Natural Resource Status and Conservation Strategy for Giri River Catchment in North Western Himalayas, India

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Abstract: Giri river is one of the major tributaries to Yamuna river system. Its catchment is stretched between 30° 4′ 30″ to 31°15′ 40″ N latitude and 77° 0′ 0″ to 770° 43′ 45″ E longitude covering an area of 2,600 sq. km. divided in 36 sub-catchments. The geology of the catchment consists of Eocene rocks referred as *Subathu* formations. Common rocks are rough slates, phyllites, micacious schist, sand stone, limestone and quartzite. Soils of the upper reaches of the catchment are formed under coniferous vegetation. They are rich in organic matter and lacks in free lime at surface. In lower areas soils are generally sandy with loose boulders. The hydrological functioning of catchment soils is influenced by the land uses. The forest and pasture lands showed better physical parameters governing retention and infiltration of the water than cultivated lands and therefore are ideal for regulating water and sediments to the river. The climate varies from place to place as a direct result of varying altitude. Annual average rainfall of the area is about 1600 mm. Snow melt is recorded only in and around Churchandni ranges at an elevation of 3626m. The physiography is mountainous and hilly with slopes ranging from 15%—50 %.

The forest covers about 17% of the geographical area. Lower areas are generally covered with scrubs, but middle areas corresponding to sub-tropical climate have *Pinus roxburghii* as most prominent specie. The higher temperate zone bears Oak together with conifers like *Pinus wallichiana* and *Cedrus deodara*. Fir and spruce occur in extreme north. Pastures and grazing lands occupies about 45% of the catchment area. Most of the grasslands or meadows are on steep slopes. The predominant species are *Agrostis, Poa, Bromus, Festuca, Dactylis, Agropyron, Dicanthium, Setaria* and *Chrysopogon*. Agricultural land occupies around 26% of the area growing temperate fruits like apple, cherry, plum and other crops like cereals, pulses, condiments & spices, fibers, oilseeds and narcotics.

The river has a great hydroelectric and irrigation potential, which depends to great deal upon steady sediment free water yields from the catchment areas. This obviously calls for sound ecology in the catchment. One of the most deterrent factors for catchment ecology is the increased soil erosion triggered by ever increasing human and livestock population through onslaught on the soil, water and biotic resources. The large-scale denudation of the forestlands, indescriminate grazing, unscientific cultivation of mountain slopes and many developmental activities like road construction and mining are some of the important factors for continued land degradation in the catchment. The mean annual runoff in the river based on 12 years data was $1039 \pm 771 \times 10^6$ m^3, carrying annual suspended sediment load of $2488 \pm 3828 \times 10^3$ tons. Also, the physiographic and morphometric parameters like relief ratio, drainage density, drainage texture, bifurcation ratio, and sediment delivery ratio depicted the catchment under varying categories of erosion.

Therefore, based upon the qualitative and quantitative assessment of soil erosion hazard in the catchments suitable long and short terms safe guards that finds an acceptance with the local populace and economical as well, have been suggested.

Keywords: Himalayan catchment, sediment load, runoff, natural resource, land use, soil water conservation

1 Introduction

The Central and Himachal Pradesh Governments are according great priority for the restoration of deteriorating natural resources of the major river valleys of the state, offering large opportunities for the development of water, and power resources. It may ensure adequate and sustained supplies of water and power to agricultural, industrial and domestic sectors. Adequacyof power would also reduce pressure on depleting forests for energy needs, fostering environmental protection effects in the mountain state. However, the viability of the water and power resource development projects depends to a great deal upon sustained sediments free water yields into the river system. This requires the proper maintenance of soil and vegetation resources, governing hydrological functioning of the mountain catchments. The soil properties such as infiltration rate, water retention mean weight diameter, aggregate stability, and bulk density are reported to the influence the erosion by water. Organic matter increases the stability of aggregates and thus plays a dominant role in stabilizing soil structure (Baver *et al*., 1968) and reducing crust strength (Bryan, 1973).

There is a wealth of information to suggest that forest soils having high organic matter contents generally have higher infiltration rates and storage capacity than those having less organic matter (Gilmour *et al*., 1987). Balla (1988) reported annual stream flow totals from forested basin to be less by 130 mm compared to adjacent agricultural basin in lower middle hills of west Nepal.. A common notion about the role of forests is that the complex of litter and root acts as a sponge socking up water during rainy spells and releasing it evenly during dry periods (Ekholm, 1976).

