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Landform Evolution of Kabani River Basin, Wayanad District, Kerala.

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Abstract

Landform evolution is driven by the interference of a broad spectrum of processes involving atmosphere, hydrosphere, biosphere and tectonosphere. Hypsometric analysis gives an insight to the landform evolution. The hypsometry of the whole basin and its 11 fifth order sub catchments has been analysed. Based on the shape of the hypsometric curve the sub basins are grouped into three sets: old, late mature and mixed character. Hypsometric integral, catchment aspect ratio, maximum concavity of the curve, height of the hypsometric curve at 20%, 50%, 80% of the area coverage, relative upliftment value, asymmetric factor have been calculated. It is possible to identify two erosional processes like fluvial (advective) and slope dependent (diffusive), from the hypsometry of the sub basins. In this paper, some observations have been made on the evolution of Kabani river basin in Wayanad District by analysing selected aspects of hypsometry of the basin supported by the geological and geomorphologic data.

Keywords: *Landform Evolution, Hypsometry, Kabani river basin, Relative upliftment.*

Introduction

Study on landform evolution has drawn attention of the theoretical geomorphologists from time to time and various theories have been proposed. Landform is a function of structure, processes and stage (Davis, 1909). The drainage system, therefore, is a key element of the physical landscape. The form of that system, especially the orientation and spacing of its components stream to determine the essential charactater of the landscape. Secondly, evolutionary studies of drainage system provide information about the denudational history of an area (Small, 1978). Morphometric and hypsometric analysis of drainage basins are important techniques to understand the landform evolution and to assess the roll of geologic and tectonic factors on topography. It integrates three dimensions, combining area on the x-axis with elevation on the y-axis (Dowling, et.al, 1998). The hypsometric integral is appealing because it is a dimensionless parameter and therefore allows different catchments to be compared irrespective of scale. Relative uplift and asymmetry factor are calculated here to analyse the basin uplift and tilting. Various parameters of hypsometric curve have been computed and their implications are discussed here.

Materials and Methods

This study is based on 1:50,000 scale topographic maps of Survey of India and ASTER DEM data (Fig.2 see page 77). ASTER DEM (The Advanced Space born Thermal Emission and Reflection Radiometer) has been used for preparing cross profiles. Hypsometric, or area-altitude analysis, relates horizontal cross sectional

area of a drainage basin to the relative elevation above the basin mouth was first described by Strahler (1952). As a measure of the erosional state or geomorphic age of the catchment. In theory hypsometric values ranges from 0 to 1.

Low value are interpreted by Strahler to represent old eroded landscapes and high values as young, less eroded landscapes. Geology map was obtained from Geological Survey of India. Eleven fifth order basins are selected for detailed analysis. Maps are prepared by using Arc GIS software.

Study Area

The east flowing Kabani river, a tributary of the Cauvery river system has been selected for this study (Fig.1). Kabani is a seventh order stream, spreading over an area of 1648 Km^2. The basin drains major part of the Wayanad plateau. This erosional surface has a general slope towards east and north east and merges with Mysore plateau. The elevation of this area ranges from 900-1200m above MSL. More than 60% of the area lies within 700m to 800m (Chattopadhyay and Mahamaya, 2009). The drainage is quite often deeply incised over the dissected plateau with broad and flat valley floor commonly filled with slope wash material (ie. colluviam) and alluvium (Nair and Rao, 1981).

Geomorphology, geology and lineaments

Wayanad is one of the high level plateaus found in Kerala. Plateau landscape is generally graded. On an average, this area receives around 3,500 cm of rainfall, 75 per cent of which precipitates during south-west monsoon. Landuse is dominated by

