

Analysis of Regional Hypsometric Integral to Identify Landscape Evolution in Kushkarani River Basin

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Authors' contributions

This work was carried out by both the authors. Author SP designed the framework of the work, designed the approaches of mapping and tables. He also provided sample analysis support. Author SK prepared the maps and also contributed in analytical part. Literature reviews are mainly carried out by author SK. Both the authors finally read and approved the manuscript.

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ABSTRACT

This paper aims to find out the regional pattern of hypsometric curve (HC) and hypsometric integral (HI) over the Kushkarani river basin, a Chhottanagpur plateau fringe low relief basin. The paper also attempted to know how far different driving factors control HI. From the result it is found that most of the curves are slightly concave and HI value ranges from 0.35 to 0.55 for the selected sub basins. So, basins are now experiencing mature stage of geomorphic evolution. Such stage will create an equilibrium condition of erosion and transportaion. Fluvial process is mightier than hill slope process. Analysis of the impact of shape, size, hierarchy, elevation, geology, soil erosion, tectonic intensity etc. on HI do not highlight any significant result. Hypsometry of this basin is scale independent as scale effect is almost negligible. Tectonic influence is not prominent over the basin as indicated by the HI in reference to tectonic index map. Predicted soil erosion is not also high over the areas where HI is high.

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1. INTRODUCTION

Hypsometric analysis refers the relative ratio of an area at different elevation on the earth surface [1]. Langbein [2] first time introduced hypsometric analysis to express the over all slope and forms of drainage basin. Hypsometric curves (HC) and hypsometric integrals are vital indicators of watershed conditions [3]. Hypsometric analysis is highly popular because of its dimensionless nature that permits comparison of watersheds irrespective of scale issues [4]. The HI is expressed as a percentage, and is an indicator of the residue of the present volume as compared to the original volume of the basin [3]. The hypsometric integral thus helps in explaining the erosion that had taken place in the watershed during the geological time scale due to hydrologic processes and land degradation factors [5]. Besides this, it also provides a simple morphological index with respect to relative height of the elevation distribution within the area considered, which can be used in surface runoff and sediment yield prediction from watersheds [6,7]. On the other hand, this parameter also reflects ambiguity in estimation due to the fact that the hypsometric curves of different shapes can yield the same hypsometric integral value [8]. Surface runoff and sediment losses are the two important hydrologic responses from the rainfall events occurring over the watershed systems. The hypsometric integral value can be an indirect estimator of the erosion from the watershed systems. The shape of hypsometric curve represents the geomorphic stages of landform evolution. Convex shape indicates younger, undissected, disequilibrium landscapes stage, smooth S-shape shows mature or equilibrium stage and concave shape curve is related to an old deeply dissected and peneplain landscapes stage [1,9-12]. Differences in the shape of the curve and the hypsometric integral value are related to the degree of disequilibria in the balance of erosive and tectonic forces [13].

Lifton and Chase [14] suggested that HI is strongly affected by tectonic activity at large scale about 1000 sq km and lithological activities at small scale about 100 sq km. They also explained that uplift rate is strongly correlated to HI. So for detecting regional upliftment pattern of a region, HI is a frequently used technique. Several studies have shown that HI is related to morphometry of the basin, such as basin area

and relief [11,15,16], basin planform and basin perimeter [14,17].

There are different techniques for measuring hypsometry e.g. Elevation–Relief Ratio (E) Relationship [18], planimeter based measurement, Leaf Area Meter (LAM) Equipment, Integration of Hypsometric Curve [19,20]. HI is a summative expression of watershed condition and it helps to predict some of the geomorphic processes going on there or have experienced thereon. From theoretical understanding, scholars have established relationship of different driving factors with HI. But most of the relationship is highly case specific because established finding of one region is become null and void in another basin. Perhaps, it is because of the multifaceted influence of different parameters. Present paper likes to find out regional pattern of hypsometry selecting some sub basin within main Kushkarani river basin. Also it is tried to identify whether control of different factors on HI is significant.

Present paper concentrates on the investigation of regional pattern of HC and HI selecting some of the sub basins within Kushkarani river basin. It also attempts to find out the influence of different drivers on HI. How far HI is applicable for predicting soil erosion of a region can also be investigated in this paper.

2. MATERIALS AND METHODS

2.1 Study Area

Kushkarani is an upstream tributary of Mayurakshi River situated in Birbhum district of West Bengal and Jamtara district of Jharkhand. The basin is demarcated by 23°54' 36" N. to 24° N. latitudes and 87°14'24" E. to 87°30' E. longitudes with a total area of 172 sq. km. (see Fig. 1). The east-west elongated basin of the 35 km. long river is situated in the eastern margin of the Chhotonagpur plateau, where the highest elevation (155 metres) is seen in the western side near the source of the river and lowest elevation (62 metres) is seen in the eastern side near its confluence (see Fig. 1). Maximum area of the basin is occupied by rugged topography with an average elevation of 108 metres. On an average 120 metres contour roughly demarcates upper catchment, 80 metres contour delimits middle and lower catchments. The basin falls

under the hot and sub-humid monsoon climatic region. Annual average rainfall of the region is 1444.50 mm, to which 82% rainfall happens during monsoon months (June to September). Granitic gneiss formation dominates 90% of the basin area and rest part is characterized by laterite formation (Fig. 1). There is variation of soil qualities in different parts of the basin viz. upper catchment is dominated by coarse lateritic soil, and rest part is composed with laterite and relatively old alluvial soil. The extreme confluence part of this river frequently submerged by extension of the water logged storage unit of Tilpara Barrage over Mayurakshi River.

2.2 Methodology

This work is based on the extraction of height and area data from ASTER DEM in Arc GIS software. A specific number of sub basins are demarcated in this study and HC have prepared following Strahler [1] percentage method, plotting the ratios a/A and h/H . HI is also calculated for all the subbasin for detecting their niche in stages of geomorphic evolution.

Where,

a/A is relative area; h/H is relative height

h = mid height of the basin; H = total height of the Sub Basins; a = area above the elevation h ; A = total area of the basin.

Entire basin has been subdivided into 29 sub basins and HC has been drawn and HI is calculated for each. HI is considered as an indicator of the stages of "cycle of erosion" [1,21] and considering this fact, HI is calculated and classified following Stahler [1]. $HI \leq 0.3$ means old stage, $HI \geq 0.3$ to ≤ 0.6 means mature stage and $HI \geq 0.6$ indicates youth stage and this stage usually is highly erosion prone.

