ABSTRACT

The Balason basin includes the south-western part of the Darjeeling hills and a section of the North Bengal *terai,* falling within 26° 41' N to 27° 01' N latitudes and 88° 7' E to 88° 24' E longitudes, covering an area of 367.42 sq. km.

Implementation of various development schemes, construction of human settlements and roads to cater to the ever-increasing population, exploitation of forest produce to generate employment, unscientific agricultural practices, growth in tourism, tea plantation and quarrying have triggered huge and complex disasters, on a scale, never encountered before in the fragile Balason basin.

Geologically, it can be seen that the study area is a young, fragile region, with intensely metamorphosed rocks like phyllites, schists, slates and gneisses covering most of the area. These rocks are highly weathered, fractured and jointed and have a tendency to produce slope instability during intense rainstorm.

The Balason basin can be geormophologically classified into two broad zones: while the northern hilly part forms the erosional zone; the lower southern piedmont zone constitutes the accumulative form. Active down cutting is evident in a number of places along the Balason valley. The numerous geomorphic forms that occur in the study area are a result of tectonic disturbances and neo-tectonic activities. Major geomorphic forms have been identified in the study area that include denuded outliers, dome like summits, broad ridges, trough- like valleys, wide valleys, landslide scars, landslide tongues, debris fans, deep V-shaped valleys, alluvial fan plains, river terraces etc.

The quantitative analysis of the various morphometric properties of 55 third order basins also reveal some striking results regarding their multiple process-response

relationships. That the basin area (A_3) is often highly correlated to many other morphometric variables is very much apparent. The strong correlation between the basin area (A_3), the stream lengths (ΣL_3, L_1, L_2 and L_3) and stream numbers (ΣN_3, N_1, and N_2) suggest that local reorganization of drainage basin area may be expected to lead to a reduction in stream length and number. On the contrary, the negative relationship between basin area (A_3) with drainage density (D_3), stream frequency (F_3) and relief ratio (Rh_3) suggest that they are likely to increase as the basin area decreases. The increase in the efficiency of the drainage network may be responsible for the reduction of first order streams within the third order basins, as fewer streams are needed to meet the conditions in the area in which it has entered in the early stages. The still young and active Balason basin is in a state of inequilibrium and moving towards a state of early maturity in the future.

The soils of the Balason Basin can, basically, be sub-divided into 2 orders, 4 sub-orders, 4 great groups and seven sub-groups. The soils have an inherent low nutrient status. The entire southern half of the study area shows deficiency in organic matter, nitrogen and phosphate. The dominant soil taxonomic order has been recognized as the Inceptisols, which cover the entire northern hilly tracts and show deficiency in phosphate and potassium.

The drastic reduction of the natural forest, combined with the high annual rainfall exceeding 3000 mm in most parts of the basin, makes the area highly vulnerable to soil erosion and landslides, reducing the soil fertility, choking the streams and leading them to change their courses. Thus, the study area, which is geologically highly vulnerable and experiences very high precipitation, coupled with heedless deforestation and unscientific changes in the land-use pattern, poses a threat to both the life and property of the local inhabitants.

Pedological studies reveal that the soil of Balason basin is erosion prone and is extremely precarious along the northern hilly tracts. Very high slope gradient (30° -

40°), along with high and concentrated rainfall (2500–4500 mm) aggravate erosional hazards. Solum mixing, truncation and the presence of coluvial stone horizons have been identified in many cases, due to excessive soil erosion.

Observations from several statistical relationships show that while most of the soil properties are inversely related to the slope, the rate of infiltration is positively related to the slope. This is most probably due to complex interactions among a number of variables like soil texture, organic matter, thickness of A horizon etc. The multiple correlation studies also show some striking results. The spatial distribution of the relationships and their interactions in different lithological, altitudinal and slope environment are analysed statistically.

Significant relationships have been found around the broad summits in the northern hilly part, i.e. the gneissic area, with higher elevation (>1000 m), and southern, undulating plains having a gradient of less than I5°. But the pedo-geomorphic parameters obtained from areas having unconsolidated parent materials with moderate altitude (300 –1000 metre), steep gradient (>15°) fail to achieve statistically significant relationships. This is most probably due to the fact that the northern summit and the southern undulating plains of the Balason basin have achieved, pedo-geomorphically, a more stable state where the pedogenic and geomorphological processes have achieved some sort of equilibrium as a process - response system.

