Agroforestry in North East India: Opportunities and Challanges.Eds. B.P. Bhatt and K.M. Bujarbaruah © 2005, pp. 33-53, ICAR Research Complex for NEH Region, Umiam, Meghalaya

Soil and Water Conservation Techniques for Sustainable Land Use

D.K. Sonowal, B.P. Bhatt, K.K. Satapathy and B. Baishya

INTRODUCTION

Adequate soil and water conservation measures are required towards sustained agriculture in the erosion prone North Eastern Himalaya Hill Region. The conservation measures are required to protect the soil from loss and improve in fertility and productivity alongwith water harvesting for assured irrigation to crops during lean season besides fishery and livestock rearing etc.

There are wide scope of sloppy land development and management in the hilly region with application of agronomical, mechanical soil and water conservation measures and intervention of agro-forestry systems. However, suitable eco-friendly methods are to be applied for true and all round agricultural development in the hills. The soil conservation measures and agroforestry systems are to be generally planned and taken up in the areas retrieved from *jhuming*, buns etc. to provide protective cover to the barren lands. These will help in prevention of soil erosion, improving water regime particularly of the catchments areas and general restoration of the balance of ecology of nature (Bhatt, 2003).

For proper planning and development of such combination, adequate knowledge of engineering procedures of soil conservation is the prerequisite. Attempt has been made here to explain in details for the basic engineering know-how towards planning, development and execution of such soil and water conservations as well as agroforestry systems on watershed basis.

WATERSHED BASED LAND USE

Effective planning, development and utilization of all the natural resources in hills towards sustainable production are possible on the basis of watershed programmes, mainly to aim to check soil erosion, improve fertility and productivity (Satapathy, 2003). The rain water can be retained *in situ* within the watershed through proper land uses and with adoption of suitable soil and water conservation measures in the watershed in increasing the discharge rate of stream in down stream locations. Observations in NEH Region shows soil loss under a traditional farming system *of jhuming* to be around 49.40 t/ha/yr, whereas mixed land uses such as agrihortisilvipasture on watershed based with soil conservation measures like bench terracing and half moon terracing system, showed the soil loss only by 1.80 t/ha/yr. Thus agroforestry interventions with adequate soil and moisture conservation measures could reduce the soil loss by > 90 % compared to the traditional method of cultivation (Prasad, *et al.*, 1987). Watershed based land use systems on the steep slopes in the region have shown the feasibility of adoption at farmers level, and towards the aim and objectives of the resource management in micro-watershed level.

Details About Watersheds

Watershed is a natural hydrological drainage unit. In other words, watershed is an area above a particular point of a waterway or a drain from which run-off or excess rain water contributes to flow through that point.

Fig. 1 and 2 represent the concept of a watershed. Excess rainwater is contributed from the area above the point "B" (Fig. 1) to flow as runoff in the drain CA through outlet point. The run-off contributing area or catchments area is the *watershed* of the particular waterway or drain (CA) with reference to the outlet (B) point.

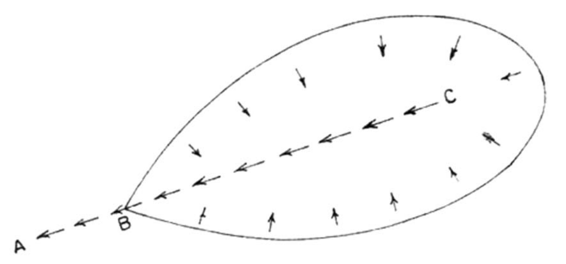

Fig. 1. Watershed concept

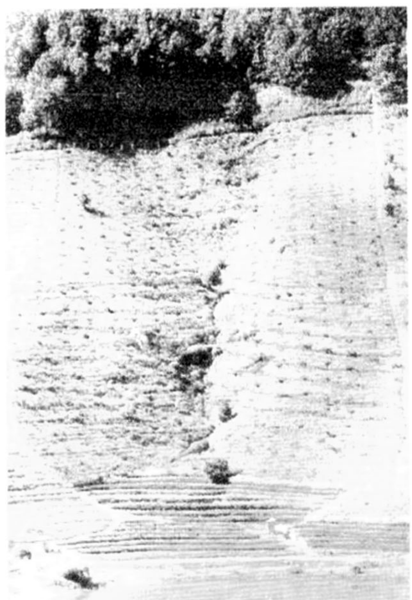

Fig. 2. Watershed concept

Size of Watershed

The size of watershed can be as small as few hectares for small drainage units or as large as thousand of square kilometers for large basins. Some artistic terms such as micro-watershed, mini-watershed, small watershed, large watershed, macro-watershed are used to classify watershed in different sizes. For example, the basin of the river Brahamputra is the macro-watershed and the small drainage unit of a farmer's plot may be the micro or mini-watershed. A large watershed can be divided into different sub-watersheds based on the independent tributaries (Fig. 3).

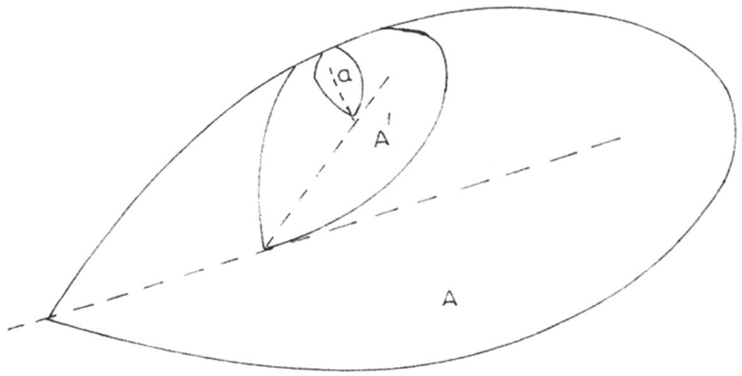

Fig. 3. Watershed sizes

example
A = Macro-watershed of the main river
A´ = Subwatershed of the main tributary
a = Micro-watershed of smallest drainage unit.

Important Watershed Parameters

The important watershed parameters include:

Area (ha); shape – round, oval etc.; relief (elevation differences of highest and lowest points) (m); maximum length (m); maximum width (m); slope range (%); average slope (%); details of area in slope ranges (ha); perennial stream (nos.); seasonal stream (nos.); natural springs (nos.); existing road (km); buildings/structures (nos.); other details of populations/habitations/socioeconomic status etc.; ecology of soil, and vegetation and land uses etc.

