A Quantitative Analysis of Baitarani Drainage Basin (Odisha) Using Geographical Information System

SIVA PRASAD PANDA
P.G. Department of Geography, Utkal University, Bhubaneswar, Odisha
Email-pandasivaprasad@gmail.com

Abstract: Basin morphometry is a means of numerically analysing or mathematically quantifying different aspects of a drainage basin. In the present study, morphometric analysis of the Baitarani basin has been carried out using earth observation data and geographical information system (GIS) techniques. The morphometric parameters considered for analyses include the linear, areal and relief aspects of the basin. The Baitarani basin covers an area of 10,982 sq km. It is a 6th order drainage basin with mainly dendritic drainage pattern. The mean bifurcation ratio is 4.58 indicating the basin is largely controlled by structure. The basin has medium drainage density of 0.64 per km² and is elongated in shape. The length of overland flow values of the basin is 3.13, indicating high relief. The study has strengthened in understanding the hydrological, geological and geomorphological characteristics of the Baitarani basin.

Keywords: Quantitative analysis, Baitarani river, GIS

INTRODUCTION

Morphometry is an essential means in geomorphic analysis of an area. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth’s surface and of the shape and dimension of its landforms (Clarke, 1966). Morphometric methods, though simple, have been applied for the analysis of area-height relationships, determination of erosion surfaces, slopes, relative relief and terrain characteristics as a whole. The morphometric analyses of different basins have been done by various scientists using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957) and earth observation data and GIS methods (Narendra and Rao, 2000). The use of earth observation data and GIS techniques in morphometric analysis have emerged as powerful tools in recent years particularly for remote areas. In the present study using Earth Observation Data and GIS technology have been effectively used to compute basin morphometric characteristics by taking linear, areal and relief parameters of the Baitarani river basin. Such analysis aided in understanding the hydrological, geological and topographical characteristics of the very complicated and unique Baitarani drainage basin.

The river Baitarani is one of the important east flowing rivers of peninsular India located in northern Odisha. The river is flashy in nature having a total length of 355 km. and an area of 10,982 km². The basin is situated approximately between east longitude of 85° 10’ to 87° 03’ and between north latitude 20° 35’ to 22° 15’.The basin is surrounded by the Brahmani basin on the south and west and Subarnarekha basin on the north, the Budhabalanga and the Bay of Bengal on the east. The covers an area of 10,982 km² of which 10,246 km² (93.3%) lie in Odisha and 736 km² (6.7%) in Jharkhand. The northern portion comprises of rugged hilly terrain. The basin perimeter measures 622.22 km.
MATERIALS AND METHODS

The delineation of Baitarani basin is done from SOI topographical sheets no. 73F, 73G, 73J, 73K, and 73L using ArcGIS 9.3 software. Morphometric analysis has been carried out of the following parameters: stream order (U), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio (Rbm), relief ratio (Rh), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), circulatory Ratio (Rc), elongation ratio (Re) and length of overland flow (Lg). The methodology for the calculation of above mentioned parameters is given (Table 1).

RESULTS AND DISCUSSIONS

The study of basin morphometry relates basin and stream network geometries to the transmission of water and sediment through the basin. Systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear, areal and relief (gradient) aspects of the channel network and contributing ground slopes. In the present study, the morphometric analysis has been carried out about parameters as stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, basin relief, relief ratio, channel gradient using mathematical formulae as given in Table 1 and the results are summarized. The properties of the stream networks are highly important to study the landform making processes. Morphometric parameters such as basin relief, basin shape and stream length also influence basin discharge pattern strongly through their varying effects on lag time. The natural runoff is one of the most potent geomorphic agencies in shaping the landscape of an area. The land area that contributes water to the main stream through smaller ones forms its catchment area or the drainage basin. The arrangement of streams in a drainage system constitutes the drainage pattern, that in turn reflects mainly structural or lithological controls of the underlying rocks. The drainage pattern of Baitarani Stream basin is dendritic to sub-dendritic in nature.

