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A comparison between Regular Square Grid and Basin or Sub-basin based analysis of Hypsometric Integral: A Case study for Maheshkhali, Inani & Dakshin Nhila Anticline of Cox's Bazar, Bangladesh

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Abstract— This study aims to find out a comparison between regular square grid and basin or sub-basin based analysis of hypsometric integral: a case study for Maheshkhali, Inani & Dakshin Nhila anticline and their drainage basins of Cox's Bazar district of Bangladesh. It is necessary to study the hypsometric integral (HI) of the study area because of its location and it has been occurred several landslide incident, flash flood and also the area experienced a major earthquake in 1999. SRTM DEM and GIS software used to study the hypsometry of the area. In order to identify the hypsometry indices, also it has been used surface geology, lithology and structural maps. The study area comprises 34 small and medium size drainage basins and divided into 62 square grids by 4.29×4.29 km area per grid delineated by GIS tools. HI values found ranges from 0.13 to 0.55 for basins and sub-basins based analysis and 0.09 to 0.54 for regular square grid of the study area. The HI contour map for basins and regular square grids comparison shows some similar range of values. The intensity of values is different in some area. The comparison showed that the Hi values in Ukhia Upazila have some similarities but regular square grid showed higher Hi value in Ramu Upazila. The basin based Hi value of southern Maheshkhali and northern Cox's Bazar sadar shows higher than the square gird based value. But in case of northern Maheshkhali and Teknaf upazila, the HI value showed similar range of values and distribution. Also the distributions of Hi values are similar in Ukhia and Middle Maheshkhali upazila. In this case, the Hi value analysis on both basins based and square grid based have some similarities but basins based analysis are more accurate for this study area.

Index Terms— Hypsometric Integral, Drainage basin, Regular square grid, Maheshkhali Anticline, Inani Anticline, Dakshin Nhila Anticline, Cox's Bazar

1 INTRODUCTION

The HI is thought to be influenced by basin parameters such as basin geometry, drainage area, and basin elevation drop [1], [2], [3], [4]. Hypsometry describes area distribution at different elevations [5], [6] and can be estimated using the hypsometric curve or the hypsometric integral (HI). The hypsometric integral corresponds to the area below the hypsometric curve and therefore is correlated with the shape of this curve [7], [8]. The hypsometric integral can be approximated by means of the following equation:

$$HI = \frac{\text{mean elevation - minimum elevation}}{\text{maximum elevation - minimum elevation}}$$

Hypsometry is affected principally by tectonic, lithologic, and climatic factors. Masek et al. [2] proposed a climatological effect on hypsometry by comparing two large-scale drainage basins in the central Andean plateau. Lifton and Chase [1] pointed to the influence of lithology in the hypsometric integral at small scales (100 km2) and an influence of tectonics at larger scales (1000 km2). They also showed, through a numerical model, that the hypsometric integral is positively correlated with the uplift rate. Chen et al. [4] used values of the hypsometric integral to differentiate morphotectonic provinces in the foothills of Taiwan.

Walcott and Summerfield [9] demonstrated that HI values obtained for several basins and sub-basins along the southeast margin of southern Africa did not correlate with basin area or basin shape. Their HI values showed complex relationships with indices of vertical scale as relief and dissection. According to Van der Beek and Braun [11], in this case (for regular square grid), HI value do not strictly represent a measure of dissection but instead represent how rapidly elevation changes within each square grid. This study is to find out the comparison and preferences use of Hi values of an area calculated from square grid based analysis or basin or sub-basin based analysis.

2 STUDY AREA

Cox's Bazar bearing the world's longest sandy beach about 120 km long. The study area lies in the last south-east part of Bangladesh. The area is bounded by N 20° 51' 9.3" to N 21° 43' 50.62" latitudes and E 91° 50' 45.36" to E 92° 18' 22.32" longitudes.

