MORPHOMETRIC ANALYSIS OF PAIRI RIVER BASIN USING REMOTE SENSING AND GIS

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ABSTRACT: Pairi River is the tributary of Mahanadi River providing a perennial source of irrigation and holds a significant place in the economic scenario of Chhattisgarh. The study area is located in between $20^0$14'N to $20^0$47'N and $81^0$58'E to $82^0$26' E covering an area of 1305.82 KM^2 with 360 metre average height above mean sea level. The present study is based on secondary data which is collected from Survey of India topographical sheet (Scale1:250,000, date-1979-80), ASTER GDEM (Spatial Resolution 30 metre, 20 metre vertical accuracy, 9 metre positional accuracy, date-1999) and Landsat ETM+ (Spatial Resolution 30 metre, date-2001). Morphometric parameters like relative relief, dissection index and hypsometric curves and profiles etc. are calculated and mapped from ASTER GDEM and drainage pattern is updated from Landsat ETM+ and drainage order, drainage density, bifurcation ratio are calculated and mapped from Survey of India topographical sheet on Remote Sensing and GIS platforms.

The study reveals that the Pairi River Basin is dominated by metamorphic rocks mainly gneisses in the middle and upper part and quartzite is very limited in the lower part of the basin covering with dendritic drainage pattern. The basin is elongated in shape (Form factor =0.38) which shares the area about 44.76% plain (284-400m AMSL) in the east, 52.47 % flat plateau (400-800m AMSL) in the middle and 2.77% hilly area (800-1002 m AMSL) in the west of the basin. The basin is slopping down from west to east mostly sharing with gentle slope (0^0-5^0) to moderate slope (5^0-20^0) which covers 96.41% (72.01%+24.40%) of the total area. The study of dissection index reveals that the rate of dissection is high in plateau area (DI=0.29-0.33), moderate in plain area (DI=0.25-0.29) but low in hilly area (DI=0.20-0.25) due to lack of sufficient streams, comparatively hard rock and vertical cliff shape hills. Therefore, the overall study suggest that the Pairi River Basin passes through the early mature stage (DI= 0.20-0.33) of development.

INTRODUCTION:

The ground surface which supplies rain and or melt water to particular stream and its tributaries which drain that area is called drainage basin which is demarcated by well defined perimeter on the basis of water divides (Savindra Singh, 1998, 2007). The fluvially originated drainage basin has gained currency as a 'geomorphic unit' because of its topographic, hydraulic and hydrological unity, which laid the keystone of Horton's 'morphometric systems' (1945), wherein quantitative analysis emphasized on drainage basin characteristics and erosional landforms (Savindra Singh and R. Srivastava, 1974). The Pairi River Basin is also consider as a hydro-geomorphological unit where Pairi is the main River originates from Bhathidongari hill, Mainpur, and confluence with Mahanadi River at Rajim which is expressed as holy place and also called Parayag of Chhattisgarh State and Chaoningi and Kholajhola are its main tributaries. Besides, Pairi River provides perennial sources of irrigation and holds a significant role in the economic scenario of the Chhattisgarh state towards making the highly productive agricultural lands and irrigates the lands in such a way that the farmers are never worried about the quality and fertility of land.

The overall importance of the Pairi River basin leads to the study of morphometric analysis and to investigate the present situations of the basin using Statistical tools on Remote Sensing and GIS platforms. The morphometric analysis incorporates quantitative study of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the concerned area (Savindra Singh, 1972). The Remote Sensing and GIS are new emerging geospatial technology and widely used tools in which one provides real time information and another makes its solutions. The study reveals that, the Pairi River Basin is dominated by metamorphic rocks mainly genesis and quartzite covering with dendritic drainage pattern. The basin is elongated in shape (Form factor = 0.38) and passing through early mature stage (Dissection Index = 0.20 to 0.33 and Hypsometric Integral = 0.68) of development.

