TREATMENT TECHNOLOGIES FOR WATERSHED DEVELOPMENT AND MANAGEMENT IN NORTH EAST HILL REGION

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INTRODUCTION

Land, water and vegetation are the three basic resources of the life support system. These resources are under intense pressure in the North Eastern Region due to natural and human induced factors. The ecosystem in this region tends to become fragile and precariously balanced due to rapid increase in human and bovine population, over exploitation of natural resources to meet their food, fodder and fuel requirement and unscientific management of these resources. Traditional food production system prevailing in the region, undulating terrain and high and intense rainfall, has further accelerated the resource degradation and depletion processes leading to the deterioration of the overall ecosystem. Soil erosion not only affects the on-site by way of loss of fertile soil but also off-site in form of frequent incidences of flash floods in the lower valleys and plains with consequent damage to fertile farms, water resources and irrigation systems, dams, roads and bridges and loss of life and property.

The agricultural production system in the region is mostly rainfed, mono-cropped and at subsistence level. It is estimated that 76.6 t ha^{-1} yr^{-1} of soil is lost every year due to traditional system of farming (Prasad et al., 1981). The soil erosion from hill slope (60-70%) with jhum (shifting cultivation) during first year, second year and abandoned during the 3rd year was estimated as 147, 170 and 30 t ha^{-1} yr^{-1}, respectively (Singh et al., 1995). "Bun Cultivation" is another form of food production system, which is practiced mostly in Meghalaya for cultivation of tuber crops such as potato, ginger, turmeric, etc. It was observed that from every tonne of potato produced by the system, soil loss was two tonnes (Singh and Singh, 1981). About 57.41 lakh ha area is categorized as degraded land in the region (Sehgal and Ibrol, 1994). This necessitates a long term developmental approach aimed not only at optimum utilization of natural resources but also at development of the natural resources such as land, water, vegetation and man power for restoration of ecological balance.

WATERSHED APPROACH FOR RESOURCE CONSERVATION

The scope of soil conservation is very wide and encompasses much more than physical work for erosion control. The concept of soil conservation, now-a-days has been expanded to mean protection of the soil against physical loss by erosion or against chemical deterioration. Thus, the effective conservation and management of land, water and vegetation resources aimed at obtaining optimum and sustained return from these resources without degrading them can be achieved by adopting watershed as basic unit of development. Watershed being a natural hydrological entity, it responds most effectively to various engineering, biological and cultural treatments. Monitoring of runoff and silt at the outlet of the watershed can help assess the impact of various treatments aimed at conserving soil and water, and protecting vegetation. Watershed management involves protection of land against all forms of degradation, restoration of degraded land, sediment control, pollutants control, and prevention of floods, etc. A workable size of the watershed can be decided in accordance with the aim and objective of the particular system as well as the size of the stream for which it forms a catchment. Watershed of smaller size has distinct advantage of involving a smaller number of families within a resource unit with a common social and economic pattern. Demarcation of watershed and subsequently sub watersheds can be done either by using topo sheet of the area

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available with Survey of India or by interpretation of remotely sensed imagery of the area. Prioritization of sub watershed should be done on the basis of sediment yield and pollutants concentration in the runoff from the sub watershed. The entire watershed can be treated gradually over a number of years as per the availability of financial and other resources. Numerous treatment technologies in form of engineering measures and agronomic practices are available. But identification of most suitable technologies as per the site condition and their application in correct way is most important to achieve the desired results. These technologies when adopted within the boundary of watershed, facilitates favourable interaction among various watershed factors such as physiography, land slope, soil characteristics, land use, hydrological behaviour etc, land, and water resources to produce food, fodder, fuel and fibre on sustainable basis. In present article only engineering measures suitable for the region are discussed.

ENGINEERING MEASURES

Engineering measures are also called mechanical measures. These measures are aimed at arresting the movement of eroded soil by reducing the slope length and / or slope steepness or gradient. Some of theses measures suitable for agricultural lands and their design and potential land use models are discussed.