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Most of the area is covered by Maheshkhali, Inani and Dakshin Nhila anticline. The study area comprises Maheshkhali, Cox's Bazar Sadar, Ramu, Ukhia, Teknaf and part of Chakaria upazila of Cox's Bazar district. The Inani structure is represented by NNW-SSE trending low hillocks attaining maximum 542 feet elevation above sea level. The elongated Inani structure is bisected into two major parts by Reju Khal across the northern plunging area. Topographic sheet indicates 84 C/3 of Survey of Bangladesh over's the area. The area was first systemically mapped by the Indian Geological Survey in 1937. But, later, a very few geological works have been carried out in the Inani hillrange. Pakistan Petroleum Limited (1951) worked on the stratigraphy and structure of Inani hill range based on earlier work undertaken by Burman Oil Company Limited. O.G.D.C (1963 & 1976) carried out geological studies on the Inani structure to establish the stratigraphy, structure and the petroleum prospects. Petrobangla (1980, 1981 & 1993) surveyed Inani and Dakhin Nhila area for stratigraphic classification and hydrocarbon prospect.

3 GEOLOGICAL AND GEOMORPHOLOGICAL SETTINGS OF THE AREA:

The eastern Folded Belt of the Bengal Basin exposes mainly geosynclinals molasse sediments of Neogene age, comprising alternating shale, mudstone, siltstone and sandstone in varing proportions. This succession has been lithostratigraphically subdivided into Surma (Bhuban and Bokabil), Tipam and Dupi Tila Groups following the classification of Evans [12]. Most of Bangladesh is covered by Tertiary and Quaternary sedimentary deposits which thicken to the south, where they locally exceed 20,000 m in thickness [13]. The strata are deltaic to shallow marine in the north, but become progressively more marine to the south [14]. The evaluation of landforms and soils of the Cox's Bazar and adjoining areas in a part of the coastal region of the north–south trending fold belt of Bangladesh during the Late Quaternary Period [15]. After (below) Recent deposit Bokabil Formation has been found in the western side of the Cox's Bazar city [16].

The deposits of the Inani Anticline have been divided into Middle and Upper Boka Bil, Tipam Sandstone, Girujan Clay and Dupi Tila Formations. Inani is a narrow and elongated structure in which the Tipam Sandstone Formation is characterized by steep zone in both the flanks. The Tipam Sandstone Formation is unconformably underlain by the Boka Bil Formation in a gradual low dip. The oldest exposed rock is the Boka Bil Formation [17]. Inani anticline is elongated, broad crest, steep flank, box-like and asymmetrical anticline. It is characterized by monotonous alternation of arenaceous and argillaceous beds with subordinate intra-formational conglomerates in the older exposed sequence. The entire western flank has been washed away by the sea except a segment of Middle Bokabil Formation in the axial part [17]. From the Fig. 4 it has been delineated that major regional fault existed in the northern part (Maheshkhali anaticline) and NNW-SSE directed fault in the Inani anticline.

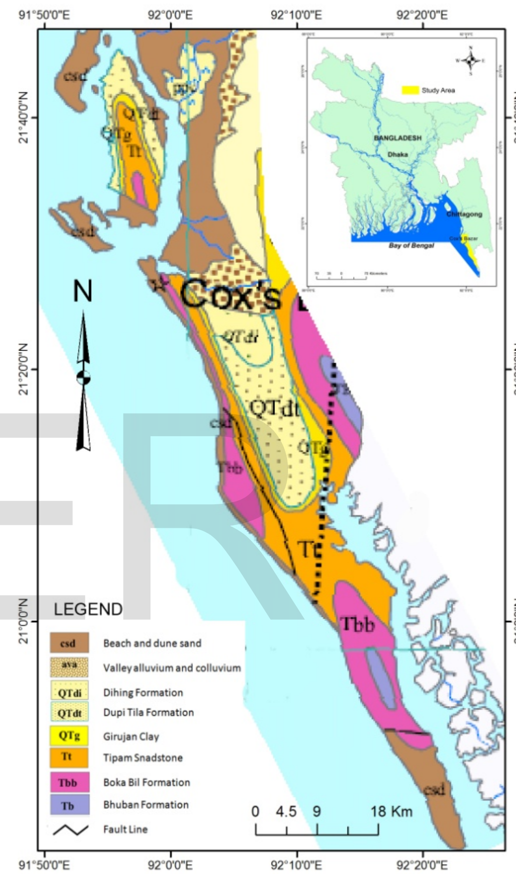

Fig. 4: Surface Geology map of Cox's Bazar, Bangladesh [18].

