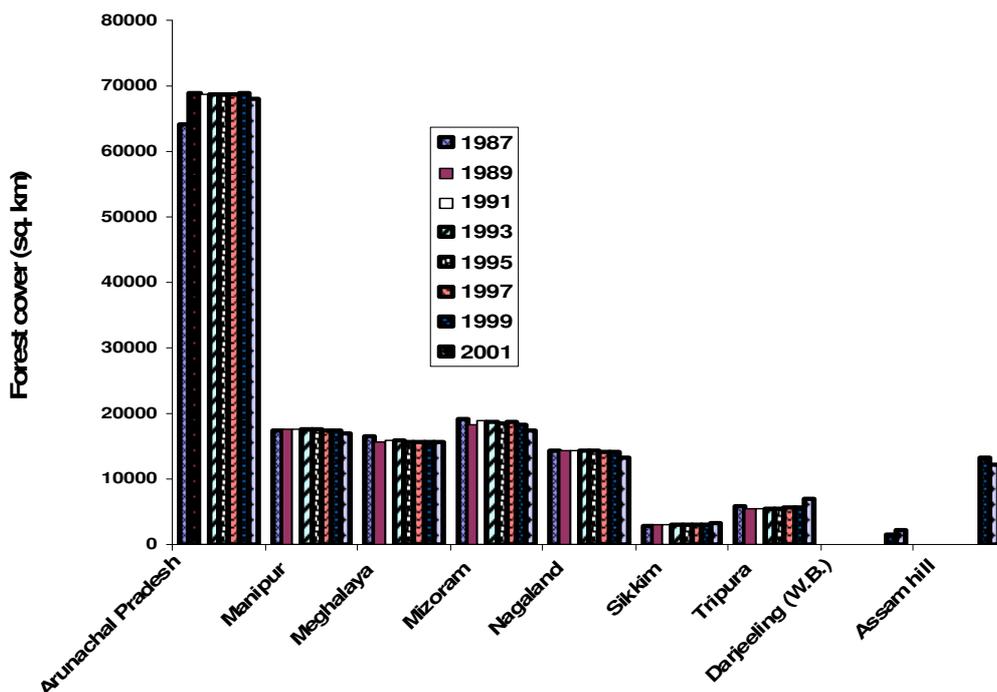


Fig. 1. Changes in forest cover of NE hills

Under the present system of unrestricted grazing of animals during seedling of broad-leaved trees are grazed or lopped frequently and die due to overgrazing and trampling. In this way overgrazing prevents the replacement of trees cut for timber and fuel wood. The deforestation, which includes the cutting of agricultural terraces on steeper and more marginal mountain slopes and *jhum* in north eastern hills, has led to a catastrophe in soil erosion and loss of productive land through accelerated landslide incidence. The deforestation of hill slopes has resulted increased sediment load of rivers emerging from the hill and mountains, causing the greater sedimentation load in Brahmaputra and its tributaries as compared to Ganges and local damage being proportionate to angle of slope.