Development and management of watershed projects requires mainly the knowledge of the following aspects-demarcation of watershed; detailed topographical/contour map of the watersheds; detailed soil survey, land capability classification and present land use pattern including drainage systems; preparation of resource inventories; planning soil and water conservation measures/proposed land use plan/farming systems, and execution – development and management.

Listing above, the important aspects pertaining to land developments on watershed basis in context to the farmers field are tried to narrate in this presentation within the theme of watershed development and management.

Watershed Demarcation

Properly demarcated watershed with conservation measures will have full control over the rain water production including arrangement of water storage and utilization. Generally in demarcated watersheds, the topographical survey works are carried out for planning and development works.

- Physical demarcation of watershed in hills is very easy by identifying the ridge lines and gully or valley lines. As per the concept, the area will comprise a valley or drain or waterway bounded by a peripheral ridge (Fig. 4a).

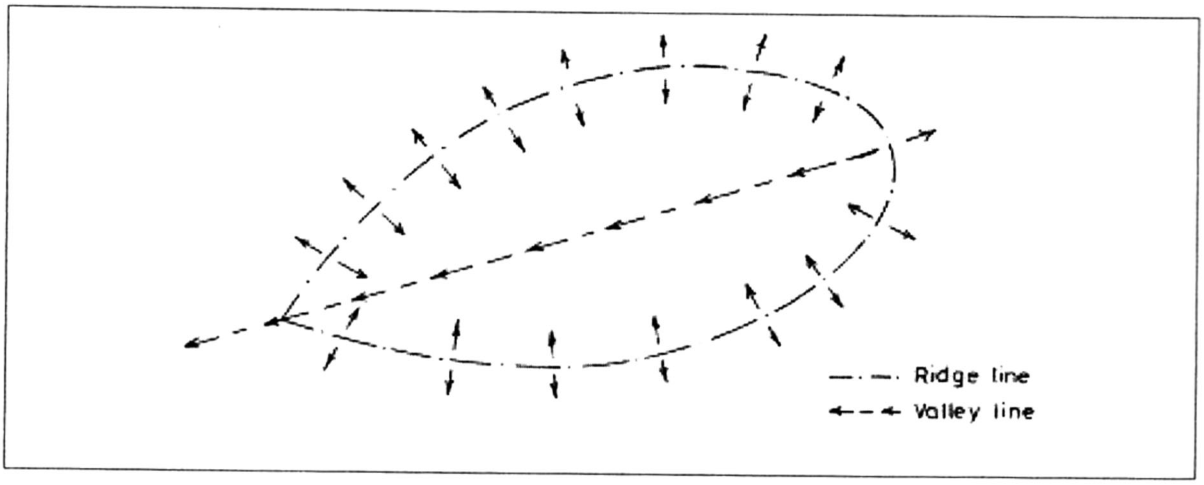

Fig. 4a. Physical demarcation of watershed

- Technical person can demarcate the watershed from the topographical map for the suitable land uses and development planning (Fig. 4b). Toposheet available with the Survey of India in the respective jurisdiction area can help in delineating watersheds or drainage unit towards initial formulating the watershed or soil conservation projects.

Watershed Survey and Mapping

The work of watershed survey and mapping is a highly technical job, but it is essential for planning the development works of the project. In the difficult hilly terrain and forest lands, the conventional surveying methods using dumpy level, theodolite etc. are not feasible. Hence some practical means of surveying and preparation of watershed are adopted by use of the following simple instruments - hand level; leveling staff; prismatic campus; measuring tape, and other accessories like ranging rod (2 nos.), plum bob, pegs drawing equipments etc.

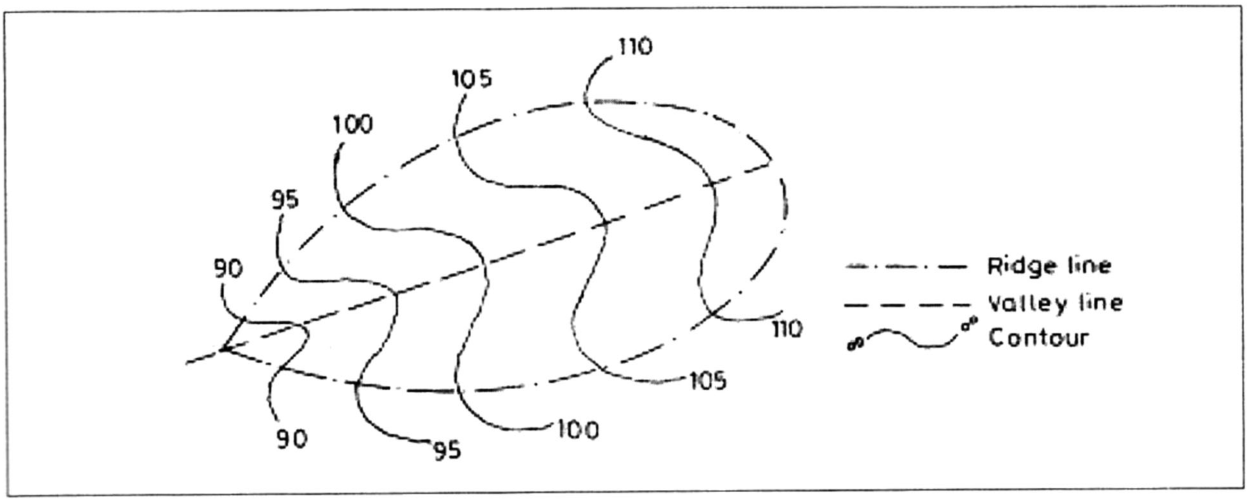

Fig. 4b. Watershed demarcation on the topographical map

Procedures

The procedure involves laying out a single line starting from a known point of elevation in zigzag manner passing through the undulating land and even forest vegetations (Fig. 5). The movement needs to be properly planned so that topographical variations are covered. Simple hand level is used to record reduced level of each station, where bearings are observed by prismatic compass for direction of the routes. Distance in between two stations should not be more than 10 metres so that the reading of the leveling staff is clearly visible and the horizontal distances covered can be measured correctly. Every day the plotting of the observed points are done on a graph sheet for developing contour map. The fresh vegetations need not to be disturbed or cut entirely, but the routes of survey lines are to be cleared. Maps on 1:500 or 1: 1000 are convenient for developing land use plans for individual land uses and villages. A team of four persons can easily map out about 2 to 10 ha of land in a day with desired level of accuracy depending on the type of land (Prasad *et al.*, 1987).

