DOI: http://doi.org/10.4038/tjata.v2i1.55

TRIVALENT/ත්‍රිසංයුජ: Journal of Archaeology, Tourism & Anthropology, Department of Archaeology, University of Kelaniya Volume II Issue I 2021

Quantitative Geomorphic analysis in Geoarchaeological Investigations: A Case Study of Man-land relationship of Hanga River basin, Ahmednagar district of Maharashtra

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Abstract

Geomorphology is the study of landforms, their processes, form, and sediments at the surface of the earth which includes the earth's surface processes, such as air, water, and ice, which can mould the landscape. Since, from the beginnings human being attracted towards such suitable landscape for the establishment of their settlements. The present geoarchaeological work involves the study of the characteristics and evolution of landscapes, geological settings based on quantitative morphometric analysis, and availability of the natural resources of these areas with the man-land relationship of the Hanga river basin. The previous history of the region indicates that it is rich in prehistoric and chalcolithic settlements. The present basin is not explored systematically so far. Hence, this work is an attempt to fill these lacunae by the way of a systematic, intensive, village to village survey to understand the man-land relationship in the region. Field surveys and laboratory works were carried out to fulfil the aim and objectives of this work.

***Keywords**: Geomorphology, Landscape, Landforms, Man-land relationship, Settlements, Geoarchaeology.*

Introduction

A geomorphological study leaves their imprints in the form of typical assemblages of landform on the earth surface through the different geomorphic processes which are available in the forms of mountains, River basins, bedrocks, slopes, sand dunes, surface deposition, etc. The branch of science which deals with the study of landforms is called Geomorphology (Thornbury 1968). This study is based on the certain principles that landforms can be related to the geological process and the landforms accordingly develop may evolve with time through a sequence of the deposition of forms. all the geomorphological activities are dynamic processes and played a crucial role in the development of the landscape.

The morphometric analysis provides refinement to the subject with more precise and accurate methods of studying the different landforms. According to Clarke (1967), morphometry may be defined for the measurement and mathematical analysis of the configuration of the earth's surface and the shape and dimensions of its landforms.

The information and skills provided by two essential archaeological cognate scientific disciplines, geology and geomorphology, both of which are branches of earth sciences, play a critical part in the archaeological investigation. To answer archaeological difficulties, it combines geological knowledge. It investigates archaeological records that can be applied to a wide variety of scales in the reconstruction of paleoenvironments at various locations, as well as human involvement with the landscape and the associated features preserved in the sediments, utilising earth science approaches (Goldberg and McPhail 2006). Geoarchaeology research in the field and the lab elucidates a site's micro, meso, and macro environments as well as human activity patterns over time and space.

The present work deals with the quantitative geomorphic analysis carried out to understand the man-land relationship of Hanga, a left side tributary of Ghod River, from the Ahmednagar district of Maharashtra.

Objective

The objective of this study is to determine the archaeological significance of the Hanga River basin, other goals are (i) Classify the landform with reference to the potentiality of the finding of the archaeological sites, (ii) Identify the areas that have high potentiality for the preservation or distribution of archaeological sites by geomorphic procedure, (iii) Identify the archaeological site and the associated of landform, (iv) Identification of sites of different cultural periods. This approach defines the relation between the known archaeological settlement and the associated geomorphic features which are involved in identifying the known archaeological sites. Such characteristics are evaluated to predict the location of the unexplored site according to this geomorphic context.

The main attributes of this aspect examined are the area, altitude, volume, slope, profile and texture of the land and the varied characteristics of small and big drainage basins". Such methods have been often used to describe certain relief features, like erosion surfaces and slopes. This type of investigation has been carried out by various researchers such as Horton (1932), who have developed laws of drainage composition. His empirical methods have been later modified by Strahler (1950), Morisawa (1957), Miller (1953), Melton (1959) and Schumm (1956). Dury (1952), presented firstly this analysis in a systematic form, while Wentworth (1930), employed some important techniques in the analysis of erosion surfaces, which are average slope, relative relief. Smith (1935), dissection index Nir (1957), generalized contours (Miller 1964), hypsometric and altimetry curves (Clarke 1967).

