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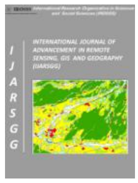

# WATERSHED PRIORITIZATION OF HIMALAYAN TERRAIN, USING SYI MODEL

***Peeyush Gupta[I*], Swati Uniyal[II]***

[I*] *Indian Council of Forestry Research and Education, Dehradun, Uttarakhand, India. (*peeyushgis@gmail.com)*
[II] *Uttarakhand Space Application Centre, Dehradun, Uttarakhand, India. (swatiuniyal@rediffmail.com)*

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**ABSTRACT: Watershed prioritization on the basis of soil erosion has become inevitable component of watershed management in order to conserve the soil resource. To assess the sediment deposition it is necessary to characterize the erosion process on the watersheds and to highlight the areas most affected. This research aims to describe the implementation of the sediment yield index (SYI) for the mapping and quantification of potential soil erosion in Karmoli watershed of the Himalayan terrain. In this method the terrain is subdivided into various watersheds and the erodibility is determined on relative basis. SYI provides a comparative erodibility criteria of watersheds (low, moderate, high, etc.) and do not provide the absolute sediment yield. SYI method is widely used mainly because of the fact that it is easy to use and has lesser data requirement. The specialization of this model is implemented using the data processing and mapping functionalities on GIS platform from input data which included a digital elevation model (DEM), a soil map, and land use/land cover map.**

**Keywords: Sediment yield index (SYI), GIS, DEM**

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**1. INTRODUCTION:** Out of 329 million ha geographical area of India about 175 million ha land are subjected to some kind of land degradation. The area affected by different types of erosion is estimated around 150 million ha, out of which 69 million ha is in the critical stage of deterioration. Encroachment of forest and pasture lands are faulty management of cultivable lands aggravates the problems of soil erosion. Soil erosion is serious global problem that threatens sustainable agriculture but also ecosystems (1).

Soil erosion due to rainfall and run-off is one of the critical issues contributing to land degradation problems and is vital aspect of land management. The eroded soil in the form of sediments moves downstream due to flow of rain water. The amount of sediment load passing through the outlet of a watershed is known as sediment yield (2).

The major factors influencing the sediment yield are the land use particularly the vegetation, the soil, the slope, and the intensity of rainfall. Watersheds have been identified as planning units for conservation of this precious resource (3). The watershed management recognizes the inter-relationship between land use, soil, water and the linkages between uplands and downstream areas . Estimates of sediment yield are needed for conservation for soil and water, study of reservoir sedimentation etc.

In order to adopt remedial measures to prevent soil erosion, the priority areas are identified within the watershed. For this, usually the whole watershed is subdivided into much smaller segments known as micro-watersheds. Micro-watersheds are considered for estimating sediment yield of each one and thereafter prioritizing. This type of research could be useful particularly for decision makers (4).

The advent of remote sensing images from satellite based plate forms has provided opportunities for extraction of up-to-date information on land use and soil of a watershed and then used to identify critical soil erosion areas within the watershed for prioritization (5).

Geographic Information systems (GIS) play a very important role here due to spatial variability of these site parameters. GIS are computerized resource data base systems that are references to some geographic coordinate system (real coordinate system in this case). A GIS is primarily used to store, manipulate, analyze and display various spatial data. In addition, GIS combine special hardware and software to perform numerous functions and operations on the various spatial data layers residing in the data base. It makes it capable to perform analysis of large databases in relation to a set of established criteria (6).

**2. RESEARCH AREA:** Karmoli watershed is located in Uttarkashi District of Uttarakhand. The location is lat 31$^0$06’04” N and long 78$^0$ 8’05” E. The study area is showing in Fig I.