STUDY AREA:

The Pairi River Basing is considered as a hydro-geomorphological unit which spread over the bank of Pairi River and its tributaries. The study area is located in the southern part of Raipur district, Chhattisgarh, India, and extends in between $20^0$14'N to $20^0$47'N and $81^0$58'E to $82^0$26' E covering an area of 1305.82 KM^2 with 360 metre average height above mean sea level. The study area is belongs to Monsoon type of AW climate (Koppen) with 160 cm annual rainfall which is maximum in June 55 cm and minimum in December 0.20cm and average annual temperature is 26.36^0 C which is maximum in May 41.70^0C and minimum in December 10.40^0C. The Pairi River plays a very important role in enriching the serene environment of Rajim since it is on the confluence of the river and Mahanadi River where the Kaleswar temple is established fascinating tourist destinations and expressed as the religious heritage which is called Parayag of the Chhattisgarh state.

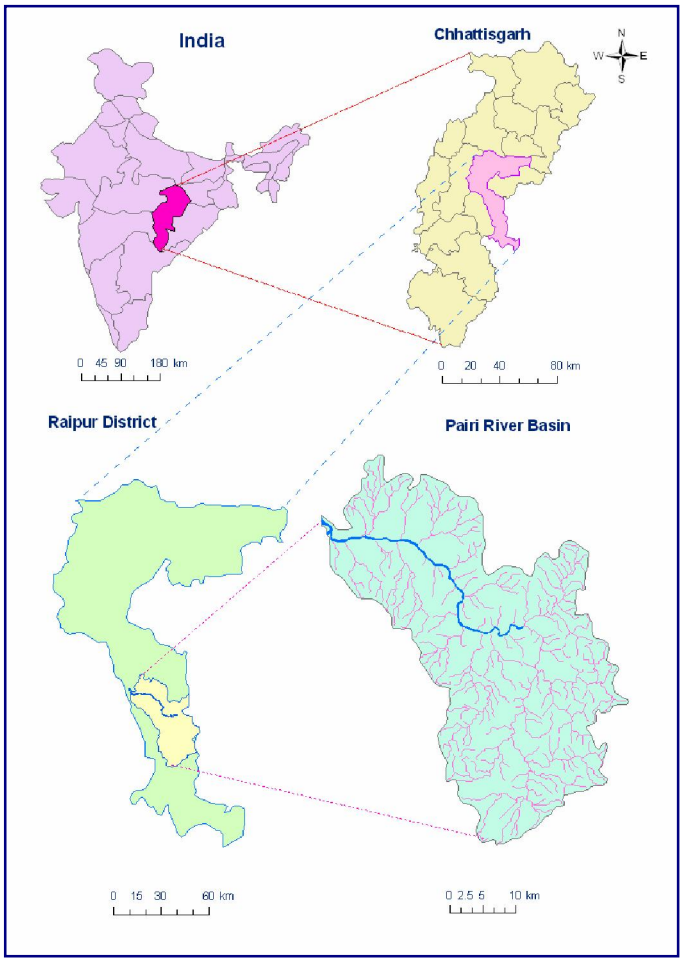

Fig-1: Location map

OBJECTIVES:

The study is outlined based following objectives e.g.

i) To find out the spatial extent and arrangements of drainage systems.
ii) To find out the basin morphometry and stage of development of Pairi River basin in the present context.

METHODOLOGY:

The present study is based on secondary data which is collected from Survey of India topographical sheet (Scale-1:250,000, date-1979-80), ASTER GDEM (Spatial Resolution 30 metre, 20 metre vertical accuracy, 9 metre positional accuracy, date-1999) and Landsat ETM+ (Spatial Resolution 30 metre, date-2001).

The extraction of drainage pattern and its updation and basin area demarcation are made by the heads up digitization from the integrated study of Survey of India topographical sheet and Landsat ETM+ satellite imagery

on Remote Sensing and GIS platforms. The morphometric parameters like Drainage order, Drainage density, Bifurcation ratio, Circularity index, Elongation ratio, Relative relief, Slope, Profiles, Dissection index, Hypsometric integral etc.(Table 1, 2 & 3) are calculated and mapped from ASTER GDEM using statistical tools of host of scientists, geographers, geomorphologists on Remote Sensing and GIS platforms. The whole research paper is prepared on MS-Office 2003 (Word & excel), CorelDraw 11, Paint, Arc GIS 9.3 and ERDAS Imagine 9.1 and result is expressed in the form of text, table and maps to draw final conclusion and making decisions.