In India, morphometric evolution of landforms has been attempted for Rajmahal highlands, the neighbourhood of Almora and Mirzapur upland firstly introduced by Singh (1967), Kharakwal (1970), Pal (1972), and others. The work carried out by Sabale (2006), in the upper reaches of Bhima and Krishna River threw light on the morphotectonic setting of southern Deccan Volcanic Provinces of India.

Most of the geomorphologists have delineated the regional landform units into the physiographic and natural region while a few have demarcated based on morphometry. The work of Powell (1896) who has delineated the natural region of North America, based on physiography was followed by Fenneman (1914), is important in this connection.

This technique is successfully used for the geoarchaeological exploration in different basins of Maharashtra by various researchers. Sabale and Kshirsagar (2011) were carried out it detailed geoarchaeological exploration in Sina River and documented several cultural sites of various periods. Sabale (2015) carried out detailed geoarchaeological exploration in the upper and middle reaches of the Bhima River. Similarly, Sabale *et.al* (2015), carried out geoarchaeological exploration in the Khadakpurna basin. Kshirsagar (2017) carried out geoarchaeological exploration in the lower-middle reaches of Bhima including the Bori River from parts of Osmanabad and Solapur districts of Maharashtra.

Study area

The Hanga River is originated in Parner and further flowed towards Srigonda tehsils in Ahmednagar district (Maharashtra) confluence to the main – Ghod, at Hangewadi, Chimbhle. This is having 72km length and 12km width, so it is a narrow stream having comparatively more extension and less width, with an asymmetric drainage pattern. The Balaghat hill range – a ridgeline between Mula, a tributary of the Godavari on the northern side, and Bhima (Krishna basin) on the southern side, is the source region of the River.

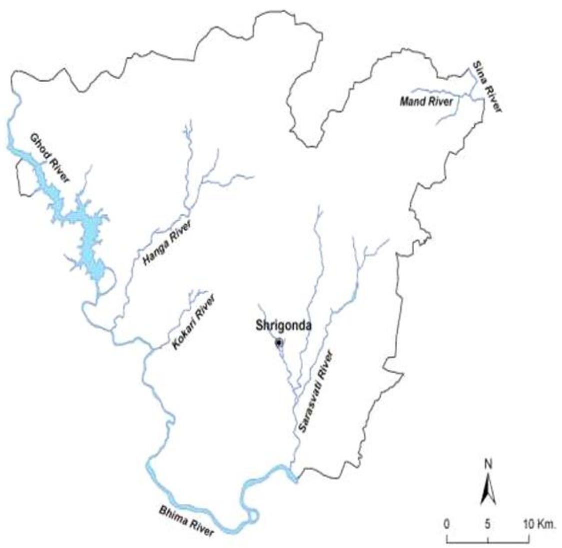

Fig. 1 Location map of Hanga River basin

Methodology

The approach has been divided into pre-field, field, laboratory investigation. To learn about prior work in the topic area, a thorough literature review was carried out. Fieldwork and lab analysis was done with the use of toposheet maps.

To calculate the quantitative geomorphic analysis Survey of India, a toposheet map of 1:50000 scale was used to study the whole basin and geomorphic features present in the same. This means the area is equally divided into equal rows and columns, i.e., grids of an area km^2 each. To give the number to each grid, it is divided into a sequence, such as 1, 2, 3…to 24 vertical columns and horizontal rows, viz, A, B, C……...to T. In addition to the basin boundary, some additional surrounding areas of other basin were taken for the study. The basin covers a total 260 number of grids hence, it covers 260 ×2=520km^2.

The Quantitative geomorphic aspects required for the geo-archaeological investigation of the basin were studied and the details of these observations with reference to field geomorphic features are described below.

Relief aspects

The meaning term 'relief' may be defined as the earth's surface or relative vertical inequality of land surface. These morphometric elements are absolute relief, relative relief, slope, dissection index, etc. helps to classify morpho units of terrain.

