INTEGRATED SPATIAL DATA OF A WATERSHED FOR PLANNING

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ABSTRACT

Geographic Information System (***GIS***) coupled with Remote Sensing has proved as a powerful tool in the field of land evaluation and management. Various studies have been reported across the world, illustrating the application of GIS in the evaluation and management of landform, soil and water resources.

In the present study, GIS capabilities have been utilized to understand the erosional potential and slop stability characteristics of a small catchment zone from a highly important terrain segment of bio-diversity hot spots in peninsular India. A multi- thematic analysis based on different physical factors has been adopted to generate integrated maps on erosion proneness as well as on critical slope under a GIS platform for terrain evaluation. The spatial data on erosion proneness has demonstrated that 17.62 Square Km. Area, out of –140 Square Km. in the catchment zone, needs careful attention for Eco- restoration.

In the critical slope map four land stability classes have been demarcated. The area represented as unstable and moderately stable is found to be important for slope stability problems. Temporal change as well as the extent of loss in the perennial status of tributaries has been recorded to evaluate the landform changes. A catchment treatment planhas also been suggested.

Key Words: Spatial Data, Critical slop, and Temporal change

1. Introduction

The upper catchment of Neyyar river in Kerala state hosts one of the important wildlife sanctuaries in the country. Since it falls physiographically in the high land category of the state and also forest degradation processes are reported to be significant in this area, conservation of land and water resources, against landslides and deterioration of landform-landuse pattern, forms an important aspect for sound ecosystem management.

Efforts are regularly made by the Government to provide drinking water to bigger animals during summer periods in the forest by making ponds, as a management option. Focus is also given to fire reduction, afforestation, elimination of poaching, control against misuse of forest resources etc., as part of forest protection measures. In this scenario, it is strongly felt that a genuine effort is also required for improving the environmental status of forest ecosystems by adopting long term land management concepts to minimize the natural degradation processes. In order to achieve this goal a catchment treatment plan is necessary for sanctuary areas based on the status of different terrain parameters. Terrain conservation, next to water conservation, against landform-landuse degradation and landslides forms an important aspect for maintaining the health of forested lands.

In addition to the major floral species and mega fauna, a large number of micro-flora and fauna survive in the soil and vegetative cover of humid forest ecosystem of Neyyar sanctuary. It is well known that they need adequate temperature, humidity and climatic controls for their habitat sustenance, for which a proper terrain/land management is inevitable. However, the creation of specific data regarding the actual requirement of these sensitive parameters for individual wild life species does not come under the purview of present work. In turn, the key objectives of this study are (1) to monitor land and water systems and (2) to prepare a catchment treatment plan or a terrain management plan for better environment protection in the forested area.

Geographic Information System has proved as a powerful tool in the field of land management over the years. Several case studies have already been reported from different terrain segments across the world as well as in our country, illustrating the application of GIS in the management of landform, soil and water resources (Ghosh ET al., 1996; Das ET al., 1996). In the present study, GIS capabilities have been utilized to understand the erosion potential and slope stability characteristics of a small catchment zone (~140 km2) from a highly important terrain segment for biodiversity hot spots in Peninsular India. The results of this study will act as a prelude in the preparation of a comprehensive information system for the Neyyar sanctuary, which hosts a number of endemic and endangered species of biota.