However, the increased anthropogenic intervention as a sequel to ever growing human and live stock population is leading to a break down in the biophysical equilibrium of the Himalayan mountains causing large scale sedimentation of river and water bodies (Tejwani, 1987). Many activities like road construction, mining, overgrazing and deforestation are playing havoc with land and water resources of the catchment, which may jeopardize all developmental efforts aiming at the prosperity of peoples of hills and plains. Thus the present study was an attempt to assess the natural resource status and its interactive effects on runoff and soil erosion in the catchment; an information so vital for planning and development of water and power resources of the basin.

2 Materials and methods

The studies on various aspects were conducted in the entire catchment area of Giri River. The whole catchment draining about 2600 Km^2 of Himalayan mountains ranges, lies between 30°-4′30″ to 31°-15′-60″ North latitude and 77°-0′-0″ to 77°-43′-45″ East longitude and is divided into 36 sub catchments, generally forming drainage network of tributaries. Its waters have been diverted putting a barrage at Dadahu to generate power at Girinagar and provide irrigation in and around Paonta valley.

For the long term land use conservation planning, the status and role of land uses on the hydrological functioning of catchment has been elucidated. For the purpose, entire catchment was traversed and distinct land types viz. forest, pasture and cultivated lands were studied to assess their status and impact on hydrological functions. The equipments necessary to carry out the studies pertaining to infiltration behavior of soils, mass volume relationships and stability parameters was carried out during field survey and the disturbed and undisturbed samples for determining different physico-chemical properties, were transported to laboratory after careful packing. The different parameters studied were infiltration (Richards, 1954), bulk density (Singh, 1980), aggregate size distribution (Yoder,1936), water stable aggregates (Kemper, 1965), and soil water retention characteristics (Richards, 1954). Available and total, N, P and K were determined by standard methods (Jackson, 1973).

The rainfall data for representative sites, and area under various land uses were complied from Department of land Records, Shimla, and computed to obtain mean monthly and mean annual figures. The daily runoff and suspended sediment data measured along the calibrated segment of river at Dadahu site over the past 12 years (1991—1992) by Himachal Pradesh State Electricity board were compiled analyzed and interpreted in terms of monthly and annual hydrographs. The information was gathered in respect of human and livestock growth and other anthropogenic factors influencing erosion from various sources. The relief ratio, drainage density, drainage texture, bifurcation ratio and sediment delivery ratio were derived from the toposheets obtained from Geological Survey of India, on 1:50,000 scale.

3 Results and discussion

Geology: The geological formation of the area consists of stratified rocks, which can be divided into Himalayan and sub-Himalayan system. The geography of the Himalayan part consists of Eocene rocks referred to as Sabathu formations. The common rocks are rough states, pyrites, micaceous schists, sand stone, limestone and quartzite that are more resistant to erosion. The Himalayan region have been subjected to active glaciations in the past. Mass movements are frequent along waterways along steeper slopes. The main central thrust zone is highly fractured due to intense mass movements. The Shiwaliks consists of highly erodible fluvial sediments. Giri river passes all along this formation.

Climate: The climate varies from place to place as direct results of varying attitude. Aspect causes same localized variations at same attitude. There is a variation in rainfall too along the length of the river. Only its source at Giri forest in Kot-khai Tehsil has restively less rainfall, which goes on increasing downwards. The annual rainfall of the area is about 1,600 mm and major part of it is received during the monsoon months. Snowfall is recorded only in and around Churchandni ranges on elevation of around 3,626 m. The mean annual and mean monthly rainfall over 12 year is given in the Fig. 1(a&b).

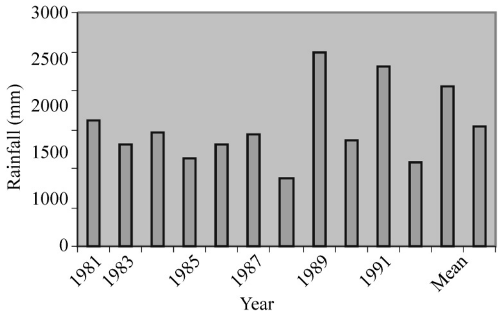

Fig.1a Annual rainfall in Giri catchment

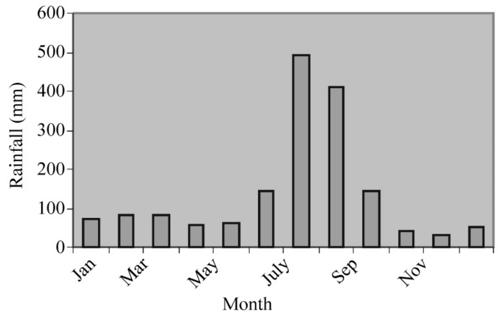

Fig.1b Mean monthly rainfall(1981—1992)