MORPHOMETRIC ANALYSIS:

'Morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms' (J.I. Clark, 1970).

Table 1
Formula for Morphometric Analysis

Morphometric Analysis		Formula	References
Aspects	Parameters		
(A) Linear	(1) Stream Order (u)	Hierarchical rank	A.N. Strahler (1969)
	(2) Bifurcation Ratio (R_b)	$R_b = N_u/N_u+1$ Where, N_u = No. of streams of 'u' order N_u+1= No. of streams of next higher order.	R.E. Horton (1945)
	(3) Sinuosity Index (SI)	$SI = O_L/E_L$ Where, O_L= observed (actual) path of a stream, E_L= expected straight path of same stream.	S.A. Schumm (1963)
(B) Areal	(1) Drainage Density (D_d)	$D_d = L_k/A_k$ Where, L_k=Total length of all stream segments of a basin, A_k= Total area of the Basin	R.E. Horton (1945)
	(2) Form Factor (F)	$F = A/L^2$ Where, A= Basin area L= Basin length	R.E. Horton (1932)
	(3) Circularity Index (C)	$C = 4\prod A/p^2$ Where, A= Basin area P= Basin Perimeter	V.C. Miller (1953)
	(4) Elongation ratio (R_e)	$R_e = (2\sqrt{A/\prod}) /L_b$ Where, A= Basin area, L_b= Basin length	S.A. Schumm (1956)
(C) Relief	(1) Relative Relief (R_R)	R_R =(Maximum altitude-Minimum altitude)	Smith(1935)
	(2) Slope (θ)	$\theta = \tan^{-1}(N \times i/K)$ where, N= No. of contour crossing per mile/kilometer i = Contour interval, K= Constant (3361 for mile grid & 636.60 for kilometer grid)	Wentworth (1930)
	(3) Dissection Index (DI)	$DI = R_R/A_R$ Where, R_R=Relative Relief A_R =Absolute Relief	Dov Nir (1957)
	(4) Hypsometric Integral (HI)	HI= (h/H)/(a/A) Where, h= absolute relief, H= highest relief in the area; a = area of absolute relief (h) A= Total basin area	A.N. Strahler (1952)

Morphometry incorporates quantitative study of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the area concerned (Savindra Singh, 1970). Pairi River Basin is considered as a hydro-geomorphological unit which is studied under fluvial morphometry includes the consideration of linear, areal and relief aspects of a fluvially originated drainage basin.

A. LINEAR ASPECTS:

Linear aspects of the basin are related to the channel patterns of the drainage network including stream order bifurcation ratio and sinuosity index are considered in the study, e.g.:-

1. STREAM ORDER (u):

'Stream order is defined as a measure of the portion of a stream in the hierarchical tributaries' (L.B. Leopold et. al., 1969). A.N. Strahlar (1969) law is used for the determination of stream order to find the bifurcation rate in the Pairi River Basin. There are 5^{th} orders of 289 streams covering an area of 1305.82 km^2 throughout basin.

2. BIFURCATION RATIO (R_b):

Bifurcation ratio is related to the branching pattern of the drainage network and is measured by the ratio between given order (Nu) to the next higher order (Nu+1) to find out the bifurcation pattern of the stream related with geomorphology of the basin. 'Mean bifurcation ratios vary from about 2.00 for flat or rolling basins to 3.00 - 4.00 for mountainous, hilly dissected basins' (R.E. Horton, 1945). The mean bifurcation ratio of the Pairi River Basin is 4.00 which indicate the basin comes under mainly flat topped dissected plateau and partly cliff form dissected hilly area.

3. SINUOSITY INDEX (SI):

The sinuosity index is used for the study of channel shape which calculated from S.A. Schumm's law (1963). The sinuosity index of Pairi River is 1.48 which indicates that the Pairi River is sinuous in shape showing in longitudinal profile of Pairi River (Fig- 5).

