CS-135

Remote Sensing and GIS for Estimation of Denudation and Consequences of Flood Hazard in a Siwalik Watershed of Central Nepal (I)

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1. INTRODUCTION

Wide spread and intensive soil erosion has resulted gradual land degradation in most parts of Nepal. Land utilization practices lead to high degree of degradation of land and loss of natural forest resources, subsequently, increasing the vulnerability of associated floods and sedimentation. Limited information pertaining to land, social environment, and insufficient knowledge of natural events and disasters could hinder proper land management practice and prevention and mitigation of hazards. Satellite remote sensing data could offset this information gap as they could provide timely, and repetitive data of a phenomena, specifically in this mountainous country where the transportation facilities are yet to develop. In this study, attempt was made to investigate the applicability of satellite data in land degradation assessment, and monitoring.

2. STUDY AREA

Ratu watershed, which is situated in the Siwalik area was selected for the present study. This river originates at an altitude of 700 meters and drains into Terai region. Siwalik area is composed of young tertiary strata, and contains easily erodible lithologies including unconsolidated sand and gravel. About 70% of the watershed is dominated by forest with varying cover densities. *Shorea Robusta* , locally called *Sal* is the major species found in the area. Ratu river runs dry during the dry season and transport heavy load of sediment during the rainy season discharging into its floodplain extends southwards from the East-West Highway. Terai region is formed by accumulation of sediment transported by rivers originates from Himalayan region.

3. DATA ACQUISITION

3.1 Acquisition of Remote Sensing and Field Verification Data

It was decided to obtain satellite remote sensing data over a long time span to estimate the forest cover and its change that could be used as a key to land degradation. Referring to available satellite data sources, Landsat MSS (1973.03.14 and 1977.03.20), Landsat TM (1993.03.16 and 1995.03.22), and LISS-II (1995.03.15) were acquired. Further, aerial photographs of 1979 and 92 were obtain for the study. Scale of the photographs is 1:40,000, and taken in the wet season limiting the comparison with satellite data due to seasonal variations. Therefore, helicopter flights were scheduled to photograph the watershed during the dry season.

3.2 Database Creation

Spatial resolution of acquired satellite data are 30m, 57x79m and 34m for TM, MSS and LISS, respectively. Therefore, these data were brought into a common map projection (UTM) by constructing mapping function through identifying control points on 1:25,000 topographical maps. Conventional maps were digitized in establishing a GIS database in the same projection. Further, aerial and helicopter photographs were scanned, rectified and registered into UTM projection. Thus, the completed GIS database consisted multi-sensor temporal satellite data, aerial photographs, elevation and land cover information.

4. RESULTS AND DISCUSSION

4.1 Land Degradation Assessment by Vegetation Index

Estimation of forest cover and its change in 1973-95 period was attempted using Normalized Difference Vegetation Index (NDVI). 1992 aerial photographs were taken as ground truth information to classify 1993 TM data. Also, these photographic information were further compared with other dates satellite data re-establishing the observation conditions to that of 1992 satellite pass. Aerial photographs covering the study area were digitized, classified, and digitally compared with NDVI images of fours dates for evaluation of forest cover changes in the watershed. Open lands within the forest cover is smaller than the spatial resolution of the sensors limiting the delineation of forest densities and open lands. Therefore, photographs were overlaid and compared to investigate the possibility of identifying them using spectral characteristics of satellite data. Degraded mountain ridges, and soil deposited tributaries are very prominent in 1992 aerial photographs and helicopter photographs. These photographs were classified assigning a value zero for forest covered pixels, and 100 for non-forested pixels. Therefore, digital value of classified photographs represented the bare land percentage (Bareland%) of each 4x4 m.

Denudation, NDVI, Remote sensing, GIS

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pixels. Subsequently, digitized photographs and satellite data original pixels were resampled into 100x100 meter pixels representing the average of original pixels that falls in each of new pixel. Using re-sampled satellite data, NDVI images were created, and the relationship of NDVI and the Bareland% was compared to identify the potential of NDVI in recognizing the change of forest density. Categorized Bareland% into 10% intervals, and the corresponding averages of NDVI values are shown in Table 1.