Land uses versus vegetation under dominant land uses: The dominant land uses are forest, pastures and agricultural lands, which occupy an area of 16.9, 14.9 and 25.9% of the total geographical area of the catchment, respectively.

a) Forest: The lower areas are generally covered with scrubs. Middle area corresponding to sub tropical climate have *Pinus roxburghii* as the most prominent specie. The higher temperate zone bears oak together with conifers, like *Pinus wallichiana* and C*edrus deodara*. Fir and spruce occur in extreme north. The main forest types found in the area are:

i) Northern mixed deciduous forest (700m—1,200 m elevation): The main species found are *Erythrina suberosa, Acacia catechu, Terminalia tomentasa, Zyzyphus jujuba, Flacoutchie ramoutchie* and *Pyrus pashia* etc. The stocking is very poor and the density varies from 0.2 to 0.4. The area under this type is 1,239.5 ha.

ii) Upper Himalayan chil forest (1,200m—1,700m elevation): These are found on drier aspects, mixed with Ban- Oak. In upper story, species like *Pyrus pashia, Mallotus spp, Carrisa spp, Myrsine africana, Flacourtia spp., Robus spp.* etc are found. The area covered under this type is 25,931 ha.

iii) Himalayan Moist Temperate Ban Oak Forest (1,800m—2,000m): The main species are Ban-Oak, with mixture of *Rhododendron arboreum* and *Pieris ovalifolia.* The density varies from 0.4 to 0.7. The area covered is 8,096 ha.

iv) Himalayan Moist Moru Oak Forest (1,900m—2,400m): The main species are *Quercus dilatata, Quercus incana* and *Pinus wallichiana.* Density varies from 0.4 to 0.7 and area covered is 2,376 ha.

v) Western Mixed Coniferous Forest (2,200m—2,800m): The main crop comprises of spruce mixed with *C. deodara* and *P. Wallichiana* in hotter places. However, fir dominates in damp and moist localities in the lower limit. Density varies from 0.5 to 0.8. The area under this type is 10,230.5 ha.

vi) Sal Forest (700m—860m): Sal (*Shorea robusta*) is found mixed with *Terminalia tomentosa* and *Lagestroemia spp*. Sal quality being poor, the stocking is very poor. Density varies from 0.3 to 0.5. The area covered is 327 ha.

b) Pastures: Areas under grazing are being used either as grazing land or hay fields. Grasslands as a distinct form of land use are met within the area either as biotic or edaphic ecological formations. The grasslands or meadows of temperate region above 1,800 m are on steep slopes. The predominant species are that of *Agrostis, Poa, Bromus, Festuca, Dactylis, Eragrostis, Agropyron* and *Calamagrostis* with low occurrence of hedges and herbs. Dry matter yield of about 1.5 t ha may be expected. There is common practice of feeding foliage of *Quercus* species during the lean winter periods. In tropical and sub-tropical regions grasslands with scattered tree and bush infestation were found. Predominant grasses in the region are; *Heteropogon lartortus, Chrysopogon gryllus, C. fulvus, Arundinalia nepalensis, Dicanthium annulatum, Setaria glauca, Imperata cylindrical, Themada anathera, Bothrichola pertusa* etc.

c) Agricultural land: The main agricultural crops are wheat, maize, rice and barley grown on about 74% of the total area under cultivation. Pulses vegetables, oilseeds, condiments and spices, drugs and narcotics etc. are grown on about 13% of the area. Apples are grown on 6.09% of the cultivated land. Other fruits like mango, peaches, pears and citrus fruits are also grown in small areas.

Human and Livestock population: The human and livestock density has increased from 98 and 75 per square km (in 1969) to 122 and 148 per sq. km (1989), respectively (Table 1). Due to no embargo on illegitimate occupations, the forest area is likely to shrink over a periods. These forests are also victim of large scale demand of growing population, having T.D. rights in the forests for materials needs of timber and fuel wood etc. The demands are generally more than the genuine needs. Reports reveal that the removals under TD are even more than the annual yields of forests (Sharma and Minhas, 1993). In the absence of any strict control on the encroachments, large scales of forest adjoining orchards are being cleared and brought under cultivation.