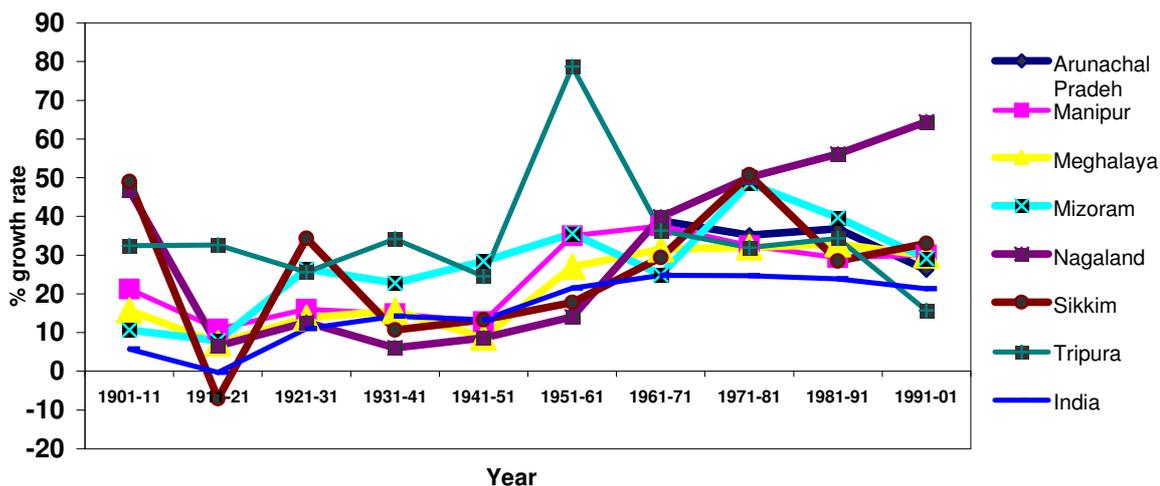


Fig. 2. Decadal population growth in NEH states

Cultivation along the steep hill slopes with increasing population pressure: Most of the land belongs to VI and VII classes of land capability and being used for agricultural crops production along the slope. The population density in mountain areas has moved from low to very high and rate of population growth in NEH states was always higher than the national

average (Fig. 2). The increased population in subsistence mountain society has led to: (a) reduced amount of land per family, (b) increased poverty, (c) massive deforestation, and (d) cultivating marginal infertile sloppy lands, which are the major causes of the degradation of land productivity. The loss of soil through runoff on such lands varied from 10.8 t/ha to as high as 62 t/ha depending upon land use for different types of agriculture (Prasad *et al.*, 1986). The loss of topsoil reduces the inherent productivity of land through the loss of nutrients and degradation of the physical structure of the soil. It also increases the cost of food production.

Due to cultivation of crops like potato and ginger for quick returns, the land resources are being intensively utilized unmindful of its long-term implications along the slope under the *jhum* (closed burning of biomass on raised beds ‘*bun*’) in *Khasi* hills of Meghalaya. Under this system of cultivation, shallow hill soil gets eroded very fast and continues till the entire ridge becomes barren/wastelands. In such uplands, the soil productivity cannot be fully restored even by heavy applications of fertilizers and manures.

Infrastructure development: The Chinese invasion in 1962 and its military presence on the Himalayan frontier prompted a massive road construction in great haste for military purposes, which outweighed concern for careful planning and sound engineering. After road construction, the extensive slope instability resulted in the production of enormous volume of debris, usually dumped on road and further down slope during heavy monsoon storms in the form of debris flows, rock falls, rockslides and mudflow. The annual debris production per linear kilometer of roadbed for specific roadways calculated for eastern Himalayas (Arunachal Pradesh) as 719 m³ (Valdia, 1987). Thus debris causes destruction of downslide vegetation cover as well as the agricultural terraces of local subsistence farmers. It is assumed that landslides produced by road construction are responsible for increase of suspended load in the local head streams of the river Brahmaputra. Road development, air links and electronic communication together with spread of market economy and policy intervention have produced a major socio-economic impact, which includes greater accessibility of hither to remote forests for commercial logging, ease of movement of people both from the mountains to cities of the neighboring plains and from the plains to the mountains for exploitation of natural resources of the region. The spreading of urban and peripheral urban areas along with other infrastructures causes the shrinking of agricultural and forestlands. It has reduced the biomass production, buffering and transformation of soils as well as the biological gene reserve.