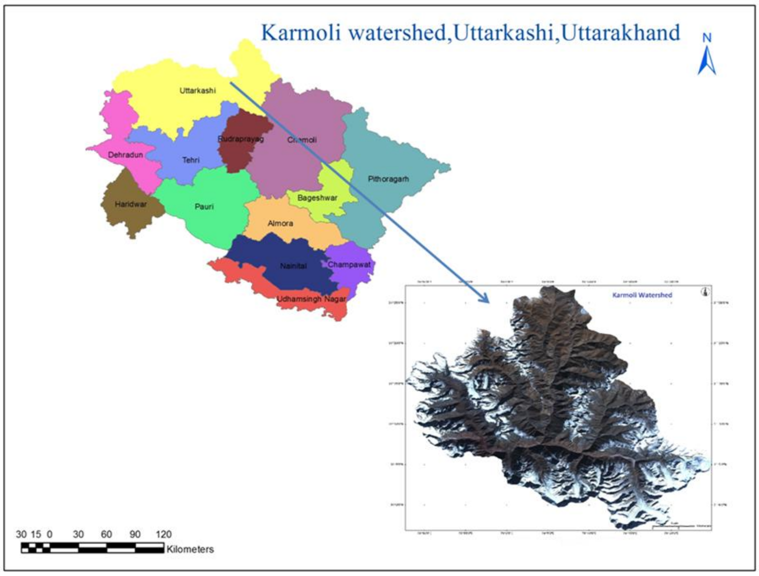


Fig I: Karmoli watershed

## 3. MATERIALS AND METHODS:

**3.1 ETIMATION OF SEDIMENT YIELD INDEX (SYI):** Prioritization leads to adopt a selective approach and helps to phase out the planning in systematic manner. The identification and demarcation of watersheds that are prone to yielding higher sediment yield should be the primary task for soil resources management (7).

The Sediment Yield Index (SYI) is defined as the Yield per unit area. SYI value for hydrologic unit is obtained by taking the weightage arithmetic mean over the entire area of the hydrologic unit by using suitable empirical equation.

The Sediment Yield Index Model, considering sedimentation as product of erosivity, erodibility and arial extent was conceptualized in the All India Soil and Land Use Survey (AISLUS) as early as 1969. Since has been in operational use to meet the requirements of prioritization of smaller hydrologic units of watershed.

**Sediment yield =**Erosivity × Erodibility

The erosivity is an expression of rainfall (velocity, angle, frequency and duration) where erodibility indicate the soil detachment and transportation potential of the detached material. The erodebility factor is governed by the empirical equation as given below.

$$R=P-F$$

Where, R stands for run-off, P is the precipitation and F is the infiltration capacity of the soil and land attributes.

The area of each of the mapping units is computed and sediment yield indices of individual sub watersheds are calculated using the following equations:

$$SYI= \frac{(Weightage \times Delivery\ ration \times 100)}{\text{Area of the micro-watershed}}$$

SYI has been calculated based on the methodology developed by All India Soil & Land use Survey (AIS & LUS). The sediment yield weightage is a function of climate, physiography, slope, soil, land use and management practices. The delivery ratio is defined as the proportion of the detached soil material from the source area reaching the sink area through surface flow or travelling through drainage. The maps generated namely the land use, the soil and the slope have been used as the vital input to obtain the erosivity (weightage) and the delivery ration.

**3.2 GRADING OF MICROWATERSHED FOR PRIORITY FIXATION:** The gradation and assignment of priority category to the micro-watersheds are based on the descending values of SYI values for deciding upon the boundaries of various categories namely, very high, high, medium, low and very low category. The following values of SYI have been used as boundaries for various categories which are given in Table I.

| SYI Values | Priority |
|---|---|
| > 1300 | Very high |
| 1200-1299 | High |
| 1100-1199 | Medium |
| 1000-1099 | Low |
| <1000 | Very low |

Table I: SYI values based on priority

**3.3 PRIORITIZATION OF WATERSHEDS/SUB-WATERSHEDS:** The prioritization of smaller hydrologic units within the watershed is based on the Sediment Yield Indices (SYI) of the smaller units. The boundary values or range of SYI values for different priority categories are arrived at by studying the frequency distribution of SYI values and locating the suitable breaking points. The watersheds/sub watersheds are subsequently rated into various categories corresponding to their respective SYI values.

The application of SYI model for prioritization of sub-watersheds involves the evaluation of:

a) Climatic factors comprising total precipitation, its frequency and intensity,
b) Geomorphic factors comprising land forms, physiography, slope and drainage characteristics,
c) Surface cover factors governing the flow hydraulics and
d) Management factors.

The data on climatic factors can be obtained for different locations in the watershed from the meteorological stations whereas the field investigations are required for estimating the other attributes.

**4. METHODOLOGY:** The Survey of India topographical map and LISS III satellite image have been used for identification of the major landscape and land use on 1:50 K scale (8). The methodology of Priority Delineation Survey comprises the following steps.