1. **Absolute relief:** The maximum elevation of an area above the mean sea level contrast relative relief and it is denoted by 'H'.
2. **Basin Relief or Relative relief:** The term 'Relative Relief' means the actual variation of height i.e., the difference between the maximum and minimum height per grid. It can be expressed by the formula for basin relief is H= H1- H2. Where, H= basin relief, H1= highest point, and H2= lowest point of the basin.

Linear aspect: A linear aspect of the drainage basin includes the channels and their network in terms of open links, wherein the topological properties of the stream segments are analyzed. For this purpose, the numbers of all the stream segments (Nµ) are counted and their hierarchical orders are determined.

Drainage order: It is the number used in geomorphological studies to indicate the level of branching in a system.

Drainage density: A ratio of the total length of all stream segments in a given drainage basin to the total area of the basin and thus it can be derived as follows. Dd =Lu/A. Where, Dd = Drainage density; Lu= length of all stream segments of the basin in km, and A= total area of the basin in km (Horton 1945).

Drainage Frequency: It is also known as stream frequency, which is given by the formula, Fµ = ∑N⁄A. Where, Fµ= Drainage frequency, ∑Nµ= Sum of all streams in a basin and, A= Total area.

Bifurcation ratio: The bifurcation ratio is denoted by symbol 'Rb'. It can be expressed by the formula, Rb= Nµ/Nµ+1. Where, Rb= Bifurcation ratio; Nu = Number of streams of order and, Nµ+1= Number of streams of next higher order.

Areal Aspect: Anderson (1957) termed the basin as a 'devil's variable because almost every watershed characteristic is correlated with area'. The first order basins have the smallest mean basin areas, and the successive higher orders show an increase in the areas culminating in the largest area of the highest order of the trunk stream.

Slope: A slope is an area of land that makes a definite angle to a horizontal landscape. In geomorphology, the landscape is made-up of slope units and can be defined as the vertical inclination between the hilltop and valley bottom, stands with the horizontal line and is expressed generally in the degrees. i.e., Sz= H× 2Dd, Where Sc= ground surface slope, H= Basin Relief, Dd= Drainage density.

Dissection index: It is expressing the ratio of the maximum relative relief to maximum absolute relief. It is an important morphometric indicator of the nature and magnitude of the dissection of terrain.

Observations

Dissection index: While observing the quantitative morphometric data of the dissection index, the highest ratio of absolute and relative relief is 0.2 in the source region of the basin and the lowest value of 0.001 is observed in the confluence region. In the middle reaches, the value ranges 0.109-0.133and 0.068-0.1. According to the observation, the details of the category and its value is as given below.

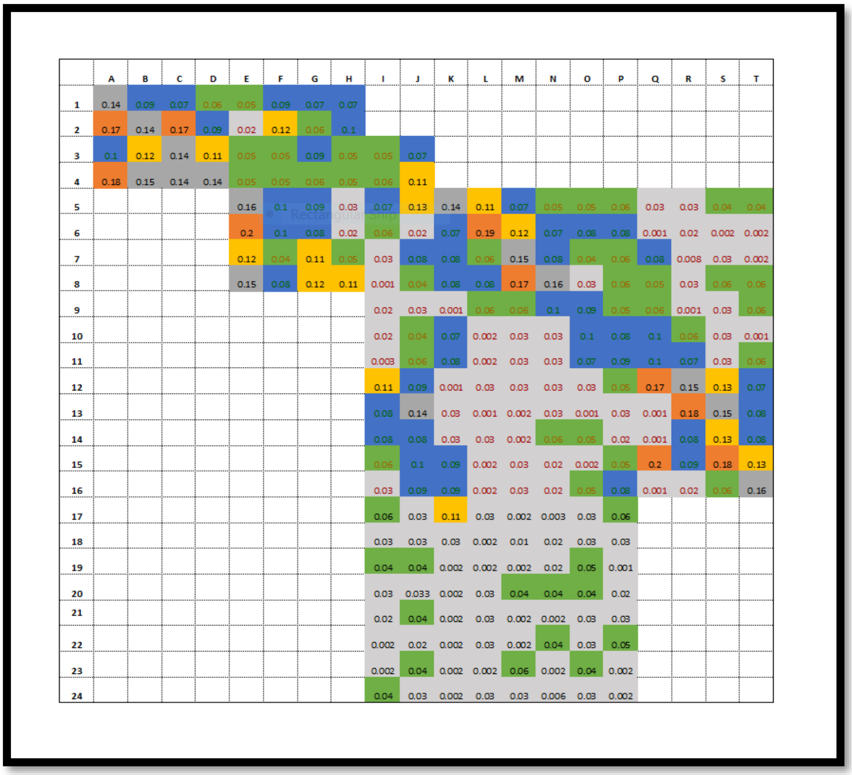

Fig. 2 Dissection index of Hanga River basin.