Mining activities: Mining operation in Jaintia hills of Meghalaya are small-scale venture controlled by individuals who own the land. Coal extraction is done following primitive mining method commonly known as ‘rat hole’ mining. The mined coal is transported by trucks to the larger dumping places near the highways for its trade and transportation. The piling of coal on roadsides and in and around mining area causes the air, water, and soil pollution (Das Gupta *et al.*, 2002). In coal mining operation, only land is not spoiled but also degradation of vegetative cover occurs due to dumping and storage of coal and associated vehicular movement. The extensive surface excavation of sloping land not only damages the ecosystem within the periphery of mined area, but also sets a chain of ecological disturbances for down the watersheds. The water in the coal mining areas has been found highly acidic with low dissolved oxygen, high in sulphur and unpleasant colour (Table 5) as a result, the rivers, streams, and springs which had supported extremely rich biodiversity and traditional agriculture for the source of drinking water and irrigation have become unfit for human consumption.

Table 5: Physico-chemical properties of the some rivers water of Jaintia hills surrounding the coal mine areas of Meghalaya (Swier and Singh, 2003)

Rivers/streams location	Water colour	pH	DO (mg/L)	Sulphate (mg/L)	Conductivity (mMHOS)	Remarks
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Waikhyrwi Sutnga	Brownish	3.96	5.94	78.7	NA	Polluted
Rawaka Rymbai	Reddish brown	2.31	4.24	166.5	1.35	Highly polluted
Kmai-um Rymbai	Reddish brown	2.66	5.84	144.0	0.74	Highly polluted
Metynka Rymbai	Reddish brown	2.42	4.24	168.0	2.70	Highly polluted
Um-Mynkseh Ladrymbai	Brownish orange	3.52	5.04	118.7	0.67	Polluted
Thwai-Kungor Bapung	Brownish	4.01	5.68	82.9	0.18	Polluted
Umkrypon	Light	3.67	4.40	161.3	0.37	Polluted
Khliehriat Myntdu Jowai*	Orange bluish	6.67	10.20	3.66	0.10	Clean

* Away from coal mine area, DO = dissolved oxygen

Land tenure system. In most of north eastern hill states, land system is governed by traditions and customs. The land belongs either to the village or community/clan and everyone has an autonomous right to own land. It is very difficult to change the existing system because there is vested interest at stake such as chief having special right. In this tenancy system most of the cultivators have no land right. This has resulted the loss of soil productivity because tenants have the short-term linkage to that piece of land. Without ownership or security of tenure, farmers find it difficult to invest in conservation and to invest in new technologies. Most of the politician and political parties pay lip services to the ideal of good land husbandry and conservation of natural resource. In practice, they know that the reform of land tenure systems cannot get the support of village heads or community chiefs. In many instances, the tenants fail meet their basic consumption requirements as a result of land degradation and reduction in agricultural production.

RESTORATION OF DEGRADED LAND

Understanding the processes, factors and causes of land degradation is a basic prerequisite towards successful restoration of the productivity of degraded lands. The basic concept for restoring the degraded land is:

1. exact knowledge about the actual condition of the problems, including causes and impact,
2. monitoring of the problems to get an insight into temporal development whether stable, increasing or decreasing, and
3. Restoration measures to conserve of nutrients in degraded lands.

All forms of land/soil degradation have negative manifestation and disastrous consequences for fragile mountain and hill ecosystem of this region. The fragile and marginal lands degrade easily and have limited resilience to recover to original state. 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. Erosion may be controlled by maintaining soil infiltration rates at such a level as to allow excess water drain rapidly through the profile, and by providing safe discharge of runoff water into natural waterways when rainfall exceeds infiltration (Lal, 1984). The prevention, conservation of resources and restoration of the productivity of degraded soils in the northeastern hills can be successfully restored by practices such as residue mulching, no tillage cultivation, mixed cropping, and crops which can provide good ground cover during early period of rain to protect the soil from surface erosion.