The topographical map provides almost all the watershed parameters. The present land use map, drainage map and land capability map are to be prepared separately based on the watershed/topographical map prepared so. Other social aspects can be covered through PRA techniques as advance progress is made towards preparing resource inventories in the watershed.

Present land use map

The present land use map shows the area under different land uses in the watershed viz. area under agriculture crops, orchards, forest land, pasture/grass land, wasteland, habitation, roads, river, stream, pond, lake etc. Different colours and patterns are used to demarcate the different types of land uses on the map. The planners use this map for working out the proposed development works of the area.

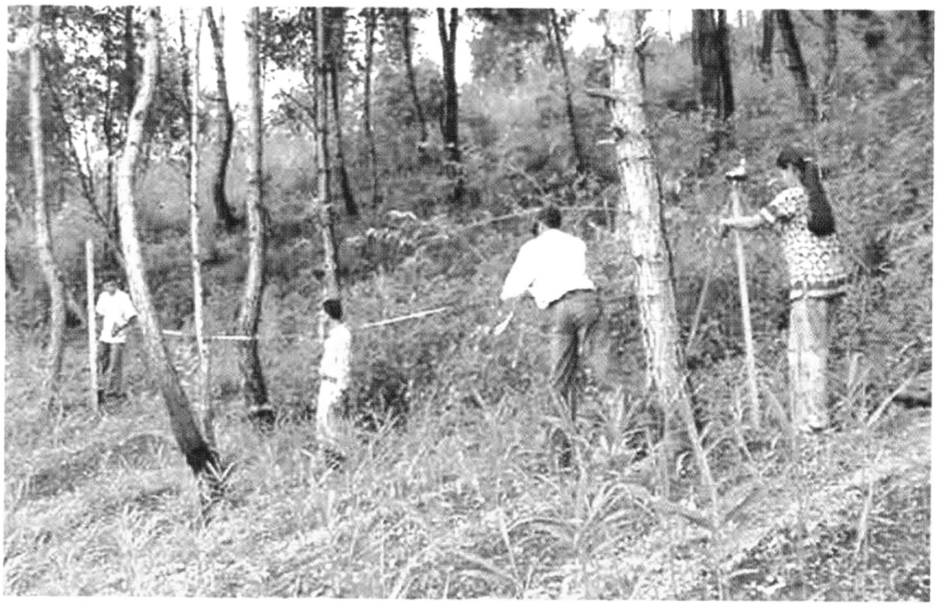

Fig. 5. A view of topographical surveying, Mawpun watershed, Meghalaya

Drainage map

Every stream/valley line and ridgelines are delineated and marked on the topographical map. The drainage units (numbers of micro-watershed), river, stream, springs, ponds, lakes etc. are shown in this drainage map including the number of perennial and seasonal streams. The drainage map helps in assessment of water resources available in the watershed area and to formulate the irrigation and drainage networks including water resources development.

Land Capability Classifications Map

Land capability classification (LCC) map is prepared though detailed soil survey. LCC is a systematic arrangement of different kind of lands according to their properties that determines the ability of land to reproduce on a virtually permanent basis. The LCC has three major categories viz. capability class, capability sub-class and capability unit. The I to VIII land capability classes indicate the degree of total limitation on the agriculture (USDA), and the capability class is further divided into four sub-classes, depending on the nature and kind of limitation for its use viz:

(i) Climate (c): Restriction on the use of the land imposed by climatic condition.

(ii) Erosion (e): Moderate hazards of erosion by wind, water or gravity or a combination.

(iii) Soil condition (s): The use of the land is restricted by soil condition such as low water holding capacity or low nutrient content.

(iv) Wetness (w): The land use restricted by an excess of water, adequate drainage facilities have thus to be provided.

Numerous parameters of the detailed soil survey procedures are available towards preparing the LCC map, however, the following basic important aspect to the watershed planners required to be made familiar.

A) Slope class

Symbol	Slope class	Slope (%)
A	Nearly level	0-1
B	Gently sloping	1-3
C	Moderately sloping	3-5
D	Strongly sloping	5-10
E	Moderately steep	10-15
F	Steep	15-25
G	Very steep	25-33
H	Very-very steep	> 33

B) Soil erosion phase

Symbol	Erosion phase	Characteristics
e_1	No apparent or slight (sheet)	0-25% top soil or original plough layer lost
e_2	Moderate (sheet and rill)	25-75% top soil removed
e_3	Severe (sheet, rill and small gullies)	75-100% top soil and up to 25% sub soil removed
e_4	Very severe (shallow gullies)	Gullied land
e_5	Very very severe (big gullies)	Very severely gullied land or sand dunes

C) Colour notation

Capability class	Colour notation	Land suitability
I	Light green	Land suitable for cultivation
II	Yellow	-do-
III	Red	-do-
IV	Blue	-do-
V	Dark green	Land not suitable for cultivation but suitable for other uses like agroforestry etc.
VI	Orange	-do-
VII	Brown	-do-
VIII	Purple	-do-

D) Gully classification

Symbol	Description	Specification
G_1	Very small gully	Up to 3.0 m deep, bed width greater than 18.0 m and side slopes vary.
G_2	Small gullies	Up to 3.0 m deep, bed width not greater than 18.0 m and side slopes vary.
G_3	Medium gullies	Deep between 3.0 to 9.0 m, bed width not less than 18.0 m. side slopes uniformly sloping between 8-15%.
G_4	Deep or narrow gullies	a) 3.0 to 9.0 m deep, bed width less than 18.0 m and side slope vary. b) Depth greater than 9.0 m, bed width varies and side slopes may mostly steep or even vertical with intricate and active branch gullies.