Index	Category	Range	Grids	Area	Area %
	Very high	0.2-0.17	10	20	4
	High	0.166-0.134	15	30	6
	Medium-High	0.109-0.133	15	30	6
	Low – Medium	0.068-0.1	51	102	20
	Low	0.035-0.067	57	114	22
	Very low	0.001-0.034	108	216	42

Table 1. Dissection index of the basin.

Slope: In the present basin the gradient/slope of the landform is found varying reaches to reaches. In the case of the upper reaches the hilly area - the slope is very high to high category while in the case of the middle reaches which consist of foothill region where the steepness is decreased and resulting it becomes slightly moderate to the gentle category while in lower reaches of the plain grounds start and River flow on nearly gentle to plain area.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	0	0	0	0	0	0	0	0												
2	0	0	0	8.3	27	6.3	0	0												
3	0	0	4.4	7.5	17	15.5	9.5	6.4	5.4	4.8										
4	0	0	0	5.6	16.5	19.7	16	17.5	15.6	7.6										
5					2.8	7.5	9.3	42	9.3	3.3	4.83	3.7	0	0	0	0	0	0	0	0
6					1.1	8.5	9.1	34	12	26.5	10.1	2.93	2.9	0	0	0	0	0	0	0
7					3.1	14	4.6	15	28	7.6	7.8	13	4.6	0	0	0	0	0	0	0
8					1.7	5.3	6.8	5.3	530	24.3	10.5	8.8	4.7	2.7	0	0	0	0	0	0
9									27	37.5	620	16.4	15.8	5.9	4.7	3.5	0	0	0	0
10									18	19	6.61	590	22.5	29.5	7	4	1.5	0	0	0
11									260	12.8	6.16	650	17.4	30	11.3	10.7	4.5	0	0	0
12									1.6	7.42	520	21	30.5	33.5	20	12.3	2.08	0	0	0
13									3.3	4.8	21	580	570	27	350	15.5	0	0	0	0
14									0	2.5	30.5	37	600	11.5	0	0	0	0	0	0
15									0	1.4	10.1	520	29	29.1	0	0	0	0	0	0
16									0	0	5.5	640	29.5	510	0	0	0	0	0	0
17									0	31	5.8	32.5	580	280	17	10.5				
18									0	25.5	43	530	60	54	29	17				
19									26.5	27	460	220	370	0	0	0				
20									19.5	32	340	0	0	0	0	0				
21									28.3	3.5	0	0	0	0	0	0				
22									790	21	0	0	0	0	0	0				
23									50	0	0	0	0	0	0	0				
24																				

Fig.3 Slope of the Hanga basin.

Absolute relief: The highest value observed here is 978m in the source region of the basin while the lowest value observed is 520m in the confluence of the basin.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	860	860	886	891	880	860	840	843												
2	840	840	920	987	860	892	860	857												
3	760	820	860	920	840	840	853	858	860	860										
4	780	820	880	907	820	800	808	800	820	860										
5					910	846	840	760	800	880	880	883	814	805	780	768	700	680	686	670
6					880	848	810	740	763	780	760	860	860	800	780	760	680	674	661	660
7					776	770	810	760	720	747	747	726	827	780	730	720	740	720	680	640
8					776	762	792	790	700	710	740	720	820	840	720	720	760	720	700	700
9									700	700	660	704	700	760	774	740	772	700	700	700
10									715	710	739	640	660	680	760	763	760	740	700	680
11									662	700	700	640	663	660	696	700	760	749	700	723
12									721	710	620	640	640	640	662	680	804	800	800	709
13									700	700	640	620	620	640	640	660	660	800	800	720
14									680	680	640	620	600	640	650	650	640	780	780	800
15									640	671	660	600	600	611	600	650	653	700	800	849
16									600	660	660	600	600	580	633	650	640	653	680	760
17									594	600	652	600	580	582	620	638				
18									580	580	580	560	580	590	615	620				
19									560	560	560	560	580	590	607	600				
20									560	560	560	575	580	580	580	593				
21									552	560	560	576	560	560	580	580				
22									540	530	540	550	540	560	580	590				
23									520	540	520	540	550	540	560	560				
24									542	540	520	536	540	543	560	560				