Regression models are prepared to show the influence of different driving parameters like size of the basin, shape of the basin, elevation category and hierarchical orders of the basins on hypsometric integral. The value of R^2 represents the degree of control of these parameter on HI. Markose and Jayappa [22], Farhan et al. [23] also adopted same approaches for detecting scale dependency of HI.

a/A and h/H

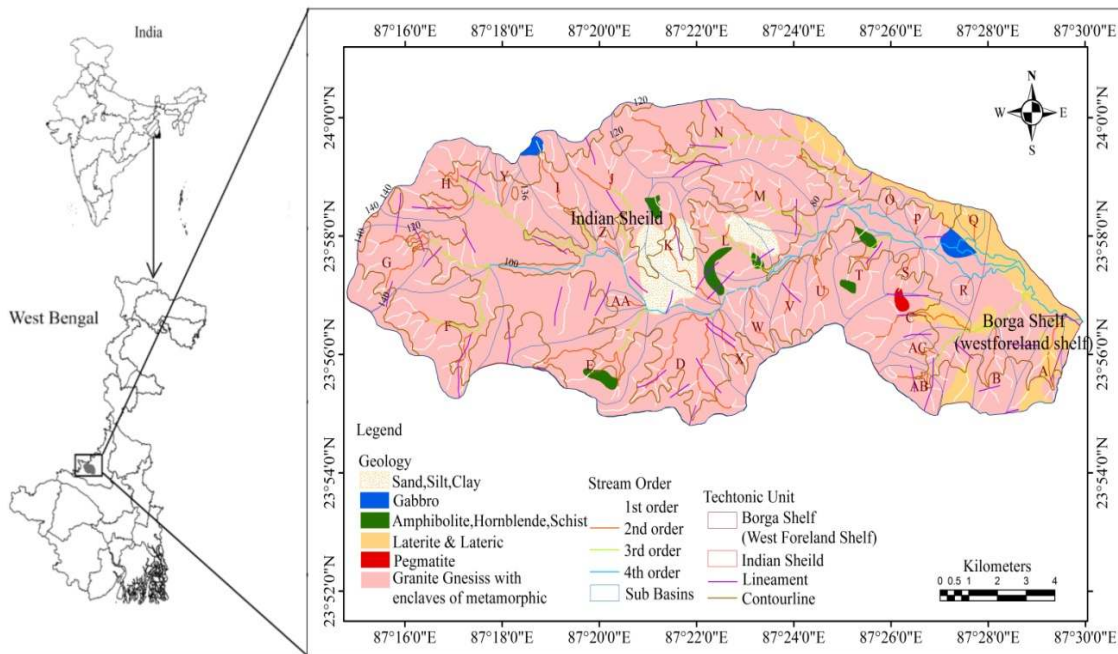


Fig. 1. Study area map showing selected sub basin overlaying on the geological structures

HI values are also compared with soil erosion potential areas in aim to detect whether there is any accordance between HI and soil erosion potential. Soil erosion potential model is prepared based on Revised Universal Soil Loss Equation (RUSLE) model [24].

$$A=LS*R*K*C*P$$

Where

A = annual soil loss (tons/ha/year)

LS = slope length factor

R = rainfall erosivity factor (MJ mm ha⁻¹ ha⁻¹ yr⁻¹)

K = soil erodibility factor (metric tons ha⁻¹ MJ⁻¹ mm⁻¹)

C = land cover and management factor dimensionless, ranging between 0 and 1)

P = conservation practice factor (dimensionless, range between 0 and 1)

In the present study, annual soil loss rates are computed based on RUSLE in GIS environment using Arc GIS 9.3 and ERDAS Imagine 9.2.

For showing tectonic influence on HI, tectonic index map of the basin is created based on eight parameters (hypocentral depth 0-25, hypocentral depth 25-75, hypocentral distance map, T-index, form factor, gravity anomaly, regional sinuosity and isobase slope map). For preparing the individual dataset for the selected parameters, continuous raster maps are prepared. The WLC is a simple additive weighting based on the concept of a weighted average [25] is used here for compositing the parameters. As this process executes on the basis of raster based weighted linear combination, required data layers have been converted into raster images using grid based raster surface like DEM in ERDAS Imagine Soft ware. Each attribute (map layer) is categorized into 10 classes ranking 1 to 10 (adopting 10 point scale) considering the fact that greater rank will reflect greater potentiality of tectonic influence. To fulfill this purpose, all the attributes have been reclassified into 10 classes and ranked them accordingly. The logic behind ranking to intra attribute classes from 1-10 is described in Table 1. Weightage of each attribute has been defined objectively (see Table 1) considering the degree of correlation of each driving factor. The logic behind this consideration is that highly correlated parameter maximally explains the spatial variation of tectonic activities. Normalization of respective weight (values of r

for respective parameters) based on dimension index has been done for framing it in a scientific scale. The result of each normalized value is called attribute weight.

Expression of weight calculation is as follows:

$$w_j = \frac{a_{jr}}{\sum_{j=1}^n j_r} \quad (1)$$

w_j=weight of jth parameter; a_{jr}= correlation coefficient of jth attribute; $\sum_{j=1}^n j_r$ = summation of correlation of all jth variable.

Rank of all sub classes under each attribute is then multiplied by the defined weight of each individual attribute. This function can be presented using the following formula.

$$WLC = \sum_{j=1}^n a_{ij} w_j \quad (2)$$

Where, a_{ij}= ith rank of jth attribute; w_j= weightage of jth attribute.

Table Selected parameters for identifying tectonic index map and their weights

3. RESULTS AND ANALYSIS

3.1 Hypsometric Curve and Integral of Different Sub Basins

Hypsometric curves (Fig. 2) shows the hypsometric pattern of different sub basins of Kushkarani River Basin. Most of the sub basins represent concave curve. This type of curve is originated when soil are eroded from the basin, downslope movement of topsoil and bedrock materials and washout the soil mass and cutting of stream banks [30]. All the deriver curves are categorized into three groups based on their shape. Table 2 shows the characteristics of HC of 29 subbasins. First group is chaterised by slightly concave shape with average HI 0.387. This group represents late mature stage of geomorphic evolution. Second group is characterised slightly by concave upward with average HI 0.446. This group indicates the sub basins (see Table 2.) are passing through mature stage of evolution and the last group represent the convexo-concave shpe with average HI

0.498. According to Morkose and Jayappa [22] this type of curve originated due to fluvial and slope wash processes of landform.