Mechanical Approaches: Mechanical approaches are used in cases of extreme degradation, where other approaches are not possible or slow. Mechanical measures use infrastructures to

manipulate land surfaces and minimize, if not control, accelerated surface runoff, soil erosion, loss of nutrients and other degradative processes. These measures include: check dams (masonry, stone, loose rock, log check dams, etc.), level bench terraces, stone terracing, contour drains, contour ridges, contour bunds, earthen dam/reservoirs, gabion, stream channeling, etc., to absorb most of the surface water into the soil before reaching to streams. By adopting terracing and protected waterways, the steep slopes could be cultivated safely and profitably. Any small damages in terraces should be immediately repaired before it becomes worse. The terrace risers can be planted with local grasses to protect the soil loss and produce forage for cattle. The main drawback of the mechanical measures is the high cost of construction and maintenance. In this region, where engineering works are not compatible with the socio-economic condition of the community/farmers, they lose interest in maintaining these structures when project funds dry up or withdrawn. 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.

Biological approaches: Contour ridges, check dams, and bench terraces involve high cost of construction and maintenance, which poor farmers cannot afford to invest. Vegetative practices not only protect soil but also have the economic benefits in terms of yield and production. Vegetation protects the soil from erosion by intercepting raindrops and absorbing their kinetic energy harmlessly. Biological measures are more effective when used in combination with engineering techniques. Vegetative cover protects the soil by following processes:

- Physical binding of soil by plant roots.
- Enrichment of soil nutrient reserves by recycling between roots, litter fall and soil.
- Improvement of soil infiltration along the dead and living root channels.
- Build up of soil organic matter for structural and moisture retention qualities.

Vegetative practices are the first line of defence against soil erosion by running water. Many terrace areas have failed not because of design or construction, but owing to negligence in protection and maintenance. Mechanical methods of soil conservation are acceptable to farmers where these are the part of traditional culture (e.g. terracing in Nagaland and Sikkim for the cultivation of irrigated rice). Slope stabilization includes re-vegetation and other engineering measures to control surface erosion on road cut and fill slope and waste and borrow areas.

The vegetative approaches involve the manipulation of inherent soil processes to check the soil degradation. Practical methods of controlling water erosion require that a cover be maintained over the soil at all times to break the erosive force of the rain. These approaches include vegetative barriers on field boundaries, contour bunds and ridge, appropriate agroforestry practices, vegetative filter strips, live checks, etc., to promote *in-situ* moisture conservation with the objective of:

- 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.

For the reclamation and afforestation of any type of degraded/wastelands, the choice of species of grasses and other plants should be such that the demand for inputs is least and attention needed is negligible. They should have deep and large root systems preferably be hardy, fast growing and suckering. The trees should be coppicing, pollarding, and

encouraging the growth of grasses and weeds under their canopy, besides being economically useful. The tree canopy and cushion formed by the grass absorb the force of raindrops and the root system holds the soil together to prevent the runoff and soil loss. Such species helps in buildup of lost top fertile soil. 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 there in and planting of deep-rooted trees and/or shrubs on steep slopes.

Change of land tenure system: In the northeastern hills most of the land belongs to community, chiefs or headmen leaving the most population as tenants without any right, which discourages the farmers taking interest to build the soil resource. The Mizoram Government has taken the positive step in this direction by declaring all land belongs to government without affecting socio-economic structure of the society. The government has given the land depending on the duration of cultivation from temporary to permanent settlement. If the other state governments can take such type of steps with the existing systems, farmers would take interest for the restoration of soil degradation.

Restoration of mined areas: Land after mining generally does not remain conducive to tree growth. In a progressive mining operation over a large area by an open cut, the surface covering has to be stripped and subsequently deposited. It is possible and it does cost money. The ecological rehabilitation can be attempted by using plant species of economic value to local population and also compatible to the degraded sites. Within the range of grasses, legumes, trees and shrubs, there are certain species that are more likely to survive in the initially poor soil conditions (Bradshaw and Chadwick, 1980). The selected plant species must have the following characteristics (Anonymous, 1993).

1. species capable of colonizing degraded sites,
2. species capable of fixing atmospheric nitrogen as well as conserve the soil,
3. species capable of producing fuel, fodder, fibre for local population, and
4. species, which are of aesthetic value.