The northern, non-gneissic terrain and the southern piedmont areas experience heedless deforestation, mass movements and the streams draining through the region are in the habit of depositing enormous amounts of fresh silts during rains each year. Thus, the continuous depletion of the slope materials in the northern hilly terrain and the continuous increment of highland refuges in the southern piedmont areas have detrimental effect towards achieving the stability of the pedo-geomorphic parameters.

The assessment of soil loss by water erosion has been attempted through the study of its process and mechanisms and apprehending a number of diagnostic criteria. The heedless destruction of the forest cover has had its toll on the natural landscape. The degradation of the forest cover with increasing population pressure has elevated the natural soil erosion manifold. The complete severance of the fertile topsoil has gradually led to the loss of fertility and the natural regeneration of the forest cover has dwindled. Thus, the compactness of the soil of the study area has been lost and this has led to various environmental hazards.

The worst affected area lies in the central parts of the Balason basin. This area is deforested and characterized by skeletal soil and very steep slope (>30°); and needs the immediate implementation of conservation measures. Special attention must be given to areas along the roads, railways, tea gardens, agricultural terraces and existing settlements.

Large-scale afforestation, with suitable tree species, along with terracing and drainage facilities is necessary to check massive soil loss. The southern parts have shown very low to negligible soil loss, below 5 tons/h^{-1}/y^{-1}. Among the various conservation measures, the agronomic measures should be given preference because they are less expensive and deal effectively in reducing the impacts of raindrops, increasing infiltration, reducing run-off volume and decreasing water velocities.

An examination of the geological setup, process of slope evolution, precipitation, slope cover, landuse, soil characteristics and hydro-geomorphic processes shows that the study area has a high potential for landslide hazards. The landslides are more frequent in densely settled areas, along transportation lines tea gardens and steep deforested valley side slopes. The study area exhibits various types of slope failures, of which slumps, soil-slips, debris-slides, mud-rock flows and debris-flows are important.

A close look at the landslides of the area reveals that the unscientific and unplanned human interferences have greatly contributed to the disruption of the fragile hill eco-system. In some other cases, the slides have been caused by toe-erosion of the drainage elements. The present study emphasizes the fact that the choice of remedial measures to prevent the landslides should be made after careful analysis of the causative factors. Consequently, the preventive structures should be designed taking the geomorphological and geological framework of the region and the strength of the materials involved in the landslide. Treatment of slope configuration, improvement of drainage facilities and retaining walls, afforestation and restricting human settlements are identified as the most important corrective and preventive measures to be adopted in the study area.

The cross-sectional areas, the wetted perimeter and hydraulic radii of the Balason river reveal very little variations from year to year in the dry months; while the variations are pronounced in the monsoon months. However, the river quickly readjusts itself, either by erosion or deposition, in the instances when changes do occur. An analysis of the hydrograph reveals that high intensity discharge concentrating within a short period, relates to rainstorms, consequently, causing severe floods. The analysis of the suspended load of the river shows an increasing trend, which, accompanied by similarly increasing bed load has resulted in an increase in the braiding tendency of the river. The boulders and gravels carried to the foreland by the annual floods of the river are intensively exploited at the rate of 20 cm/year, thereby eliminating the possibilities of large-scale river bed rising as can be seen in most of the other sub-Himalayan rivers of West Bengal.

Moderately dense forest cover along the foothills reduces the run off as well as the soil erosion, keeping some water available to form good ground water reserves. On the other hand, high intensity of rainfall on steep degraded slopes of the Balason basin causes high runoff and thereby, less amount of water becomes available to saturate soil and recharge aquifer and inducing phenomenal degradation along the hill slopes. Consequently constructing a number of check dams, across the river at suitable sites to preserve the monsoon supplies for re-distribution during the non-monsoon months, would serve immediate purpose adequately.

A quantitative assessment of the environmental impact of the developmental activities has been attempted based on Leopold's matrix. Under the prevailing conditions of environmental degradation in the study area, it becomes essential to create a comprehensive plan to offer remedial measures for each and every kind of adverse environmental effect of development projects. The pertinent precautionary measures will then have to be taken up and followed seriously, if the developmental activity is to have minimal adverse effect on the environment.

Unscientific development activities, without taking into consideration the fragile nature of the Himalayan ecosystem, can lead to serious environmental degradation. And at this juncture, whether we opt for a 'green earth' or a 'barren landscape' – the choice is entirely ours ! And if the rampant, heedless exploitation of Mother Nature continues at the present rate, Hans Reiger has already sounded the alarm : *" There is only one Himalaya to lose ! ! "*