Expectedly, if other deriving factors remain favourable, soil erosion rate will be quite high in the basin passing through youth stage of cycle of erosion and it is implicit that the hydrologic response of the sub basins attaining the mature stages will have slow rate of erosion [3] unless there is very high intense storms leading to high runoff peaks. The shapes of HC of O and P sub basins are slightly concave, it indicates these sub basins are quite lagging behind erosional cycle of

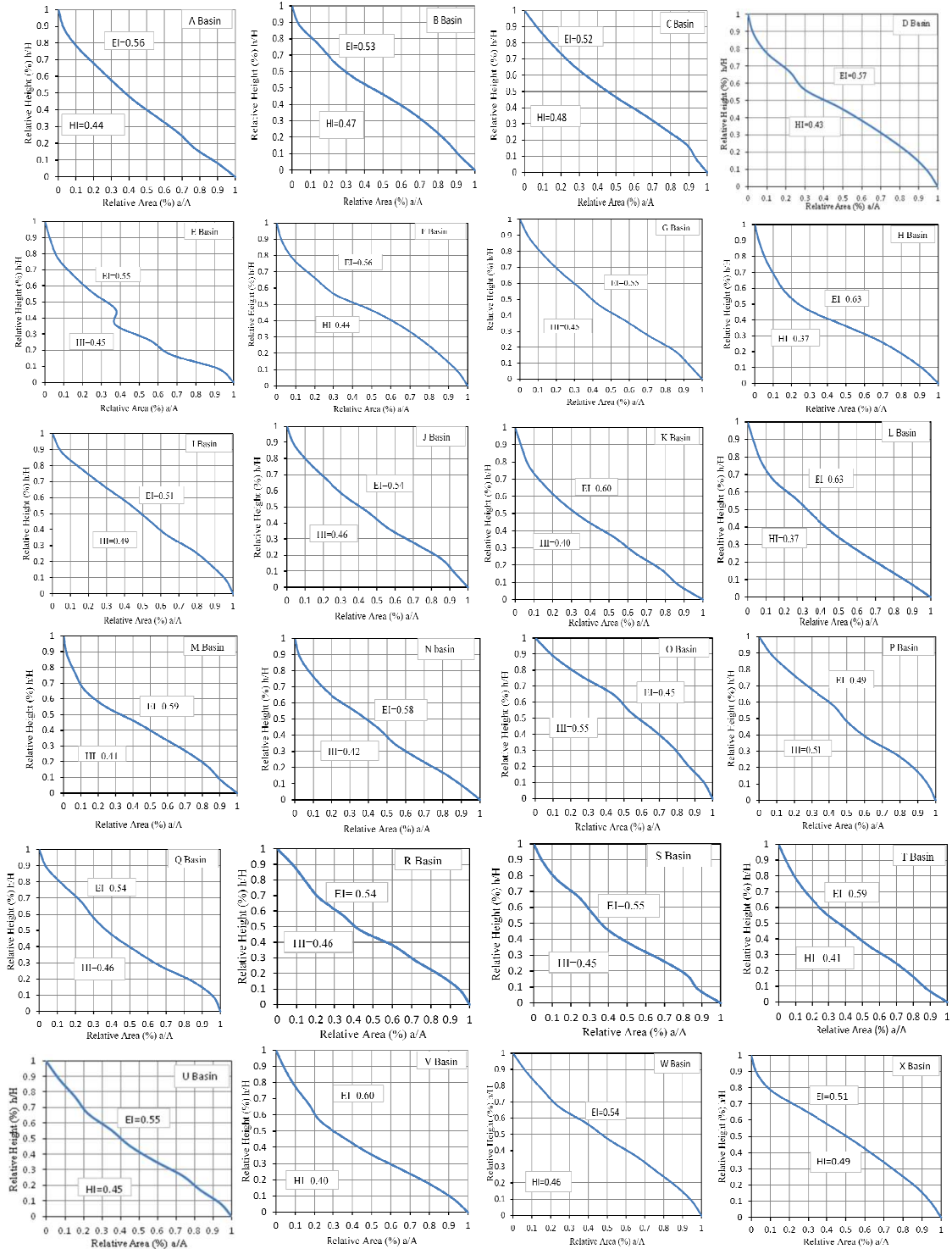
erosion and obviously, these sub basins are in early mature stage. HC of the sub basins are regular in most of the cases except E, AA, AB, AC where clear-cut notch is observed indicating break of slope. Such break of slope can empower basins toward more erosivity. It can also increase bifurcation ratio in a particular segments merging a good number of stream into few. Typical landforms like alluvial fan and coarse debris heap etc. are found just below break of slope. Fig. 3 denotes the HC of the entire basin as a whole. Slightly concave shape is also noticed here as it is found for most of the sub basins.

Table 1. Scaling of parameters, logic of the parameters and weights

Parameters	Scaling	Logic	Weights
T index	10 rank at highest value.	Active Tectonic influence is observed at asymmetric basin [26]	0.45
Gravity anomaly map	10 rank at highest anomaly.	More value of gravity anomaly indicates greater tectonic influence.	0.94
Form factor	10 rank at lowest value	Tectonic activity is more active at elongated basins [27]	0.40
Sinuosity index	10 rank at lowest value	Drainages are few sinuous at active tectonic region [28,29].	0.37
Isobase slope map	10 rank at maximum isobase change.	Isobase slope is changed at tectonic unstable zone.	0.29
Hypocentral depth (0-25 km)	10 rank at lowest depth	Tectonic activities is more dominant at nearest seismic	0.99
Hypocentral depth (25-70 km)	10 rank at lowest depth	hypocentral depth and distance.	0.1
Epicentre buffer map	10 rank at lowest distance.		0.98

Table 2. Categorization of sub basins based on the shape of the HC and their position in the stages of geomorphic evolution