Soil amendments for enhancing productivity: The decline of soil productivity to grow crops depends on the extent and severity of soil degradation, cultivation system that is being imposed and how the soil is being managed. The most serious effects of soil erosion are loss of fertile topsoil and exposure of infertile acid subsoil, decrease of plant available water capacity, degradation of soil structure and ultimately decrease of economic return on production. Soil amendments are used to improve the physical, chemical and biological nature of degraded soil. These are: (1) the replenishment of plant nutrients depleted during cultivation, (2) the maintenance of soil physical condition (structure) by managing soil organic matter, (3) the suppression of weeds, pests, and diseases, (4) the correction of soil acidity associated stress and (5) the control of soil erosion (Greenland, 1981). Soil restoration involves judicious land use and choice of appropriate soil and crop management systems to reverse degradative trends. Land use and management options are selected to alleviate specific soil and ecological constraints for achieving agricultural sustainability. Appropriate land use (as per land suitability assessment) and judicious soil nutrients and crop management (as per soil capability and crop requirements) would reverse the degradative trends by setting in motion soil resilience characteristics.

In most cases, soil acidification does not cause serious degradation until the pH falls below 5.5. As soil becomes acid, CEC decreases and often AEC increases, which result in a reduced capacity to hold essential cations. Both symbiotic and non-symbiotic N fixation is reduced by acidification and many legume crops do not grow well under acid conditions. Under agronomic conditions, topsoil, which have been acidified, are readily ameliorated by the incorporation of lime in the plough layer, which results in the precipitation of toxic Al and

Mn and enhanced level of Ca and Mg. 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 aluminium toxicity (Patiram *et al.*, 1994).

Multiple cropping, mixed cropping, inter-cropping, relay cropping, inclusion of legumes in rotation, strip cropping, which provide good ground cover during the early period of rainy season, are also effective to ensure better crop productivity, besides maintaining soil fertility and erosion. 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 in a crop rotation and to a particular plot. 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) is a step in the direction of sustainable agricultural development through necessary modification of the conventional technology to improve soil health 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. This region is very much favourable for the agricultural development based on biomass production as a result of humid climate. Efforts are needed for its adaptability at farmers level, because in most of the cases farmers have the availability of organic manure and biomass available around the habitat with the limited purchasing power of households for fertilizers.

Soil organic matter (SOM) is the primary sink and source of plant nutrients in natural and managed terrestrial ecosystems. So, SOM is necessary prerequisite for the restoration of wasteland health and productivity. Carbon (C) in plants is derived principally from atmospheric CO₂ and plays a major role in soil fertility and nutrient balances. Due to dominant role of C in biogeochemical cycles, loss of C stored in litter and soils via, e.g., burning in shifting agriculture and erosion is tantamount to loss of plant nutrients and soil fertility. Soil organic matter plays key role in crop sustainability through interactions with soil chemical and physical properties in relation to nutrient release, action retention and soil structure. It is directly or indirectly responsible to the soil physical environments suitable for the growth of crops. The benefit largely comes through its effect on soil aggregation which in turn influences soil incrustation, water infiltration, moisture retention, drainage, tith, aeration, temperature, microbial activities, and root penetration (Allison, 1973). Application of organic manures also reduces phytotoxic level of Al resulting good crops productivity (Patiram, 1996).

Afforestation and Agroforestry: From the hydrological and erosion control point of view, forests provide more protection due to closed system as long as they are maintained. Open/degraded forestland + forest blank + scrubs in reserve forest and alpine scrub can be restored with an integrated approach through afforestation to change the unpleasant look into pleasant view of the site. Restoration or afforestation makes the unproductive lands productive by minimizing erosion and rebuilding 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.