a) Contour bund

Contour bunds are mechanical (earth made) barriers created across the slope following the line of contour. Contour bund may follow exactly the line of contour in the low rainfall areas where the objective is to conserve entire amount of rainfall in-situ. But in high rainfall areas such as this region, where in addition to the in-situ conservation of rainfall, safe disposal of runoff is also one of the objectives, the contour bunds may deviate from the line of contour in order to attain longitudinal gradient. This gradient will help guide the runoff to grassed waterways safely. Owing to the generation of large volume of runoff due to high rainfall amount and intensity, and land gradient, 0.5% longitudinal gradient to the contour bund should be provided. Such bunds are called graded bunds. The graded bunds divert the excess runoff during rains to the grassed waterways and retain eroded soil. For making of the graded bunds, first contour lines are demarcated by putting stakes on the ground. Then another line is demarcated by deviating from contour line so as to attain 0.5% grade. The graded bunds are made along this line. These bunds on steep slopes are created by way of excavating parabolic channel (0.3 m top width x 0.2 m deep) along the grade line and the dug out soil is placed in a form of bund at the downstream of the channel. The height of bund should be such that it can allow maximum 30 cm impounding of water near the bund. In the region normally 40-45 cm height is appropriate. The vertical interval between two consecutive bunds may be kept at 0.5 to 1.0 m depending on the slope, land use and soil depth. Theoretically, bunding is suitable for lands with slopes ranging from 2 to 10 % but experiences indicate that it can be adopted for land with slope upto 30%. But the height of the bunds should be raised once before commencement of the monsoon season. Other bunds being used in watershed programmes are as under:

1. **Side bunds:** These are constructed along the slope at extreme ends of the contour bunds.
2. **Lateral bunds:** The safety of contour or graded bunds from excess accumulation of runoff is very essential. This bund is constructed along the slope in between two side bunds to prevent concentration of runoff.
3. **Supplemental bunds:** If the horizontal spacing between two contour bunds is large, supplemental bunds are constructed at those places across the slope to limit the horizontal spacing.
4. **Marginal bunds:** These bunds are constructed along the margin of watersheds, streams, roads and gullies.

Crop cultivation practice is continued in the area within the two bunds; with the slow process of silt deposition within the bunds, the area between the two bunds gets leveled up and takes shape of terrace in due course of about 4-8 years time. It has been found that developing bench terraces through slow process with the help of contour bunds is very effective, as this method avoids sudden disturbance of the soil profile exposing the subsoil as happens in case of bench terracing by cut-fill method. The results of an experiment in the ICAR showed that after cultivating 3 crops, slope of land surface reduced to an average slope of 7.8% from original slope of 28.8%. Pineapple may be planted on the bunds. Pineapple planted on contour bunds yields 9300 fruits per hectare after 20 months of planting. Golden timothy grass, guinea grass, dallies grass can be planted on bund for its stabilization and fodder production (Singh et al., 1996). These bunds require care and maintenance during first two years.

b) Bench terracing

Bench terraces are flat beds constructed across the hillslopes along the contours with half cutting and half filling. They serve as barriers to break the slope length and also reduce the degree of slope thereby eliminating the all erosion hazards. On sloppy and undulating lands, agricultural practices can effectively be performed on these bench terraces. All the external nutrients supplied to the crops in form of manures and fertilizers remain in the cropped field. In micro-watersheds involving steep slopes (up to 33%) few bench terraces only at foothills may easily be constructed to produce food crops. Experiences show that, construction of dry bench terraces even up to 40 to 50% slope in NE region is feasible. The vertical interval of such terraces should not be more than 1.0 m. Such measures can be adopted where soil depth is more than 1 m. Requisite slope for risers usually 1:1 (riser to batter) slope is to be maintained for the vertical drops of the terraces. Bench terraces can also be developed with vertical stone walling and are in use by the farmers of the region. Side bunds on the outer edge of the terrace should be provided to prevent slipping down of soil and overtopping of excess runoff from the terraces. To maintain top soils in terraces, the construction should start from the foot hills.

Normally three types of bench terrace should be used in the region depending upon requirement of crops and availability of funds. They are as under:

1. **Level bench terraces:** Benches are almost leveled to ensure uniform depth of impounding water. This type of bench terrace is used for paddy cultivation. Therefore, they are also called table top or paddy terraces.
2. **Inwardly slopping bench terraces:** These types of bench terraces are preferred for cultivation of tuber crops such as potato, ginger, turmeric, and sweet potato, which are susceptible to water logging. Benches are made inward slopping to drain runoff as quickly as possible. The longitudinal gradient of 0.5 to 1% and inward gradient of 2.5% may be followed in the region.
3. **Puertorican or California type of terraces:** These terraces are formed by gradual conversion of land between two barriers into terrace by natural leveling process. Mechanical barriers (bunds) or vegetative barriers (grasses or shrubs) or combination of both, are laid along the contours. Due to ploughing and interculture operations soil is eroded and gets deposited at the barriers. Thus, in due course terraces are formed.