HC shape	Basin id with HI	Average HI	Evolution stage
Slightly concave	AA(0.35), T(0.41), M(0.41), L(0.37), H(0.37), K(0.40), V(0.40)	0.387	Late mature stage
Slightly concave upward	AC(0.44), Z(0.42), W(0.46), U(0.45), S(0.45), R(0.46), Q(0.46), N(0.42), J(0.46), G(0.45), F(0.44), E(0.45), D(0.43), B(0.47), A(0.44)	0.446	Mature stage
Convexo-concave	AB(0.48), Y(0.49), X(0.49), P(0.51), O(0.55), I(0.49), C(0.48)	0.498	Early mature stage



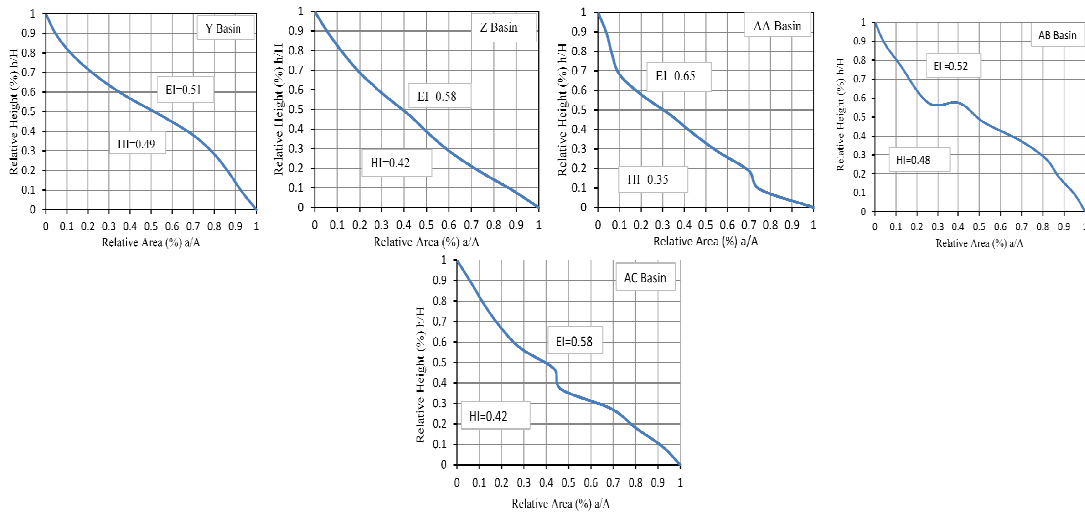


Fig. 2. Hypsometric curves of different sub basins within Kushkarani river basin with their calculated HI; A to AC indicates basin id as shown in Fig. 1

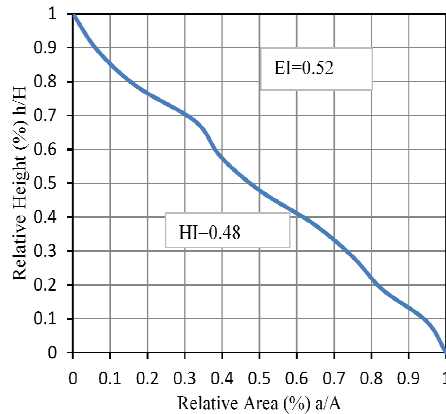


Fig. 3. Hypsometric curves and integral of the Kushkarani river basin as a whole

3.2 Regional Hypsometric Pattern and Hypsometric Anomaly

Based on the calculated HI at different sub basins, regional hypsometric integral (RHI) map (Fig. 4) has been prepared. No specific trend is noticed regarding HI. In the middle catchment HI is below 0.41. Maximum HI is found in two small sub basins in the left hand water divide fringe of lower catchment which is seemed to be quite irregular result ($HI > 0.50$). In the present study HI value ranges 0.35 to 0.55. To show the HI pattern all sub basins, HI are classified into three categories followed by Dehbozorgi et al. [31] and Farhan et al. [23]. Fig. 5 shows the HI status of the individual sub basins within the categories. In case of sub basins O and P HI values are 0.55

and 0.51 respectively and it seems to be quite higher than other sub basins. Perhaps, harder geological composition and less erosive power of those basins are mainly responsible for this expression. Tectonic history of the region speaks that the confluence part of the basin experienced two earthquakes of medium intensity, still it can't be considered as a tectonically driven event considering its small size. In support of this view, some other information can be cited out. Confluence segment of the basin is characterized by relatively depressed land which is an adjoining part of the storage unit of Tilpara barrage. If it is considered that such depression is neo tectonically driven, there should not be such small scale regional upliftment in very proximate region of such depression. Fig. 6 and

Table 3 indicate that there is no significant influence of tectonic activity on patial distribution of HI.

Fig. 7 represent the sub basin specific regional pattern of hypsometric anomaly. Anomaly is calculated in reference to the HI value of the entire basin which is 0.48. From this figure it is found that out of total sub basins, 24 sub basins are positively and 5 sub basins are negatively anomolous. No such definite regional trend of anomaly is noticed where from few vivid findings can be drawn.

Hamdouni et al. [26] reported that High values of HI are perhaps associated with young stage,

active tectonics and low values of HI are related to older landscapes that have been more eroded and less impacted by recent tectonic activities. In the high intensity tectonic zone, HI value ranges from 0.45-0.55. So, from this association it can't be stated that this area is tectonically uplifted. If these sub basins were tectonically uplifted, certainly these sub basins could have carried higher HI than surrounding sub basins. Presence of a thick, resistant unit in the headwaters of a catchment will tend to decrease its hypsometric integral, while exposure of such a unit near the mouth of the basin will tend to increase its hypsometric integral [32]. Higher HI in sub basins O and P may be due to this factor.

