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Application of GIScience to Assess the Actual and Potential Soil Loss of Panchanoi Basin, Darjeeling, West Bengal

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Abstract: *The occurrence of soil erosion is the amalgamation of the geomorphological, hydrological as well as anthropological determinants. It simultaneously considers several aspects like relief, slope, flow direction, flow accumulation, type of conservation and land use/ land cover. The paper emphasises on the basin scale analysis of soil erosion by using GIScience. This is Reconnaissance Level Assessment (RLA) of watershed, using the Watershed Assessment of River Stability and Sediment Supply (WARSSS) model of Rosgen (2007). SRTM DEM has been used to assess the linear, areal and relief properties of watershed with the association of LANDSAT 8 (OLI) image to observe the change in land use and land cover of the basin. Soil erosion measurement at basin scale has been assessed by using Universal Soil Loss Equation (USLE) and RUSLE (Revised USLE) model. Flow direction and flow accumulation path has been considered from SRTM data to consider the slope length (LS). Soil erodibility (K factor) of the watershed has been evaluated on the basis of Harmonized World Soil Grid Database (HWSD). R factor has been determined on the basis of global grid data of Tropical Rainfall Measuring Mission (TRMM). Conservation practice (P) factor and crop management (C factor) have been taken into consideration to delineate the spatial extension of actual and potential soil erosion zones of Panchanoi watershed. The study has reflected on the approximate amount and rate of soil erosion in the Panchanoi basin. The geo-coded reference of areal extension of soil erosion prone area will be helpful for the micro-level planning of the Panchanoi river basin.*

Introduction

Natural resource utilization with increasing population is an area of concern in Panchanoi river basin, which is situated over a part of older Mahananda fan at the periphery of Siliguri Township. Over-utilisation of land resources cause vicious cycle of soil erosion. Occurrence of soil erosion takes place due to amalgamation of geomorphological, hydrological as well as anthropological determinants. It simultaneously considers several aspects like relief, slope, flow direction, flow accumulation, type of conservation, land cover/ land use etc. Universal Soil Loss Equation (USLE) provides the opportunity to delineate the areal extent of potential and predicted soil erosion for future prioritisation and conservation purposes. The empirical equation is used to quantify the actual and potential soil loss in that particular area of study.

RS-GIS integration is widely used by several geographers to assess the intensity and areal extent of actual and potential soil erosion (De-Jong *et al.*, 1999; Desmet and Govers, 1996; Angima *et al.*, 2003; Amore *et al*., 2004; Debicki, 1994, Ghosh *et al*., 2013). Empirical equations are popular tools used to assess soil erosion in the basin-scale analysis (Choubey 1994; Chaudhary and Sharma, 1998; Nayak and Jaiswal., 2003). Wischmeier, *et al.* (1971) dealt with soil-erodibility evaluation for soils affected by surface runoff as soil erosion has great impact on sediment yield of the river basins.

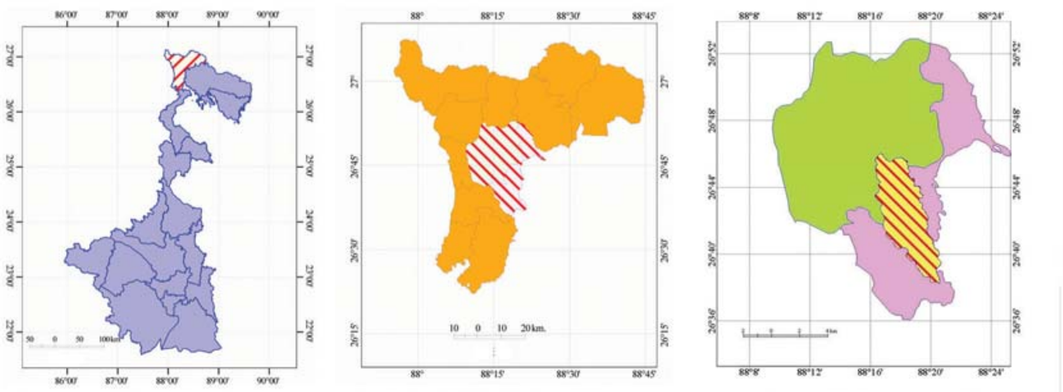
The soil erosion process is controlled by the physical environment, which in turn is a function of the interaction between climate, terrain and ground surface cover. Climatic factors responsible for soil erosion include intensity, amount and frequency of rainfall. Important terrain characteristics for studying soil erosion process are gradient, length and aspect. Ground surface cover gives a strong effect to dissipate the energy supplied by agents of soil erosion (Saha and Pande, 1993). Remotely sensed data has been well recognised in mapping and assessing landscape attributes controlling erosion, such as physiography, soil, land use, erosion pattern. Multi dated satellite images provide valuable information of the geographical space related to seasonal land use dynamics. GIS has emerged as basic tool for data management, mapping and analysis of automated spatial and non-spatial geo-referenced data. There is considerable potential for the use of GIScience in erosion modeling and hazard assessment (Chemeda,sp 2007cf. ; Bocco and Valenzuela, 1985). Soil erosion may cause physical changes on the surface landscape and such changes can be measured both spatially and temporally using RS data and GIS analysis before going to the field for the necessary field observation. The development of RS and GIS technology as well as emerging availability of basic GIS database also enabled formalised assessment based on several empirical models. The empirical models take into account the complex interactions between several variables that affect rates of erosion and based on those interactions simulate the erosion process. Soil erosion is three stage process, namely detachment, transportation and deposition. Those processes are mathematically represented in this type of scientific modeling is very useful in mapping the actual soil erosion prone areas and also assesses the soil erosion potential zones for future management purpose (Morgan and Finney, 1984).