4 METHODOLOGY

In the field of tectonics geomorphology and landscape evolution, the use of GIS is relatively recent. The availability of the DEM has produced a great revolution in this field. It has replaced old topographic maps, allowing for better and faster analysis of topographic parameters [19]. Geographical information system has been used for data preparation, data manipulation and analysis of data. ArcGIS 10.2 has been used for the present study. The Digital Elevation Model (DEM) with 30 m spatial resolution has been used as a base map. In fact, the purpose of this study is to use the procedure and the information of geology and geomorphology to understand the hypsometry properties with two different methods of the

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study area. Surface geological map of this area has been taken from USGS website.

The elevation value of DEM has been used to find out the hypsometric integral for each basin in the study area. In case of regular square grid, DEM is used to calculate HI for each square grid. Programming in excel has been used to determine the hypsometric integral values showed in table 1 & 2. In order to generate the map of HI value, at first, find out the middle point of grid and basin for HI value and then the spatial analyst has been used. The drainage basins boundary has been identified through a Hydrology tool (fill, flow direction, flow accumulation, basin) in ArcGIS software using DEM model as input. Then the drainage basins and sub-basins value of HI has been calculated using ArcGIS directly. Finally, we classified the study area based on the classification of El Hamdouni et al. [20] and Ramu and Mahalingam [21].

5 Results

According to El Hamdouni et al. [20], The hypsometric integral does not relate directly to relative active tectonics. High values of the index generally mean that not as much of the uplands have been eroded and may suggest a younger landscape perhaps produced by active tectonics. High values of HI could also result from recent incision into a young geomorphic surface produced by deposition. High values of the index are possibly related to young active tectonic and low values are related to older landscapes that have been more eroded and less impacted by recent active tectonics. High value of HI are generally >0.5, intermediate values are generally between 0.4 and 0.5 and lower values are <0.4.

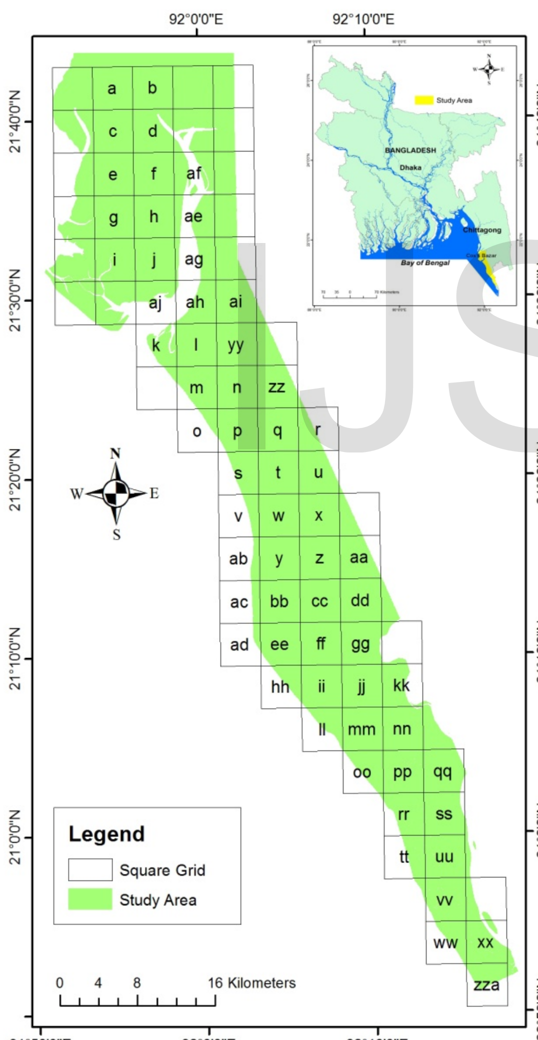

Fig.2: Division of regular suare grids of the study area.