E) Thickness of top soil

Symbol	Depth (cm)	Description
d_1	0-15	Less thick
d_2	15-30	Moderate thick
d_3	30-60	Thick
d_4	60-90	Very thick
d_5	> 90	Very-very thick

Apparently the given land class appeared on a LCC map may be read as follows:

$$\text{The notation unit on the map} = \frac{cl - d_4}{D - e_2} \quad \text{III}$$

where, class of the land = III cultivable land; soil texture = clay loam (cl); soil depth = d_4 (Very thick – 60 to 90 cm); slope class = D (Strongly slopping – 5 to 10%) and soil erosion = e_2 (Moderate sheet and rill erosions) .

Modified Land Capability Classification

Land capability classification (USDA) is widely employed as the basis for land use planning. When this classification is applied in North Eastern Himalayas, there is no class I and class II land; the region has very little class III land and very few class IV land available. As a consequence, large area falls under class VI and class VII lands (non arable classes) and used for cultivation and therefore, the concept comes into conflict with the current land use. Areas of sloping land are already being used to grow subsistence food crops. It would be socially undesirable to attempt to change this situation. Owing to the typical soil and climatic conditions in the northeastern region, a modified land capability classification have been tried in NE Region (Table 1).

Table 1. Modified land capability classification

Class	Slope (%)	Recommendations
A-1	0-5	Suitable for cultivation without special soil conservation measures.
A-2	6-50	Suitable for cultivation with special soil conservation measures.
B-1	51-100	With shallow depth less than 1.75 m, suitable for pastures and fodder crops.
B-2	51-100	Having soil depth more than 1.75 m, suitable for orchards, cash crops, plantation crops etc.
C	>100	Suitable for forest.

Source : Borthakur (1992)

Proposed land use

Having full knowledges about the watershed, land, people, climate and other resources including status of the soil erosion, land capabilities etc. the proposed land uses map of the area is to be worked out for development purposes. This is also termed as *Development Plan or Master Plan,* which includes generally the soil and water conservation measures, farming systems under different land uses including agroforestry systems.

Soil and water conservation measures: Agronomical and mechanical soil conservation measures for arable lands, gully control measures etc. for non-arable lands and agroforestry systems on the hill slopes are the approaches towards conservation of natural resources in the entire process.

Agronomical measures: Agronomical soil conservation practices like contour cropping/planting, contour strip cropping, crop rotation, green manuring, cover cropping, mulching etc. are generally followed on mild hill slopes.

Contour cropping/planting: All agricultural operations are carried out following contour guidelines for velocity control of run-off on hill slopes to check soil erosion. Planting of crops, trees, shrubs, grasses following contour lines are generally advocated. Even the tilling operations are to be carried out following contour guidelines.

Contour strip cropping and cover cropping

Strips of food grain crops are followed by leguminous crop strips vis.a-vis on rotations on mild slopes. It will help in improving fertility status as well as checking soil erosion.

Cover crops mainly leguminous variety help in disseminating the raindrop splash action against soil erosion too.

Crop rotation

Crop rotations are followed on mid hill slopes along with other scientific methods and practices with improved seeds, sowing time, application of manures and fertilizers and timely cultural operations etc. Timely intercultural operations, weeding and surface hoeing will help in conservation of rain water and its efficient utilization, which will bring increased production.

Green manuring

Green manuring crops are grown and buried into the soil once in three years. It improves structure and organic matters to the soil.

Mulching

It is a common method to spread dried vegetative matters over the exposed inter areas mainly in between the rhizomatous crop lines and in the orchard during the dry and drought period. This acts against moisture stress and rain drop splashes.

Mechanical Soil Conservation Measures

The agronomical measures are not adequate alone in the high hill and steep slopes. Specifically when the steep slopes are cultivated, certain mechanical or engineering soil and water conservation measures have to be adopted. The bench terracing, contour bunding, half moon terracing, grass water ways, drop pits, gully plugging, earth dams for water harvesting, contour trenching and straggerd trenching for land uses, drainage line treatment structures etc. are common mechanical measures adopted for watershed land use systems. Combination of agronomical measures and agroforestry systems are also to be followed.

Bench terracing

Bench terraces are flat beds constructed by earthen embankments across the hill slope with half cutting and half filling methods on the contours. Agricultural practices can efficiently be performed in bench terraces. In micro-watershed involving steep slopes (up to 33%), few benches only at foothills may easily be constructed to produce food crops. Experience shows that construction of dry bench terraces even up to 40 to 50% slope in NEH Region are feasible. The vertical interval of such terraces should not increase more than 1.0 m. However, such measures can be adopted where soil depth is more than 1.0 m. Requisite slope for risers, (usually 1:1), is to be maintained for the vertical drops of the terrace. Bench terraces can also be developed with vertical stone wall. One side bund on the outer edge of the terrace should be provided against the land sliping and over topping of excess runoff water from the terraces. To maintain topsoil in terraces, the construction should start from the foothills side. Figure 6a shows different types of bench terraces, which are selectively constructed according to the necessity in the required situations. The bench terrace cross section is shown in Fig. 6b.