Study area

The Panchanoi river basin is located within 26°42′N to 26°51′N and 88°20′E to 88°24′E in the district of Darjeeling, West Bengal (Fig. 1). The basin mostly falls under the southern piedmont plains of Terai at the foothills of Darjeeling Himalaya, particularly in Kurseong and Matigara block. Panchanoi is one of the right bank tributaries of the river Mahananda and it drains an area of 64.26 km².The studied basin is a part of Mahananda alluvial fan, which is a part of Himalayan foothills. River Panchanoi originates from Kurseong hill and flows over a steeply sloping terrain, debouch onto Mahananda alluvial fan near Sukna (Plate 1) and finally joins with the Mahananda river near Jalpai crossing. River Mahananda and Balasan are flowing in the eastern and western side of Panchanoi basin respectively (Fig. 2).

Geomorphic set up of the study area

Panchanoi is a non-perennial tributary of Mahananda, flowing from 156 m to 96 m above m.s.l. The Siwalik sandstone forms the catchments of all the small Himalayan rivers in the North Bengal area (Nandy and Chattopadhayay, 2016). The Panchanoi drainage basin has a dendritic drainage pattern which is an indication of homogeneous sub-surface strata. Stream ordering of a basin is the first step in drainage basin analysis, which is an expression of the hierarchical relationship between stream segments, their connectivity and the discharge arising from the contributing sub-basins (Damilola, 2016). The streams have been ranked on the basis of Strahler's method (1964) and delineated from the DEM. The basin is designated as a 5th order drainage basin. The total number of streams in the studied Panchanoi basin is 383. As the stream order increases, the stream number decreases. The main tributaries - Rongtongkhola and Chamta is 3rd and 4th order basins respectively.


Darjeeling district within the state of West Bengal

Kurseong and Matigara block within the district of Darjeeling

Panchanoi Basin within Kurseong and Matigara block

Figure 1. Location map of the study area

Panchanoi originates from the Pre-Quarternary surface of Kurseong hill, enters into Mahananda alluvial fan which belongs to the Samsing formation. The surveyed stretch of Sukna belongs to Matiali surface. Major part of the surveyed stretch mostly belongs to Chalsa surface of late Pleistocene to early Holocene. The Chalsa surface is delimited by Baikunthapur formation in its eastern and western fringe, which represents the top of the youngest fan above the present-day flood plain (Das and Chattopadhyay, 1993). The Panchanoi basin and its surrounding experience a humid subtropical climate dominated by the southwest monsoon with high precipitation during June to September. The soil in the Panchanoi basin and in its neighbourhood is mostly transported material with heterogeneous provenance.

The dominant land cover (Fig. 3) in the upper catchment is forest, which is under the territory of Mahananda Wild Life Sanctuary (MWLS). But the isolated green patches in the middle and lower part of the basin refer the existence of tea gardens, which are basically converted land use form of Sukna forest. The dominant land use category in the lower part of the basin is agriculture (Table 1).

Vegetation cover of the basin has been decreasing through the last decade with fallow land also showing the similar trend. Majority of the converted land falls under the category of settlement and agriculture. Many of the areas under the tea gardens are being converted into housing estates. As most of the forested area falls under the Mahananda Wild Life Sanctuary, there is no scope to encroach in the northern forested area of the Panchanoi basin. But the isolated parts of vegetation cover in the middle and the southern part of the basin are under decay. The changing land use in this area may lead to serious event of rapid soil erosion and land degradation. Hence LULC data base has been taken into consideration to determine the C and P Factor of Universal Soil Loss measurement.