Agroforestry is a combination of tree and crops, which offers viable alternative to arrest the degraded land. In the NEH region, tribal people are surviving directly or indirectly tree on based farming system. Agroforestry would also attract the community at large because the same patch of land is capable of supplying food and fodder to the farmer, timber and wood product to artisans for cottage industry. Agroforestry has a long tradition in this region, where grain crops, rhizomatous crops, pineapple, coffee, tea, spices and vegetables are being taken with a number of fruit and other trees such as pine, pear, plum, areca nut, mandarin, guava, coconut, jackfruit, banana, nitrogen fixing trees (mainly *Alnus nepalensis* and *Schima wallichii*) and fodder trees (*Erithrina* sp., *Ficus* sp., *Bauhinia* sp., *Artocarpus lakooch*,

Litsaea polyantha, etc.) in the different agroclimatic zones. The land not suitable for agriculture due to high slope (50%) can be used for grasslands or forestry. Agroforestry has the advantage of better soil protection against erosion, tapping nutrients from different depths by shallow rooted agricultural crops and deep rooted tree crops.

The agroforestry practices enhance the soil productivity by (i) pumping up of nutrients from subsoil by deep-rooted perennials, (ii) reduction in leaching losses through the capture of mobile nutrients by the well developed deep spreading root systems of perennials, (iii) maintenance of soil organic matter through the supply of above-and belowground litter and pruning of tree leaves and branches, (iv) addition of nitrogen through biological N-fixation by nitrogen fixers, (v) protection from soil erosion, and (vi) maintenance or improvement of soil physical properties. Appropriate agroforestry 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, where trees are integrated extensively with crop and livestock production. In NEH region, Nagas use the *Alnus nepalensis* for fertility rejuvenation of *jhum* land. Large cardamom with shade trees on hill slopes unsuitable for crop production, an integral part of the farming system in Sikkim, is ecologically sustainable (Patiram *et al.* 1996). *Thysanolina maximum* can be planted on degraded lands for broom and fodder, and minor forest produce such as food, fibre, and medicine.

Improvement of shifting agriculture: The bench terraces built by state governments under different schemes to settle the shifting cultivators could not be adopted permanently as they weathered out after the government subsidies are withdrawn. The three-tier system developed by the ICAR Research Complex for NEH region for sloppy hills (lower 1/3rd bench terraced for agriculture, middle 1/3rd for horti-pasture with grasses on contour bunds and remaining 1/3rd to agroforestry with contour bund) with flexibility according to specific needs (Borthakur *et al.*, 1987) also met the same fate. The short-term fallow periods (3-5 years) of weedy species are not only resulting in poor soil fertility build up but also posing a major threat to the cropping phase due to build up of weed seed pool accompanied by low yield of crops taken. Rapid restoration and maintenance of soil productivity can be achieved by improved fallow with woody and herbaceous legumes with primary purpose of fixing N as a part of short fallow (2-3 years) to increase the accumulation of large quantities of N and to provide a residual effect to two or three subsequent crops. The main legumes of the genus *Sesbania*, *Tephrosia*, *Leucaena*, *Mucuna*, *Centrosema*, *Pueraria*, *Crotolaria*, *Cajanus*, *Indigofera* and *Mimosa* can be successfully used for the short fallow to rejuvenate the soil fertility lost during cropping (Sanchez, 1999). In addition, such fallow systems may reduce the impact of weeds on crops. Herbaceous cultivated fallow species require less time for establishment and fertility restoration, but they do not provide the secondary products associated with woody species (such as wood for building and fuel). However, planting an improved fallow is quite different from the traditional *jhum* and may not be culturally acceptable.

The introduction of plantation and horticultural crops like rubber, coffee, tea, banana, citrus, black paper, cashew, spice trees, pineapple, etc., on *jhum* fields on sloppy hills are the promising alternatives. The locals without breaking their traditions can achieve this through a reasonable share of profits after processing and marketing.

Proper land use planning on watershed basis: The planning of an 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 by maintaining ecological balance through continued long-term efforts and commitments such as maintenance of infra-structure, protection and judicious use of land, water and forest resources to meet the continued demands, etc. Land use planning at catchment for the hilly terrains should have the 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 biomass 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 value addition of indigenous knowledge through technical know-how.