B. AREAL ASPECTS:

The areal aspects of drainage basin include areal attributes of basin area, perimeter, length, Form factor, Circularity index, Elongation ratio, and drainage density e.g.:-

1. DRAINAGE DENSITY (D_d):

Drainage density refers to the total length of the streams per unit area governed by the law of R.E. Horton (1945). The drainage density is expressed as kilometer per square kilometer which is classified into four types, e.g. Very low (Below 0.41), Low (0.41-0.81), Moderate (0.81- 1.21), High (1.21- 1.61) and Very High (1.61-2.02) covering an area of 19.71%, 38.13%, 28.47%, 11.79% and 1.90% of the total area. The average drainage density of the basin is 1.21 which indicates the basin is comes under area of moderate drainage density characterized with permeable subsoil, dissected flat topped plateau and sparse vegetation.

2. FORM FACTOR (F):

Form factor is defined as the ratio of basin area to the square of the basin length (Horton, 1932). The form factor of Pairi River basin is 0.38 which indicates the basin is elongated in shape suggests that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basin are easier to manage than of the circular basin (Onosemuode Chrisopuer et.al. 2010).

3. CIRCULARITY INDEX (C):

Circularity Index is the ratio of basin area to its perimeter in respects of the area of a circle. The circularity ratio of the Pairi River Basin is 0.34 which indicates the basin is elongated in shape characteristics with permeable subsoil materials.

4. ELONGATION RATIO (R_e):

Elongated ratio is proportional of Horton's form factor (S.A. Schumm, 1956). The elongation ratio of the basin is 0.35 which indicates the basin is elongated in shape.

(C) RELIEF ASPECTS:

The relief aspects of basin is the study of three dimensional areal extent including area, volume and attitude through slope, hypsometric curve, relative hypsometric curve, Profiles, Dissection Index and Relative Relief, e.g.:-

1. ABSOLUTE RELIEF (A_R):

Absolute relief is the actual height between two successive contours is called absolute relief. The basin is divided into three physiographic Zones as Low altitude-flat plain (248-400 metre), Moderate altitude-flat topped dissected plateau (400- 800 metre) and High altitude-Cliff form dissected hilly area (800-1002 metre) covering an area of 44.76%, 52.47% and 2.77% of the total basin area (Table 2).

2. RELATIVE RELIEF (R_R):

Relative relief is the difference value between highest altitude and lowest altitude in a unit area which is used for the study of the overall assessment of morphological characteristics of terrain and degree of dissection. The relative relief of the basin is categorized into three types, e.g. Low (Below 150 metre), Moderate (150 - 200 metre) and High (Above 200 metre) covering an area of 44.98%, 52.39% & 2.63% which is represented into 1km by 1km grids and indicates that the basin is moderately dissected and passing through early mature stage.

Table 2
Absolute Relief: Pairi River Basin

S. No.	Elevation (Metre)	Area (Sq.km.)	Area (%)	Explanation
1.	248-400	584.49	44.76	Low Altitude- flat Plain Area
2.	400-500	394.77	30.23	Moderate Altitude- flat topped dissected Plateau area
3.	500-600	96.93	7.42	
4.	600-700	98.25	7.52	
5.	700-800	95.29	7.30	
6.	800-900	32.31	2.48	High Altitude-cliff form Dissected Hilly Area
7.	900-1002	3.78	0.29	
Total		1305.82	100.00	-

2. SLOPE(θ):

The study of slope is very useful for the determination of inclination of relief, drainage pattern and rate of dissection throughout the basin. The Pairi River Basin is classified into four slope zones e.g. Very gentle (Below 2^0), gentle (2^0- 5^0), moderate (5^0-20^0) and steep (20^0-58^0) covering an area of 35.00%, 37.01%, 24.40% and 3.59% of the total area. The basin is mostly slopping down from west to east sharing with gentle slope (0^0-5^0) to moderate slope (5^0-20^0) covering an area of 96.41% (72.01%+24.40%) of the total area.

3. DISSECTION INDEX (DI):

Dissection index is the ratio between relative relief and to the absolute relief (Dov Nir, 1957) which is an important morphometric indicator of the nature and magnitude of dissection of terrain. Dissection index is also used for the determination of the stage of cycle of erosion as old, mature and young stages. The study of dissection index reveals that the rate of dissection is high in plateau area (DI=0.29-0.33), moderate in plain area (DI=0.25-0.29) but low in hilly area (DI=0.20-0.25) due to lack of sufficient streams, comparatively hard rock and vertical cliff shape hills. Therefore, the overall study suggest that the Pairi River Basin passes through the early mature stage (DI= 0.20-0.33) of development (Fig- 4).