Linear morphometric parameters

Linear aspects of the basins are closely linked with the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system are analyzed. The morphometric investigation of the linear parameters of the basins includes stream order (Sm), bifurcation ratio (Rb), stream length (Lμ), mean stream length (Lsm), stream length ratio (RL), length of overland flow (Lg), basin perimeter (P), basin length (Lb), sinuosity index. Some of the important linear aspects have been computed (Tables.1).

Stream Ordering

The foremost in a drainage basin analysis is the designation of stream orders, which is helpful not only to index the size and scale but also to afford an approximate index of the amount of stream flow which can be produced by a particular network. In this study the designation of orders by the Strahler’s system is followed, which is a slightly modified version of Horton’s system.

There are about 1389 streams over an area of 10,982 sq. km (Fig.3). First order streams constitute 77.68 percent while second stream order constitutes 16.2 percent while third, fourth fifth and sixth stream order constitute only 4.61 percent, 1.3 percent, 0.14, 0.07 percent. It is observed that there is a decrease in number of streams as the stream order increases, showing the law of lower the order, the higher the number of stream.

Stream Number

The streams, after the drainage network elements have been assigned, their order, number and segments of each order are counted and number of stream segments present in the order is found out. The number of
streams decreases as the order increases. The total number of all streams in all segments is 1389. Among this, the first order streams are 1079, which accounts for 78 percent to the total number of streams. The second order streams are 225 which contribute 16 percent. The streams of successive orders constitute the remaining 4 percent.

The first order streams in the Baitarani river basin are originated from the Eastern Ghats, arrange of mountains running east-west for the entire basin. The minimum number of first order streams at the coastal region. The high amount of the first order streams should be taken care of, because there is a possibility of sudden flash floods in the downstreams after heavy rainfall.

**Bifurcation Ratio**

Bifurcation Ratio ($R_b$) which is related to the branching pattern of the drainage network is defined as a ratio of the number of streams of a given order ($N_i$) to the number of streams of the next higher order ($N_{i+1}$) and is expressed in following equation:

$$R_b = \frac{N_i}{N_{i+1}}$$

Where, $N_i$ = number of stream of a given order.

$N_{i+1}$ = number of streams of the next higher order

It is a dimensionless property and shows the degree of integration prevailing between stream of various orders in a drainage basin. Horton (1945) considered $R_b$ as an index of relief and dissection. A perusal of the table 3.6 showing that the $R_b$ between different successive order is also constant ranging from 3.52 to 9 with the mean bifurcation ratio of 4.58 which is indicative of a dendritic drainage pattern and nearly homogeneous conditions in the development of the stream network. But regional variations in the topography and morphological conditions are revealed in the varied bifurcation ratios between different orders. But in general the stream numbers and stream length confirms to the laws of morphometric analysis where as the mean stream area and mean stream slope do not reveal the conformity thereby indicating differential topography and geology influencing the development of the streams and their network.

**Stream Length**

Stream is indicative of chronological development of the stream segments including tectonic disturbances. Thus mean stream length reveals the characteristics size of components of a drainage network and its contributing surfaces. Stream length shows the landform evaluation, geological structure and occurrence of floods. Intensity of floods will be higher due to high stream length.

It is evident that the length of the first order streams constitutes 59.58 percent of the total stream length while the second, third, fourth, fifth and the sixth order constitute 16.91, 13.76, 6.18, 3.2 and 0.55 percent respectively (Fig.4). The total percentage of the first and second order stream length constitutes 90.56 percent of the total stream length. It can be inferred that the total length of stream segments is maximum in first order stream and decreases as the stream order increases.

**Stream length Ratio**

The length ratio, which is the ratio of the mean length of a given order to the mean stream length of the next order. It is then computed for each pair of orders for the Baitarani river.

Stream Length Ratio $L_i = \frac{L_i}{L_{i+1}}$

Where

$L_i$ = Cumulative mean length of the given order;

$L_{i+1}$ = mean length of the $1^{st}$ order
A QUANTITATIVE ANALYSIS OF BAITARANI DRAINAGE BASIN

Fig.1
RL = constant length ratio and I = given order
The regression line plotted in semi-log graph (fig.4) tends to validate Horton’s law of stream length as the correlation coefficient is 0.895.