The preservation of natural ecosystems, scenic areas and wildlife habitat represents another dimension of many watershed projects. As permitted by the climate, soil, landform, hydrology, etc., of an area, the human intervention should be restricted to the choice of a crop, a livestock or a forest type. Information on soil and related properties can be obtained from soil survey and geological information system (GIS) to delineate the soil and land suitability for different useful purposes depending upon the household and community needs for sustainable hill ecosystem. In case of highly degraded lands, a period of restriction may be required until the soil can recover.

Horticulture: The wide agro-climate (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., varieties 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 popular Rabi vegetables could be grown successfully at high hills around and above 2000m during summer. Orchids are well distributed from sub-tropical to sub-alpine zone and can be exploited commercially along with other flowers to raise income of the people.

Stall feeding of livestock: The cattle, on small land holdings in the rural area in conjunction with primary agriculture production, create employment and contribute substantially to domestic income. Plenty of grasses are available during the monsoon periods and scarcity only occurs in winter (November to March). The stall feeding of animal can check the environmental deterioration through 1) rotational grazing; 2) survival of young tree seedlings; 3) non-creation of cattle track; 4) more and sustained use of dung in cultivated land; 5) less livestock parasite load; 6) reduced damage to standing crops and terrace risers (Ives and Messerli, 1989). In the interest of effective feeding of livestock, the use of trees, which provide green leaf fodder during the dry season, should be part of the rehabilitation programme, which offers an added advantage of producing timber and fuel wood as a by-product. By adopting contour grass strips on mild sloping lands with fodder trees, farmers can maintain the live stock for milk and meat to generate the cash income and excreta for recycling the nutrients removed from the land.

Farming system approach: Farming system is a natural resource management unit operated by a farm household, and comprises the entire range of economic activities of the family members including on-farm agricultural activities as well as off-farm employment opportunities. Within an agro-ecological zone, several farming systems are found in the hills with variation in resource endowment, preferences, and socio-economic position of the specific family. 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 hills. The research on different farming systems for hills of north-eastern region at Barapani, Meghalaya on steep slopes revealed that cropping system and livestock were economically viable and integration of livestock in the farming systems enhanced the income, provided manure for soil health and family labour utilization (Prasad, 1990).

Infrastructure development: The development of roads, power plants, schools, hospitals, and commercial centers are the basic need for all round development. However road construction on steep rocky hill slopes causes landslides frequently disturbing the social and economic activities of the people. 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 stage of survey. The second requirement is to use hydroelectric power resources properly without inflicting serious human or environmental damage.

Artisan manpower development: Traditional handicrafts represent the physical manifestation of tradition, whose value transcends the economy. 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 will help in the revival and revitalization of traditional crafts through education, training and financial support. The indigenous handicrafts and handloom along with other rural development initiatives would not only generate jobs, but also keep alive the land resources along with its biodiversity for protection.

Eco-tourism: This region has the congenial environments of tourism. At higher elevations above 2000 m eco-tourism is the other way to meet the peoples' needs through alternative employment opportunities leaving the land in natural way to maintain the beauty of hills. State government is providing facilities for the attraction of tourists in these states.

Organic farming: The people of this region are involved with organic manure oriented production. The organic market is special one, partly because premium prices are involved. Attention should be given to meet the requirements of a guarantee system that will ensure organic quality and allow consumers to develop their preferences for organic products with a feeling of trust. There is a plenty of export opportunities for such products from this region in the form of coffee, tea, spices, medicinal herbs, traditional agricultural and non-timber tree products and other subtropical and tropical products. The specific qualities may offer small farmers and indigenous people, particularly those working in marginal area, ways of increasing their income in an ecologically sound way. However, to unlock the opportunities of international trade in green, fair and high value products, it is very important for producers to find reliable partners who can take care of certification, financing, shipping, processing, marketing and distribution. It is well known that organic production may result in lower yield. Therefore, growing number of consumers are prepared to pay premium prices because they know they are getting premium quality products in return.

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