Table1 Human and livestock population in Giri River Catchment

	Human population		Livestock population						
Year	Total	Density, No./km^2	Cattle	Buffalo	Sheep	Goat	Others	Total	Density, No./km^2
1969	254,800	98	—	—	—	—	—	19,500	75
1976	247,000	95	188,413 (72)	36,850 (14)	55,908 (22)	73,467 (28)	2,607 (1)	357,245	137
1978	252,200	97	189,626 (73)	38,367 (15)	50,310 (19)	87,551 (34)	3,467 (1)	369,351	142
1985	314,600	121	193,041 (74)	42,510 (16)	52,598 (20)	84,344 (32)	13,520 (5)	386,013	148
1989	317,200	122	193,041 (74)	42,510 (16)	52,598 (20)	84,344 (32)	13,520 (5)	386,013	148

Figures in the parenthesis indicate the animal load per sq. Km.

The pressure of the animals, especially migratory animals of “Gaddis” migrating between lower Shiwaliks and high altitude areas, on forests are very high (Table1). The goats generally do more harm to newly established and regenerating plantations. Thus the pastures are suffering a great deal of degradation due to heavy livestock pressure beyond their carrying capacity. Invariably all pasture lands are on steep to very steep slopes.

Soils: Sub-mountain soils are met within the upper reaches with diagnostic A, B and C horizons. Detailed profile studies reveal that the soils of upper catchment formed under coniferous vegetation, were deep and dark to very dark brown showing more accumulation of organic matter. Texture varied from silt loam to clay loam and structure varied from massive to angular blocky. Soil consistence was soft to hard when dry, loose to friable when moist and sticky plastic when wet. The soils of lower catchment were reddish brown showing little accumulation of organic matter. The soils were loam to silty clay loam, structurally angular blocky showing more preponderance of fine fractions. The soils were very deep showing a good measure of acceptance for rainwater. The site characteristics suggested that erosion status of lands varied from very low to severe. The lands of lower catchment areas were severely eroded, whereas of upper catchment were only moderately eroded.

Soil characteristics under different land uses: The soils of some of the important land use viz. forest, pasture and cultivated lands were studied from erosion point of view (Table 2),. The forest and pasture soils showed low bulk density, higher water retention at different suction values higher infiltration rate, high aggregate size distribution in terms of MWD and % aggregates> 0.25 mm, compared to the cultivated lands. The forest lands, however, displayed relatively better hydraulic and stability characteristics compared to pasture lands. The better physical characteristics having bearing on the erosion behavior of soil, for forest and pasture lands are due to their better structural status conditioned by higher amounts of organic constituents. The ability of forests to decreased flood peaks and sediment losses by 90% and 96% respectively can be found in the history of Tennessee valley authority (TVA, 1962). Similarly higher water retention under grass and forest lands compared to cultivated lands in Himachal (India) was reported by Sharma and Qaher (1989) and Sharma and Minhas (1993). The well protected forest and pasture lands, therefore, have a greater role to play in proper hydrological functioning of Giri catchment.

Table 2 Some physical properties of soils of Giri catchment under different land uses

Site	B.D. ($Mg \cdot m^{-3}$)	MWD (mm)	WSA (%)	Infilt. Rate ($mm \cdot h^{-1}$)	Moisture retention (% by Vol.) at 0 kPa	33.3 kPa	1500 kPa
Forest							
Simla, Surface	0.62	5.43	98.19	--	41.95	30.22	21.72
Deha, PF							
0-14, cm	0.84	4.70	95.19	5.40	72.42	47.15	31.97
14-80, cm (Avg.)	--	1.62	41.83				
Koti, RF							
0-23, cm	0.60	3.26	80.8	12.6	58.62	35.47	22.2
23-150, cm	1.36	1.04	63.16				
Nangali, RF							
0-12, cm	1.47	4.26	92.44	65.7	78.58	37.71	27.26
12-94, cm (Avg.)	1.52	3.18	45.63				
Dadu, RF							
0-12, cm	1.23	4.18	82.76	58.5	67.52	39.02	22.9
12-155, cm (Avg.)	1.40	0.93	35.06				
Pasture							
Gajheri ,Surface	0.92	5.70	98.40	--	57.73	23.47	20.35
Dhanech							
0-17, cm	1.07	3.75	88.39	--	48.28	31.70	24.92
17-99, cm (Avg.)	1.32	1.41	63.22	--			
Cultivated							
Deha							
0-21, cm	1.30	1.25	6.36	20.2	40.34	35.25	19.37
21-120, cm (Avg.)	--	0.68	51.57				
Gazta , Surface	1.10	4.69	92.81	--	47.73	29.6	15.9
Koti , Surface	1.31	0.45	31.89	--	40.96	27.17	13.78

