Chapter 4
Structural Classification and monitoring of impounded Water bodies

Fish farming has actually been running for thousands of years. The fish farming or pisciculture has converted from 'humble beginning' into fishing industry, today (Julie, 2016). The detail about the rapid growing fish industry is discussed in chapter 1. Fish industry directly related with available fish farm, distribution of existing suitable water bodies, fish production etc. It involves the commercial raising of fish in tanks or enclosures, such as fish ponds, fish farms etc.

This chapter focuses on impounded waterbody distribution & growing pattern, density measurement, concentration status and their classification. First of all, the distributions of water bodies were mapped by visual interpretation technique from high resolution satellite data of four years interval i.e. 2010, 2014 and 2018. Further, the time series thematic layers are categorized into water class based on their area and characterize spatial distribution pattern. The growth rate (GR), density and entropy analysis method have been applied to characterize the temporal and spatial distribution. The most important distinction between conventional indices and entropy analysis of spatial distribution is the value with its value of zones, continuous with the number of observations.

Growth rate (GR) describes the changes over time while density reflects the distribution of an entity in respect to space. On the other hand, the time scale analysis helps to manage and make a decision for future planning. Therefore, the analysis of growth rate and density measurement is very important consideration for present status of impounded water body and its distribution. This section contained and described by the characteristics that include: (1) Variable size (Class), (2) Variable growth and (3) Variable density.

4.1 Size and classes of water body

Considering fisheries resources, a uniform concept is essential for categories of the various freshwater resources. The reservoir, lake, estuary, brackish water impoundments, river, freshwater pond and tank etc, are categories as inland fisheries resources (Gupta et al., 1991). Ponds are usually shallow excavated water bodies. The water bodies having an area less than 5 ha. with full water level known as pond while an average 5-10 ha. water bodies are classified as a tank (Gupta et al., 1991). A documentary handbook, department of Fisheries, West Bengal mentioned the pond categories like smaller water bodies (0.032 - 0.4 ha.), small water bodies (0.4 - 1 ha.), medium water bodies (1 - 2 ha.) and large water bodies (>2 ha.). The water bodies having an area less than 0.032 ha. are not categories as a pond. Kumar D. (1992) outlined that the pond having 0.02 to 0.06 ha. area is suitable for nurseries (Depth: 1 to1.5 m) while the 0.06 to 0.10 ha. (Depth: 1.5 to2 m) are preferable as rearing ponds (RP). The undrainable ponds with 0.25 to 1.0 ha areas were recommended by Kumar D (Kumar, 1992).

Based on strength of the GIS, the potential fish pond is divided into three major classes in small, medium and large water bodies. Through GIS technology, water body information was generated from the high resolution satellite data of Sentinal-2B and Google earth imagery. The water bodies in this study area are classified into three classes, arranged by degree of area.

1. Small water bodies (< 0.5 ha.)
2. Medium water bodies (0.5-1 ha.)
3. Large water bodies (>1 ha.)

4.2 Growth Rate (GR):

The growth rate measures how fast the area of water body is growing. It does this by comparing the area of one year to the previous year. So the most elementary level is used to state annual innovates in variable as a percentage of growth rates. GR also explain the rate of recession or expansion of a variable. If the area of water bodies declines for two consecutive years, it is considered as a recession. Conversely, the growth of the area is increase for two successive years, deliberated as an expanding. The growth rate (GR) is defined as:

$$G_r = \frac{y_{pre} - y_{prev}}{t_{def}} \% = \frac{y_{pre} - y_{prev}}{t_{pre} - t_{prev}} \%$$

Where, G_r : Growth rate, y_{pre} and y_{prev}: Water of present year and previous year, t_{def} : Time duration, t_{pre} and t_{prev}: present year and previous year. In the present study, the GRs were calculated for each block of the district with the years 2000, 2014 and 2018.

4.3 Distribution of waterbody density

Density depends on size and quantities of population occur. The distribution of existing and past population can affect the growth rate and density per unit of the population (Turchin, 1999; Myrvold and Kennedy, 2015). The advancement of GIS is valuable to deriving the kernel density (KD). Kernel density is a nonparametric way to estimate the probability density function of random variable and calculates the density of point feature around each output raster cell, based on the quadratic kernel function (Silverman, 1986). KD calculates the density of point features around each output raster cell. GIS based kernel function is capable of calculating the magnitude per unit area of agglomeration point or line features.