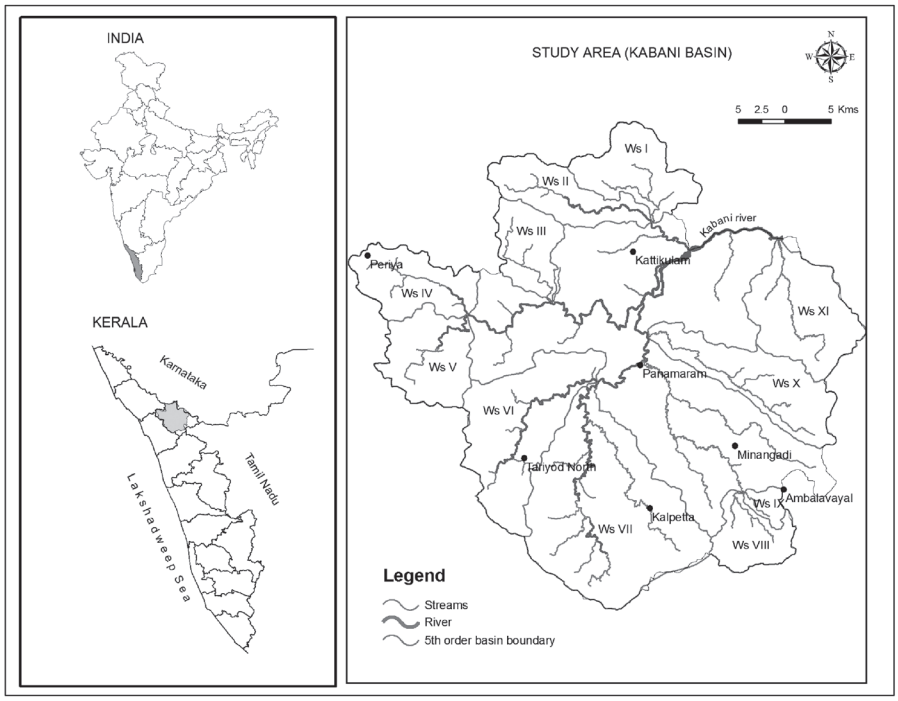

Fig. 1 : Location Map

paddy, pepper, ginger and plantation crops of tea, coffee, pepper and cardamom. Forest covers a sizeable area. Both denudational and depositional processes have been operative in this area. Scarp slopes, hills, highly undulating terrain, low undulating terrain of denudational orgin, isolated hills, flood plain, terraces and valley fills are main geomorphic units (Fig.3). The valleys are quite broad and mostly flat-bottomed. Terrace formations due to river incision have been frequent (Chattopadhyay, et.al, 1989). In all probabilities the area is undergoing 2nd cycle of erosion. Broad valleys, misfit rivers, incised valleys are some of the evidences. In Wayanad plateau the valleys are broad. The rivers flowing through these valleys are not capable of carving out such broad valleys. These broad valleys/ flood plains are possibly the remnants of the previous cycle of erosion (Chattopadhyay, et.al, 1995). It is also noted that these wide valleys/flood

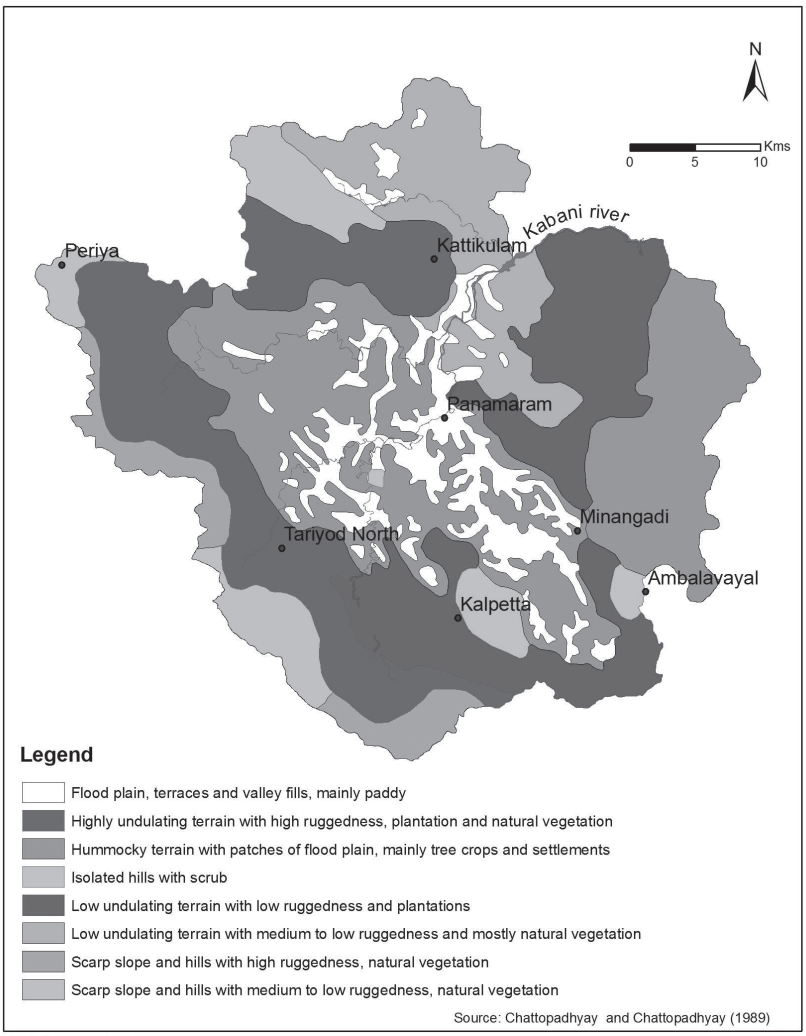

Fig. 3 : Geomorphology

plains are always associated with lineaments. This signifies that the weaker zones, being subjected to high intensity erosion might facilitate lateral expansion of valleys.

Geological formations of Wayanad range from Archean to the recent. Major rock types are Wayanad supracrustals, gneisses, and charnockites of Archaean age, basic and acidic intrusives of Proterozoic age, laterites of sub recent age and the alluvium of recent age. The area consists of different gneissic varieties. They are Biotite gneisses, Hornblende-biotite gneiss, Augen gneisses, and Mylonites. Biotite gneiss is seen all over the district. Hornblende-biotite occurs in the vicinity of fault and shear zones and contains pink potash feldspars as augens. The high grade Wayanad schist complex