Table 1. Land Use Land Cover Scenario of Panchanoi Basin (Data used: LC08_L1TP_139041_20170115_20170311_01_T1, Sensor: L8 OLI), 2017

Land Use/ Land Cover classes	% of area
Vegetation Cover	62.27
Agriculture	23.49
Settlement	11.20
Fallow Land	03.04
Total Area (%)	100.00

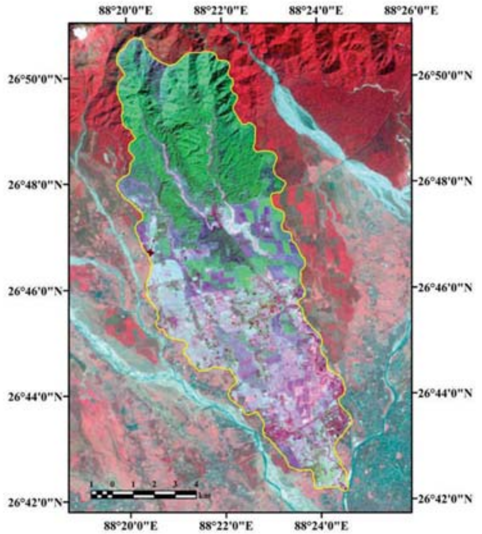


Figure 2. Location of Panchanoi basin as the interfluve of river Mahananda and Balasan. Mahananda and Balasan are flowing in the western and eastern side of the basin respectively

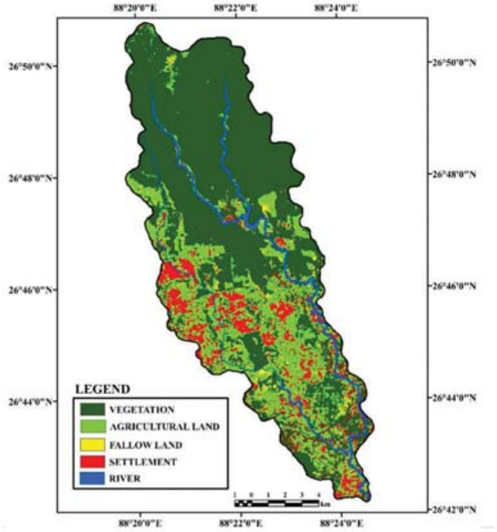


Figure 3. Land Use Land Cover Map of Panchanoi Basin of Year 2017 extracted from LANDSAT 8 (OLI)

Objective

The main objective of the present research is to assess the rate of actual and potential soil erosion in Panchanoi river basin. The study also attempts to delineate the spatial extension of actual and potential soil loss occurrence zones.

Methodology

Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) an empirical model for predicting the annual soil loss caused by rainfall (Wischmeier and Smith, 1965). The Universal Soil Loss Equation (USLE) has been widely applied at watershed level to delineate the soil erosion prone areas for future management practices **(**Williams and Berndt, 1972**)**. The output of RUSLE is useful for conservation and management activity of the studied basin. It clearly shows the soil erosion affected areas which need more attention for management practices. It is very hard to take the whole basin area under conservation; hence, selection of the target area is most important to make any effort to reduce the rate of soil erosion.

The empirical equation of RUSLE is useful to assess the quantity of eroded soil removed by rainfall, debris flow and by stream action. Monthly mean rainfall from 1901 to 2000 (www.ndc@imdpune.gov.in) has been taken into consideration to calculate the amount of soil eroded from the basin. R factor is the most important criteria of RUSLE equation, which is most dynamic in nature and depends on the occurrence of mean annual rainfall of that area. LS factor is considered as constant as no major tectonic activity has taken place in last 100 years in the studied area (Fig. 4).