In the present study all individual water body plotted with individual point id using ArcGIS 10.3 software package and estimated the kernel density of per point with unit area and weight distance. The detail about workflow is presented in figure 4.1. Kernel density is useful to locate the pinpoint of agglomeration from inequalities distribution. The KD is calculated by weight distances (search radius) of all individual data points fall within the search radius. The presence of more points within the search radius of a point, the estimated result will be higher. The density of the point (new x, y location) is calculated by the equation below (Pro.arcgis, 2019).

$$KD = \frac{1}{(radius)^2} \sum_{i=1}^{n} \left[\frac{3}{\pi} pop_i \left(1 - \left(\frac{dist_i}{radius} \right)^2 \right)^2 \right]$$

Where, i is 1,…, n are the input points within the radius (weight) distance of the (x, y) location, pop_i is the optional field value of population point and $dist_i$ is the distance between point i and the (x, y) location.

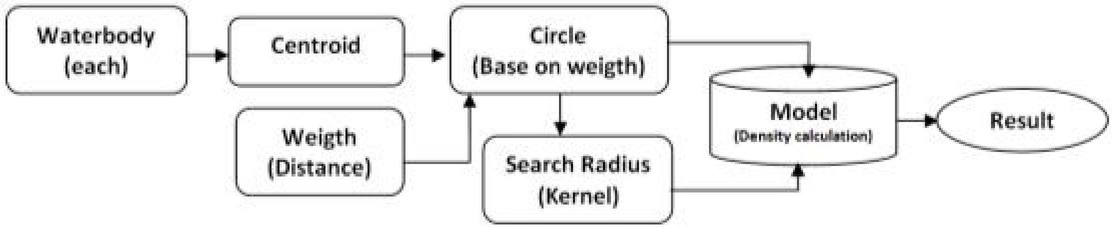

Figure 4.1 Workflow diagram of water density (KD) estimation

4.3.1 Shannon's entropy:

In the next step, Shannon's entropy method has been applied for the studies of water distribution and concentration pattern. Shannon's entropy analysis is an indicator of the degree of spatial concentration or dispersion can express the alignment and frontage of spatial patterns that is applicable on to any geographical variable. This method is also compatible with GIS. In the present study, the proximity function of the GIS has been used to generate the buffer or zone for the entropy calculation.

Here, the variables used to make a character of individual water bodies and entropy, are logarithms of probability for their layout, collectively with the relative proportion of the character. The calculation comprise that water distribution area is divided into four (4) zones, i.e. A, B, C and D (Figure 4.7). The influences of the zone in these locations were measured using the proximity functions of the GIS. The thematic layers of buffers were generated based on the proximity to centroid of high dense kernel using ArcGIS Analysis tool. Six km. buffer for each zone with one km. interval are calculated from the centroid point of highly dense KD result to calculate the absolute entropy of each zone (Figure 4.9). The variable (area of water bodies) takes as a value X_i for each zone with sub-zone i (Buffer zone: 1, 2, . . n). The values of entropy (absolute entropy) range from 0 to 1 or log (n). The value of zero (0) indicates totally concentrated or very compact distribution while log(n), for a totally dispersed distribution in nature. Shannon's absolute entropy (H_n) is calculated as:

$$H_n = \sum_{i}^{n} P_i \log\left(\frac{1}{P_i}\right)$$

$$P_i = X_i / \sum_{k}^{n} X_k$$

Here, The P_i is the probability or proportion of water bodies' area or variables within zone i.

4.4 Result and Discussion:

There are different numbers of pond and tanks of different size in area are available.

The rapid development of aquaculture, side by side water conservation policy in last few years resulted in extreme increase of impounded waterbody and tanks. In this present study the impounded water bodies over the year of 2010, 2014 and 2018 were classified into different scale and size. It has been observed that the total overall water bodies are tremendously growing from the year 2010 to 2018 (Figure 4.2). Result shows that in the year 2010, 2014 and 2018 the total area of small water bodies (< 0.5 ha.) are 4703.386, 4999.643and 5342.028 ha., respectively. In case of medium water bodies (0.5 - 1.0 ha.) class, the area of waterbody are 1493.265, 1774.247and 2043.893 ha. respectively. The large water class (> 1 ha) shows that area of waterbody are 13491.9, 17306.29 and 23885.84 ha respectively.