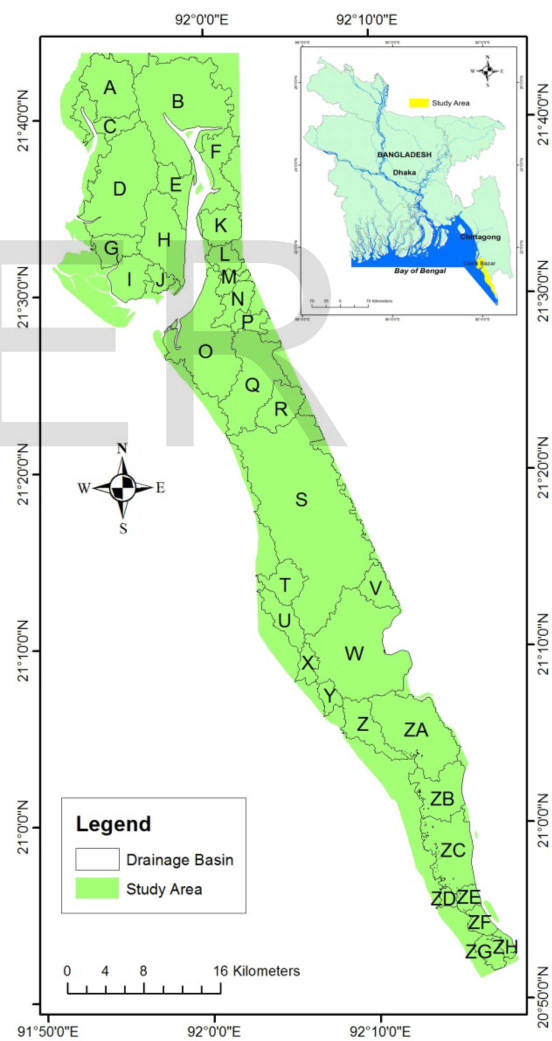

Fig. 3: Drainage basins and sub-basins of the study area.

Ramu and Mahalingam [21] have been classified the HI values as following. If the result value was between 0.6 and 1; it indicates the youthful state of dissection; if the result value was between 0.3 and 0.60, it indicates a maturely dissected landform; and if the result was less than 0.35, then it indicates an equilibrium or old state of dissection.

For the square grids the study area has been divided into 62 square grids by 4.29x4.29 km area per grid (Figure 2). In case of drainage basin it has been found 34 drainage basins and sub-basins in the study area (Figure 3). In this study we obtain HI value for both regular square grids and basins and sub-basins (Table 1 & Table 2). In case of the HI value of regular square grids, the basin geometry and drainage area are not required to obtain.

5.1 HI value of Basin & sub-basin

Hypsometric integral values found ranges from 0.13 to 0.55 for basins and sub-basins in the study area (Table 1). 34 basins and sub-basins are found for HI analysis. Most of the basins and sub-basins are small because of coastal hilly area and the hills are parallel to the beach.

TABLE 1: HYPSOMETRIC INTEGRAL (HI) BASED ON DRAINAGE BASINS AND SUB-BASINS OF THE AREA.