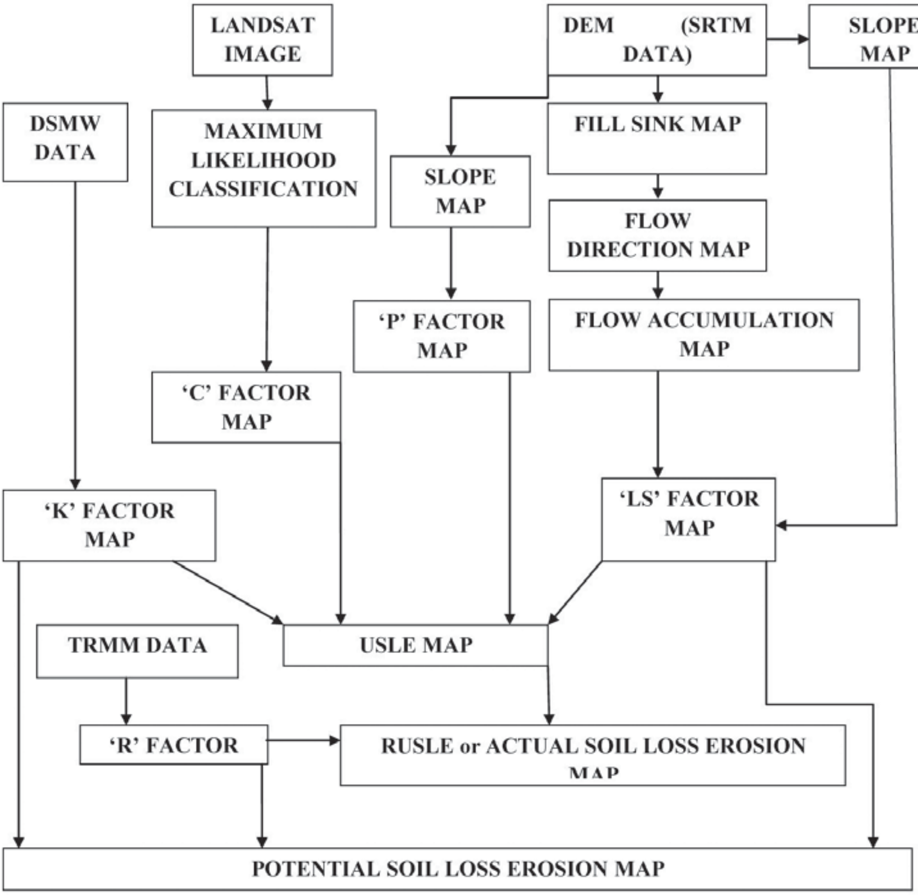


Figure 4. Schematic diagram of the methodology of the present research

Empirical models are primarily based on observations and are usually statistical in nature. The USLE is the most widely used empirical overland flow or sheet-rill erosion equation. The equation aims to quantify soil loss based on the complex interrelation among the soil erodibility factor (K), slope length factor (L), slope gradient factor (S), vegetation cover factor (C), and conservation protection factor (P). The equation is expressed as:

USLE=K. LS. C. P

Rainfall Erodibility Factor (R)

World Raster Grid data has been used to estimate R factor using the above formula. The calculated R factor for each station can be converted to raster surface with 30 m grid cell using IWD interpolation techniques (Chemeda, 2007). But this kind of detailed meteorological data is not available for the study area.

A simple relationship between Erosivity Iindex (R) and annual or seasonal rainfall (X) was developed by Singh *et al*., 1992 in different rainfall zones throughout India (Ahmed and Verma, 2013):

$R=50+0.389*X$ ……………... Equation 1

The formula was modified by Chaudhury and Nayak in 2003. The R factor was determined using formula given below (Chaudhry and Nayak, 2003):

$R=79+0.363*X$ ………………… Equation 2

Where, R = Annual R factor, X= Average Annual Rainfall in mm.

The Rainfall Erodibility is calculated on the basis of the Tropical Rainfall Measuring Mission (TRMM) global grid raster data by using the equation used by Choudhury and Nayak (2003). Soil erosion is closely related to rainfall through the combined effect of detachment by raindrops striking the soil surface and by the runoff. Rainfall Erodibility (R) is calculated as a product of storm kinetic energy (E) and the rain fall intensity. This relationship helps to quantify the impact of rain drop over a piece of land and the rate of runoff associated with the rain (Pancholi and Prakash, 2015). The temporal variation of R factor in Panchanoi basin has been estimated from 1993 to 2014 (Fig. 5). The yearly rainfall data has been collected from Patra *et al*. (2013).

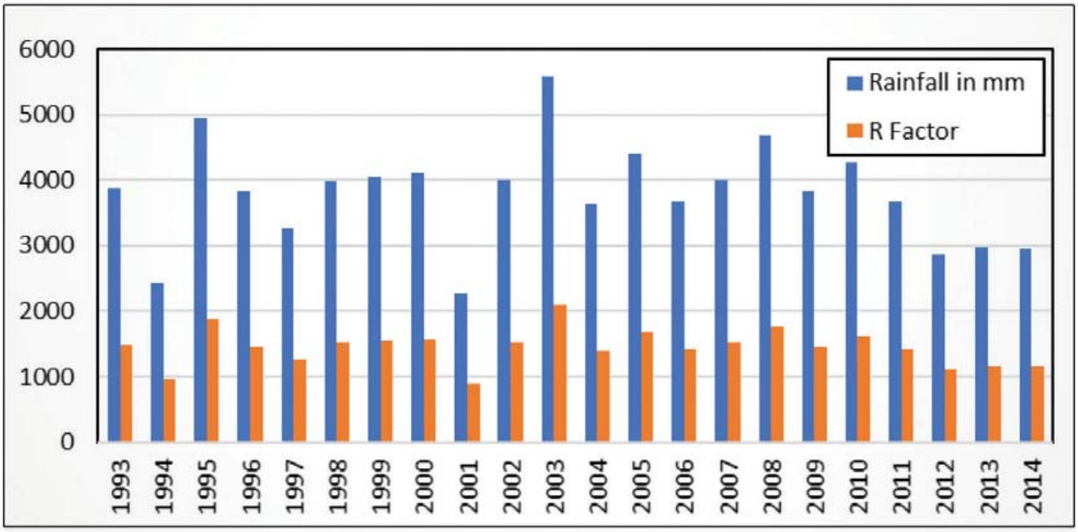


Figure 5. Temporal variation of rainfall and R factor of Panchanoi basin (1993 to 2014)