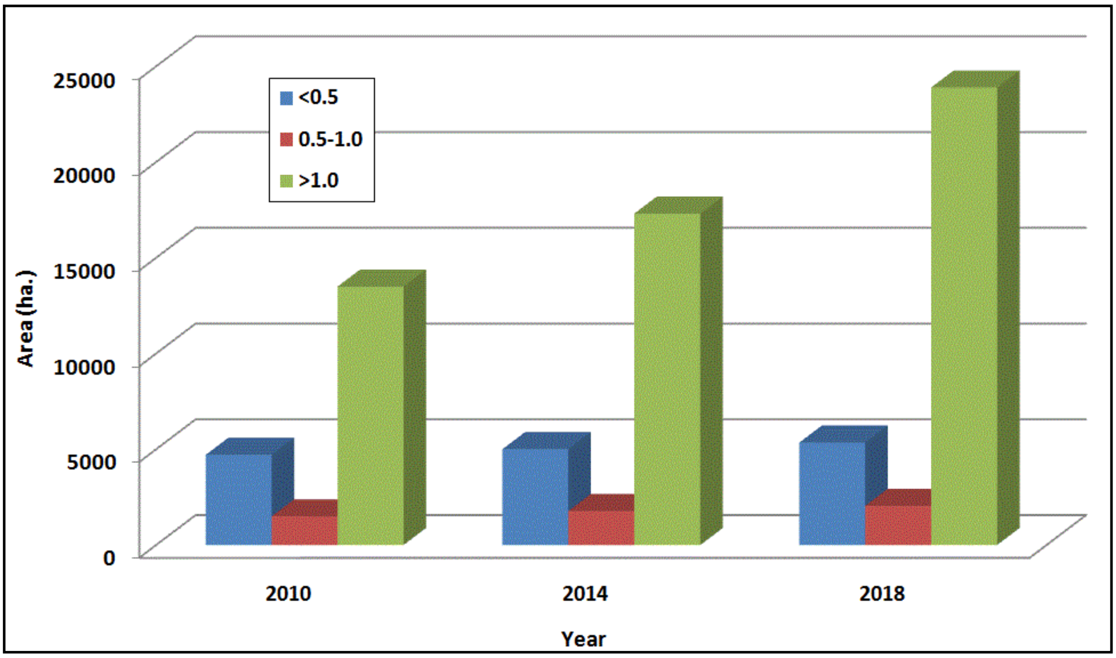

Figure 4.2 Year and class wise growth of water bodies- small water bodies (< 0.5 ha.), medium water bodies (0.5-1 ha.) and large water bodies (>1 ha.)

Table 4.1 Category wise impounded water body statistic of the district (area in ha.)

Year	2010			2014			2018		
Area of water class	**< 0.5**	**0.5 - 1.0**	**> 1.0**	**< 0.5**	**0.5 - 1.0**	**> 1.0**	**< 0.5**	**0.5 - 1.0**	**> 1.0**
No. Of waterbody	36619	2179	1725	37921	2575	2423	39666	2954	3505
Minimum	0.001552	0.500008	1.000773	0.001552	0.500008	1.000773	0.001552	0.500008	1.000728
Maximum	0.499996	0.999822	661.927	0.499996	0.999822	981.4486	0.499996	0.999822	981.4486
Sum	4703.386	1493.265	13489.61	4999.643	1774.247	17295.42	5342.028	2043.893	23874.94
Mean	0.128441	0.685298	7.82139	0.131844	0.689028	7.142505	0.134675	0.691907	6.814791

The use of growth rates of water body as well as area of water body is one of the simplest methods of estimating the future growth of water body with time and space. In the last 8 years since 2010 the impounded waterbody of most of the community development block has been increased sustainably. Between 2010 and 2014, the highest rates of growth in the district were experienced in Moyna, Contai – III, Tamluk, Contai-II, Bhagwanpur- II and Nandakumar block and between 2014 to 2018 the maximum growth rates has been observed in the block of Moyna, Tamluk, Nandakumar, Panskura- II, Sahid Matangini and Panskura- I (Figure 4.3). The details about growth rates of these investigated years are presented in the Table 4.2.