BASIN	Mean Elevation (m)	Min Elevation (m)	Max Elevation (m)	HI	BASIN	Mean Elevation (m)	Min Elevation (m)	Max Elevation (m)	HI
A	6.80	-9	61	0.23	R	11.73	-6	46	0.34
B	9.32	-22	72	0.33	S	20.58	-11	88	0.32
C	7.74	-7	61	0.22	T	35.87	0	84	0.43
D	14.68	-15	75	0.33	U	44.92	0	121	0.37
E	27.43	-2	80	0.36	V	15.88	3	41	0.34
F	2.28	-11	22	0.40	W	18.05	-31	79	0.45
G	3.88	-8	44	0.23	X	40.50	0	90	0.45
H	18.43	-5	81	0.27	Y	23.85	0	62	0.38
I	3.72	-11	18	0.51	Z	29.84	-4	251	0.13
J	5.54	-6	15	0.55	ZA	19.98	-27	251	0.17
K	3.21	-10	20	0.44	ZB	27.32	-18	261	0.16
L	4.25	-16	22	0.53	ZC	44.77	-4	253	0.19
M	2.57	-9	16	0.46	ZD	78.61	0	203	0.39
N	5.83	-10	40	0.32	ZE	49.73	1	217	0.23
O	9.78	-11	73	0.25	ZF	57.30	0	210	0.27
P	5.97	-9	31	0.37	ZG	38.50	-2	207	0.19
Q	12.05	-8	81	0.23	ZH	42.10	-3	175	0.25

5.2 HI value of square grid

Hypsometric integral values have been found for each square grid of the study area ranges from 0.09 to 0.54 (Table 2). 62 square grids considered to calculate Hi value of this area. The border square grid also considered for the calculation.

TABLE 2: HYPSOMETRIC INTEGRAL (HI) BASED ON REGULAR SQUARE GRIDS OF THE AREA.

Grid	Mean Elevation (m)	Min Elevation (m)	Max Elevation (m)	HI	Grid	Mean Elevation (m)	Min Elevation (m)	Max Elevation (m)	HI
a	10.23	-9	58	0.29	l	7.57	-10	42	0.34
aa	17.05	6	32	0.42	ll	13.43	-2	45	0.33
ab	6.49	-3	19	0.43	m	22.66	-4	73	0.35
ac	15.09	-2	73	0.23	mm	21.44	-4	74	0.33
ad	33.02	-1	104	0.32	n	9.50	-8	57	0.27
ae	5.25	-11	54	0.25	nn	15.69	-21	73	0.39
af	3.03	-10	38	0.27	o	42.03	0	90	0.47
ag	3.39	-17	52	0.30	oo	19.76	-1	76	0.27
ah	3.35	-11	32	0.33	p	30.94	0	81	0.38
ai	3.79	-10	30	0.34	pp	66.87	4	251	0.25
aj	1.73	-5	21	0.26	q	18.18	-4	42	0.48
b	7.39	-8	53	0.25	qq	6.33	-18	72	0.27
bb	37.84	2	83	0.44	r	22.15	-1	42	0.54
c	12.70	-5	62	0.26	rr	77.61	-1	261	0.30
cc	29.73	5	59	0.46	s	36.66	-5	88	0.45
d	22.54	-7	72	0.37	ss	14.51	-3	188	0.09

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dd	16.44	1	41	0.39	t	17.56	1	46	0.37
e	10.08	-8	48	0.32	tt	73.04	-2	249	0.30
ee	48.50	0	126	0.38	u	16.09	2	37	0.40
f	36.57	5	81	0.42	uu	44.37	-3	244	0.19
ff	34.56	6	78	0.40	v	19.43	-11	77	0.35
g	8.52	-15	48	0.37	vv	72.43	0	223	0.32
gg	12.29	-14	43	0.46	w	11.98	-3	55	0.26
h	26.88	2	77	0.33	ww	37.49	-8	224	0.20
hh	27.04	-3	90	0.32	x	12.40	-1	25	0.52
i	4.17	-11	42	0.29	xx	44.47	-4	210	0.23
ii	30.42	0	88	0.35	y	27.13	1	84	0.31
j	10.81	-6	49	0.31	yy	8.02	-7	36	0.35
jj	17.22	-31	56	0.55	z	12.93	0	41	0.32
k	2.05	-8	20	0.36	zz	5.81	-6	29	0.34
kk	3.99	-37	52	0.46	zza	8.73	-4	58	0.21