Soil Erodibility Factor (K-factor)

K factor or soil erodibility factor represents susceptibility of soil to detachment and transportation under particular amount of runoff for a specific rainfall event. The K factor is calculated on the basis of Digital Soil Map of World (DSMW), which is a FAO (Food and Agriculture Organisation) key database under the head of HWSD (Harmonised World Soil Database v 1.2). The K factor is rated from 0 to 1, where 0 is for least susceptibility of soil for erosion and 1 is for high susceptibility of soil for erosion by water (Pancholi and Prakash, 2015). It defines the inherent resistance of the soil to both detachment and transportation. Soil texture, structure, organic matter, porosity and permeability play significant roles to regulate soil erodibility. Two major soil categories have been identified in the studied part of the basin. After assigning values for each soil type, the soil map was reclassified using the K values of grid data with 30 m spatial resolution.

As per raster data base of HWSD, the upper and older lobe of the fan is dominated by the AH group of soil which is known as Acrisol as per DSMW. The middle-lower and younger part of the fan is covered by the JE group of soil as per HWSD and it is known as Fluviosol according to DSMW soil database.

The textural composition of these two soil groups is quite different (Table 2).

The following formulae have been used to find out the value of K factor for the said soil groups such as:

Fcs and= (0.2+0.3*EXP(-0.256*ms*(1-(msilt/100))))................................Equation 3

Fcl-si=(msilt/(mc+msilt)) ^0.3 ....Equation 4

Forgc=(1-(0.25*orgc)/(orgc+EXP(3.72-2.95*orgc))) …..............................Equation 5

F-hisand=(1-((0.7*(1-(ms/100))/((1-(ms/100) +EXP(-5.51+22.9*(1-(MS/M)))))))) .....Equation 6

K usle=(Fcsand*F cl-si*F orgc*F hisand) ……Equation 7

K=Kusle*0.1317 ……………… Equation 8

present MountainSlope Length and Steepness Factor (LS-factor)

LS factor or slope length and slope steepness factor is such an index through which two dimensions can be used in a single platform for of soil loss areal delineation (Wischmeier and Smith, 1978). LS factor is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel that may be part of a drainage network (Chemeda, 2007). There is a positive relation between soil erosion and slope. Slope length in its turn is associated with the increase in the velocity of stream flow and volumetric amount of surface runoff (SRO). The values of slope length (X) and slope (S) were derived from SRTM 1 Arc Second DEM (30 m resolution). For the present study, modified Land Surface (LS) factor map is generated from the slope and flow accumulation map has been derived from the DEM of Panchanoi basin (Fig. 6) after conducting Fill and Flow Direction processes by using Arc Hydro tool in ArcGIS 10.3.1 (Pancholi and Prakash, 2015). The modified equation for computation of the topographic factor (LS factor) in GIS environment is employed by the formula recommended by Griffin *et al*. (1988):

Slope Length

(X) = (Flow accumulation * Cell value)

By substituting the X value, LS equation will be:

LS = (Flow accumulation * Cell value/ 22.1) m (0.065 + 0.045 S + 0.0065 S …Equation 9

Where S = slope gradient (%)

Crop management Factor (C-factor)

C factor or crop management factor is used to reflect the effect of cropping and crop management on erosion rates. It represents the ratio of soil loss under a given crop to that of the base soil. It is considered the second major factor (after topography) controlling soil erosion (Morgan, 1994). An increase in cover factor indicates an increase in potentiality of soil loss (Pancholi and Prakash, 2015). Area under any kind of vegetation cover even under crop land (Plate 4) is less susceptible to soil erosion. The C factor is calculated as per Wischmeier and Smith (1978). Land use/ land cover map (Fig. 3) of Panchanoi basin for the year 2017 has been used as base map to calculate the C factor.

Table 2. Calculation for K factor

Soil Sample HWSD	Soil sym DSMW	Sand ms %	Silt msilt %	Clay mc %	Orgc %	F csand	F cl-si	F org	F hisand	K usle	K
AH	Acrisol	31.3	24.8	43.8	3.34	0.2007	0.7369	0.7501	0.9999	0.1109	0.015
JE	Fluviosol	70.8	12.8	16.5	1.15	0.2000	0.7800	0.8866	0.9421	0.1303	0.017

Conservation Practice Factor (P-factor)

P factor or conservation practice factor refers to the effect of conservation practices that reduce the amount and rate of runoff and decreases the intensity of soil erosion (Pancholi and Prakash, 2015). It includes different types of agricultural management practices which takes place in the middle and lower part of the basin. The northern part of the Panchanoi basin has P factor value nearer to 1.0. The conservation practices principally affect erosion by modifying the flow pattern and direction of surface runoff (Chemada, 2007). Land use/ land cover map (Fig. 3) of Panchanoi basin for the year 2017 has been used as base map to calculate the P factor.