4. HYPSOMETRIC INTEGRAL (HI):

Hypsometric integral is calculated from the relative hypsometric curve to find out the development stage of the basin. Hypsometric integral is the ratio between relative height (h/H) and to the relative area (a/A). A.N. Strahlar (1952) related the hypsometric integral of above 0.70 (70%), 0.70- 0.30 (70%-30%) and below 0.30 (30%) to the youth, mature and old stages. Therefore the hypsometric integral of Pairi River Basin is 0.68 (68%) which indicates that the basin is passing through early mature stage of development (Fig-6).

Table 3
Calculation for Relative Hypsometric Curve

Absolute Relief (metre)	Relative Relief (Meter)	Relative Height (h/H)	Area(Km^2)	Cumulative Area	Relative Area (a/A)	Hypsometric Integrals
1002	754	1.00	0.00	0.00	0.00	0.00
900	652	0.86	3.75	3.75	0.028	30.71
800	552	0.73	32.31	36.06	0.027	27.04
700	452	0.60	95.29	131.35	0.100	6
600	352	0.47	98.25	229.60	0.175	2.68
500	252	0.33	96.93	326.53	0.250	1.32
400	150	0.20	394.77	721.30	0.552	0.36
248	0	0.00	584.49	1305.80	1.00	0.000
∑ Hypsometric Integrals						68.11 (0.68)

5. PROFILES:

Profiles provide a visual perception of the actual nature of terrain which reflects a clear idea of the surface configurations (Sujit Singh Shin, 2009). Two types of profiles are considered under study, e.g.:-

A. BASIN PROFILES:

The profiles of the Pairi River Basin is drawn along east to west and north to south at 500 metre intervals through superimposed and composite profiles. Superimposed profiles reflects the different levels of planation surfaces where projected profile provide a panoramic view of the whole landscape of the region as if seen from above and they also present a vivid picture of the magnitude of relief and general nature of dissection of the region (Savindra Singh, 1998,2007). The superimposed profiles across east to west and north to south provides the distribution of various planation surfaces and clustering of residual hills and the composite profiles represent the highest summits levels of the area (Fig-5).

B. LONGITUDINAL PROFILE:

Longitudinal profile of Pairi River is drawn from source of origin (Bhathidongari hill, Mainpur) to the mouth (confluence at Mahanadi Raiver, Rajim) at the distance of 85.90 km. There are three courses along the longitudinal profile of Pairi River are identified on the basis of breaking of slope, increases in the width of river, slope etc. and represented as A= Young, B= mature and C= old (Fig-5).

CONCLUSION:

The Pairi River Basin is dominated by metamorphic rocks mainly gneisses and partly quartzite covered by 5^{th} order of 289 streams designing with a well defined dendritic drainage pattern covering with an area of 1305.82 km^2 with 360 metre average height above mean sea level. The basin have mean bifurcation ratio is 4.00 and mean drainage density is 1.21 which indicates the basin is dominated by dissected flat plateau (52.47%) and partly dissected hilly area (2.77%) characterized with permeable subsoil and sparse vegetation. The basin is elongated in shape (F= 0.38, elongation ratio = 0.35, circularity index = 0.34) which mostly slopping down from west to east sharing with gentle slope (0^0-5^0) to moderate slope (5^0-20^0) covering with an area of 96.41% of the total area which suggest that the basin have flatter peak of flow for longer duration and easier to manage. The Pairi River is sinuous in shape (SI= 1.48) and three course as old, mature and young are identified along in longitudinal profile (Fig-5) on the basis of breaking of slope, increases in the width of river, slope etc. and the study of dissection index ((DI= 0.20-0.33)) and hypsometric integral (HI = 0.68) reflects that the basin is passing through early mature stage of development.