**1.** Carto DEM is used for preparation of framework of micro-watershed through systematic delineation.
**2.** Codification of different stages of delineation by using Alpha-numeric symbolic code.
**3.** Ground truth on 1:50,000 scale base (SOI Toposheets, LISS III satellite image and other base material) leading to the generation of a map indicating Erosion Intensity Mapping Units (EIMU).
**4.** Assignment of weightage values to various Erosion Intensity Mapping Units based on their relative sediment yield.
**5.** Assignment of delivery ratio to various Erosion Intensity Mapping Units
**6.** Computation of sediment Yield Index for individual micro-watersheds
**7.** Grading of micro-watersheds into very high, high, medium, low and very low priority categories.

Formulation of Erosion Intensity Mapping Unit (EIMU) Legend comprises soil and land characteristics for mapping. The mapping legend is updated based on field information and a progressive legend is developed and finalized.

EIMU is an assemblage of land and soil characteristics, viz., physiography, slope, land use and land cover with density, surface condition, soil depth, texture and structure of surface and sub-soils, colour, drainage condition, salinity and alkalinity, stoniness and rockiness, erosion condition and existing management practices (9).

**5. RESULTS:** Thematic maps have been used for delineating areas prone to soil erosion viz. Land use/Land cover map, slope map, soil map. The watershed has been derived from Carto DEM (10 m) along with the boundaries of smaller sub-watersheds.

**5.1. LAND USE/LAND COVER ANALYSIS:** Land use/Land cover has been derived using the latest cloud free satellite imageries. Data has been generated from Indian Remote Sensing (IRS) Satellite 1D/P6, LISS III sensor. The land use classification has been mapped in Fig II and classified in Tables II. The data has been procured in raw digital format and has been geo-referenced using Survey of India 1:50,000 scale topographical sheets with the help of standard data preparation techniques in image processing software (10). The interpretation of geo-referenced satellite data has been done using visual interpretation techniques and ground truth data.

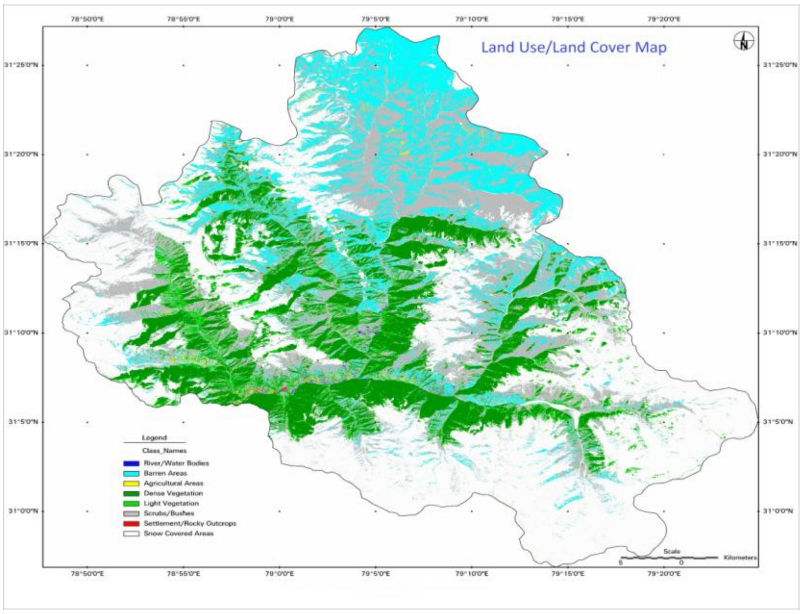


Fig II: Land use/land cover map

| S. No. | LULC | Area in ha | Area in % |
|---|---|---|---|
| 1 | River/Water Bodies | 93.24 | 0.04 |
| 2 | Barren Areas | 26110.64 | 12.97 |
| 3 | Agricultural Land | 1604.28 | 0.79 |
| 4 | Dense Forest | 38098.57 | 18.93 |
| 5 | Open Forest | 10814.22 | 5.37 |
| 6 | Scrub Forest | 45963.31 | 22.83 |
| 7 | Built-up Areas | 339.89 | 0.16 |
| 8 | Snow Covered Areas | 78220.85 | 38.86 |
| | **Total** | 201245.00 | 100.00 |

Table II: Land use/land cover classification

**5.2 SLOPE GRADIENT ANALYSIS:** Slope map has been generated through standard triangulation techniques (TIN) using Carto-DEM derived contours at 10 m interval. The areas falling under various standard slope categories have been mapped in Fig III & tabulated below in Table III.