6 DISCUSSIONS

Hypsometric integral value has been found for regular square grids of the study area and each value has been plotted in map to find out whole area value. The map (Fig. 4) based on table-1 data shows HI value distribution for regular square grids. The map drawn from the HI value obtained for the 62 regular square grids. In the map, HI value is greater than 0.5 found in the middle three region of the study area. Two place of the Maheshkhali upazila showed greater than 0.4 value of HI. The contour map (Fig. 4) shows that the Ukhia and Ramu upazila have greater value of Hi and have greater than 4 Hi values and also found greater than 5 Hi value indicating mature and youthful stage of dissection of the area. Some of the areas of Maheshkhali upazila have greater than 4 Hi value indicating youthful stage of dissection. Besides lower Hi values found in the Teknaf upazila and some of Cox's Bazar sadar Upazila.

Hypsometric integral values for 34 basins and sub-basins have been plotted in the map for contouring. The map (Fig. 5) based on table-2 data shows HI value distribution for basins and sub-basins of the study area. In the map, Hi value has been found greater than 4 in the Ukhia upazila of the study area and also the southern side of Maheshkhali upazila and northern Cox's Bazar sadar upazila have greater than 5 values indicating youthful and mature stage of dissection. Besides this, the lower value of Hi has been found in the Teknaf upazila.

6.1 Comparison and suitability of method for Hi analysis

The Hi contour maps for basins and regular square grids comparison shows some similar range of values. The intensity of values is different in some area. The comparison of Figure-4 and Figure-5 showed that the Hi values in Ukhia Upazila have some similarities but regular square grid showed higher Hi value in Ramu Upazila. Beside this, the Hi values in Maheshkhali have some differences. The basin based Hi value of southern Maheshkhali and northern Cox's Bazar sadar shows higher than the square gird based value. But in case of northern Maheshkhali and Teknaf Upazila, the maps showed similar range of values and distribution. Also the distributions of Hi values are similar in Ukhia and Middle Maheshkhali Upazila.

Zakaria [10] studied the relative tectonic activity of this study area. He also used basin based Hi value for his study. He showed that the basin of Ukhia upazila, southern Maheshkhali and northern Cox's Bazar sadar are experiencing relatively high tectonic activity in this area. Although according to El Hamdouni et al. [20], the hypsometric integral does not relate directly to relative active tectonics and high values of the index generally mean that not as much of the uplands have been eroded and may suggest a younger landscape, perhaps produced by active tectonics. So, it can be say that in this case the Hi value analysis on both basins based and square grid based have some similarities but basins based analysis are more accurate for this study area.