Fig.4 Absolute relief of Hanga basin.

Index	Category	Range	Grids	Area km^2	Area %
	Very high	1000-921	1	2	0.39
	High	920-841	28	54	10.9
	Medium -High	840-761	46	92	17.9
	Low - Medium	760-681	58	116	22.7
	Low	680-601	57	114	22.4
	Very low	600-520	66	132	25.7

Table 2 Absolute relief of the basin.

Relative relief: The highest Relative relief observed here is 180m in the upper reaches while the lowest is 1m in lower reaches and observed in the middle reaches.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	120	80	66	51	40	80	60	63												
2	140	120	160	87	20	112	60	57												
3	80	100	120	100	40	40	73	78												
4	140	120	120	127	40	40	48	40												
5					150	86	80	20	60	120	120	103	54	45	40	48	20	20	26	10
6					180	88	70	20	43	20	60	160	100	60	60	60	1	14	1	1
7					96	30	90	40	20	67	67	46	127	60	30	40	60	60	20	1
8					116	62	92	90	1	30	60	60	140	140	20	40	40	20	40	40
9									20	20	1	44	40	80	74	40	52	1	20	40
10									15	30	59	1	20	20	80	63	80	40	20	1
11									2	40	60	1	23	20	46	60	80	49	20	43
12									81	70	1	20	20	20	22	40	144	120	100	49
13									60	100	20	1	1	20	1	20	1	140	120	60
14									60	60	20	20	1	40	30	10	1	140	100	60
15									40	71	60	1	20	11	1	30	13	60	140	109
16									20	60	60	1	20	1	33	50	1	13	40	120
17									34	20	72	20	1	2	20	38				
18									20	20	20	1	8	10	15	20				
19									20	20	1	1	1	10	27	1				
20									21	20	1	15	20	20	20	13				
21									12	20	1	16	1	1	20	20				
75									1	10	1	10	1	20	20	30				
23									1	20	1	20	30	1	20	1				
24									22	20	1	16	20	3	20	1				

Fig. 5 Relative relief of Hanga basin.

Index	Category	Range	Grids	Area(km^2)	Area (%)
	Very high	180-151	3	6	1.2
	High	150-121	11	22	4.3
	Medium -High	120-91	22	44	8.6
	Low – Medium	90-61	27	54	10.6
	Low	60-31	64	128	25
	Very low	30 - 0	129	258	50.4

Table 3 Relative relief of the basin.

Drainage Frequency: The drainage frequency of the basin is observed here is highest in the middle reaches of it, i.e., 50, and lowest in lower reaches at the confluence i.e., 1.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	12	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	18	12	17	18	13	11	7	0	0	0	0	0	0	0	0	0	0
4	0	0	0	3	13	9	19	25	21	15	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	22	32	22	21	18	18	27	6	0	0	0	0	0	0	0	0
6	0	0	0	0	2	46	23	11	14	20	19	28	13	0	0	0	0	0	0	0
7	0	0	0	0	1	19	40	8	13	12	21	30	24	2	0	0	0	0	0	0
8	0	0	0	0	1	3	29	13	12	16	25	18	21	16	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	21	20	19	15	19	30	23	0	0	0	0	0
10	0	0	0	0	0	0	0	0	19	43	50	13	9	16	36	26	7	0	0	0
11	0	0	0	0	0	0	0	0	12	22	23	8	7	11	47	42	15	0	0	0
12	0	0	0	0	0	0	0	0	6	14	9	9	15	13	25	16	3	0	0	0
13	0	0	0	0	0	0	0	0	1	19	12	7	7	7	9	5	0	0	0	0
14	0	0	0	0	0	0	0	0	0	3	7	14	9	15	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	5	14	16	12	15	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	14	19	25	2	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	3	26	21	12	9	10	10	0	0	0	0
18	0	0	0	0	0	0	0	0	0	26	25	14	13	6	15	3	0	0	0	0
19	0	0	0	0	0	0	0	0	6	24	15	10	7	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	1	22	9	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	10	17	1	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	15	7	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 6 Drainage frequency of the basin.