Table 4.2 Growth rate (GR) of impounded water body of Purba Medinipur district

Sl.No.	Blocks		Area (ha.) of Waterbody			Growth rate (GR) in %	
	Block Name	**Area (ha.)**	**2010**	**2014**	**2018**	2010-2014	2014-2018
1	Ramnagar -I	13144.73	1395.45	1409.65	1437.33	0.32	0.38
2	Ramnagar -II	15997.12	2309.04	2271.65	2384.55	-0.85	1.57
3	Contai – I	17202.13	640.08	678.39	911.05	0.87	3.24
4	Contai – II	17645.33	2232.51	2721.81	2910.06	11.16	2.62
5	Egra - II	18469.75	248.91	297.78	357.67	1.12	0.83
6	Egra - I	21797.42	421.43	420.85	434.55	-0.01	0.19
7	Contai – III	16064.79	590.66	1217.29	1509.58	14.30	4.06
8	Khejuri - II	13506.21	635.02	844.28	950.69	4.77	1.48
9	Khejuri - I	12314.35	481.58	729.24	824.12	5.65	1.32
10	Bhagawanpur - II	18184.34	559.99	941.70	1019.76	8.71	1.09
11	Nandigram - I	16484.65	665.38	910.66	1187.05	5.60	3.84
12	Potashpur -II	19174.05	320.09	335.98	363.09	0.36	0.38
13	Nandigram - II	10578.92	348.30	406.47	492.66	1.33	1.20
14	Potashpur -I	17463.53	320.09	311.63	314.61	-0.19	0.04
15	Bhagawanpur - I	18485.13	1434.46	1461.31	1606.36	0.61	2.02
16	Nandigram - III	13971.75	662.52	770.80	940.79	2.47	2.36
17	Haldia	12688.77	569.89	602.79	732.99	0.75	1.81

18	Sutahata	11123.61	341.31	392.01	481.80	1.16	1.25
19	Nandakumar	16096.40	1048.93	1319.19	1980.65	6.17	9.20
20	Moyna	15554.28	2645.14	3291.65	5176.71	14.75	26.21
21	Panskura -I	24926.75	509.58	526.20	761.11	0.38	3.27
22	Sahid Matangini	9458.18	163.65	288.06	621.99	2.84	4.64
23	Panskura -II	15110.95	336.34	451.69	864.23	2.63	5.74
24	Mahisadal	13114.18	524.14	635.56	786.59	2.54	2.10
25	Tamluk	12821.03	281.77	832.67	2210.87	12.57	19.16

Depending on the collected data the kernel density is estimated of the present water bodies. The density of total impounded water bodies of the district has been measured of three different years of 2010, 2014 and 2018. The density values show that high density in four places of i.e. Moyna, Bhagwanpur-II, Contai-II and Ramnagar-II blocks throughout the district (Figure 4.4 to 4.7) and these highly dense areas are named as zone A, B, C, D respectively for further analysis. According to the data from 2010 to 2018 there is a distinctive difference of the water density is observed and a stretched values along a color ramp map of each year is prepared showing in Figure 4.4 to 4.7.