2. Forest wealth of the area

The area hosts a number of important plant species and wild animals. As against 4000 angiospermic plants recorded in the Western Ghats, Kerala forests contain approximately 3780 flowering plants. The Neyyar sanctuary has 148 taxa of Pteridophytes of which as many as 35 taxa face the threat of extinction. As regards the lower group of plants namely Bryophytes, the information available is scanty. As per the fauna, there are 101 mammals belonging to 73 genera falling in 38 families and 12 orders are reported. There are 53 species of reptiles, 26 hill stream fishes, 111 species of amphibians and 503 species of birds seen in Kerala forests. Similarly a large number of moths, butterflies, wasps, termite's etc. have been recorded. With regard to the microorganisms, Thallophytes have been studied well however proper information is not available on protozoa, bacteria, viruses and viroids. High amount of endemism is reported in many cases. Neyyar-Peppara sanctuaries (Agasthyamala zone) have 301 species of endemic plants. 12 mammals, 89 reptiles, 16 birds, 87 amphibians, 84 fresh water fishes and 4 butterflies are endemic to the Western Ghats. Many floral and faunal species out of these are reported to be rare and endangered. Some new species have also been discovered in the Agasthyamala area. Further the forests in Kerala are the abode of large number of medicinal plants and wild relatives of cultivated plants. A specific study undertaken in the Agasthyamala area brought out 124 very important medicinal plant species and 88 wild relatives of crop plants (Basha, 1997). Different land form land use classes, like barren rock outcrops, grass lands, fluvial systems and so on, are preferred by this multifaceted biological diversity of the area for sustenance.

3. Geographical Set up of the Study area

The are of Neyyar reservoir catchment (Fig.1) is located between north latitude 08 30'00" and 08 37'36" and east longitudes 77 08'00" 77 17'00". Geologically the area represents part of the Kerala Khondalite belt, which comprises of garnet-sillimanite and garnet-biotite geniuses. Intercalation's of charnockite and pyroxene granulite is also seen. The highest peak Agasthyamala (1866m above msl) is composed of charnockite gneiss. Geomorphologically the study area falls in the highly (~30%) and moderately (~50%) undulating terrain. The minimum elevation of the low rolling terrain is around 100 m above msl. Four prominent isolated hillocks are present in the area. The drainage network shows that 5.29 km falls in the 5th order level out of the total 447 km stream length. They travel a maximum of 15 kms from the source to join the reservoir (FRL is 84m above msl). Four mini watersheds and thirteen micro watersheds together form the catchment of Neyyar reservoir.

4. Data Used And Methodology

The terrain evaluation of the area has been carried out in a BI-phased manner with an initial analysis stage and a subsequent interpretation stage. In the terrain analysis phase various thematic maps (geology, geomorphology, drainage network, drainage density, slope, relative relief, landuse, soil thickness, soil erodibility and rainfall) have been prepared on the basis of field information, interpretation of SOI topographic sheets and remote sensing data. Digital classification of IRS-IB data (Jan 1996) has been carried out to identify the different landuse classes in the area. Information from 1:15,000 scale B/W aerial photographs (1991) has also been extracted to finalize landuse (Fig.2), drainage and geomorphologic maps. Subsequently, in the terrain interpretation, the superimposition and integration, of various thematic maps using appropriate weightages (Table 1) and formulae was executed for the generation of derived maps like erosion proneness, critical slope, and drainage change, change in perennial state and catchment management plan under GIS platform and based on manual interpretation techniques. GIS analysis using GRAM and ARC/INFO have been adopted to bring out the integrated maps of critical slope, erosion proneness and manual analytical techniques based on GIS outputs and SOI topographic sheets of 1914 and 1985 were utilized to generate the other interpreted maps on change in drainage network, change in perennial state and Catchment Treatment Plan.

5. Results and Discussions

5.1. Erosion proneness

For estimating the soil loss, USLE (Universal Soil Loss Equation) is one of the acceptable methods for general terrain conditions (Weschemir and Smith, 1978). The USLE is an erosion equation, which predicts sediment movement and does not account for deposition in the erosion/sedimentation path. According to this equation, the soil loss (t/ha/year) of an area is termed as a combination of various factors, which are related to rainfall erosivity (R), soil erodibility (K), slope length (L), slope angle (S), landuse (C) and conservation practices (P). All these factors have been included as separate thematic layers in the GIS operation to produce the erosion proneness map (Fig.3). This map shows four sub classes based on the extent of soil loss, namely Severe (>200 t/ha/year); High (101-200 t/ha/year); Moderate (51-100 t/ha/year) and slight erosion (1-50 t/ha/year). Both GRAM and ARC/INFO have been used for this purpose. The map presented here is the output received from the ARC/INFO analysis.