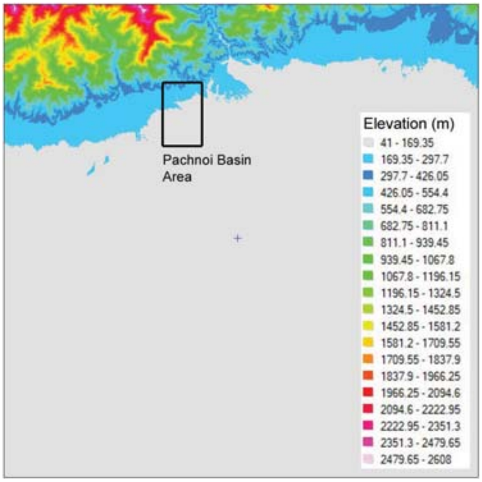


Figure 6. Location of the study area in SRTM tile no. n26e88-V3

Estimation of Actual and Potential Soil Erosion of Panchanoi Basin

The annual soil erosion estimation of Panchanoi basin is carried out based upon the principles and parameters defined in the USLE model. The input parameters were compiled into one coherent raster database for predictive model of annual soil loss prediction. The computation of model as well as model output is based on raster data formats with grid resolution of 30 meters.

The approach used for erosion modeling involved two aspects: estimation of potential erosion and estimation of actual soil loss. The equation can be expressed as follows:

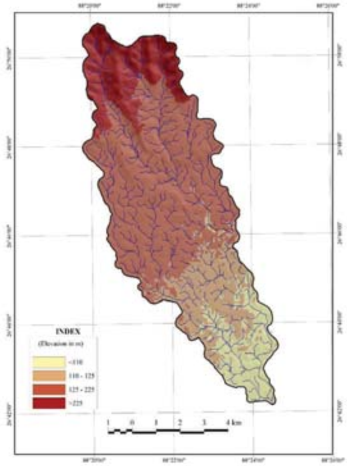


Figure 7. DEM based Relief Map of Panchanoi basin, lying on the Mahananda fan.

Actual soil erosion,
(A)= R*K*LS*C*P (Pancholi and Prakash, 2015) ....Equation 10
Potential soil erosion, (P) = R*K*LS (Pancholi and Prakash, 2015)......Equation 11
Where, A is the average annual soil loss (mass area^{-1} year^{-1}); R is the rainfall erosivity index

Result and discussion

The DEM based relief map of the Panchanoi basin (Fig. 7) represents the topographic undulation and the expression of elevated surface of the upper, middle and lower part of the Panchanoi basin. It clearly represents the altitudinal variation of surface along the long axis of the basin, from the apex to the distal part of the fan. The northern most part of the basin shows the steep edge of Himalayan Mountain in Kurseong, from where the mountainous stream Panchanoi, Rongtong, Chamta and their non-perennial tributaries initiate and comes down to the southern spur. Due to sudden decrease of slope, most of the transported debris materials are accumulated here to form alluvial cones. The accumulated materials are reworked by stream action and debris flow and deposited along the axis of the fan

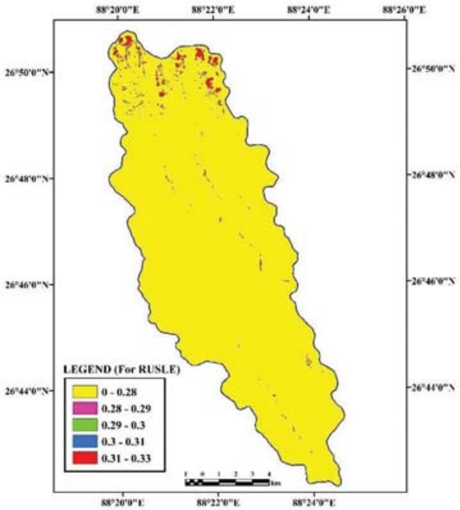


Figure 8. Actual Soil Erosion Map of Panchanoi basin.