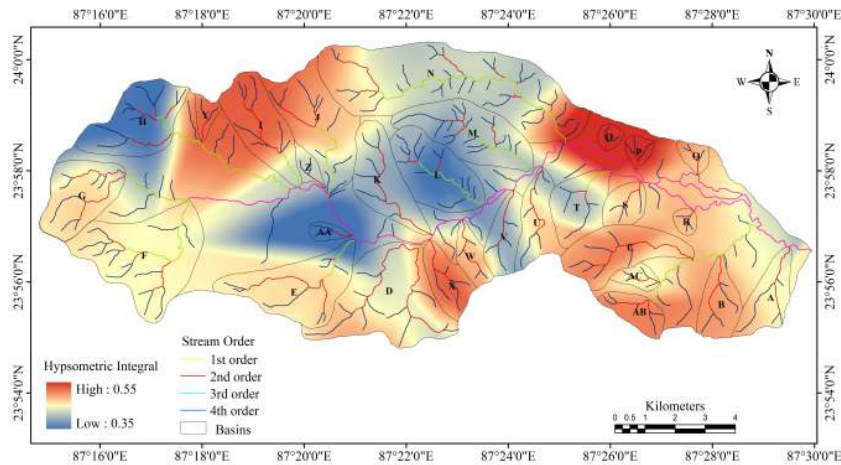


Fig. 4. Spatial pattern of hypsometric integral

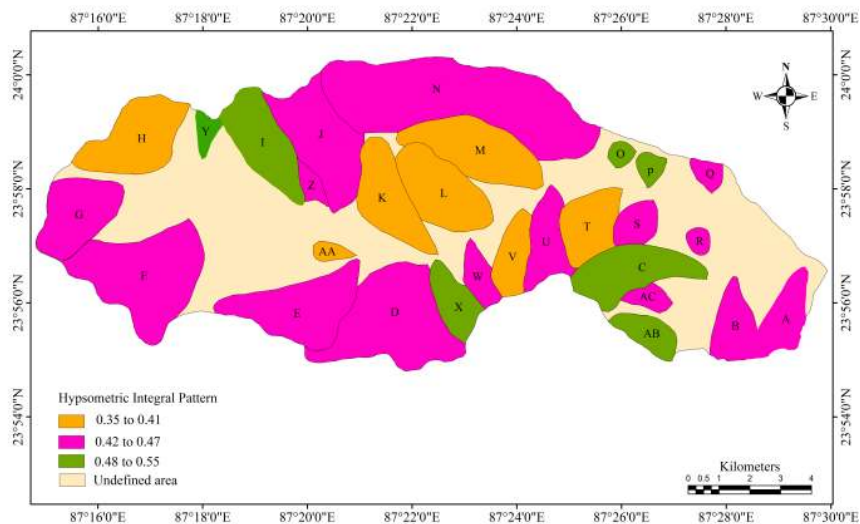


Fig. 5. HI pattern of different sub-basin

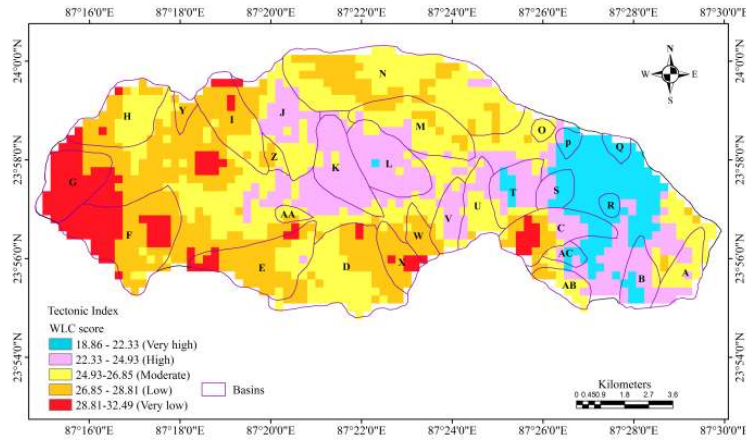


Fig. 6. Tectonic index map

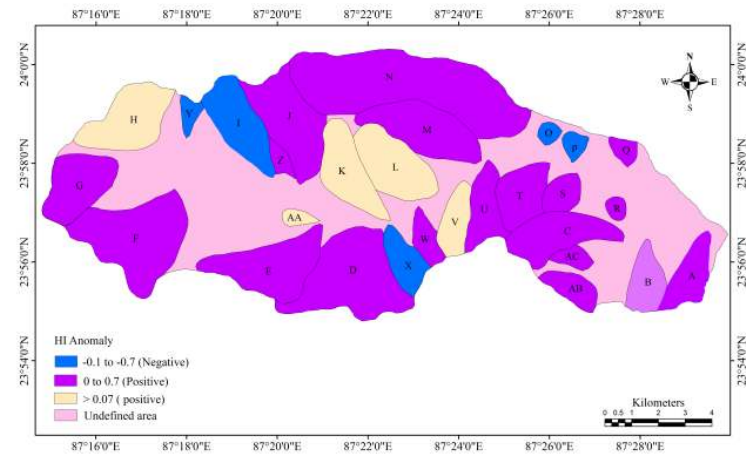


Fig. 7. Hypsometric anomaly of the sub basins based on average HI of the basin as a whole

Table 3. Tectonic intensity zone and sub basins frequency under each zone, average HI within each zone

Tectonic influence	WLC score	Basin id	Frequency	Average HI
Very low	20.29 – 24.93	B(0.47),P(0.51),Q(0.46),R(0.46),T(0.41),AC(0.44)	6	0.458
Low	24.93-27.44	A(0.44),B(0.47),C(0.48),J(0.46),K(0.40),L(0.37),M(0.41),P(0.51),S(0.45),T(0.41),U(0.45),V(0.40),AB(0.48),AC(0.44)	14	0.441
Moderate	27.44-29.36	A(0.44),B(0.47),C(0.48),D(0.43),E(0.45),H(0.37),I(0.49),M(0.41),N(0.42),O(0.55),V(0.40),W(0.46),AB(0.48),A(0.44)C(0.48)	14	0.449
High	29.36-31.47	C(0.48),D(0.43),E(0.45),F(0.44),G(0.45),H(0.37),I(0.49),M(0.41),N(0.42),W(0.46),X(0.49),Y(0.49),Z(0.42),AA(0.35),A(0.44),B(0.47)	15	0.445
Very high	31.47-35.21	C(0.48),D(0.43),E(0.45),F(0.44),G(0.45),H(0.37),I(0.49),X(0.49)	8	0.450

Value within parenthesis indicates HI (if one sub basin covers two tectonic intensity zone, that sub basin is counted under both the cognitive classes)

Table 4 describes sub basin specific stream orders, basin size, HI, EI, shape factor and height characters for understanding their interactive relations. From this table size effect, shape effect, hierarchy effect, height effect on HI has been analyzed in the subsequent sections. This dataset will help to analysis the control of different factors on HI.