The two classes mentioned as Severe and High erosion together form about 2.5 per cent, which is about 3.5 km2 area and they belong to very steep slopes with rock exposures. However, the moderate erosion-prone area (11%), covering 15 km2 of the area really needs careful attention. Soil loss within tolerance limits (0-5 t/ha/year) as reported by Zaffer (1990) can be accounted only in the valley fills. Mitchell et al., (1978) reported that annual average soil loss varies from 165.6 to 36.6 t/ha/year in USA. Soil loss due to water erosion process in Argentina (Buck, 1993), on an average, is 6-12 t/ha/yr. But in few areas soil loss exceeds 150 t/ha/yr. Abrol (1990) reported sediment production rate for various reservoir catchments and suggested contour bunding, check dams, debris basins and plantation of fast growing species to reduce soil

loss. James et. al., (1992) have reported the average annual soil loss of two catchments in Kerala viz; that of Mangalam (23 t/hr/yr.) and Peruvannamuzhi (66 t/ha/yr.). In the Neyyar catchment, an area of 17 km2 is contiguous. The Catchment Treatment/Land Management Plan map (Fig.7) shows erosion-prone areas and the suggested measures for combating erosion problems.

5.2. Critical slope

The landslide hazard zonation map applicable for the Western Ghat area on the basis of Landslide Susceptibility Index (LSI) values of slope, soil thickness, landuse, relative relief, drainage density and landform has been prepared earlier by Thampi et al., 1997. The LSI values supplemented by the landslide percentages per km2 of an area help to draw the zonation map. However, in the study area of 140 km2, ten landslide localities have only been identified. Hence, instead of preparing the landslide hazard zonation map, the critical slope map (Fig.4) was generated under a GIS environment using the thematic input maps on landuse, drainage density, slope, relative relief and soil thickness (Table 1). Since the landform characteristics are reflected in the parameters like slope, relative relief and drainage, the geomorphologic map as such has not been incorporated during GIS integration for critical slope areas. The lithological stratification has not been considered as a significant factor since the rock composition does not vary much in the area.

Four classes namely Highly-Unstable, Unstable, Moderately-Stable and Stable have been recognized (Fig.4). The Highly-Unstable portions as noted in the map are not really so because they fall mainly in the rock outcrop localities of the area. Except for certain isolated occurrences of rock fall, this zone is relatively stable and therefore the next two categories have been considered for further interpretation work. The critical slope map thus derived has been utilized along with the erosion proneness map as an input theme of arriving at the management/treatment plan map described later.

5.3. Temporal change in drainage network

It is fairly known that the stream head location and drainage density will change progressively over time. Valley gradient increases initially with increase in stream order and then decreases. Maximum gradings are found in third to fifth order streams. Increase in slope length with stream order essentially is the reason for such relations to mean gradient and steam order. In the case of expanding drainage network, generally the slope length and drainage density increases. Slopes in drainage basin undergo evolution in response to the change in local relief. As time passes, the locus of maximum relief, initially at the slope base begins to migrate upslope (Beven and Kirby, 1993).

In order to correlate with the effect of imposed maturity caused by the reservoir in the drainage network of Neyyar catchment, the alignments of drainage patterns have been compared (Fig.5). Though some errors can be attributed to the scale differences and to the survey accuracy of different periods, the change in pattern due to landform evolution based on the principles discussed in the previous paragraph are noticeably significant. The drainage patterns reflected in SOI toposheets (1914, 1965 and 1985) have been utilized for this purpose. The B/W aerial photographs of 1991 have been interpreted for detailed drainage analysis and the additional information in this regard has also been incorporated. It is estimated that there had been no appreciable change over a period of above 50 years sine 1914-1915, during which the area had been systematically surveyed initially. But after 1959, when the dam was commissioned, the catchment suffered vivid changes in stream courses possibly due to the impact of human intervention at the time of dam construction and related deforestation activities before and after the development of reservoir. Natural evolution of streams due to the imposition of new base level by Neyyar reservoir has apparently contributed further changes to the drainage patterns.