PF= Protected forest, RF= Reserve forest, B.D.= Bulk Density, MWD-Mean Weight Diameter, WSA=Water Stable Aggregates>0.25mm, kPa=Kilo Pascal

From the soil productivity point of view, the forest and pasture lands possessed higher amount of organic matter, available and total nutrients in their surface horizons (Table 3).

Table 3 Nutrient status of soils of Giri catchment under different land uses (Surface horizon)

Site	Organic matter (%)	Available nutrients (kg • ha^{-1})			Total Nutrients (kg • ha^{-1})		
		N	P	K	N	P	K
Forest							
Simla RF	15.52	407	3.02	1,100	12,544	80	30,868
Deha PF	16.03	502	20.83	1,347	1,886	159	30,868
Koti RF	16.10	750	31.36	1,459	6,272	94	40,117
Nangali RF	6.65	596	Traces	741	5,645	48	33,113
Dadu RF	3.45	470	1.68	629	5,018	39	2,250
Pasture							
Gajheri	16.03	690	3.36	8.53	5,645	55	26,940
Dhanech	6.47	429	1.68	1,078	1,568	45	20,916
Cultivated							
Deha	3.83	627	10.08	943	9,408	133	34,797
Gazta	5.56	--	--	--	--	--	--
Koti	1.81	627	7.26	808	7,526	104	34,236

The amount decreased progressively down the depth. The erosion of top soil, therefore, would render these lands unproductive as their replacement with such higher amounts of nutrients is rather impracticable.

4 Runoff and sediment losses from the catchment

Runoff: The mean annual runoff in the river was 1,039 ± 771.54 × 10 6 m^3 (Fig.2a). The mean annual runoff showed a great variation with C.V. as high as 74.26 %. A large variation for the Himalayan big rivers has also been shown by Sharma *et al.* (1991). A bulk of runoff in the river is from July to September, constituting 50%—96% of the total runoff in a year (Fig.2b). The mean monthly runoff for different months also showed a great degree of variation, the CV's for runoff in July, August and September, the month of high runoff, were 108.2%, 106.1% and 111.3% respectively.

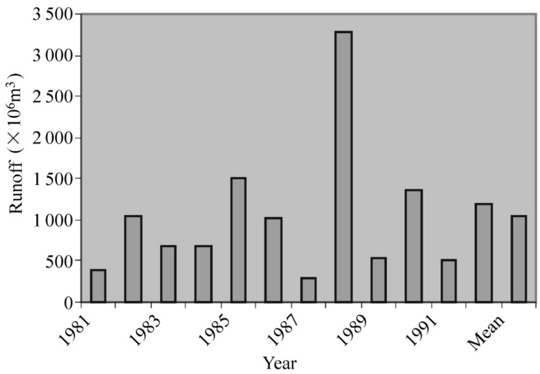

Fig.2a Mean annual runoff in Giri river

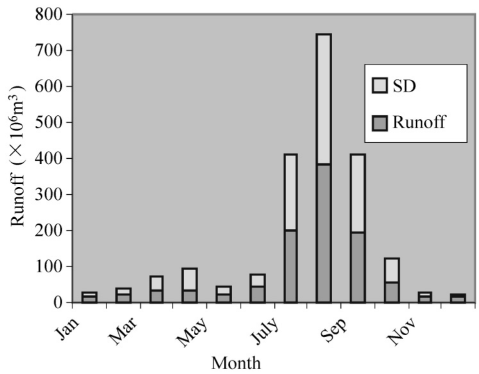

Fig.2b Mean monthly runoff (1981—1992)

Suspended sediment load: The mean annual sediment load in the river based upon seven complete years data was 2,488.2×10^3+3,827.8 tones (Fig.3a). There was great variation in the annual sediment load, the figures varying from 125.1×10^3 to 11,789.2×10^3 tones with C.V. value of 153.84%. The sediment load during 1988, the year of unprecedented rains during September, touched the all time high figure of 11,789.2×10^3 tones. The rate of sedimentation as shown by studying of seven complete years for the entire catchment is of the order of 95.7×10^3 t/100 km^2, which is quite high compared to the permissible level of 35×10^3 t /100 km^2 for rivers of northern India. The bulk of sediment transport in the river occurs in the months of July, August and September, carrying 93.5% of the annual sediment transport (Fig.3b). The maximum sediment transport in other Himalayan rivers in also during the summer period due to more rains or snow melt (Holeman, 1968; Tejwani, 1987 and Sharma *et al.* 1993).