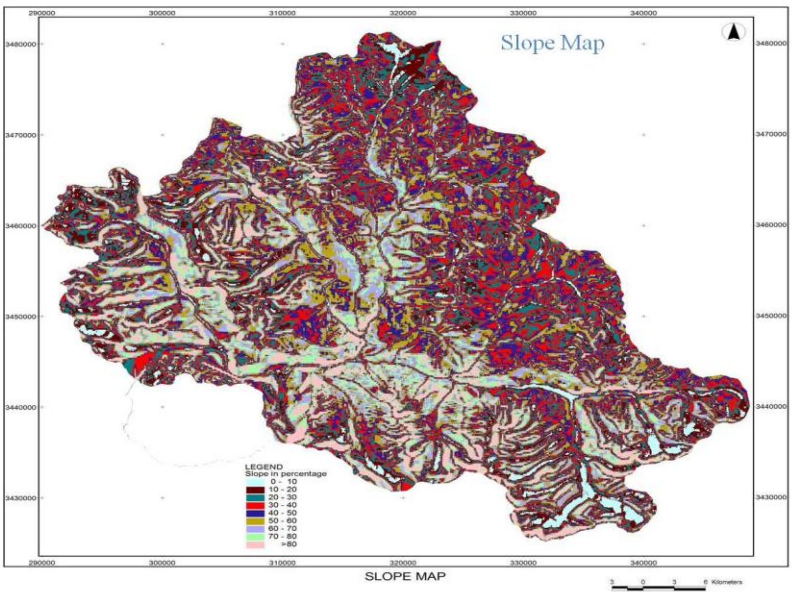


Fig III: Slope map

| Slope class (%) | Area in ha | Area in % |
|---|---|---|
| 0-10 | 5998 | 03.53 |
| 10-20 | 16058 | 09.46 |
| 20-30 | 21217 | 12.49 |
| 30-40 | 27246 | 16.04 |
| 40-50 | 30873 | 18.18 |
| 50-60 | 25817 | 15.20 |
| 60-70 | 19063 | 11.22 |
| 70-80 | 12487 | 07.35 |
| > 80 | 11071 | 06.52 |
| **Total** | 169830 | 100.00 |

Table III: Slope class

**5.3 SOIL MAP ANALYSIS:** Soil map has been digitized and produced using soil maps collected from National Bureau of Soil Survey & Land use Planning. Average rainfall data has been used for the month of July. For July, it has been taken as 450 mm and 20 rainy days .The Soil map have been mapped in Fig IV.

**5.4 SOIL EROSION ANALYSIS:** A thematic map has been prepared using these calculated soil erosion values for delineating areas prone to soil erosion of Karmoli watershed. The soil erosion map has been mapped in Fig V. SYI values for each micro-watershed marked within the watershed was calculated using assigned weightages independently. The values of the SYI for micro-watershed one to fifteen are 1043, 1225, 843, 1212, 956, 1109, 978, 868, 978, 1318, 1023, 982, 1125, 912 and 711 respectively. A map of prioritization of different sub-watersheds has been prepared highlighting priority categories as per following Table IV. Thus it could be seen that 2.3% land of area is under “very high”, 4.18 % under “high”, 12.4% under “medium”, and 9.85 % under “low” and 71.27% or more is under “very low” erosive potential area.