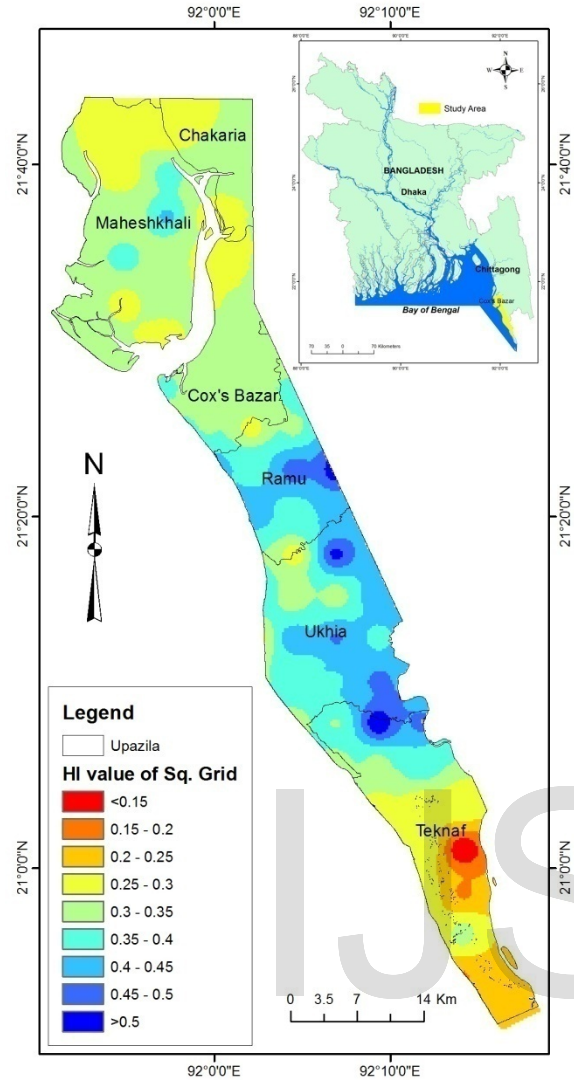

Fig. 4: HI contour map based on regular square grids of the study area.

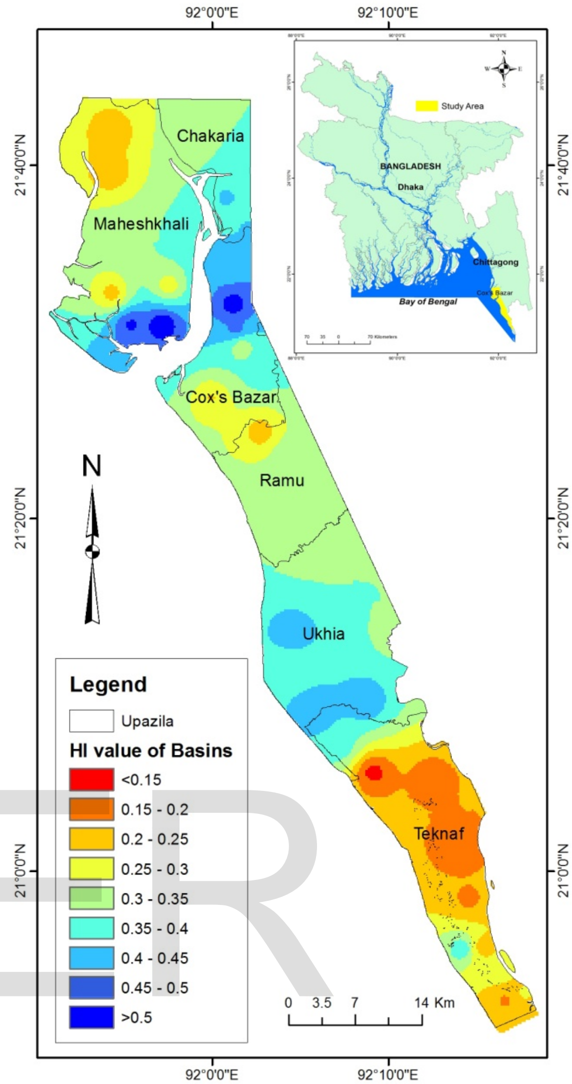

Fig. 5: HI contour map based on basin and sub-basin of the study area

7 CONCLUSIONS

Many author said that hypsometric integral value for regular square grid of an area do not strictly represent a measure of dissection. On the other hand drainage basins and sub-basins based analysis of hypsometric integral is most common used method for researcher. But some of case has different response for both basis of method. In this study area the regular square grid and drainage basins based hypsometric integral have been analysis. For the square grids the study area has been divided into 62 square grids and has been comprise 34 drainage basins.

The Hi contour maps for basins and regular square grids comparison shows some similar range of values. The intensity of values is different in some area. The comparison of both methods shows that the Hi values in Ukhia Upazila have some similarities but regular square grid showed higher Hi value in Ramu Upazila. Beside this, the Hi values in Maheshkhali have some differences. The basin based Hi value of southern Maheshkhali and northern Cox's Bazar sadar shows higher than the square gird based value. But in case of northern Maheshkhali and Teknaf upazila, the maps showed similar range of values and distribution. Also the distributions of Hi values are similar in Ukhia and Middle Maheshkhali upazila. Finally this case the Hi value analysis on both basins based and square grid based have some similarities but basins based analysis are more accurate for this study area.

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