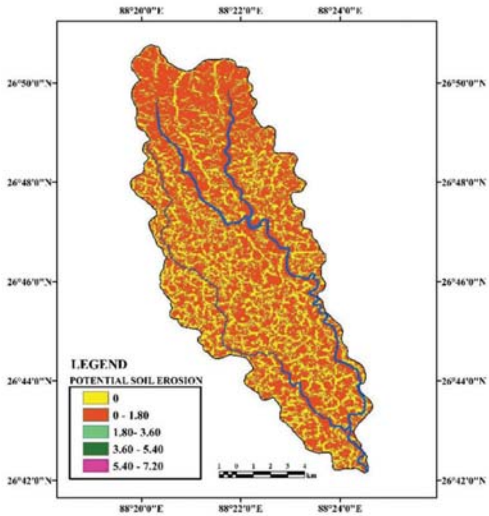


Figure 9. Potential Soil Erosion Map of Panchanoi basin.

surface. The different depositional surfaces are identified according to their elevation and maturity. Those depositional surfaces can be identified through DEM as isolated lobes. The mountainous streams incise their valleys through trenching and produce symmetrical and asymmetrical terraces.

The highest amount of soil erosion is found in the upper part of the Panchanoi basin (Fig. 8). Steep valley walls of entrenched rivers are mainly responsible for supplying loose unconsolidated debris to the foothills. These materials are transported through the rivers during high discharge regime and create several micro-geomorphic features on the river bed (Plate 3). The debris flow from either side of the steep valley walls also contributes a huge amount of soil. The outer banks of the meandering stream in the middle and the lower part of the basin also supply a significant amount of soil.

The Panchanoi and its steep banks, guided by the middle and upper terrace of the old surface (created by Mahananda) in the central part of the basin are susceptible to soil erosion (Plate 5). Significant soil erosion has been observed along selected reaches of Panchanoi river system in the lower segment of the basin. Rainfall erosivity, soil erodibility, slope gradient and length are considered as naturally occurring factors determining the sheet and rill erosion process (Plate 2). Together, they are considered as indicators of erosion susceptibility or potential soil loss of an area.

The potential soil erosion map (Fig. 9) indicates that an extensive part of the steep southern part and upper basin catchment area are very much susceptible to soil erosion. Sukna forest acts as an apron over the loose surface of huge accumulation of unconsolidated debris at the upper segment of the basin. Further deforestation flowed by landslide occurrence may cause an increased rate of land degradation and soil erosion. A specific gap (Fig. 10) exists between the actual soil erosion estimates and the potential soil erosion estimates due to active measures of conservation practices.

Unscientific construction of embankments and retention walls (Plate 6) may be responsible for increasing bank vulnerability and invites instability of the middle and lower part of the basin. As upper part of the basin is under the Mahananda Wild Life Sanctuary and it has already been declared as a Protected Forest, the erosion susceptibility of the upper part of the fan can easily be controlled through proper monitoring. The middle and lower portions of the basin

Table 3. Calculation for actual and potential soil loss of Panchanoi basin

Year	Mean rainfall (in mm)	R Factor (Chaudhry *et al.*, 2003)	Actual soil loss rate (ton ha^{-1})	Potential soil loss rate (ton ha^{-1})	Actual soil loss (m^3 yr^{-1})	Potential soil loss (m^3 yr^{-1})
1993	3871.5	1484.355	3.4108	17.9637	20884.1	109988.9
1994	2427.6	960.2188	2.2065	11.6206	13509.8	71151.1
1995	4940.4	1872.365	4.3024	22.6594	26343.3	138740.0
1996	3829.3	1469.036	3.3756	17.7783	20668.6	108853.8
1997	3268.8	1265.574	2.9081	15.3160	17806.0	93777.6
1998	3983	1524.829	3.5039	18.4535	21453.6	112988.0
1999	4046.9	1548.025	3.5572	18.7342	21780.0	114706.8
2000	4118.1	1573.87	3.6165	19.0470	22143.6	116621.9
2001	2266.4	901.7032	2.0720	10.9124	12686.5	66815.1
2002	3997.1	1529.947	3.5156	18.5154	21525.6	113367.3
2003	5580.3	2104.649	4.8362	25.4705	29611.4	155952.0
2004	3621.6	1393.641	3.2024	16.8658	19607.8	103267.1
2005	4392.5	1673.478	3.8454	20.2524	23545.0	124002.7
2006	3673.6	1412.517	3.2458	17.0943	19873.4	104665.8
2007	4007.2	1533.614	3.5240	18.5598	21577.2	113639.0
2008	4678.7	1777.368	4.0842	21.5097	25006.7	131700.9
2009	3823.1	1466.785	3.3705	17.7510	20637.0	108687.1
2010	4257.7	1624.545	3.7330	19.6602	22856.6	120376.9
2011	3675.5	1413.207	3.2474	17.1026	19883.1	104716.9
2012	2867.5	1119.903	2.5734	13.5531	15756.5	82983.5
2013	2970.5	1157.292	2.6593	14.0055	16282.5	85753.9
2014	2943.4	1147.454	2.6367	13.8865	16144.1	85025.0