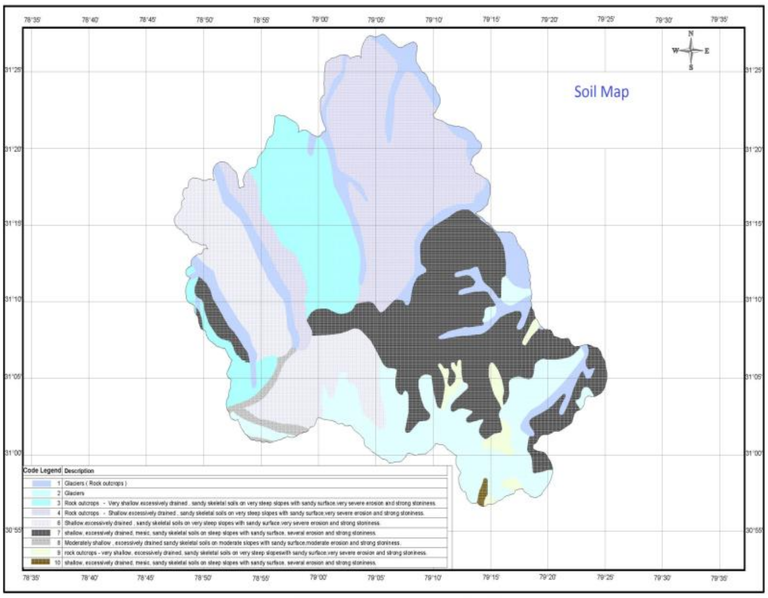


Fig IV: Soil map

| Priority | Area (in Ha) | % of Area |
|---|---|---|
| Very high | 3868 | 2.30 |
| High | 7095 | 4.18 |
| Medium | 21072 | 12.40 |
| Low | 16744 | 9.85 |
| Very low | 121051 | 71.27 |

Table IV: Priority categories

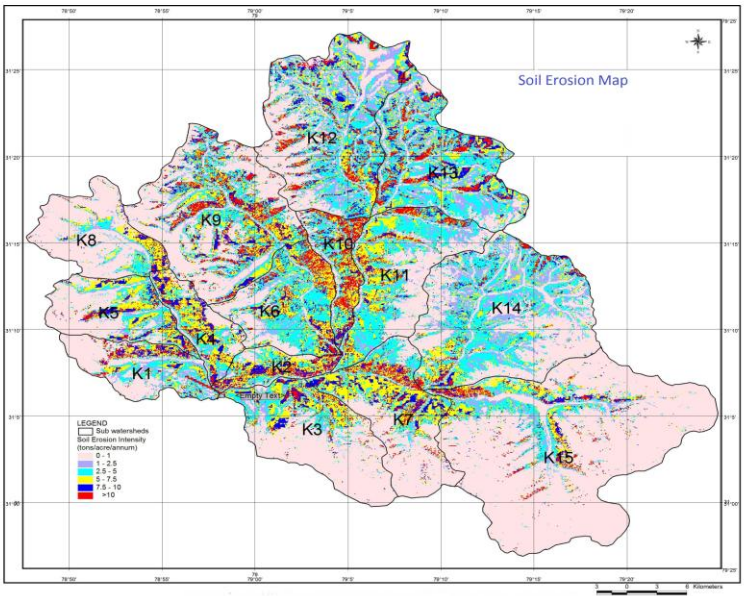


Fig V: Soil erosion map

Different soil loss ranges in the river catchment have been given below in Table V.

| Soil loss range in tons/acre/annum | Area in ha | Area in % |
|---|---|---|
| 0 - 1 | 79754 | 46.96 |
| 1 – 2.5 | 14182 | 8.35 |
| 2.5 – 5.0 | 30817 | 18.15 |
| 5.0 – 7.5 | 24207 | 14.25 |
| 7.5 – 10.0 | 10457 | 6.16 |
| > 10 | 10413 | 6.13 |
| **Total** | 169830 | 100.00 |

Table V: Soil loss range

**5.5 SOIL PRIORITIZATION ANALYSIS:** Soil prioritization of Karmoli watershed have been mapped and tabulated highlighting SYI values and areas of each sub-watershed as given in Fig VI and in Table VI.