3.3 Size Effect on HI

Willgoose and Hancock; and Hurtrez et al. [17,33] documented that HI is high and shape of the HC is convex in case of small basins. In this study area within 29 sub basins 4 sub basins (O,P,Q,R) are small in size(0.43 to 0.79 sq. km.) with HI value 0.55,0.51,0.46,0.46 respectively. High HI value indicates that the sub basins are under early mature stage of geomorphic evolution. Dominance of hill slope process in small basins creates convex HC and dominance of fluvial process produces concave HC [33,34]. So from this finding of these scholars it can be recognized that where to be dominant hill slope process or fluvial process is found among the sub basins. To know the size effect on HI, linear regression has been carried out between size of the basin and HI of the respective sub basins in general and order specific basin size and HI in particular. The R^2 value considering all sub basins in this reference is 0.099 (Fig. 8) which indicates that size of the basin does not capable to control HI. But in case of size of the 3rd order sub basins and HI, R^2 value is 0.0031 indicating the fact size of the basin positively control HI. In case of second order sub basins again no definite control is detected as indicated by very small co efficient of determination ($R^2 = 0.058$). From this analysis, it can be infered that basin

with greater size can control HI in to some extent greater intensity. Exceptionally, all though sub basins O and P carry very small size but having greater HI. It is perhaps due to the result of regional structure of influence and less cumulative fluvial force as stated earlier also. Markose and Jayappa [22], Farhan et al [23] also established identical relation between basin size and HI except few cases. Few exception is found by Marcose and Jayappa because few of the sub basins are directly controlled by dykes. Singh [16] on the other hand found mixed responses (R^2 ranges from 0.13 to 0.95) in different parts North west Himalayan part. So, studying all these it is to be interpreted that range of hieght of the studying basin is one of the important parameter.

3.4 Shape Effect on HI

Hypsometric curves are directly dependent on the topographical shape of the catchment [17,35]. Basin shape are mainly measured with the aid of elongation ratio [10], form factor [36], circularity ratio [37] etc. Anlysis of regression between form factor, elongation ratio and HI of the respective sub basins established the fact that there is no significant control of shape factor on HI as indicated by very small R^2 value (0.027) (Fig. 9A). Same result is found when regression is carried out between elongation ratio and HI ($R^2=0.014$) (Fig. 9B). In the study area within 29 sub basins 22 are elongated (elongation value range form 0.39 to 0.89) and 7 are near to circular (elongation value range form 0.91-0.99) see Table 4. Average HI of elongated and circular bains are 0.44 and 0.47 respectively indicating that the circular sub basins are quite younger than elongated sub basins.

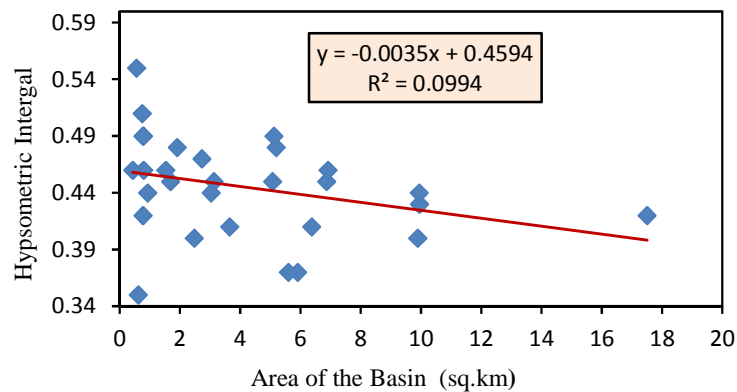


Fig. 8. Regression model between hypsometric intergal and size of the sub basins

Table 4. Hypsometric and erosional integral of different sub basins in reference to different driving factors

Name of basin	Stream order	Size of basin in sq. km	Hypsometric integral	Erosional integral	Form factor	Elongation ratio	Altitude range in metre	Mid height in metre
A	2nd	3.03	0.44	0.56	0.28	0.60	65-99	82
B	2nd	2.72	0.47	0.53	0.41	0.72	69-99	84
C	2nd	5.19	0.48	0.52	0.31	0.63	70-103	86.5
D	3rd	9.95	0.43	0.57	0.42	0.73	86-116	101
E	3rd	6.86	0.45	0.55	0.34	0.65	92-129	110.5
F	3rd	9.94	0.44	0.56	0.62	0.89	108-147	127.5
G	2nd	5.07	0.45	0.55	0.59	0.87	115-155	135
H	3rd	5.90	0.37	0.63	0.65	0.91	112-144	128
I	3rd	5.12	0.49	0.51	0.30	0.62	96-134	115
J	3rd	6.91	0.46	0.54	0.44	0.74	99-132	115.5
K	2nd	9.89	0.40	0.60	0.60	0.87	85-122	103.5
L	3rd	5.60	0.37	0.63	0.42	0.74	82-117	99.5
M	3rd	6.37	0.41	0.59	0.28	0.59	78-116	97
N	3rd	17.50	0.42	0.58	0.25	0.56	76-120	98
O	2nd	0.55	0.55	0.45	0.77	0.99	89-76	82.5
P	2nd	0.74	0.51	0.49	0.75	0.98	85-73	79
Q	2nd	0.79	0.46	0.54	0.78	0.99	77-68	72.5
R	2nd	0.43	0.46	0.54	0.77	0.99	80-68	74
S	2nd	1.68	0.45	0.55	0.72	0.96	98-72	85
T	3rd	3.64	0.41	0.59	0.52	0.81	74-103	88.5
U	2nd	3.12	0.45	0.55	0.27	0.58	80-113	96.5
V	2nd	2.47	0.40	0.60	0.33	0.65	83-115	99
W	2nd	1.53	0.46	0.54	0.35	0.67	85-115	100
X	2nd	0.77	0.49	0.51	0.12	0.39	89-117	103
Y	2nd	0.79	0.49	0.51	0.42	0.73	110-128	119
Z	2nd	0.77	0.42	0.58	0.54	0.83	96-116	106
AA	2nd	0.62	0.35	0.65	0.39	0.71	91-107	99
AB	2nd	1.90	0.48	0.52	0.68	0.93	81-97	89
AC	2nd	0.93	0.44	0.56	0.59	0.87	78-98	88