**Length of Overland Flow (Lg):**

Lg is one of the most important independent variables affecting both hydrologic and physiographic development of drainage basins and relates reciprocally to the average slope of the channel and is quite synonymous with the length of sheet flow to a large extent. It indicates the length of the runoff of the rain water
A QUANTITATIVE ANALYSIS OF BAITARANI DRAINAGE BASIN

Fig. 2
STREAM NUMBER AND STREAM ORDER

Fig. 3
CUMULATIVE MEAN STREAM LENGTH AND STREAM ORDER

Fig. 4
Table 1. Morphometric parameters and their mathematical expressions

<table>
<thead>
<tr>
<th>S. No</th>
<th>Parameter</th>
<th>Symbol</th>
<th>Formula</th>
<th>Reference</th>
<th>Result of the Morphometric analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stream Order</td>
<td>( N_u )</td>
<td>Hierarchical rank</td>
<td>Strahler (1950)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bifurcation Ratio</td>
<td>( R_b )</td>
<td>( R_b = \frac{N_u}{N_u+1} ) Where ( N_u ) = Total no. of stream segments of order ‘u’ ( N_u+1 ) = Number of stream segments of the next higher order</td>
<td>Schumm (1956)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mean Bifurcation Ratio</td>
<td>( R_{b_m} )</td>
<td>( R_{b_m} ) = Average of bifurcation ratios of all orders</td>
<td>Strahler &amp; Chow (1964)</td>
<td>4.58</td>
</tr>
<tr>
<td>4</td>
<td>Stream Length</td>
<td>( L_u )</td>
<td>Length of the stream (kms)</td>
<td>Horton (1945)</td>
<td>7052.93</td>
</tr>
<tr>
<td>5</td>
<td>Mean Stream Length</td>
<td>( L_{sm} )</td>
<td>( L_{sm} = \frac{L_u}{N_u} ) ( L_u ) = Total stream length of order ‘u’ ( N_u ) = Total no. of stream segments of order ‘u’</td>
<td>Strahler &amp; Chow (1964)</td>
<td>1175.5</td>
</tr>
<tr>
<td>6</td>
<td>Stream Length Ratio</td>
<td>( R_L )</td>
<td>( R_L = \frac{L_{sm}}{L_{sm-1}} ) ( L_{sm} ) = Mean stream length of a given order and ( L_{sm-1} ) = Mean stream length of next lower order</td>
<td>Horton (1945)</td>
<td>2.9</td>
</tr>
<tr>
<td>7</td>
<td>Basin Length</td>
<td>( L_b )</td>
<td>( L_b = 1.312 \times A^{0.568} ) Where ( A ) = Area of the basin</td>
<td>Schumm (1956)</td>
<td>217.44 km</td>
</tr>
<tr>
<td>8</td>
<td>Basin Perimeter</td>
<td>( P )</td>
<td>( P = ) Outer boundary of drainage basin measured in kilometers</td>
<td>Schumm (1956)</td>
<td>629 km.</td>
</tr>
<tr>
<td>9</td>
<td>Sinuosity Index</td>
<td>( SSI )</td>
<td>( SSI = \frac{O_l}{E_l} ) ( O_l ) = Observed (actual) path of the stream ( E_l ) = Expected straight path of the stream</td>
<td>Schumm (1956)</td>
<td>2.27</td>
</tr>
<tr>
<td>10</td>
<td>Length of Overland flow</td>
<td>( L_g )</td>
<td>( L_g = \frac{1}{2} \times D_d ) Where, ( D_d ) = Drainage Density (Km/Km²)</td>
<td>Horton (1945)</td>
<td>3.13</td>
</tr>
<tr>
<td>11</td>
<td>Basin Area</td>
<td>( A )</td>
<td>Area from which water drains to a common stream and boundary determined by opposite ridges</td>
<td>Strahler &amp; Chow (1964)</td>
<td>10,246 sq. km</td>
</tr>
<tr>
<td>12</td>
<td>Drainage Density</td>
<td>( D_d )</td>
<td>( D_d )</td>
<td>Horton (1945)</td>
<td>0.64</td>
</tr>
<tr>
<td>13</td>
<td>Stream Frequency</td>
<td>( F_s )</td>
<td>( F_s = \frac{N_u}{A} ) Where, ( D_d ) = Drainage density (km/km²) ( A ) = Area of the basin (km²)</td>
<td>Horton (1945)</td>
<td>0.13</td>
</tr>
<tr>
<td>14</td>
<td>Circulatory Ratio</td>
<td>( R_c )</td>
<td>( R_c = \frac{A}{A_c} ) ( A ) = Basin Area ( A_c ) = Area of a circle having the same perimeter as the basin</td>
<td>Miller (1953)</td>
<td>0.35</td>
</tr>
<tr>
<td>15</td>
<td>Form factor</td>
<td>( R_f )</td>
<td>( R_f = \frac{A}{L_b^2} ) Where, ( A ) = Area of the Basin (km²) and ( L_b ) = Basin Length (km)</td>
<td>Schumm (1956)</td>
<td>0.217</td>
</tr>
<tr>
<td>16</td>
<td>Drainage Texture</td>
<td>( D_t )</td>
<td>( D_t = \frac{N_u}{P} ) Where, ( N_u ) = Total no. of stream of all orders and ( P ) = Basin perimeter measured in km</td>
<td>Horton (1945)</td>
<td>2.21</td>
</tr>
<tr>
<td>17</td>
<td>Infiltration Number</td>
<td>( I_f )</td>
<td>( I_f = D_d \times F_s ) Where = Drainage density (km/km²) and</td>
<td>Zavoiance (1985)</td>
<td>4.92</td>
</tr>
</tbody>
</table>
on the ground surface before it gets concentrated into definite stream channels and it approximately equals to half of reciprocal of drainage density (Horton, 1945). The length of overland flow depends primarily on the degree of relief fragmentation, and hence on the drainage density. In this study, the length of overland flow of the Baitarani basin is 3.13 kms, indicating a high surface runoff in the basin and it further confirms the high susceptibility of the basin for both soil erosion and flooding.