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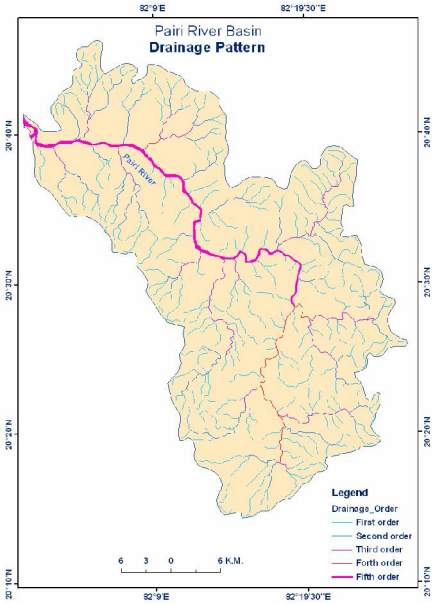

Fig-2: Drainage Pattern

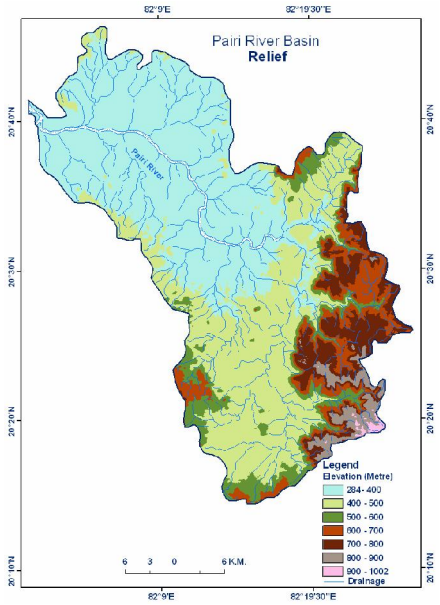

Fig-3: Relief

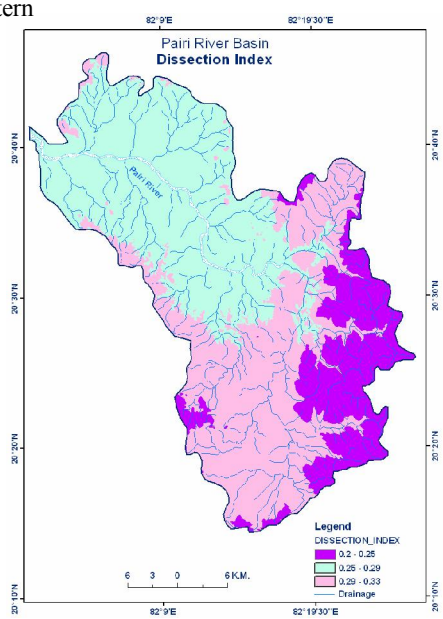