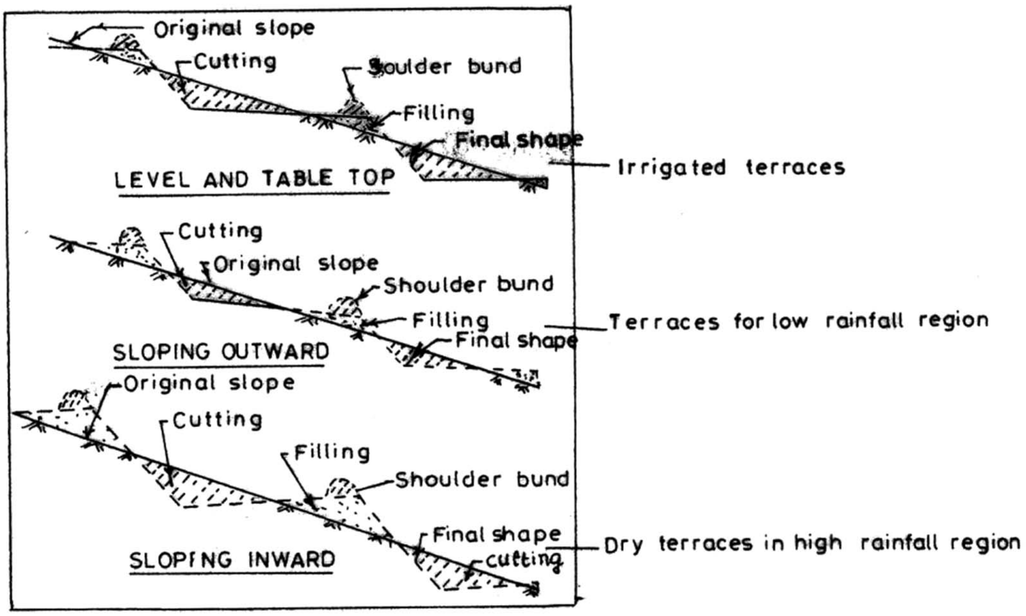

Fig. 6a. Different types of bench terrace

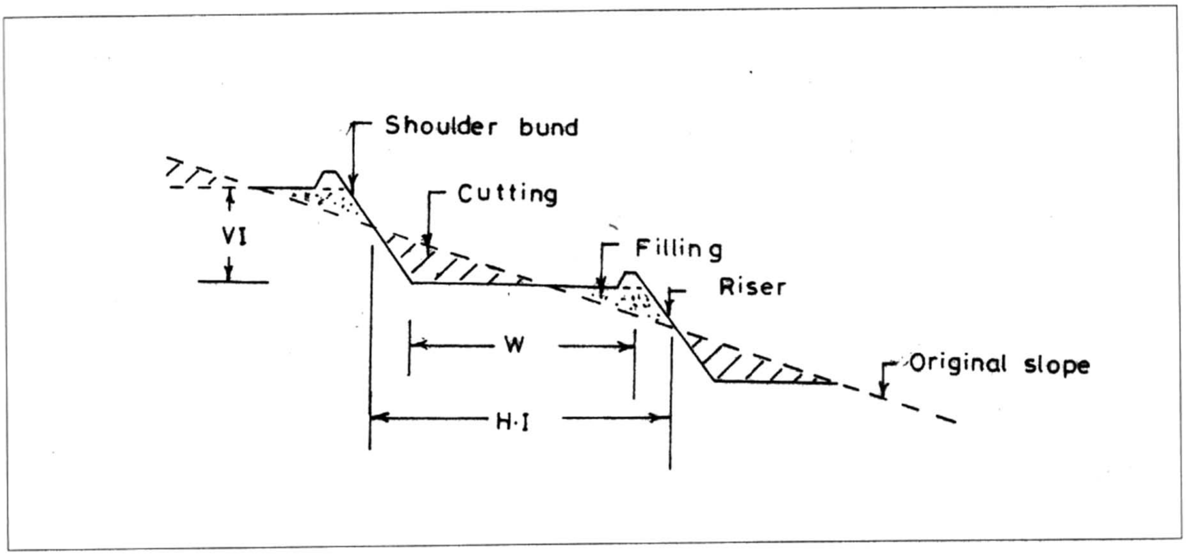

Fig. 6b. Cross section of bench terrace

Design of bench terraces

Vertical Interval (VI) design for bench terraces: Vertical Interval (VI) is restricted by the depth of cut available and soil should be left on the half by at least 15 to 21 cm for the crop root zone. Thus maximum VI is determined by

VI (max) = 2 (D – 0.15) m, where D is the cultivable soil depth.

However, this has to be again qualified by the economic width or practicable width for farming, which can be worked out from the following formula:

$$\text{Vertical Interval (VI)} = \frac{WS}{100 - S}, \text{ and}$$

$$W = VI \times \frac{(100 - S)}{S} \quad \text{for batter to riser ratio (1:1)}$$

Which is most commonly used and practicable.

Where, W is width of the terrace (convenient with 3 to 5 m), and

S is the hill slope per cent (to be determined by the Abney Level or through the topographical map).

Terrace width (W) : For better cultivation, bench width is to be considered in relation to the power to be used. However, in most cases, benches are cultivated by manual labour in the region. The minimum general used widths are 5 m for slope up to 25%, and 3 m for slopes between 25 to 33%. This limit may well suit the operation of small power tillers and bullock driven implements. For terraces of 1.0 m width, which are found in the NEH Region, only manual operations are needed.

Terrace gradient: Proper drainage of the bench terrace is provided by longitudinal and inward gradient. Generally, the longitudinal gradients followed are between 0.5 to 1 %, and 2.5 % inward gradient is safely practiced.

Length : The actual length is often dictated by the size of the holdings and physiography. For economy of construction, greater length is desired. However, for good moisture condition shorter one is better. On an average, terrace length of 100 m seems to be the most appropriate, considering the ability of the toe drain to take out runoff without causing detrimental water stagnation, erosion hazard and moisture condition.

Total length of benches per hectare for a given vertical interval and slope percent is obtained as follows:

$$Lh \times HI = 10{,}000\ m^2$$

Where, Lh is total length of terraces per ha (m) and HI is horizontal interval.

$$\text{Or } Lh = \frac{10{,}000}{HI} = \frac{10{,}000}{100\ VI / S},$$

$$\text{since } HI = \frac{100VI}{S} = \frac{100\ S}{VI}\ (\text{m ha})$$

where, S = Hill slope per cent and VI = Vertical interval.

Cross section of cut:

$$\text{The cross section is given by c.s. of cut} = \frac{1}{2} \times \frac{W}{2} \times \frac{VI}{2}\ (m^2)$$

$$= \frac{WVI}{8}\ (m^2),\ \text{when batter to riser is 1:1}$$

where, "W" is the net width variable with slope per cent and vertical interval (VI)