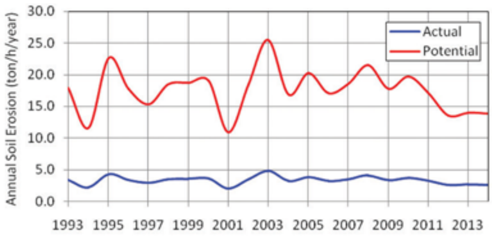


Figure 10. Actual (RUSLE) and Potential soil erosion of rate of Panchanoi basin (1993 to 2014)

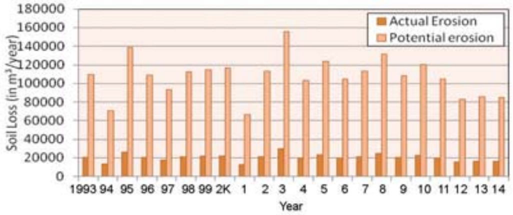


Figure 11. Actual (RUSLE) and Potential amount ofs loss from Panchanoi Basin (1993 to 2014)

will have to be managed on priority basis, since these portions fall under the buffer continuum of Siliguri, experiencing vicious land use change due to the enormous

Plate 1. Panchanoi river near the Siwalik front at Sukna

Plate 2. Formation of sedimentary structures on Panchanoi river bed

Plate 3. Monsoon flow with high suspended sediment load near Rongtong Bridge

Plate 4. Cropped land cover as a measure of conservation of soil erosion

Plate 5. Exposed bank with coarse and loose particles at Dagapur Tea Garden susceptible to soil erosion

Plate 6. Erosion prone oxidised bank sediment at Sukna with three tier boulder wall

pressure of city expansion. The acceleration of river bank erosion in the middle and lower parts of the fan will be responsible for the colossal soil erosion in future. Any kind of land use change in the middle and lower parts of the basin may accelerate the rate of soil erosion. Encroachment of built-up area on the river banks and deforestation has increased the vulnerability of these portions and are responsible for aggravating soil erosion, The potential soil erosion map (Fig. 9) indicates that the upper part of the basin is less erosion prone. The valley walls are however, susceptible to erosion due to steep slope. The unconsolidated loose particles easily come down as debris flow from the valley walls and accelerate soil erosion. The stream transports the sediment load from the top to the middle basin area. Entrenchment of river in the upper part of the fan increases the rate of soil erosion. The incision of the river valley at this tectonically active foothill region is responsible for the detachment of top soil. All the narrow but steep walls of rills and gullies in this area are susceptible to soil erosion. Although afforestation measures have been introduced in the area, but erosion may be enhanced if human intervention continues unabated.

The estimated potential soil erosion map (Fig. 9) shows that the middle part of the basin is susceptible to soil erosion, though at present the area is not under the active soil erosion zone. The major land use in the middle part of the fan is tea garden, which indicates that the surface has already experienced a change of land use. The middle part of the basin is in a tectonically active area, composed of unconsolidated, very loose reworked material of the upper basin. Further major change in land use and land cover may cause enormous amount of soil degradation either by stream action or any mass movement processes from the steep edges of the middle and upper terraces of Mahananda, now used for the tea plantations.

The lower part of the Panchanoi basin is not presently under the active soil erosion zone, but the potential soil erosion map (Fig. 9) shows that a large area has . This part is already under severe modification. The areas neither have forest cover nor tea gardens, which can reduce the rate of top soil degradation. Most of the area is occupied by either settlements or by agriculture plots. The latest trend is to convert agricultural land or fallow land into the settled area. Such change of land use may cause soil loss in future.

Conclusion

Steep walls of entrenched river valleys in the upper part of the basin and a few outer meanders of the middle and lower part of the studied Panchanoi basin (a portion of Mahananda mega-fan) is in the state of active soil erosion (Fig. 8). Approximately 2.66 t ha^{-1} y^{-1} top soil material is degrading in the Panchanoi basin. Approximately 14.05 t ha^{-1} y^{-1} top soil may degrade in worst (inactive conservation methods) possible condition (Fig. 10) and 16340.23 m^3y^{-1} top soil mass has been washing out through the Panchanoi river system and the estimated potential soil loss is 86057.87 m^3y^{-1} (Fig. 11).

The year wise statistics clearly shows that the intensity of soil erosion has accelerated in the last 25 years in Panchanoi basin than its average soil loss in more than 100 years. The soil erosion rate has also been accelerated in recent times than the average soil loss (2.66 t $ha^{-1}y^{-1}$) during last 100 years. 1995, 2003, 2008 denote higher rates of soil erosion. Highest soil erosion has been estimated in 2003, which is the recorded maximum rainfall year in last three decades (Fig. 11).

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