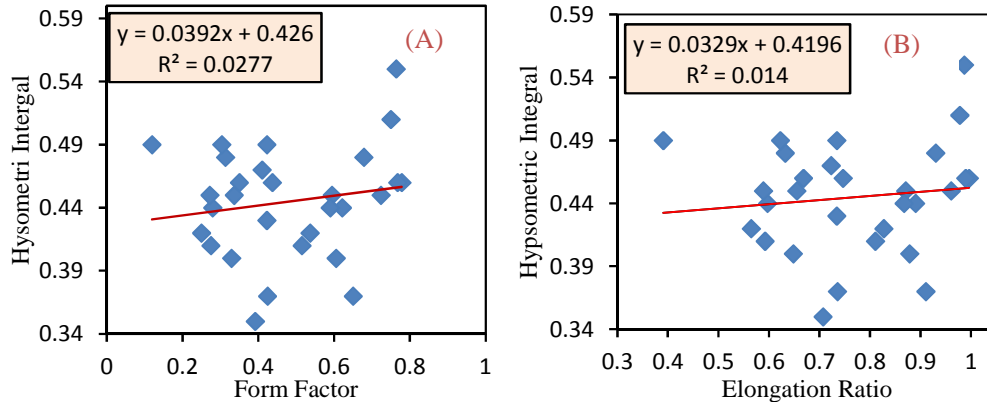


Fig. 9. Regression models between Hypsometric intergal and shape of sub basins (A) Form factor and HI and (B) Elongation ratio and HI

3.5 Height Effect on HI

Chen et al.[11] stated that the HI value could be spatially dependent on relief of the concerned area. Fig. 11 shows elevation pattern of the basin. Fig. 11 depicts the elevation classes of the basin and the location of sub basins within it. To investigate the degree of cardinality and control of height on HI, linear regression is carried out here also. R^2 value of mid height and HI of the concerned sub basins is 0.0614 which indicates that height effect does not put any significant imprint on HI. Very low relief factor can be considered as strongly operational for being such insignificant R^2 value. This type of height independent HI is also found in the work of Siddiqui and Soldati [20]. In this relation spatial relief ratio is correlated with HI and it is found that in most part of the basin there is no significant variation relief ratio (Fig. 12) and relief ratio is high only very small patch of the basin where HI is also high. Sub basins O, P and Q come under this high relief ratio patch.

3.6 Effect of Geological Unit on HI

Six geological units composed the study area (see Fig. 1). Table 5 shows sub basin frequency in different geological units. In this section it is being attempted to investigate that is there any control of geology on HI. Primary geological unit can strongly control HI but according to Hurtrez and Lucazeau; and Perez-Pena et al. [38,12] lithological unit have a minor positive impact on HI. HI value ranges from 0.37 to 0.46 in sand, silt, clay geological unit. Four sub basins partially

positioned over this unit among them 3 sub basins are 3rd order. In the same way for Amphibolite, Hornblende, Schist division, 5 sub basins are under this among them 3 sub basins are 3rd order with HI value ranges from 0.37 to 0.45. In the case of Laterite and Lateric formation, 4 sub basins are under this category under which 3 sub basins are 2nd order basins with HI value 0.44 to 0.48. Maximum part of the study area falls under Granite Gneiss complex, more than 80% area are covered with this metamorphic formation with 28 complete or part of the sub basins. Within 28 sub basins 17 are totally and 11 are partially under Granite Gneiss formation. Irregular range of HI over different geological units proves the fact that there is no strong explicit control of geological unit on HI at this stage.

3.7 Effect of Stream Order Hierarchy on HI

Willgoose and Hancock [17] shows in their study that Hypsometry depend on channel network. Generally, it is considered that 1st order streams are highly susceptible for erosion than high order basins. Fast soil erosion is caused for rapid geomorphic evolution. Table 6 shows order specific frequency of basin under different range of HI. Not for all sub basins but in few sub basins reverse result is expressed. But when all sub basins are considered it is found that HI of 2nd order sub basins is higher than HI of 3rd order sub basins. The average HI of 2nd order and 3rd order sub basins are 0.455 and 0.425 respectively. Willgoose and Hancock's results are also accordant with this condition.

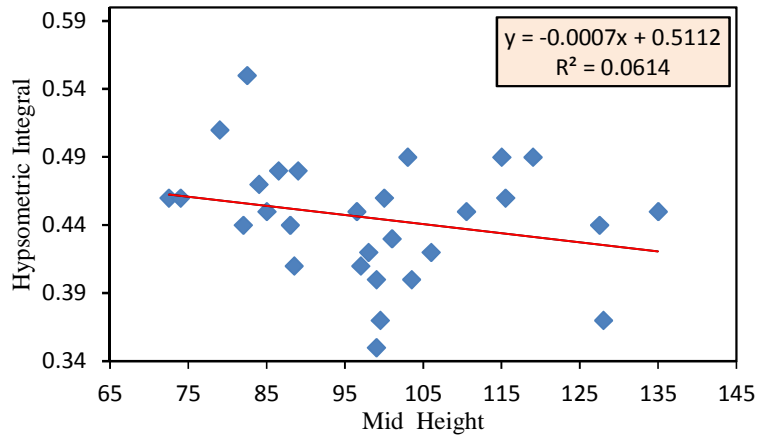


Fig. 10. Regression model between hypsometric intergal and mid height of sub basins