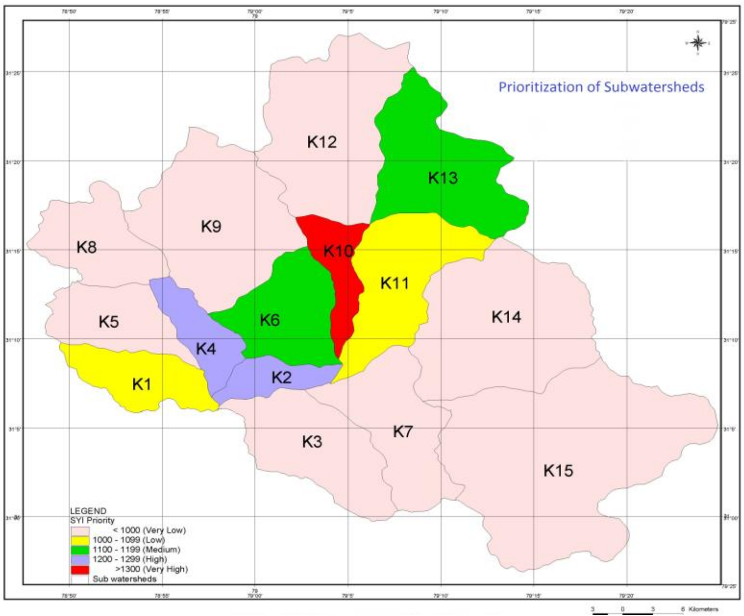


Fig VI: Soil prioritization of sub-watersheds map

| Sub Watersheds | Area in ha | SYI Value | Priority |
|---|---|---|---|
| K1 | 5884 | 1043 | Low |
| K2 | 2981 | 1225 | High |
| K3 | 10640 | 843 | Very Low |
| K4 | 4114 | 1212 | High |
| K5 | 6792 | 956 | Very Low |
| K6 | 8222 | 1109 | Medium |
| K7 | 10270 | 978 | Very Low |
| K8 | 7579 | 868 | Very Low |
| K9 | 17000 | 978 | Very Low |
| K10 | 3868 | 1318 | Very High |
| K11 | 10860 | 1023 | Low |
| K12 | 17490 | 982 | Very Low |
| K13 | 12850 | 1125 | Medium |
| K14 | 19490 | 912 | Very Low |
| K15 | 31790 | 711 | Very Low |
| **Total** | 169830 | | |

Table VI: Prioritization of sub-watersheds

**6. CONCLUSION:** Estimation of priority micro-watershed by following SYI model, The sub watershed viz. K10, K2, and K4 of Karmoli watershed falls under very high and high priority categories demanding immediate attention for soil conservation works.

The SYI model can be useful for processing the potential soil erosion mapping at a regional scale. It is compatible with integration of Geographical Information System (GIS), digital elevation model, a soil map, precipitation data and satellite images. The SYI equation used lead a better understanding of spatial distribution of the erosion hazard.

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**REFERENCES:**

**(1)** Jain, M., Mishra, K., Surendra, K., and Shah, R.B., 2010, Estimation of sediment yield and areas vulnerable to soil erosion and deposition in Himalayan watershed using GIS. Cur. Sci. 98(2), 25.

**(2)** Bhuyan, S.J., Marjen, L.J., Koelliker, J.K., Harrington, J.A. and Barnes, P.L., 2002, Assessment of runoff and sediment yield using remote sensing, GIS and AGNPS. J. Soil. Wat. Conser. Soil. Wat. Conser. Soc. USA, vol. 57, No. 6, pp 351-363

**(3)** Khan, M.A., Gupta, V.P. and Moharana, P.C., 2001, Watershed prioritization using Remote Sensing and Geographical Information System: a case study from Guhiya, Ind. J. Ari. Environ. 49, 465-475.

**(4)** Food and Agricultural Organisation (FAO), 1987, Soil and water Conservation in semi-arid areas.

**(5)** Pandey, A., Cowdary, V. and Mal, B., 2007, Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and Remote Sensing. Water Resour. Manage.21 (4), pp 729-746.

**(6)** Goetz, S. J., Wright, R. K.,Smith, A.J., Zinecker, E and Schaub, E., 2003, IKONOS Imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analysis in the mid-Atlantic region. Remo. Sens. Environ. 88,195–208.

**(7)** Kothyari, U. C. and Jain Sanjay, K., 1997, Sediment yield estimation using GIS. Hydro. Sci. – J.Sci. Hydrologique. 42(6), 833-844.

**(8)** Pal, D.K., 1998. Remote Sensing and GIS in study of land use and soil in some watersheds. Ph.D. Thesis, Dep. Agri. Food. Engg, IIT, Kharagpur (India).

**(9)** Ministry of Agriculture, Government of India, 1972, Hand book of hydrology.

**(10)** National Remote Sensing Agency, Government of India, Hyderabad, 1995, Integrated mission for sustainable development' guidelines for field survey and mapping.