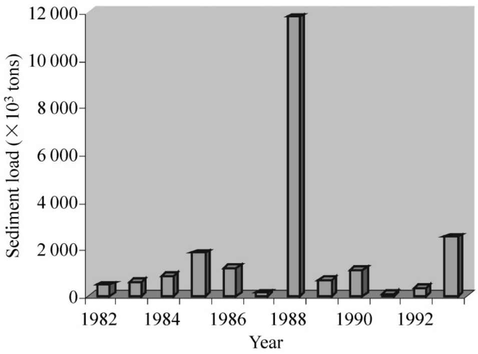

Fig. 3a Annual sediment load in the river

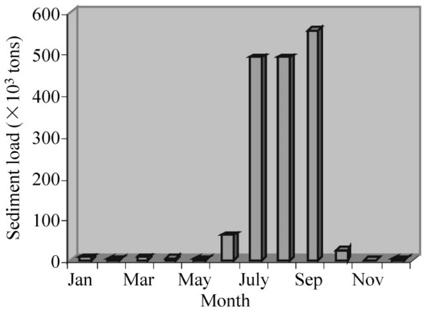

Fig. 3b Mean monthly sediment load (1982—1992)

Erosion Risk Assessment parameters: The physiographic and morphometric parameters like relief ratio, drainage density, drainage texture, bifurcation ratio and sediment delivery ratio depicted sub-catchments of Giri river under severe erosion. The value of relief ratio varied from 0.04—0.2 for the different sub- catchments, of drainage density from 0.46 km/km^2— 4.36 km/km^2, of drainage texture from 0.96—5.94, bifurcation ratio from 3.45—6.05 and sediment delivery ratio (SDR) from 0.02—0.72 with mean values of 0.104 ± 0.04, 3.02 ± 0.68km/km^2, 4.06 ± 0.97, 4.69 ± 1.39 and 0.44 ± 0.19, respectively. A majority of the sub-catchments were placed under the severe category of erosion. In general, the sub-catchment of lower pact of Giri-river valley showed greater risk of soil erosion. On the basis of aforecited parameters, priority rating of the sub-catchments has been done for treatment purposes.

Conservation Strategy

The Giri river catchment of Himalayan region is endowed with rich land water and biotic resources. The relentless soil erosion in the catchment and sedimentation downstream however would lower the operational efficiency of the projects commissioned on the river system. The forest and pasture lands being important in providing protection to the fragile sloping mountain lands need to be carefully protected allowing the least encroachments on them. The catchment regulating water and sediment down Giri river should be kept under meaningful vegetation by striking a balance between the demands for material needs and its biotic resources. The existing forest cover be carefully protected and augmented by restocking the sparse open forests. This calls for mass afforestation programmes vis-à-vis a search for alternative sources of energy to reduce the pressure of local people on forests. In lower areas of the catchment i.e. Shiwalik region, the plantation of *Acacia catechu, Delbergia sisoo, Leucacena, Morus alba, Dendrocalamus* and broad leaved species should be preferred. The unconventional sources of energy like solar cooker, *Dhauladhar Chullah* should be popularized to curtail the demand of fuel wood. The pressure of local and migratory grazing animals on forest and pastures must be minimized to carrying capacity of these land uses. The horticulture, already catching up with the minds of the people, should be given a further boost. Cash crops like ginger and potato must be encouraged to uplift the economy of the local people. The cultivation of these crops on the slopes be discouraged by introduction of bench terraces gently sloping inwards.

The land slides/slips must be stabilized by providing diversion channels, retaining toe walls and vegetative measures. The wattlings, grass and shrubs may be preferred for low cost. Active gully heads may be treated with suitable vegetative barriers and wire bolsters. Small and medium gullies should be converted into small water regulating / silt detention dams. Riverbanks vulnerable to erosion have to be provided with water deflecting structures like embankments, gabions and spurs. The concept of phased construction of roads be done away with. It holds true for areas damaged due to mining activities. Providing masonry structures and vegetative barriers should rehabilitate mine areas. The activities of mining quarrying and road construction should be discouraged in slide prone areas.

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