Results of experiments conducted at Byrnihat and Barapani (Meghalaya) showed that bench terrace is able to retain up to 98% of rainfall. The risers of the bench terraces should be planted with perennial grasses and fodder legumes for its stabilization and fodder yield. Legumes - *Stylosanthus guyamensis*, Shameta, thin nappier and *Seteria sphaculata* with yield potential of 19.7, 19.0, 65.05 and 80.86 tonnes of green fodder, respectively, per hectare of riser land (Verma, 1987) were found good for plantation on terrace risers.

c) Half-moon terraces

The half-moon terraces are constructed for planting and maintaining saplings of fruit and fodder trees in horticulture and agroforestry land use system. The construction of this type of terrace is made by earth cutting in half-moon shape to create circular level bed having 1 to 1.5 m diameter. The bed may also have inward slope. This type of terraces is made at an interval of planting spacing of the fruit and fodder trees. Half-moon terrace helps retain soil fertility, moisture and added fertilizers and manures for healthy growth of the plant.

d) Contour trenching

Trenches are any form of depression or micro pit or trench constructed over the land surface. In order to prevent soil erosion and to absorb rainwater in non arable lands, trenches are constructed along the contours (called contour trenches) on hillslopes above 15% with vegetative supports for forestry and horticulture land uses. Generally trenches may be dug with a cross section of 0.30 m x 0.30 m at 1 to 2 m vertical interval. For proper drainage of excessive runoff, they may be connected with longitudinal drains and drop pits. It will improve moisture status in soil, water yield in the springs, increase in fruit and wood production. For vegetative supports economic species like broom grass can be planted. They are called continuous when there is no break in length and maximum length can be 100 to 200 m long across the slope depending on the width of the field. However, when these are laid scattered with maximum length of 2 to 4 m, they are called staggered contour trench. The trenches may be trapezoidal or rectangular in cross section but flatter upstream side slopes are preferred in order to minimize the risk of scouring by incoming runoff.

e) Grassed waterways

In high rainfall area, safe disposal of runoff is very important for safety of any trace system. The main function of grassed waterways is to drain out excess runoff from the field at non-erosive velocity. It helps protect land against rill and gully erosion. A waterway is constructed according to a proper design. Turfs or sod of perennial grasses which are drought resistant, erosion resistant and submergence resistant should be developed to protect the channel section against any kind of erosion because of the concentrated flow. The velocity in the grassed waterways should be kept within the permissible limit for different types of soil and these limits are presented below (Table 1).

Table 1: Permissible velocity in grassed waterways for different soil types

Type of soil	Maximum permissible velocity (cm/sec)
Sand and silt	45
Loam, sandy loam and silt loam	60
Clay loam	65
Clay	70
Gravelly soil	100

The trapezoidal section of grassed waterways is more appropriate because it is more stable and has larger capacity as compared to other cross sections. Moreover, trapezoidal shape will assume parabolic shape in due course.

f) Diversion drains

Diversion drains are sometimes called simply diversions. They are the channels constructed across the slope for the purpose of intercepting runoff and conveying the same to a safe outlet. Diversion drains are located above the agricultural lands at lower reaches of hill slope. Diversion drains are also constructed at the gully heads or at the upstream of bunded or terraced areas to intercept the surface runoff to avoid any damage from concentrated flow. The design criteria and maximum permissible velocity should be same as that of grassed waterways.

ECONOMICALLY VIABLE AND SUSTAINABLE FARMING SYSTEM DEVELOPED BY ICAR ON MICRO-WATERSHED BASIS

ICAR has developed economically viable and sustainable farming systems on micro-watershed basis. The above mentioned conservation measures were employed to reduce the soil and water loss from the field. Some of the promising and most suitable systems for the region are discussed below.