Cross disposal drain: Two benches from either side areas can drain into a common cross disposal drain for economy as well as for convenience. The lowest number of cross disposal drain (n) per hectare is estimated as follows:

$$n = \frac{Lh}{2K},$$ where, Lh = Total length of the terraces/ha, and K = critical terrace length

$$= \frac{100S}{VI} \times \frac{1}{2K} = \frac{100S}{VI\ 2} \times \frac{1}{100} \quad \text{when } K = 100$$

$$= \frac{S}{2\,VI}$$

When shorter benches are constructed due to same reasons, "n" will be equal to the number of terraces. The cross section of the cross disposal drain is generally a trapezoidal and its grade and size are determined by the cumulative runoff the drain has to carry. Common section used is 0.45 X 0.3 X 0.37 m. This could be designed as a grassed waterway and the vertical drop from bench along the protected risers. For this, in all practical purposes, the length of the cross disposal drain can be assumed as:

$$\text{Horizontal interval (HI)} = \frac{100\,VI}{S}$$

Hence, minimum total length of cross disposal drain $L = n \times \frac{100\,VI}{S}$

$$\text{Or } L = \frac{S}{2VI} \times \frac{100\,V}{S} = 50 \text{ m/ha}$$

Contour bund

Contour bunds are mechanical (earth made) or vegetative barriers created across the slope. The bunds divert the excess runoff during rains to the grass waterways and retain eroded soil within it. To cultivate steep slopes, the contour bunds are developed. However, the nomenclature need not be confused with contour bunds used as soil conservation measure on mild slopes. These bunds are created by way of excavating parabolic channels (0.3 m top width x 0.2 m deep) on contour and keeping the dug out soil in form of a *bund* at the lower edge of the channel (Fig. 7).

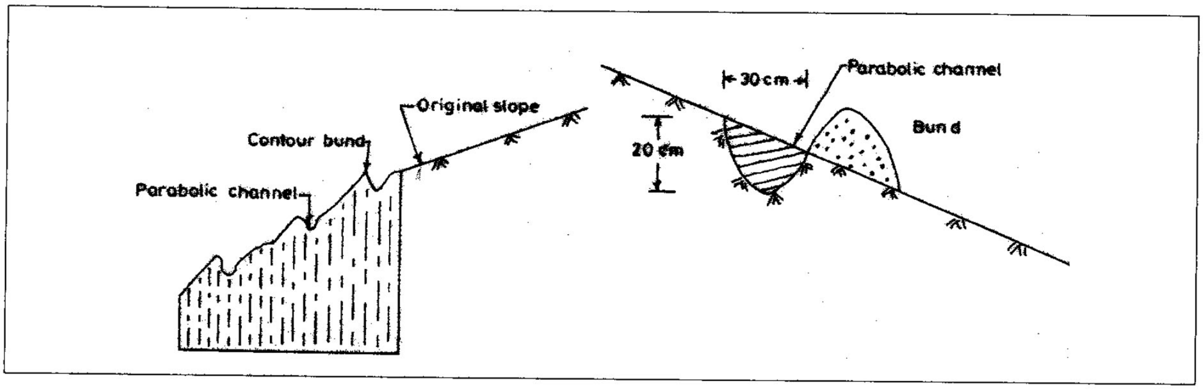

Fig. 7. Details of contour bund section

The usual cultivation practices are continued in between the area of the bunds. With slow process of silt deposition with bunds, the area within two bunds gets leveled up and takes the shape of terrace in course of 4 to 8 years. These bunds require care and maintenance during first two years. The vertical interval may range from 0.5 to 5.0 m depending upon the land use and soil depth. Experiences indicate that developing bench terraces with contour bunds are very effective. The method avoids sudden disturbance of soil profile and exposure of sub-soil compared to cut and fill method. The cost of construction is also about 1/3rd of the bench terracing. The above process of contour bunding is also known as Peutorican terraces or California type of terraces.

Half moon terraces

The half moon terraces are constructed for planting and maintaining sapling of fruit and fodder trees in horticulture and agroforestry land use system (Prasad *et al*, 1987). This type of construction is made by earth cutting in half-moon shape to create a circular level bed having 1 to 1.5m diameters. It provides facilities for retaining soil fertility, moisture, application of fertilizers and manures for healthy growth of the plant (Fig. 8).

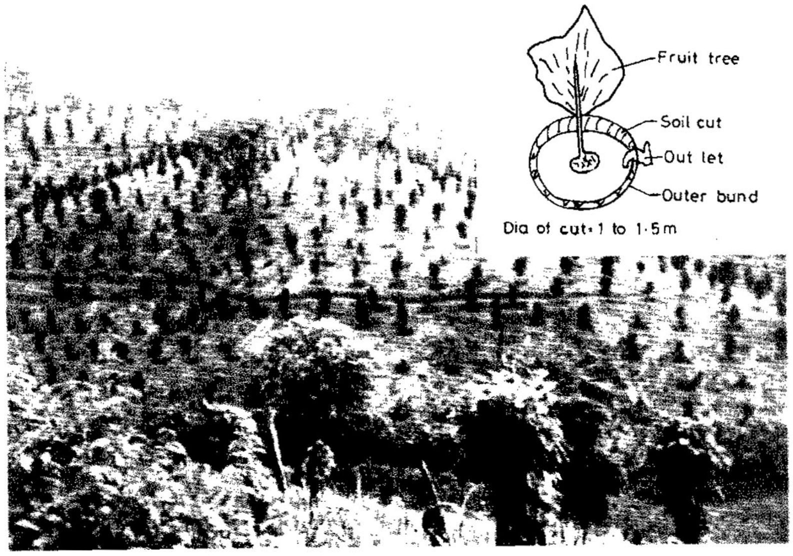

Fig. 8. Half moon terrace for growing horticulture plants on hill slope

Contour trenching

In order to prevent soil erosion and to absorb rainwater where it falls, in the non-arable lands contour trenching with vegetative supports are constructed on hill slopes above 15% under agro-forestry and horticulture land uses (Fig. 9). It will improve moisture status in the soil, water yield in the springs with increase in fruit and wood production. For vegetative supports economic species like broom grass can be planted. The trenches can be constructed at an average vertical interval of 10m. Graded trenches and staggered trenches can be constructed according to the necessity in the hills of high and low rainfall areas, respectively.