**Sinuosity Index (SI)**

Sinuosity is highly significant in studying the effect of terrain characteristics on the river course. The calculated value of the Baitarani basin is 2.27 that the stream course is irregular and tortuous. It is a significant quantitative index for interpreting the significance of streams in the evolution of landscapes and beneficial for geomorphologist, hydrologists, and geologists.

**Aerial Morphometric Parameters**

Area of a basin (A) and perimeter (P) are the important parameters in quantitative geo-morphology. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. The maximum flood discharge per unit area is inversely related to size. The total area of the Baitarani drainage basin is 10,982 km². The aerial aspects of the drainage basin such as basin area (A) drainage density (Dd), stream frequency (Fs), texture ratio (Rt), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) were calculated and results have been given (Table 1).
Drainage Density

Drainage density of the basin is defined as the length of streams per sq. km. area. The basin is elongated in shape and exhibits a dendritic pattern of drainage (Strahler, 1969) with acute stream junction angles. Because of the hard and resistant rocks and vegetation cover, the basin also reveals a low stream frequency. The drainage density of an area reflects the texture of topography and nature of its dissection. The evolution of different types of texture depends on different lithology and structure and hydrology of the area. The nature of infiltration of precipitation and presence or absence of vegetative cover controls the drainage density. The drainage density of the basin is 0.64 which is of coarser texture. Most of the tributaries in this area are seasonal in character. In winter these rivulets are usually dry or have a small amount of water which originates from small springs in the hillocks of the surrounding areas joining the main stream at different points along the course.