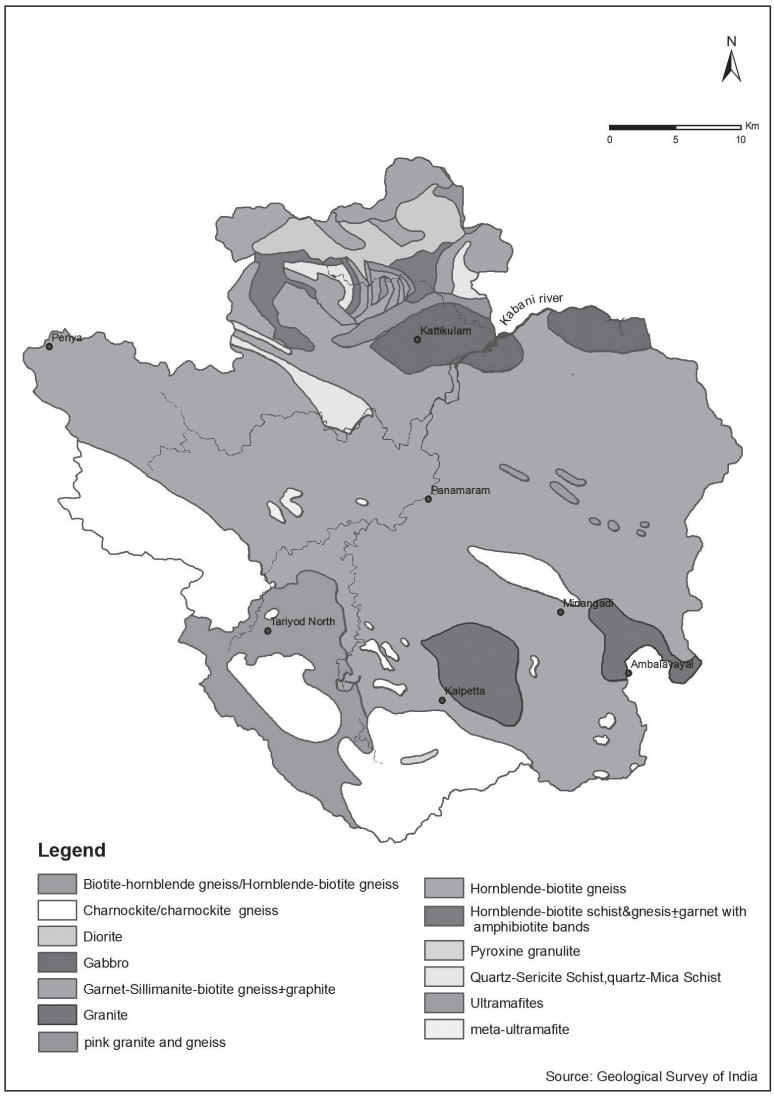

Fig. 4 : Geology

Table 1 : Geomorphology , Geology, landuse and soils of Kabani river basin

Geomrphology	Area (sq.km)	Geology	Landuse
Floodplain,Terraces & Valley fills	147	Hornblende biotite gneiss	Paddy
Isolated hills	32	Granite	Scrubs
Highly undulating terrain with ruggedness	320	Charnokite / Charnokite gneiss	Plantation and natural vegetation
Scarp slope and hills with high ruggedness	172	Charnokite / Charnokite gneiss & Biotite hornblende gneiss/ Hornblende biotite gneiss	Natural vegetation
Hummocky terrain with patches of flood plain	485	Hornblende biotite gneiss	Mainly tree crops and settelements
Low undulating terrain with low ruggedness	472	Hornblende biotite gneiss	Plantation

correlated to gneiss is well exposed in the central and northern part of the district. Augen gneisses are seen within Sargur Schist Complex of Karnataka (GSI, 2005). These rocks have undergone intense deformation, medium to high-grade metamorphism and migmatisation (Fig.4).

In this basin a strong correlation exists between geomorphology, geology and landuse (Table.1). The geomorphological units like floodplain, terraces & valley fills, hummocky terrain with patches of flood plain, low undulating terrain with low ruggedness are covered by hornblende

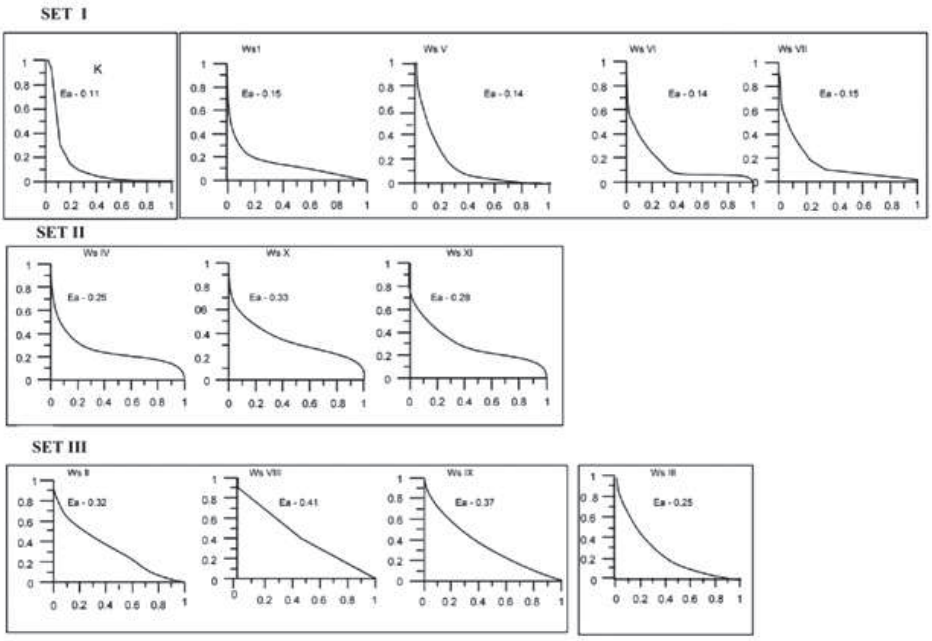

Fig. 6.