Table 1 Distribution of photographs derived bareland percentage and 1993 NDVI values

Bareland%	0	1 -10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 99	100
NDVI - 1993	125.37	124.44	122.77	120.91	120.04	118.9	114.65	113.1	107.07	104.58	100.93	98.71

This table shows that the NDVI decreases with the increase of Bareland%. The highest NDVI for this area was 125, and lowest was 99 for comparatively dense forest and 100% bare, respectively. This inverse relationship shows that NDVI can be used to represent the degradation of forest cover in the Ratu watershed. Similarly, NDVI values of 1973, 77, 95 and 95-LISS data were compared with the Bareland%. Distribution of the NDVI values and the aerial photographs established 1992 Bareland% showed similar trend that of 1993. 95-LISS data showed an incompatibility, and excluded from further analysis. There was no dramatic forest cover change found in 1973-95, except for a marginal decrease. Therefore, it could be said that forest cover exploitation is not prominent in this watershed, and the decrease could be due to continuous forest use as fuel, fodder or diminish in the forest growth due to land degradation.

5.2 Temporal Changes of Average Annual Soil Yield

Estimation of soil erosion in the Ratu watershed utilizing a model that incorporate rainfall, soil parameters etc., was questionable due to lack of reliable data. Further, no field observation what so ever is carried out in this watershed, or in the vicinity. Therefore, estimation of soil yield in the Ratu watershed was carried out based on the empirical equation $E = E_{30}\left(\frac{S}{S_{30}}\right)^{0.9}$ (Honda, 1993). Here, E is average erosion potential, E_{30} is rate of denudation at a slope of 30°, S is gradient of the pixel under consideration, and S_{30} is tan(30°). Erosion potential of each pixel is calculated with their gradient and given E_{30} value. Gradient was readily available in the GIS database. It is not realistic to have the E_{30} for each pixel, hence an indirect method was developed using NDVI and denudation rates to estimate E_{30} in pixel basis. Figure 1 shows the established relationship for 1992 dataset. Three critical values are decided for estimating E_{30} for each pixel. The average NDVI values 125 and 98 represents comparatively dense forest cover and the bareland in the Ratu watershed, Table 1. Corresponding E_{30} values were obtained from literature, 20 mm/year for bareland, and 2 mm/year for forest in Ratu watershed, (Honda, 1993 and Galay, 1995). Further, the extreme ends of the forest cover was assigned a lower erosion potential, 0.4 mm/year (Galay, 1995), which is similar to Middle Mountains where the average NDVI was 144. Denudation rate of each pixel was estimated by interpolating this relationship. Considering no appreciable change of the topography during the 22 year period from 1973- 95, proposed equation for soil erodibility was used for estimation of the denudation rate and the volume of the soil production based on NDVI derived forest cover densities. The estimated values are shown in Table 2. Reliable data for comparison with satellite data estimation was not available. The estimated denudation rates are very much comparable with published materials presented earlier justifying the satisfactory application of present model in soil yield prediction in Ratu watershed.

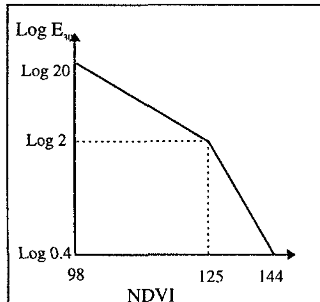

Figure 1 Relationship of NDVI and E_{30}

Table 2 Soil yield and denudation estimated for the Ratu watershed

	1973	1993	1995
Soil Yield m^3/year	271,110	321,156	293,096
Rate of denudation mm/year	3.29	3.89	3.55

6. CONCLUSION

In concluding it can be said that satellite data can satisfactorily be used in land degradation estimations. The model proposed to average annual soil yield produced land denudation rate that is very much similar to the values published by intensive field work. This validates the potential of this model in estimating soil yield in a watershed where the accurate field measurements are scarce. It is important to say that the present model was used in a watershed in the Siwalik area, and more case studies are required to identify it as a general model.

REFERECNCES

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