i) Agro-pastoral farming system

The system was developed in the area of 0.64 ha having average slope of 32.42%. The conservation measures adopted were contour bunds at higher reaches, bench terrace at lover reaches and grassed waterways in drainage channel. Top of the hillock (0.06 ha area) was kept under forest. The cost of land development under the system was around 400 man days/ha. Based on the experiences and results, two cropping systems: rice based (Rice-mustard /potato/radish, maize based cropping system (maize-groundnut/soybean/mustard) may be practiced. About 30% area was covered under bund and terrace risers. This area was utilized for fodder production. Among the perennial grasses and legumes - *Setaria sphacilata,* thin napier, guinea and stylosanthes were found suitable for plantation on terrace risers for stability of the risers and fodder production. The fodder crops should be pruned before attaining height of 50 to 60 cm to avoid any shade effects on agriculture crops in the terrace. Such system in 1 ha land can also sustain 1.25 cow or 5 pigs or 10 goats. Economics of this farming system was estimated as 1.83:1 without integration of livestock and 2.05:1 with the integration of livestock. Sediment yield from this system was found to be less than 1 t $ha^{-1}yr^{-1}$. This system can be practiced on land with more than 1m soil depth and slope upto 50%.

ii) Agri-horti-silvipastoral farming system

The system was developed in micro-watershed having an area of 1.58 ha and average slope of 41.77%. Contour bunds, bench terrace, grassed waterways and half moon terraces were the conservation measures adopted in the micro-watershed. Timber, fuel, fodder, and fruit trees were grown along with pineapple, fodder grasses, and legume crops. Labour requirement for the development of the land for this mixed land use system was estimated as 190 man days ha^{-1}. The produce from this system in 1 ha area can meet the food, fodder and fuel requirement of a tribal family consisting of 5 members. One person can maintain this system in 1 ha area through out the year except in the month of July when labour requirement exceeds 30 man days $ha^{-1}yr^{-1}$. During this month his family member can support him. The system can sustain 10 goats from the fodder obtained from risers, horticulture and silvipasture area. The system is most suitable for remote area farmers who would like to have self sufficiency in food, fodder and fuel (Singh et al., 1987). The benefit: cost ratio of the system was estimated as 2.14:1 and 1.41:1 with and without integration of the livestock component, respectively. Hydrologic evaluation of the system revealed the sediment yield of 1.22 t ha^{-1} yr^{-1}.

iii) Livestock based farming system

This system was found suitable for steep slope upto 100% and shallow soil depth. Even soil depth of 0.5 m can also sustain this system. The economic viability and sustainability of this system was established in 1.39 ha area with average slope of 32.02%. Minimum soil manipulation is required. Contour trenches and grassed waterways can provide effective conservation of soil and water in the system. Cost of land development for such land uses may vary between 150 and 335 man days ha^{-1}. Selection of leguminous and non-leguminous annuals and perennials, shrubs and trees will depend on the type of enterprises (such as milk, beef, mutton, wool, pork and poultry production). The fodder production system has to ensure stability in fertility status of soil, availing the moisture supply towards maximum fodder production for longer period during the year and conservation of fodder for lean season. Annual legumes develop 100% canopy within 45 days of the onset of rains. Combination of cultivated varieties of perennial legumes, grasses, shrubs and trees can extend availability of green fodder up to February at low altitude thereby shortening the requirement of conserved fodder for lean season. Carrying capacity of such high land use has been estimated to be 4 to 5 livestock/unit/ha with setaria and stylo (1:1) mixture of fodder production. Livestock-based farming system has potential for substantial income from the farmyard manure and self-sufficiency in the matter of fuel through biogas plants. The benefit: cost ratio for the system was 2.08:1. Such land use is expected to retain over 90% of annual rainfall and restrict the soil loss within 2 t ha^{-1} yr^{-1}.

iv) Horticultural based land use system

This land use can be adopted in a slope not more than 100% having maximum soil depth of 1.0 meter. Contour bunds, half-moon terrace at the fruit plant location, grassed waterways and few bench terraces at the lower terraces for growing vegetables crop are essential conservation measures. Such lands are expected to retain over 90% rainfall in the slope and reduce the soil loss below 1.0 tonne ha^{-1} yr^{-1}. Land development cost will be about 108 man days ha^{-1}. Variety of horticultural crops can be grown under the system depending on the market potential. Pineapple may be planted on contour bunds across the slope. Terrace riser in the vegetable blocks should be planted with fodder legumes. Hilltop should be used for forest species to meet the fuel and fodder requirement. Yield potential of newly planted Assam lemon orchard has been found to be 11,300, 12,800 and 37,200 fruits ha^{-1} during third, fourth and fifth year after planting, respectively (Singh *et al.*, 1987). Pineapple planted on contour bunds yields 9300 fruits per hectare after 20 months of planting. During the early phase of fruit trees planting bajra x napier hybids, golden timothy grass, guinea grass, dallies grass and maize can be intercropped with orange, avocado, guava and lemon having little adverse effect on tree growth but the green forage yields 70-138, 44-82, 43-74, 45-81 and 50-55 tonnes per hectare, respectively can be obtained under these horti-pastoral systems (Singh *et al.*, 1987). Fodder rice bean and fine stylo can be produced 19-22 and 22-30 tonnes per hectare, respectively, with positive effect on the fruit tree growth.