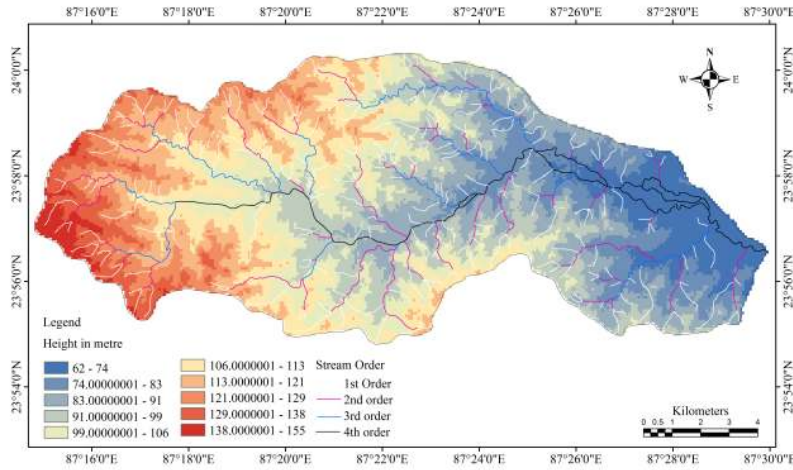


Fig. 11. Elevation map

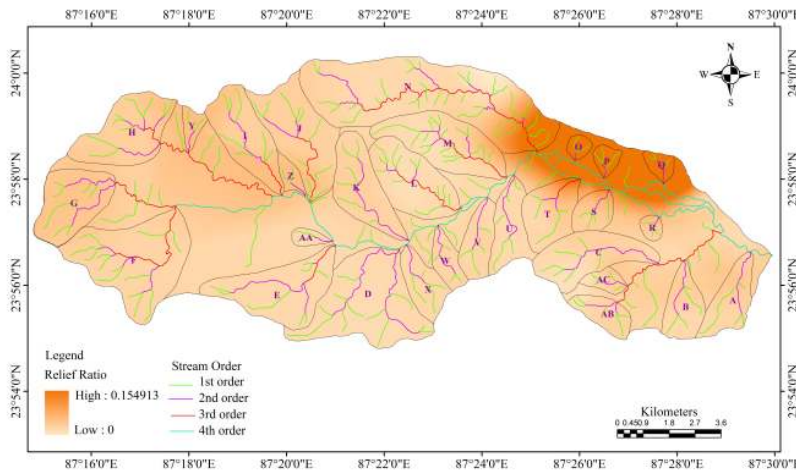


Fig. 12. Relief ratio map

Table 5. Frequency of sub basins under different geological units

Geological unit	Basin id	Frequency	Order specific frequency
Sand, Silt, Clay	J(0.46),K(0.40),L(0.37),M(0.41)	4	2 nd order 1 3 rd order 3
Gabbro	I(0.49)	1	3 rd order 1
Amphibolite, Hornblende, Schist	E(0.45),K(0.40),L(0.37),T(0.41)	4	2 nd order 1 3 rd order 3
Laterite and Lateric	A(0.44),C(0.48), Q(0.46),N(0.42)	4	2 nd order 3 3 rd order 1
Pegmatite	C(0.48),S(0.45)	2	2 nd order 2
Granite Gnesiss with enclaves of metamorphic	A(0.44),B(0.47),C(0.48),D(0.43),E(0.45), F(0.44),G(0.45),H(0.37),I(0.49),J(0.46), K(0.40),L(0.37),M(0.41),N(0.42),O(0.55), P(0.51),R(0.46),S(0.45),T(0.41),U(0.45) V(0.40),W(0.46),X(0.49),Y(0.49),Z(0.42), AA(0.35),AB(0.48),AC(0.44)	28	2 nd order 18 3 rd order 10

Value within parenthesis indicates HI

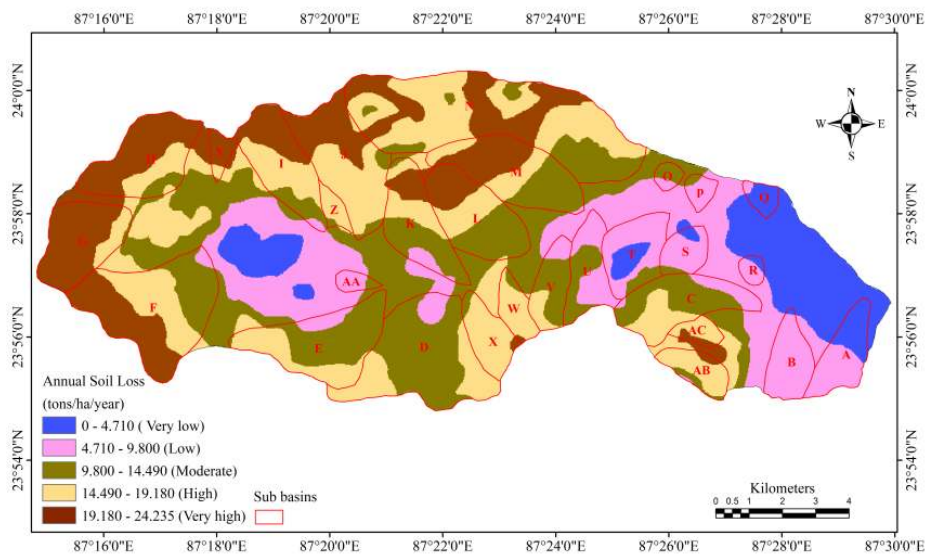


Fig. 13. Soil erosion potential model based on RUSLE and positions of sub basins

Table 6. Order specific stream frequency in different range of HI

HI	Frequency	Order specific frequency
≥0.3 to ≤0.6	29	2 nd order basin=19; 3 rd order = 10

3.8 HI in Soil Erosion Potential Areas

Bishop et al, Ritter et al, Singh et al. [3,5,19] rightly established a positive relation between HI

and predicted soil erosion rate. It does indicate that the region having greater HI will erode with very fast rate and vice-versa. In this present work no such strong relation is found. Pearson correlation coefficient (r) between estimated soil erosion based on RUSLE and HI is -0.062 which is not significant even in 0.05 level of significance. Very low relief and slope variation and monotony in geological pattern perhaps the reasons behind uniformity of HI. But unequal rainfall pattern, land use variation and regional variation of 1st order stream concentration in the upper catchment shows variant soil erosion

surface over the basin. In the upper catchment, average soil erosion rate is 17 tons/ha/year where average HI is 0.44 and in the middle catchment average soil erosion rate is 12.09 tons/ha/year and associated HI is 0.43. In the lower catchment, soil erosion rate is low (5.15 tons/ha/year) and cognitive HI is 0.48. Such result does not signify any meaningful inference.

4. CONCLUSION

In case of small river basin and rather small sub basins with low variation of relief, geological structure, mild slope it is very difficult to validate any relation as the valued findings established by the renowned scholars in this field. Regional pattern of HI does not obey any rule regarding its spatial distribution. Most of the sub basins and the basin as a whole are in mature stage of cycle of erosion. Theoretically, erosion should be in balance stage but high rate of soil erosion in the upper segment of the basin and associated sub basins is recorded. Effect of the selected parameters which can influence HI does not impart any significant impact while controlling HI pattern. Actually, HI of this basin is scale independent. It is neither determined by the shape, size and hierarchy of the basin nor by the height. Very local setting can only determine HI in very local scale which is not considered to be establishing any straightforward relation as well. But overall prediction regarding sediment yield of the basin, runoff pattern etc. can be done from the present scenario.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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