Stream Frequency

Stream frequency is the number of stream segments per square kilometer of area. It is obtained by dividing the total number of streams by the total drainage basin. In the Baitarani basin the stream frequency is 0.13 (Table.1). Stream frequency is observed to be more when the overland flow gets plenty of time to cover a considerable distance, thereby develop small stream channels. The process of physical as well as chemical erosion takes place to have a permanent depression on the land. The stream frequency reduces with decreasing in the hardness of the surface rock and decrease in the time of overland flows. Surface water either sweeps down rapidly or due to the existence of loose bed rock most of the surface. Runoff is converted into ground water. Slope of the land also plays a leading role in the stream frequency. Steeper slope has less frequency and gentle slope has more frequency. The occurrence of stream segment depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. Stream frequency is low at the mouth of the river which is attributed to the flat topography and small ridges with numerous tributaries and distributaries that result in elongated drainage with highest Fs. Poor Fs could be attributed to rugged topography and steep barren slopes.

Circularity Ratio

The basin shape is largely controlled by geological structure which is an important geometry of the stream work. Miller (1953) defined the basin circularity ratio is the ratio of the basin area (Au) having the same perimeter as the basin. The basin circularity is 0.35.

\[ \text{Basin Circularity (Re)} = \frac{\text{Area of the basin}}{\text{Area of the Circle having same perimeter}} \]

Elongation Ratio (Re)

Schumm’s 1956 used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The value of Re varies from 0 (in highly elongated shape) to unity i.e. 1.0 (in the circular shape). Thus higher the value of elongation ratio more circular shape of the basin and vice-versa. Values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). The elongation ratio of the basin is 0.544 which represents the basin is elongated shape.

Form Factor (Rf)

Form factor is the numerical index which is commonly used to represent different basin shapes (Horton 1932). Its value is varies between 0.1-0.8. Smaller the value of form factor, more elongated will be the basin. A perfect elongated basin has a form factor of 0.217. The basins with high form factors have high peak flows of
shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. In Baitarani basin Rf value is 0.217 indicating it to be elongated in shape and suggesting flatter peak flow for longer duration.

**Drainage Texture (Rt)**

It is the ratio of total stream numbers to the total perimeter of the basin (Horton, 1945).

\[ Rt = \frac{Nu}{P} \]

Texture ratio is an important factor in the drainage morphometric analysis which is depending up on the underlying lithology, infiltration capacity and relief aspect of the terrain (Nageswara, 2010). Smith (1950) has classified drainage density into five different texture i.e. very coarse (<2), Coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In the present study texture ratio of the Baitarani river basin is 2.21, which indicate coarse texture.

**Infiltration Number (If)**

The infiltration Number is defined as the product of Drainage Density (Dd) and drainage Frequency (Fs). The Baitarani basin has the high infiltration number i.e. 4.92. The higher the infiltration number the lower will be the infiltration and consequently, higher will be run off. This leads to the development of higher drainage density. It gives an idea about the infiltration characteristics of the basin reveals impermeable lithology and higher relief.

**Compactness Constant (Cc)**

Compactness constant articulates the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin (Nooka Ratnam et al., 2005). If the watershed was a perfect circle, then Cc would be equal to unity.

\[ Compactness\ Constant\ (Cc) = \frac{0.2821}{P/A^{0.5}} \]

Where, \( A \) = area of the basin (km²) and \( P \) = basin perimeter measured in km

The compactness constant of the basin is 1.75. Thus the basin is elongated and has enough time for discharge.

**Relief Morphometric Parameters**

The relief aspects of the drainage basins are significantly linked with the study of three dimensional features involving area, volume and altitude of vertical dimension of landforms to analyze different geological characteristics. Some of the important relief parameters that are related to the study (Table 1) have been analyzed.