Table 2 : Hypsometric Parameters of Kabani basin and its 11 fifth order sub basins

Basins	Drainage density	Ea	Area	Eh	Ra	h*	a*	h(0.2)	h(0.5)	h(0.8)	hm	U	Relative relief
K	2.38	0.11	1648	0.7	1.08	0.16	0.18	0.12	0.02	0	0.49	1.38	1339
1	2.14	0.15	75.41	0.66	1.49	0.21	0.2	0.21	0.12	0.05	0.54	1.39	818
2	3.43	0.32	69.57	0.27	3.22	0.54	0.2	0.54	0.3	0.07	0.61	1.61	898
3	3.06	0.25	54.46	0.39	2.2	0.21	0.4	0.43	0.14	0.03	0.6	1.60	647
4	2.89	0.25	74.93	0.47	2.15	0.32	0.2	0.32	0.22	0.17	0.7	1.45	437
5	2.49	0.14	80.56	0.6	1.27	0.12	0.3	0.23	0.05	0.01	0.4	1.26	1061
6	2.69	0.14	152.41	0.58	2.79	0.14	0.3	0.25	0.06	0.06	0.38	1.24	1339
7	2.68	0.15	272.41	0.6	1.92	0.11	0.31	0.23	0.08	0.08	0.41	1.26	1186
8	2.66	0.41	48.43	0.2	1.6	0.67	0.13	0.6	0.37	0.14	0.86	1.45	163
9	2.58	0.37	12.18	0.25	2.18	0.48	0.3	0.59	0.29	0.09	0.81	1.44	208
10	2.41	0.33	102.39	0.35	4.85	0.38	0.3	0.43	0.25	0.23	0.75	1.42	329
11	2.03	0.28	110.41	0.38	1.55	0.37	0.28	0.43	0.25	0.18	0.7	1.42	402

biotite gneiss. Paddy and settlement with mixed tree crops are the major landuse type. Isolated hills are covered with granite and scrubs are the vegetation.

Most of the stream courses are controlled by structural features such as fault, fracture and schistocity planes (Nair and Rao, 1981). The Bavali fault running WNW - ESE is the most conspicuous structural feature in this area (Sinha-Roy and Ravindra Kumar, 1983). It passes through Bavalipuzha to Mananthody and beyond Sultan battery for a distance of about 50km. The E-W and N-S trending lineaments are less prominent (Fig.5 see page 74 for lineaments).

Hypsometry

Hypsometric analysis can provide important insight in landform evolution. There is renewed interest in using hypsometry to study landform evolution under various climatic conditions (Sinha-Roy, 2002, Chattopadhyay, et. al, 2006). Kabani River basin and its 11 fifth order sub basins are selected for this study. The values of the hypsometric parameters of these catchments are given in Table 2 and hypsometric curves are shown in Fig.6. These data have been analysed to understand the evolution of Kabani River Basin.

Table 3 : Curve shapes of different basins

Set of sub basins	**Sub basin**	**Curve shape**	**Ea value (hypsometric integral)**
Set I	I,V,VI,VII	Upward concave curve	0.15,0.14,0.15
Set II	IV,X,XI	Concave convex curve	0.25,0.33,0.28
Set III	II,III,VIII,IX	Not shown concavity or convexity	0.32,0.25,0.41,0.37

According to the shape of the hypsometric curve, the sub basins can be grouped into three sets. The first set includes Ws1, Ws5, Ws6 & Ws7. All these sub basins show upward concave curves. This represents the old topography of the basins. Ea values of these basins are below 0. 15. The Hypsometric curves of set II (Ws4,Ws10,WS11) show distinct convexity in the toe and Ea value ranging from 0.25 to 0.33 (Table.3). The Hypsometric curve will be largely concave in an area predominated by erosion, and where the eroded materials are accumulated in the downstream. In these cases, material production is more than the transported amount or aggradational surface is well established due to fluvial deposition. The lower part of the curves is characterized by convexity with increased toe height. The concave-convex nature manifests that in the upper part of the concerned sub basin favourable condition exists for dominance of slope wash and in the lower part of the sub basin incision prevails over slope wash probably due to lithological differences (Ciccacci, et. al, 1992). In the case of IIIrd set of the basins (Ws2, Ws8, and Ws9) hypsometric curves do not show much concave or convex nature. These basins have Ea values ranging from 0.32 to 0.41. The hypsometric curve of the entire basin shows monadknock phase and its Ea value is 0. 11. The four sub basin under set I are also in the monadknock phase. The concave upward nature of the hypsometric curve for the Kerala region is not commensurate with strong denudation and mass removal but it is indicative of the asymmetric altitude frequency that is likely to have been caused primarily by block movement and the upliftment of Western Ghats (Sinha-Roy and Thomas Mathai, 1979). The relationship between the maximum concavity (Eh) and catchment area shows r value 0.31 (Fig.9).