The terrain segments, where channel shifts are noticed on the map, represent specific signatures on the ground to justify the changes that took place in the drainage pattern. The field evidences as prominent especially at localities where the shifts is more than 5m, in the form of boulders with smoothened surfaces, alluvial loose sediments (unconsolidated), steep cuttings in the convex side of the stream banks, slanting trees etc. Some of the representative zones depicting such morphological changes are schematically pointed out in the diagram (Fig.5).

5.4. Temporal change in Perennial state

The reservoir catchment encompasses sufficient indications of land degradation in terms of land use changes, change in hill slopes and valley floors and also in the reduction of water-retention capacity. The major degraded patches in the area have been demarcated around tribal hamlets and adjoining the reservoir. Based on comparative analysis of SOI topographical sheets of different periods (1965 and 1985), it is noted that the perennial length of almost all the streams in the basin has been reduced with a total depletion of six kilometers (Fig.6). The stream portions referred as perennial during the previous survey periods (1914 and 1965) are found to be dry during the lean seasons of current period (1997-98). This has been confirmed during field studies. Further some of the small watersheds like Bharatham Vacha Ar-Vazhumkuzhithodu and Charukkuparathodu, have fully lost their perennial nature. Certain others are at the verge of becoming non-perennial in the near future. The major reasons assumed for this phenomenon of loosing the water-retention capacity are drainage shift, changes in vegetative support and slope modifications. Changes in the soil strata due to accelerated erosion conditions (mass wasting) and the associated change in subsurface flow may also have a role to play in some cases. Precipitation records indicate that there has been no decrease in the annual rainfall during the last several decades.

5.5. Catchment treatment plan

One of the important issues related to the terrain management of Kerala forests or upper catchment of rivers in Kerala state is the effective watershed management for perennial supply of surface and subsurface water towards the down stream sector. This will also aid to other aspects like catchment erosion, reservoir siltation and biodiversity conservation. Hence, the water holding capacity in upper catchment needs to be improved at any cost to maintain the perennial flow. A multidirectional approach need be adopted to achieve this goal by providing one or more of the schemes like tiny check dams, percolation tanks, subsurface dykes, contour canals, duly plugging/nala bunds etc. in streams and by vegetative support (afforestation), terracing, application of geotextiles etc. in soil covers, wherever suitable or necessary.

In order to recommend the design and size of a particular type of intervention scheme, site-specific and detailed field studies are required. However, extreme care has to be taken before selecting the sites and plant species for each protective measure so as to gets maximum benefit and minimum environmental damage. As mentioned earlier, few rivulets have been identified as Presently Non Perennial (PNP) and Likely to become Non-Perennial (LNP) that require immediate attention (Table 2). Holding the runoff water in the soil strata (in situ) to the maximum extent with the help of artificial intervention schemes forms a viable way to conserve water in areas point that the water transmission through streams can be delayed at favorable sites so as to enhance the subsurface flow and to improve the ground water recharge by providing adequate and suitable conservation measures. A catchment treatment plan (Fig.,7) has been suggested for the consideration of the terrain managers of the Neyyar sanctuary area. Different protection measures are represented schematically in this figure based on the terrain characteristics of each zone. The terrain considerations applied for proposing the management options are presented in Table.2.

6. Summary and Conclusions

About 2 km2 area within the `Severely-prone' to soil erosion zone can be protected by employing appropriate corrective steps as they are contiguous in nature. Monitoring and field checking are warranted in critical areas of slope to make sure the free passage of natural drainage during monsoon and provide suitable vegetative support to mitigate the problem of landslides. It means that blocking of natural drainage channels, which carry storm runoff during monsoon, by constructing soil-water conservation structures should be discouraged in the vicinity of failure prone areas. Similarly, the gully protection using vegetative methods is more feasible in vulnerable sections.

Two mini-watersheds, namely Charukkuparathodu and Bharatham Vacha Ar-Vazhumkuzhithodu, (2.5 km2 area) had been identified as the most degraded zone in terms of water-holding capacity of the terrain. Induced percolation measures have to be adopted in this area to make the streams again perennial.

In the case of site specific management plans suggested, the exact location and field design need to be finalized after taking into consideration the flow characteristics and other field situations.

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