**Relief Ratio (Rh)**

Relief ratio is defined as the ratio between the total relief of a basin i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schunn, 1956).

\[ Relief\ Ratio = \frac{Maximum\ Basin\ Relief}{Maximum\ Basin\ Length} \]

This is a dimensionless height-length ratio and allows comparison of the relative relief of any basin regardless of difference in scale or topography. Relief ratio is equal to the right angled triangle and is identical with the tangent of the angle of slope of the hypotenuse with respect to horizontal (Strahler, 1964). Thus is measure the overall steepness of a drainage basin is an indicator of intensity of erosion processes operating on the slope of the basin. Normally, it has inverse correlation with drainage area and size of drainage basin. For the present study, it is 0.01.
Relative Relief (Rhp)

The Rhp is an important morphometric variable used for the overall assessment of morphological characteristics of terrain. Melton (1957) suggested a method to calculate Rhp by dividing the H with P. There are three categories of Rhp viz (i) low = 0 m – 1 m, (ii) moderate = 1 m – 3 m and (iii) high = above 3 m. The Rhp of the Baitarani basin is 0.19 and therefore, the basin has a low relative relief.

Basin Relief (H)

The H is defined as the difference in the elevation between the highest point (Z) of a basin and the lowest point (z) on the valley floor (Strahler, 1957). The elevation at Z of the Baitarani river basin is 1165 m and the z at the basin mouth is 2 m from mean sea level. Therefore, the relief of the river basin is 1163 m.

Basin Slope (Sb)

Basin Slope enables the assessment of runoff generation, direction and volume.

$\text{Basin Slope (Sb)} = \frac{\text{Basin Relief}}{\text{Length of basin}}$

The basin has a Sb of 5.35 that reflects the relatively mountainous and plateau nature of the terrain plains.

Dissection Index (DI)

Dissection index (DI) is a parameter implies the degree of dissection or vertical erosion and expounds the stages of terrain or landscape development in any given physiographic region or basin.

$\text{Dissection Index (DI)} = \frac{\text{Relative Relief}}{\text{Absolute Relief}}$

On average, the values of DI vary between ‘0’ (complete absence of vertical dissection/erosion and hence dominance of flat surface) and ‘1’ (in exceptional cases, vertical cliffs, it may be at vertical escarpment of hill slope or at seashore). DI value of Baitarani basin is 0.998 that indicates the basin is highly dissected and morphometrically the river is in young stage. But, actually this is not the state of whole basin and is found in upper reaches or mountainous areas of the basin occupied by first order streams.

Ruggedness Index (RI)

The topographic ruggedness index indicates the extent of instability of land surface (Strahler, 1956). It is derivative of long-standing interaction between available sharpness of local relief and the amplitude of available drainage density and other environmental parameters such as slope, precipitation, weathering, soil texture, natural vegetation etc. Ruggedness index is measured by taking into account both relief and drainage.

$\text{Ruggedness Number (RN)} = \frac{\text{Basin Relief} \times \text{Drainage Density}}{1000}$

The measured value of RI of Baitarani basin is 0.74.

CONCLUSION

The morphometric analysis of Baitarani basin using Geographic Information System retrieved that this tool helps the researchers to analysis the drainage basins easily and accurately in short time duration. GIS facilitates analysis of various morphometric parameters and acts as an effective tool in establishing relationship between drainage morphometry and properties of landforms. Geomorphological study of an area is the systematic study of present day landforms, related to their origin, nature, development, geologic changes recorded by the surface features and their relationship to flood hazard. Some morphometric elements (measurement of landforms) provide valuable information for vulnerability to flood. The morphometric parameters evaluated using GIS helped to understand various terrain parameters such as nature of the bedrock,
infiltration capacity, runoff, etc. Similar studies in conjunction with high resolution satellite data help in better understanding the landforms and their processes and drainage pattern demarcations for basin area planning and management (M. Bagyaraj and B. Gurugnanam, 2011). The analysis of linear aspects of drainage basin result shows that the basin has a dendritic pattern with sixth order stream. High bifurcation ratio in the study area indicates a strong structural control on the drainage. The results of aerial aspect show that the texture of drainage is high. The analysis of elongation ratio indicates the drainage basin is elongated in nature with high relief and steep slopes. The result of relief aspect shows the study area is characterized by high relief and high stream density.

Acknowledgments: Author is thankful to Prof. S.N. Tripathy, Professor and Ex-Head, P.G. Department of Geography, Utkal University, Bhubaneswar, Odisha for providing opportunity and valuable guidance for completing research work.

References