Catchment Aspect Ratio (Ra)

The catchment aspect ratio (Ra) of the Kabani River basin is 1.08 and that of the sub basins varies from 1.27 for Ws5 to 4.85 for Ws10. On the basis of Ra value three group of sub basins are identified. They are group I: Ws10, Ws2 (Ra > 3.0), Group II: Ws3, Ws4, Ws6, Ws9 (Ra - 2.0 - 3.0), Group III: Ws1, Ws5, Ws7, Ws8, WS11 (Ra < 2.0). The type of erosion processes (fluvial or diffusive) controls the catchment shape. Stronger the fluvial process, the wider and larger is the catchment the lower is the value of Ra (Sinha Roy, 2002). In the case of Kabani River basin Ws7 and Ws10 shows this trend. This may be the result of strong fluvial process. This scale dependence is mostly manifest in the case of drainage development in unconstrained physiographic situation and uniform climatic and geologic condition (Sinha-Roy, 2002). The drainage basin is structurally controlled as is evident from the lineament map. The relationship between the aspect ratio (Ra) and catchment area is very weak (Fig.10).

Drainage density of the entire basin ranges from 2.03 in Ws11 to 3.43 in Ws2 . Drainage density and hypsometric integral are positively correlated but 'r' value is very low (0.05) (Fig.11). Hypsometric integral value is an indicator for representing the percentage of area yet to be eroded. Lower Ea value indicates that significant area has already been eroded. Low drainage density is also linked to old topography.

Hypsometric Curve Height

The Hypsometric curve is further analysed for determining h (0.2), h (0.5) and h (0.8)

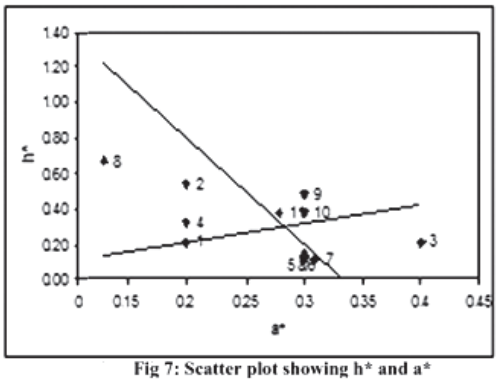

Fig 7: Scatter plot showing h* and a*

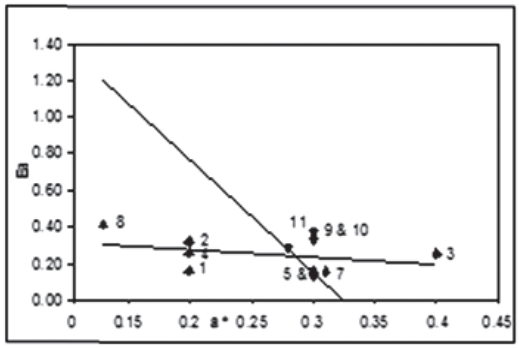

Fig 8: Scatter plot showing Ea and a*

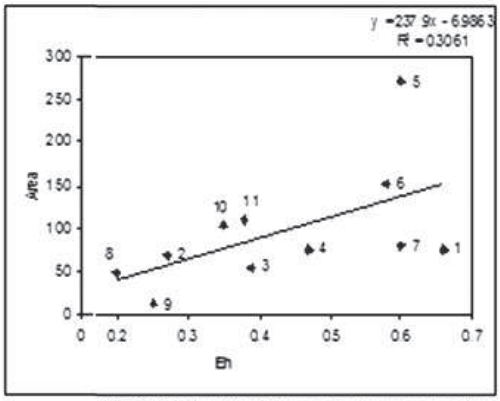

Fig 9: Relationshipt between maximum concavity and catchment area

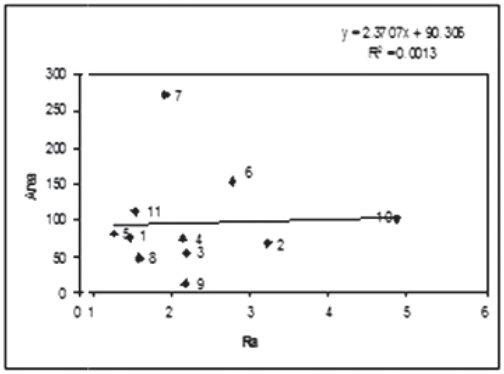

Fig 10: Relationship between Aspect Ration and Catchment Area

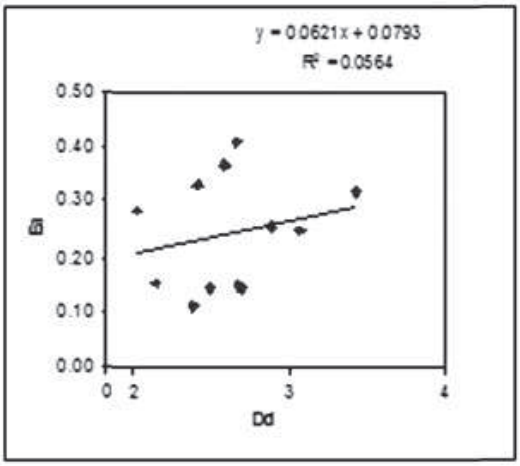

Fig 11: Relationship between Drainage Densiy and Hypsometric Integral

values (Table 2). It may be noted that the higher value of h (0.2) indicates influence of diffusive process at the headward portion of the basin and the higher value of h (0.8) results from the mass accumulation at the mouth of the basin through fluvial transportation. The Ws3, Ws4, Ws8, Ws9, Ws10 and Ws11 are highly influenced by diffusive processes. Average h (0.2) = 0.50 and the Ws4, Ws10, Ws11 shows average h (0.8) = 0.19. Fluvial process also dominates in these basins and they show large mass accumulation in the mouth.