Fig-4: Dissection Index

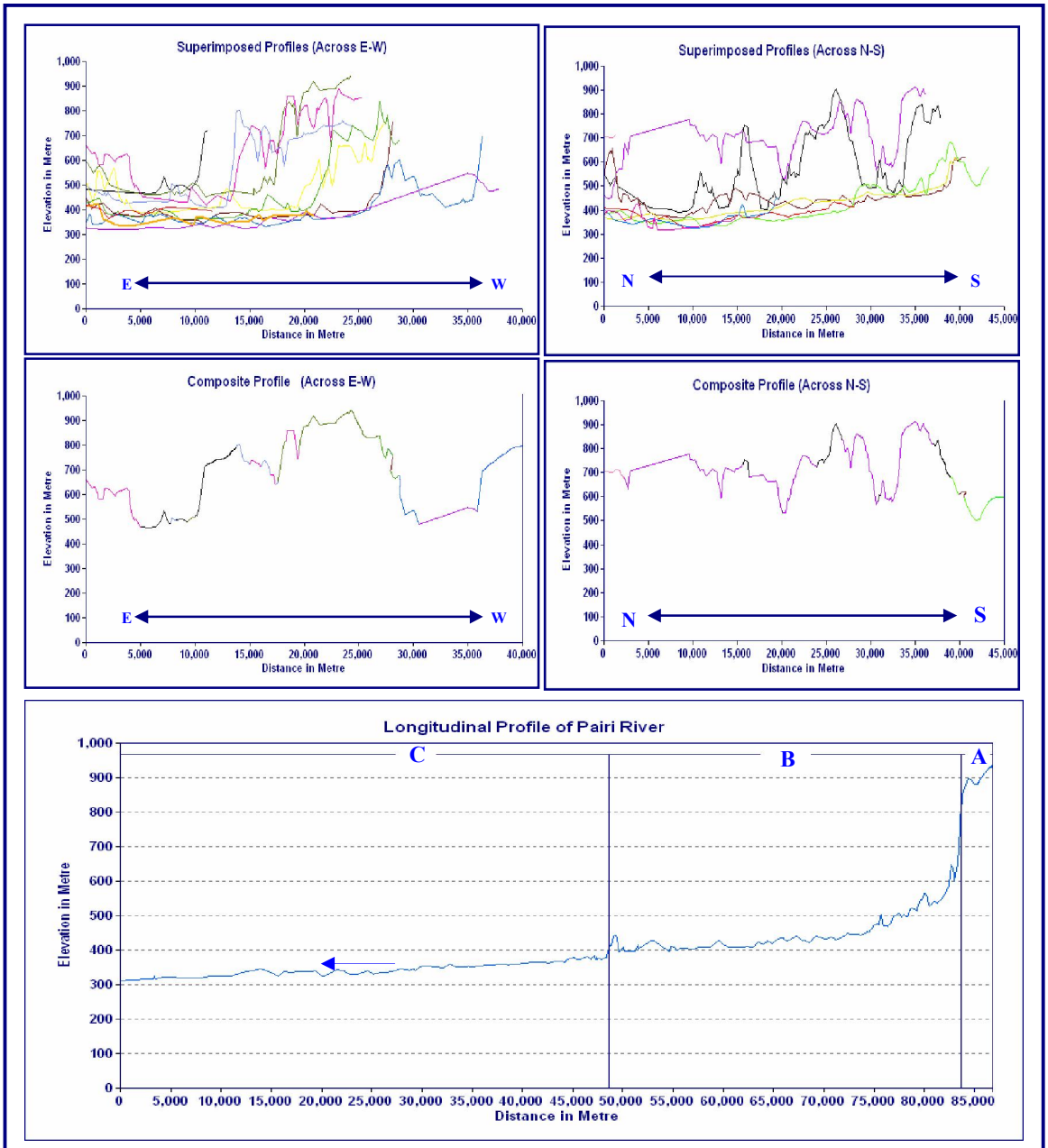

Fig-5: Profiles (Superimposed and Composite & Longitudinal profiles)

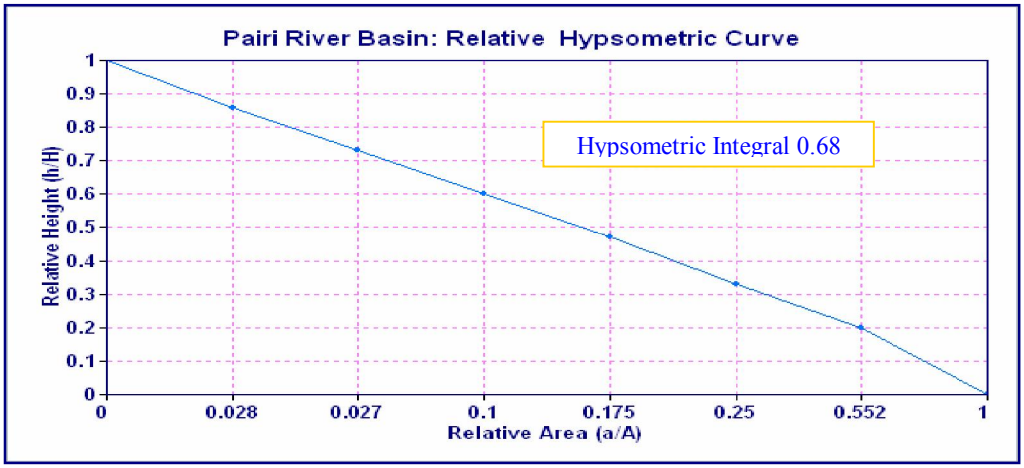

Fig-6: Relative Hypsometric Curve