v) Hydrological evaluation of land use systems

Studies in watershed based farming systems have shown the scope of using steep slopes for crop production. Soil and its losses from different farming systems were studied in two different locations, which are summarized in Table 2. Some of the potential farming systems such as agriculture on bench terraces, horticulture, agri-horti-silvipastoral systems, etc., have been evaluated at the experimental watersheds for their long term runoff, soil losses and so on. Land use practices in micro-watersheds with soil and water-conservation measures were found very effective in retention of rainfall; rainfall retained in situ varied between 80-100%. The surface runoff from shifting cultivation watershed remained higher in the range of 19.89 mm 54.99 mm in a year compared to other watersheds. Also as expected, the watershed treated with jhum (shifting) cultivation yielded the highest peak runoff (86.1 0 mm/hr) while the one left undisturbed with natural vegetation gave the minimum peak runoff (4.49 mm/hr). However, provision of trenches in fodder based agriculture most effectively conserved moisture and produced peak runoff 7.81 mm/hr. Maximum peak flow rate did not differ in mixed block forest, silvipastoral system and agri-horti-silvipastoral system showing the effectiveness of suitable soil conservation and appropriate land use system on hill slopes. The contributions to stream flow in the watersheds having substantial area under natural forest is primarily by subsurface flow (base flow). The watersheds having continuous stream flow characteristics generated base flow to the extent of 70-90% of its total water yield. The highest base flow was obtained in the pine afforested undisturbed watershed, which constituted on an average 23.5% of annual rainfall.

Table 2: In-situ retention of rainfall under watershed based land use systems

Land use	Mean slope of the watershed (%)	Soil and water conservation measures	Annual rainfall retained (%)	Soil loss (t ha^{-1} yr^{-1})
Barnihat 100m msl, Sandy loam soil, 1600 mm annual rainfall				
Bamboo forest	45	-	99.55-99.98	0.04-0.52
Agriculture (S)	40	-	90.27-98.94	5.10-83.30

Agriculture (C)	42	Bench terrace	00.00-95.03	0.00 -7.70
Agriculture (C)	43	Contour bunds	80.74-99.79	0.60-68.20
Agriculture (P)	44	Contour bunds	97.08-99.66	0.88-14.28
Agri + Hort	44	Bench terrace + Contour bunds + halfmoon terrace	93.37-99.98	0.04-10.10
Umiam, 1000 m msl, Clay loam, 2554 mm annual rainfall				
Natural fallow	52	-	Trace-98.46	0.00-0.05
Agriculture (F)*	32	Contour trench + Grassed waterways	0.00-98.68	0.00-0.16
Agriculture (C)*	32	Contour bunds + Bench terrace	98.53-99.77	Trace-0.33
Agri (C)-hort-silvi pastoral	32	Contour bunds + Bench terrace + Halfmoon terrace	98.27-99.99	Trace-1.22
Horticulture	42	Halfmoon terrace + Grassed waterways	96.18-99.75	Trace-4.37
Agro-forestry	33	-do-	96.83-99.52	Trace-0.38
Forestry	38	-	92.79-98.27	Trace-7.80

F = Fodder based, C = Food crop

CONCLUSION

Food production system on hill slope without proper conservation measures is highly resource depleting and unsustainable. Proper land use in conjunction with mechanical soil conservation measures when adopted within the boundary of watershed can enhance sustainability of the production system in the region. The technologies, as mentioned above, help conserve rainfall in situ, thereby arresting soil loss and preserve soil fertility. The farming system models - agropastoral, agri-horti-silvipastoral, livestock based system and horticulture based systems developed by the ICAR for upland ecosystem through adoption of engineering measures on micro watershed basis restricted the soil loss within 2 t ha^{-1} yr^{-1}. The above mentioned farming system models can be adopted in the region on watershed basis as an alternative to jhuming.

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