Hypsometric Integral and concavity of the Hypsometric Curve

Hypsometric Integral (Ea) and the concavity of the hypsometric curve (Eh), are controlling the shape of the hypsometric curve and there by providing clues to landform development (Sinha-Roy, 2002). Sub basins are grouped on the basis of Eh values ranging from 0.2 in sub basin Ws8 to 0.66 in Ws1. Kabani basin as a whole recorded Eh value of 0.7. It is noticed that three basins of Ws2, Ws8 and Ws9 set III show comparatively low Eh value (0.2 - 0.27) and least incised. Ws1, Ws5, WS6, Ws7 included in set I show high Eh values (0.58 - 0.66). The above mentioned basins are more eroded than set II (Ws3, Ws4, Ws10, Ws11). The correlation between maximum concavity and area shows a positive relation and r value is 0.30. Distribution of sub basins according to hypsometric indices of a* and h* are given in Table 1. The sub basins of Ws1, Ws2, Ws4, Ws8, and Ws11 show low a* value (< 0.30). Ws3, Ws5, Ws6, Ws7, Ws9 and Ws10 show a* value > 0.30. The river basin as a whole records a* value at 0.18. The distribution pattern of h* value shows that sub basins of Ws2,Ws4,Ws8,Ws9,Ws10,Ws11 are in the category of >30 and the rest sub basins of Ws1,Ws3,Ws5,Ws6,Ws7 come in the category of < 0.30, whereas the whole basin shows h* value of 0.16.

Scatter plot of h* and a* values indicate two trends (Fig.7). Similar two trends are also found in the scatter plot showing values of Ea and a*(Fig.8). The sub basins falling in the domain of positive regression trend can be clubbed under model-1 and those showing negative regression trend indicate model-2 as proposed by Sinha-Roy (2002).While model 1 indicates erosion and mass removal essentially by fluvial processes and the model 2 is characerised by hill slope retreat dominated by diffusive processes (Sinha-Roy, 2002, Chattopadhyay et al, 2006). From Fig.7 and Fig.8 it may be noticed that Ws1,Ws3 Ws4,Ws9, Ws10, and Ws11 fall under model-1, as exemplified by their distribution along positive trend line. The sub basins of Ws2, Ws5, Ws6, Ws7, and Ws11 are grouped under model-2. The sub basin Ws8 do not show any definite trend and may be influenced by both the processes. Ws10 and Ws11 have geomorphic features common to both of these two models, suggesting a complex nature of their landform development.

The relation between a* and Ea is similar to that of a*and h*.The positive correlation between a*and Ea is shown by sub catchments belonging to model 1 and negative correlation between a* and Ea is shown by subcatchment belonging to model 2.

Hypsometric Head and Toe

The value of hypsometric head h (0.2) and toe h (0.8) have significance in deciphering the operative processes (fluvial and slope wash)

in shaping of landscape (Chattopadhyay, et. al, 2006). At the upper reaches of the catchments, higher the value of the toe (h 0.8), the greater is the mass accumulation at the outfall of the sub basin derived mainly through fluvial transport (Sinha-Roy, 2002).

Considering this value of h (0.2) for the sub-basins (Table 1), it may be noted that the sub-basins of Ws2, Ws3, Ws4, Ws8, Ws9, Ws10, Ws11 recorded the h (0.2) value of > 0.30, which indicated the influence of slope wash process in the headward portion of the basin. Value of h (0.8) is high in the sub basins of Ws4, Ws8, Ws10, and Ws11 (0.14 - 0.23). This is due to fluvial deposition. Head and toe heights of theWs1, Ws5, Ws6, Ws 7 are low. Considering the Kabani basin as a whole it is observed that h (0.2), and h (0.8) are also very low. The sub basins of Ws4, Ws10 and Ws11 all have comparatively high h (0.2) and h (0.8) values. The average h (0.2) value of the basins is 0.39 and h (0.8) is 0.19. This scenario manifests that the slope wash processes are more active than the fluvial processes or removal capacity of the stream.