Serial No.	Index	Category	Classification	Drainage frequency	Percentages
1		Very high	50-41	5	4
2		High	40-31	3	2
3		Medium	30-21	29	21
4		Low	20-11	55	41
5		Very low	10-1	44	32

Table 4 Drainage frequency of the basin.

Drainage order

The highest drainage order of the stream is 7th, and the drainage number is effectively decreasing with the higher order of the stream.

Serial No.	Index	Drainage order	Drainage number
1		1st	1086
2		2nd	256
3		3rd	58
4		4rth	15
5		5th	4
6		6th	2
7		7th	1

Table 5 Drainage order of the basin.

Bifurcation ratio: The bifurcation ratios of the basin clearly indicate that according to the higher-order the ratio is decreasing and vice-versa. This is the characteristic of any normal River basin in which according to the higher-order the number is decreased. The bifurcation ratio ranges from 1 to 4.24 for the basin.

Serial no.	Category	Order number	Number of streams	Bifurcation ratio
1		1st	1086	4.24
2		2nd	256	4.41
3		3rd	58	3.86
4		4th	15	3.75
5		5th	4	2
6		6th	2	2
7		7th	1	1

Table 6. Bifurcation ratio of the basin.

Result and Discussion

The present research paper is focused on the quantitative analysis of landscape characters with the ground truth realities and its suitability for the establishment of archaeological sites in the Hanga River basin. The basin study reveals that in its upper reaches (source area) it is made up of rocky hilly- rocky terrain, which is a part of the Balaghat hill range, which divides Bhima in the south and Godavari in the north. Therefore, a sound foundation is available here for the construction of large-scale monuments like forts, *Gadhis,* heritage structures like temple complexes, *Mathas,* Churches, mosques etc. Likewise, Hattal Khindi village in the source region big monuments like Bhairavnath Temple in Punewadi, well-fortified Parashar and Pimpleswar temple of *Yadava* period and a small fort (*Gadhi*) are present in Partner. The big temple complex is like Siddheswar and Biloba temple also present in this area.

In middle reaches undulating to plain topography shows partly hilly and partially depressing basinal areas, of eroded, low relief, dissected hills formed by circumdenudation action, surrounded by plain to the gentle sloppy area. The depressed portion is unsuitable for the settlements. Therefore, some big structures on rocky foundations and some small structures rest on uneven surfaces. While some are settled very close to the fertile land, which is suitable for irrigation practices. Examples of such sites as Hangeswar temple in Hanga, Bhairavnath temple in Walvane village, a temple in Rui-Chhatrapati is observed on the steep sloppy area.

Lower reaches, where the ground is covered in fertile soil and various depressions, some of which are entirely or partially filled with water bodies. As a result of the available natural resources, this area has the ability to support large-scale agricultural activity and is well suited for the creation of large-scale towns. Since the British era, the Visapur water tank and the Visapur dam have been built to provide water to the surrounding area via railway.

Conclusion

Based on quantitative geomorphic analysis of dissection index, absolute relief, and relative relief factor, it is observed that in the study area, the rate of these factors is increasing with elevation and vice-versa. Therefore, the value of these factors is observed very high in the source area of the basin while the medium rate at the middle reaches and the lower value found at the lower reaches, where the confluence of Hanga with Ghod River, which means the land is undulating and while heading to its confluence its plains land.

The above geomorphic studies give the actual present picture of the basin in quantitative form, which is considered as a very basic analysis and important analysis to understand the ground truth condition of any basin, as per the suitability of the land for site selection for human settlement and its interrelationship with basin is a concern.

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