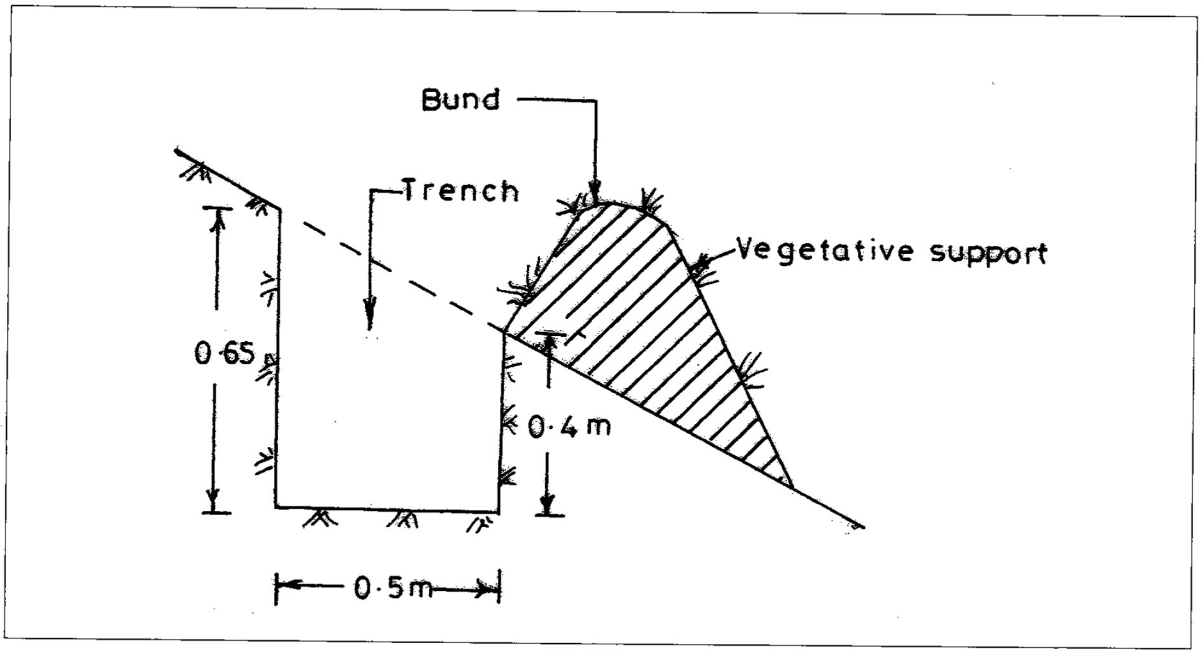

Fig. 9. Contour trench section

Water Harvesting

Dug out cum embankment type water harvesting structure can be used for creating seasonal and perennial ponds at the foothills of the micro-watersheds (Fig. 10). Only locally available materials can be utilized in this work and the pond is created by embankment of earth dam Masonry core wall in the middle of desired section and height must be provided to check seepage along with surplus arrangement by way of constructing masonry spill way and the provision of emergency earth spill way must be provided against over topping of run off. Ponds so created provide facilities for integrated fish farming with piggery, duckery and poultry where the animal excreta can be fed to fishes for early growth and quick income generation. Water bodies such created in watershed have the manifold uses for home use, irrigation, drip and sprinkler irrigations, animal rearing, recreation purposes etc.

Drainage Line Treatments/Gully Control Structures

In order to check the erosion at the up stream of drainage line and to prevent flow of sediment and debris to down stream/valley land, the vegetative and mechanical measures like live checks, bamboo/ brush wood check dam, loose boulder check dams/gabion structures are suggested. Gully control structures, temporary, semi permanent and permanent, are used for arresting gully erosion viz. Masonry Drop spill way, Chute spill ways etc. to pass heavy storm of run off in safe velocity in the high drops.

Fig. 10. Water harvesting structures in farmers' field at Nongpoh, Meghalaya

Gully control structures (gabion) with locally available dry stone, wooden and bamboo materials are used to control gully erosion in agricultural field. Earthen gully plugs are also applicable under required vigilance, care and maintenance. Some of the structures used are shown in Figures 11a to 11d below:

Fig. 11a. Drop spillway

Fig. 11b. Gully plug with loose boulder

11c. Cement Nala bund

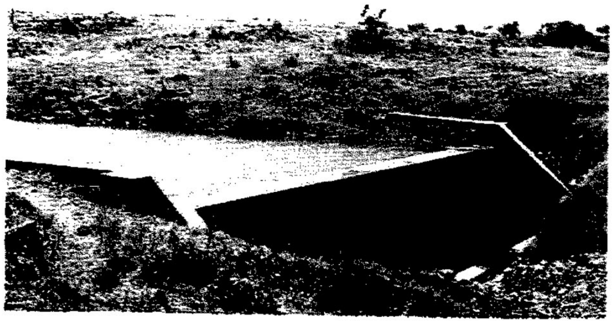

Fig. 11d. Diversion bund

Agroforestry Systems

Agrisilvicultural, agrihorticulture, farm forestry, live fencing etc. are applicable in watersheds. Mulberry plantations along with cultivation of ground nut, soybean, rice bean, pea, ginger and other cole/ remunerative crops are some examples of such recent agro-forestry system. Besides animal husbandry may be promoted for regular income generation to the farmers.

Practical Know-how of the Engineering Techniques

Percentage of Hill Slope

To calculate the percentage of hill slope, Abney level and Topographical maps are used.

Abney Level

To measure the slope of the hill, the observer stands at one end of slope and directs the instrument on the mark fixed on the ranging rod at the same height of the observer's eye, held at the other end and turns the milled wheel until the reflected image of the bubble is brought to centre of its run and intersected by the cross wire. The bubble tube is now horizontal, while the telescope is parallel to the slope of the ground. An angle will be read on the arc. This angle is to be converted to per cent slope from the rating table (Table 2) or slope (per cent) can be worked out as the percent of the tangent of the angle found from the arc under trigonometrical ratio.

Topographical Map

Per cent of slope from topographical maps are worked out specifically at the planning stage of the projects towards designing of soil and water conservation measures and estimation purposes. Hill slope per cent is worked out using the following formula:

Table 2. Percent slope corresponding to degree of slope

Angle in degree	Per cent slope	Angle in degree	Per cent slope
0.5	0.87	23.0	42.45
1.0	1.75	23.5	43.48
1.5	2.62	24.0	44.52
2.0	3.49	24.5	45.57
2.5	4.37	25.0	46.63
3.0	5.24	25.5	47.70
3.5	6.12	26.0	48.77
4.0	6.99	26.5	49.86
4.5	7.87	27.0	50.95
5.0	8.75	27.5	52.06
5.5	9.62	28.0	53.17
6.0	10.51	28.5	54.30
6.5	11.39	29.0	55.43
7.0	12.28	29.5	56.58
7.5	13.17	30.0	57.74
8.0	14.05	30.5	58.90
8.5	15.05	31.0	60.90
9.0	15.84	31.5	61.28
9.5	16.53	32.0	62.49
10.0	17.63	32.5	63.71
10.5	18.53	33.0	64.94
11.0	19.44	33.5	66.19
11.5	20.35	34.0	67.45
12.0	21.26	34.5	68.73
12.5	22.17	35.0	70.02
13.0	23.09	35.5	71.33
13.5	24.01	36.0	72.65
14.0	24.93	36.5	74.00
14.5	25.86	37.0	75.36
15.0	26.79	37.5	76.73
15.5	27.73	38.0	78.13
16.0	28.67	38.5	79.13
16.5	29.62	39.0	80.98
17.0	30.57	39.5	82.43
17.5	31.53	40.0	83.91
18.0	32.49	40.5	85.41
18.5	33.40	41.0	86.93
19.0	34.41	41.5	88.41
19.5	35.41	42.0	90.04
20.0	36.40	42.5	91.63
20.5	37.39	43.5	93.25
21.0	38.39	43.0	94.90
21.5	39.29	44.0	96.57
22.0	40.40	44.5	98.27
22.5	41.42	45.0	100.00

$$\text{Average slope (\%)} = \frac{\text{Total length of contour (m) X contour interval (m)}}{\text{Area (m)}^2} \times 100$$

Layout of Contour Guidelines

Laying out of contour guidelines is the basic need of soil conservation measures of any project to start with the development. First of all the definition of contour line should be familiar to a person or the farmer towards developing the watershed activities. Contour line is the imaginary level line joining all the equal elevation points on the ground. Engineers use certain instruments like hand level, dumpy level, theodolite etc. to lay out contour guidelines. However, a common man or farmer can use locally made handy equipments like *A-frame, Line level* etc. for contour guidelines.

A-frame

Three poles made of either bamboo or wood are tied together alike "A" alphabet and a plum bob is tied from the apex of the frame to hang vertically or a carpenter spirit level is fixed in the middle of the horizontal bar. The plum bob will hang in the middle passing the string through the centre mark of the horizontal bar or the bubble will show the centre of its run in case of the fixed spirit level when the two foots of the A-frame are stand on the equal elevations. Two persons are required, one for holding the frame and driving pegs by the other person. Repetition of the process, series of pegging will be there and the line joining so will layout the contour guide line. It is very simple technique to operate (Fig. 12).

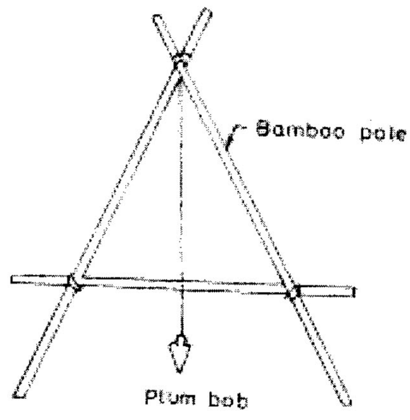

Fig. 12. A frame

Line level

The line level is the most convenient equipment to layout contour guidelines as well as graded lines in the soil conservation works and in the watersheds. It is easy to fabricate also, as a sprit level hangs exactly in the middle on a horizontal string connected at the top of two wooden poles. The poles are graduated at every 10 cm. Three persons are required for the operation of laying out contour line or grade line by this line level. Two persons hold the poles at the either end and the other person in the middle use to check the level and then to place the pegs. One pole is placed at the starting edge of the field and the other pole is moved at the string distance up and down till the bubble of the spirit level shows the centre of its run. The place of the second pole so arrived is pegged. Now the first pole is moved, holding the second pole in its place, to the string distance again to get the bubble in the centre of its run. Another peg is to be driven at this place and to continue the process until to reach the end of the field the line joining the pegs is the contour line laid out. The next or consecutive contour lines can be laid out at the designed vertical interval between the erosion control structures repeating the same process.

Grade lines are laid out easily by this line level with help of its graduated poles marked in every 10 cm. Since in between poles, distance is at 10.0 m (string distance), therefore, the drop of number of division at one end of the pole will give the per cent of grade of the control structure.

EPILOGUE

India occupies 63% rainfed agriculture land, where agricultural systems are complex, diverse and risk prone. National Agricultural Policy 2000 of India underlined the need for diversification in agriculture with the promotion of integrated development of rainfed areas on watershed basis. Watershed based technology of land use is highly significant in hill agriculture for sustained food production. Present paper describes some basics of watershed development in hilly agro-climatic zones with an objective to provide the base information to various watershed developmental agencies at field level.

ACKNOWLEDGEMENTS

Authors are thankful to Mrs. K. Makhiew and Mr. L.K. Singh for their help in cartographic works and photo editing. Thanks are also due to Miss Binalin Kharumnuid for typing the manuscript.

REFERENCE

Anonymous (1983). *Shifting Cultivation in North East India.* ICAR Research Complex for NEH Region, Umiam Meghalaya.

Bisht, B.P. (2003). Agroforestry for sustainable mountain development in NEH region. In: Rawat, M.S.S. (ed.), *Central Himalaya Environment and Development: Potential, Actions and Challenges*, Vol. I, pp. 205-223, Published by Transmedia, Media House, Srinagar, Garhwal in association with Dept. of Geography HNB Garhwal University, Uttaranchal.

Prasad, R.N.; Singh, A. and Verma, A. (1987). Application of research findings for management of land and water resources in Eastern Himalayan region. Research Bulletin, ICAR Research Complex for NEH Region, Umiam, Meghalaya.

Satapathy, K.K. and Dutta, K.K. (2002). *Integrated Watershed Management for Sustainable Development.* ICAR Research Complex for NEH Region, Umiam, Meghalaya, pp. 11-18, 73-79 and 183-188.

Satapathy, K.K. (2003). Degradation of natural resources in North East India: An overview. In: Rawat, M.S.S. (ed.) *Central Himalaya Environment and Development: Potential, Actions and Challenges*, Vol. I, pp. 297-309, Published by Transmedia, Media House, Srinagar, Garhwal in association with Dept. of Geography HNB Garhwal University, Uttaranchal.

Singh, G.; Vengkateraman, C.; Sastry, G. and Joshi, B.P. (1990). *Manual of Soil and Water Conservation Practices*, pp. 184-288, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.