Asymmetry factor

Where the stream network form in the presence of active tectonic deformation, stream pattern can reflect that deformation. One of the simple forms of deformation is tilting. This can cause by flexure or warping of an area of the earth's surface. Tilting can cause a stream network to become asymmetrical, with more area on one side of the drainage basin than on the other. The Asymmetric Factor (AF) is a morphometric indices for measuring the degree of asymmetry in a drainage basin (Pinter, 1996). AF value above or below 50 may suggest tilting. For this study asymmetry factor of the sub basins are calculated (Table 4). Among the 11 sub-basins, Ws1, Ws3, Ws6 and Ws8 show AF value above 50. In these basins right facing down stream side of the main stream is long compared to tributaries of the left facing down stream. All other basins Ws2, Ws4, Ws5, Ws7, Ws9, WS10, and Ws11 show AF value below 50. If the tilting were in the opposite direction, then the larger stream

Table 4 : Asymmetry Factor of Kabani basin and its 11 fifth order sub basins.

Basins	Asymmetry Factor	Tilted towards
Ws1	55.8	S
Ws2	43.71	N
Ws3	65.31	SW
Ws4	45.33	N
Ws5	48.16	NW
Ws6	68.08	SE
Ws7	44.11	W
Ws8	52.77	SE
Ws9	22.41	NE
WS10	23.64	NE
Ws11	46.57	NW

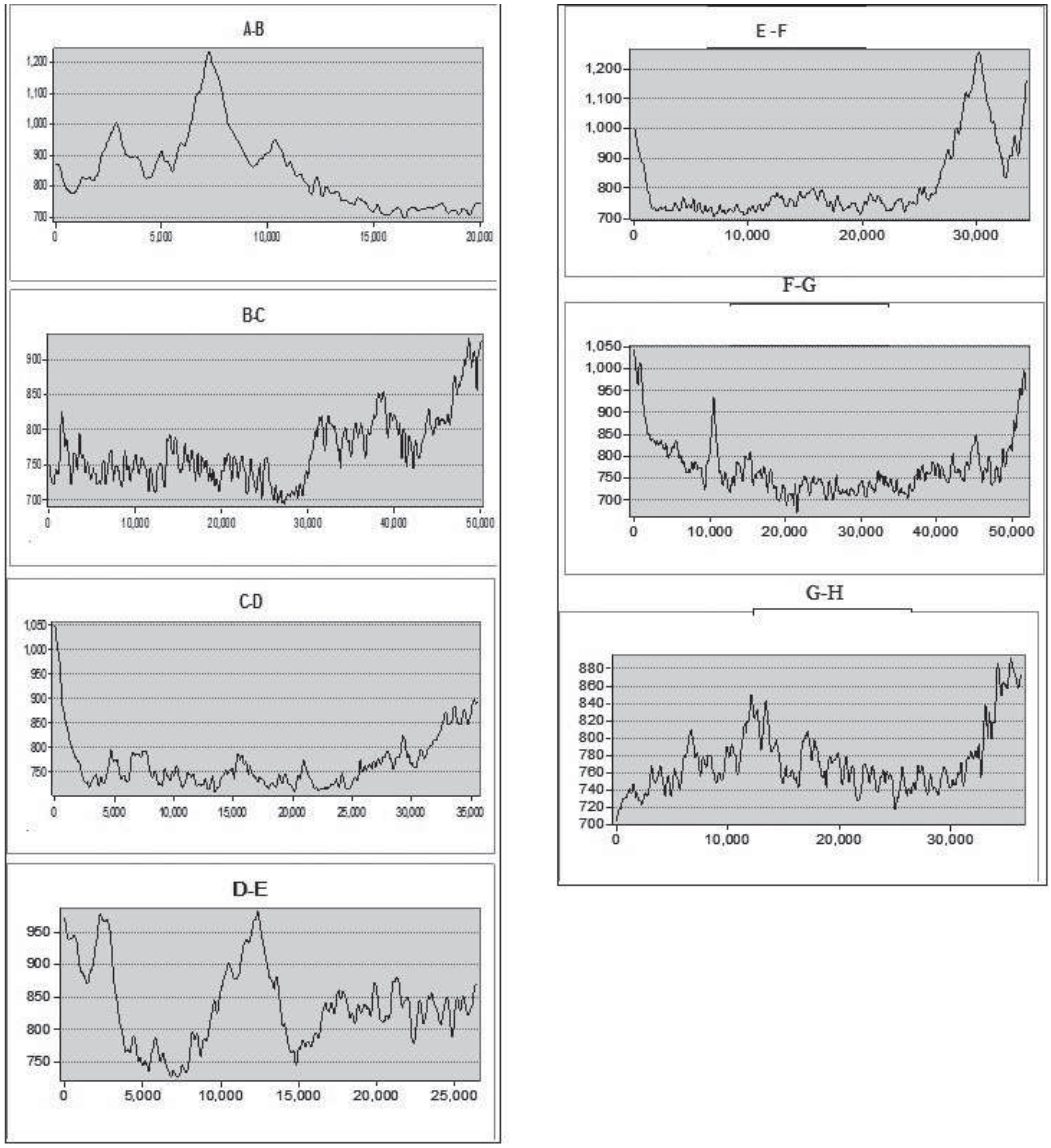

Fig. 12 : Cross profiles of Kabani river basin

would be on the left side of the main stream. As Kabani basin is near circular tilts in all direction could be observed. This tilting has also a linkage with lineaments and regional slope.

Relative Uplift

This river is mainly flowing through the Wayanad plateau. Geological formations of Wayanad range from Archaean to the recent. Relative Uplift value (U) has been

calculated for all V order basins and for the whole Kabani basin following the method proposed by Sinha Roy. The basin has a 'U' value of 1.38 and for all the sub basins 'U' value varies from 1.24 in Ws6 to 1.61 in Ws2. It can be observed that Ws2 experienced highest uplift compared to Ws6. It may be noticed that 'U' value of the whole basin in this study area are comparatively high (>1). Low upliftment is shown in the case of Ws5, Ws6 and Ws7 (Average value 1.25). These basins are relatively subsided blocks in this area. The sub basin of Ws1, Ws2, Ws3, Ws4, Ws8, Ws9, WS10 and Ws11 show high 'U' value. The cross sections drawn across this area (Fig. 2 & 12) also support this observation. These results are in tune with the suggestion by Soman (2000) that the present day physiographic feature of the Western Ghats in Kerala had been influenced by the vertical movement along shear zones, as exemplified by the higher uplift history of the Wayanad Plateau in North Kerala and the Ponmudi block in South Kerala.

Conclusion

This study has brought out a significant relationship between hypsometric character, morphogenic processes and landform development. The shape of the hypsometric curve provides an important evidence to recognize the type of erosional processes controlling the landform development. The Wayanad plateau experienced successive uplift in various geological time scale. The landform drained by Kabani is of mixed nature. The area has undergone prolonged fluvial erosion due to high rainfall, experienced uplift, there by topographic rejuvenation, which is evident in valley configuration and gradation in slope formation. It is suggested that hypsometric analysis can help in understanding landform evolution.

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References

ASTER data Downloaded: (http://asterweb.jpl.nasa.gov).

Chattopadhyay, S, Chattopadhyay, M and Sakunthala, C (1989): Terrain Evaluation of Wayanad Plateau. Technical Report, No.52, Centre for Earth Science Studies, Thiruvananthapuram, 24p.

Chattopadhyay, S, and Chattopadhyay, M (1989): Application of remote sensing in terrain analysis: A case study of the Wayanad plateau, Kerala, India. Int.J.Remote Sensing, vol.10, No.6, pp .1075-1084.

Chattopadhyay, S, and Chattopadhyay, M. (1995): Terrain Analysis of Kerala: Concept, Method and Application. Technical Monograph No.1/95.STEC,Govt.of Kerala, Thiruvananthapuram, pp. 41p.

Chattopadhyay, S, Saji Kumar, S. and Chattopadhyay, M (2006): Landscape Evolution in Parts of Vamanapuram Drainage Basin, Kerala-A Hypsometric Approach. Jour.Geol.Soc.India, vol.68, pp. 841-856.

Chattopadhyay, S and Chattopadhyay, M (2009): Impact of Terrain Characteristics on Catchment Yield: A case of Kabini River Basin, Kerala: Perspectives in Resource management in Developing countries (ed. Baleswar Thakur). vol. 4, Land Appraisal and Development, Concept publ. Co. New Delhi, pp. 145-157.

Ciccacci, S, D'Alessandro, L, Fredi, p, and Palmeri Lupia, E (1992): Relation between Morphometric Characteristics and Denudational Processes in Some Drainage basins of Italy. Annals of Geomorphology, v.36, pp. 53-67.

Davis, W.M (1909): The Geographical Cycle. Geog. Jour. 14, pp. 481-504.

Dowling, T.I, Richardson, D.P, Sullivan, A.O, Summerll, G.K and Walker. J (1998): Application of the Hypsometric Integral and other Terrain Based Metrics as Indicators of Catchment Health: A Preliminary Analysis. Technical Report 20/98, CSIRO Land and Water, Canberra, pp. 1-48.

Geological Survey of India (2005):.Geology and Mineral Resources of Kerala. Miscellaneous Publication No.30, Part IX-2nd Revised edition, 83p.

Small, R. J. (1978): The Study of Landforms. Cambridge University Press, Cambridge, 502p.

Sinha-Roy, S. and Thomas Mathai (1979): Development of Western Continental Margin of India and Plateau Uplift as Related to Geology and Tectonics of Kerala. Professional Paper No. 5, Centre for Earth Science Studies, Thiruvananthapuram, 41 p.

Sinha-Roy, S. (2002): Hypsometry and Landform evolution: A Case Study in the Banas Drainage Basin, Rajasthan with Implication for Aravalli Uplift. Jour. Geol. Soc. India, vol. 60, pp. 7-27.

Sinha-Roy, S and Ravindra Kumar, G.R. (1983): Geology of an Area in the Bavali Fault Zone of the Wayanad Schist Belt, North Kerala. Technical Report, No.25, Centre for Earth Science Studies, Thiruvananthapuram, 23p.

Soman, K. (2002): Geology of Kerala. Geological Society of India, Bangalore, 335 p.

Strahler, A. N. (1952) Hypsometric (area-altitude) Analysis of Erosional Topography. Bull. Geol. Soc. America, v. 63, pp. 265-276.

Nair, M. M and Rao P. P, (1981): Geo-Environmental Analysis of Mananthavady Area, Wayanad District, Kerala. Proc. Environmental Studies in India, pp. 85-91.

Pinter, N. (1996): Exercises in Active tectonics – An Introduction to Earthquakes and Tectonic Geomorphology. Prentice-Hall, Upper Dadle River NJ 07458, 166p.

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