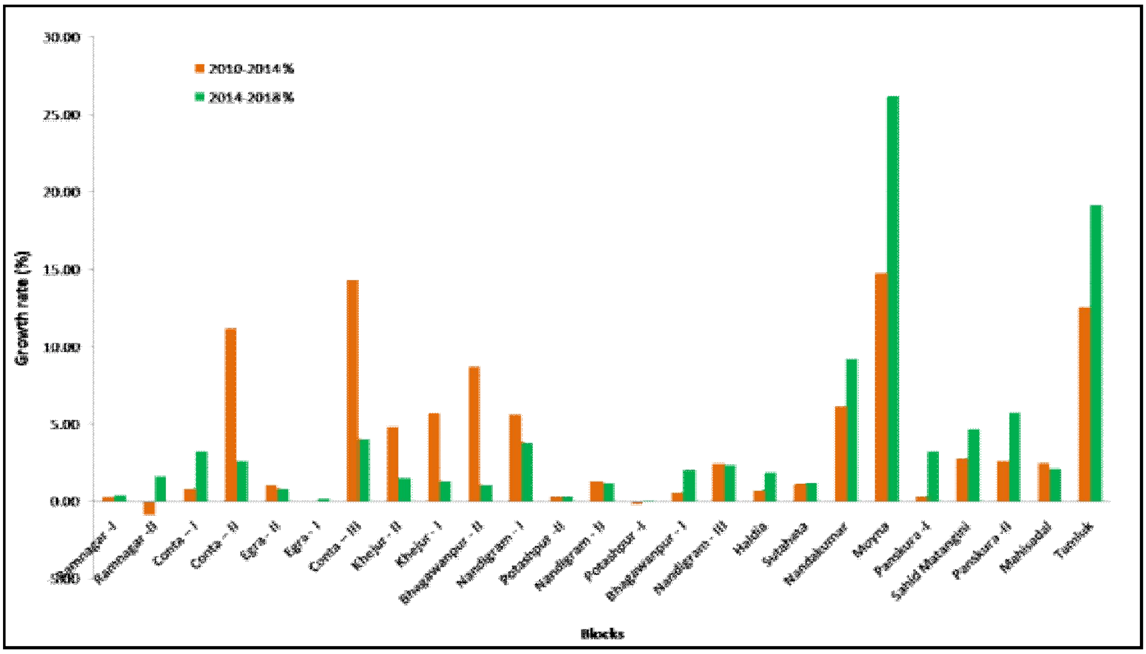

Figure 4.3 Year wise GR of impounded water body of Purba Medinipur district

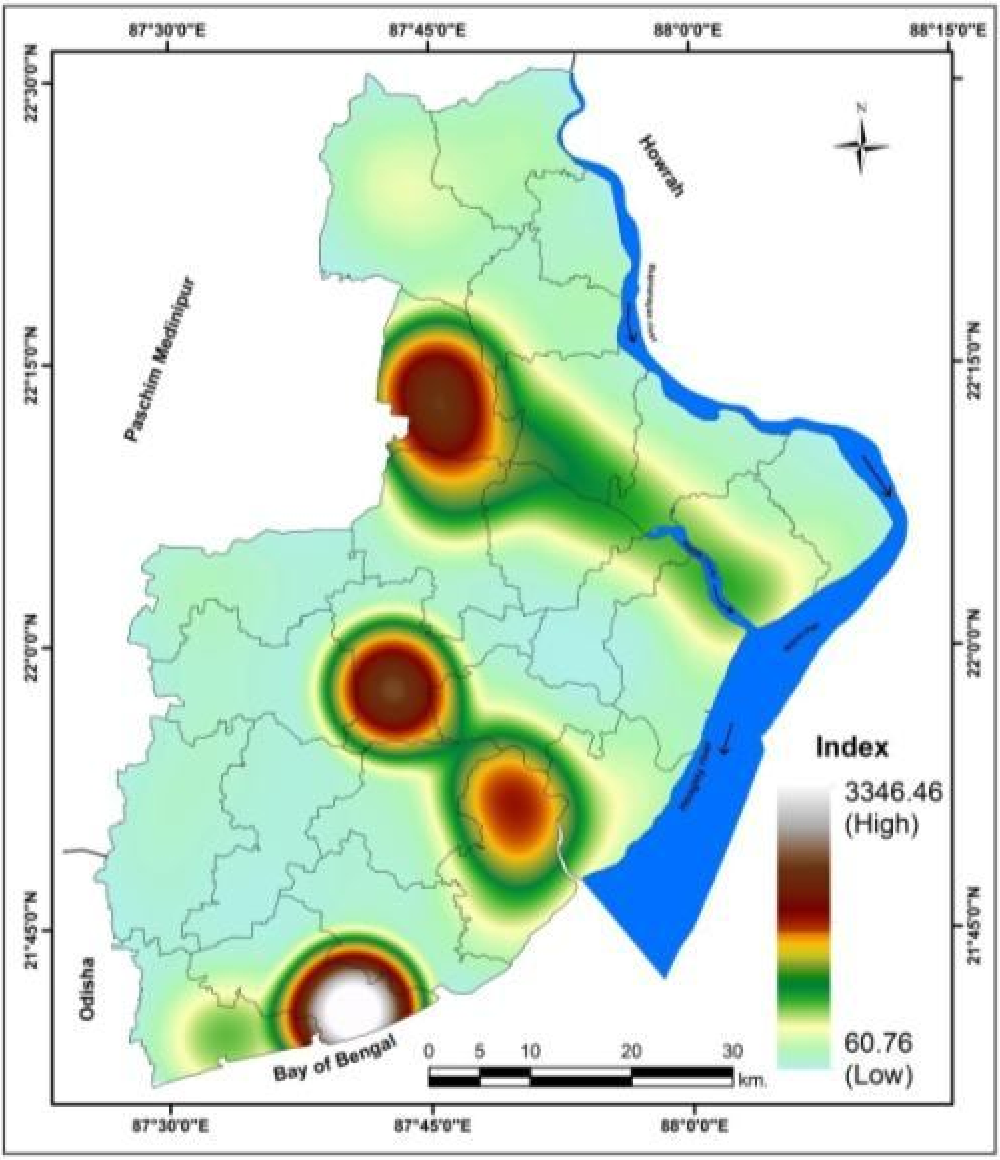

Figure 4.4 Density distribution of impounded water body, 2010

In respect to the area of pond water bodies, it is clear that in 2010 it was 22790.02 ha., increased to 27006.71 ha. in 2014 and reached a peak at 34202.88 ha. in 2018. The district statistical data indicate that the net area under effective pisciculture of the Purba Medinipur district is 22302.05 ha. in 2010-2011 and increased to 22912.24 ha. in 2014 (District Statistical Handbook, 2010-2011 and 2014).

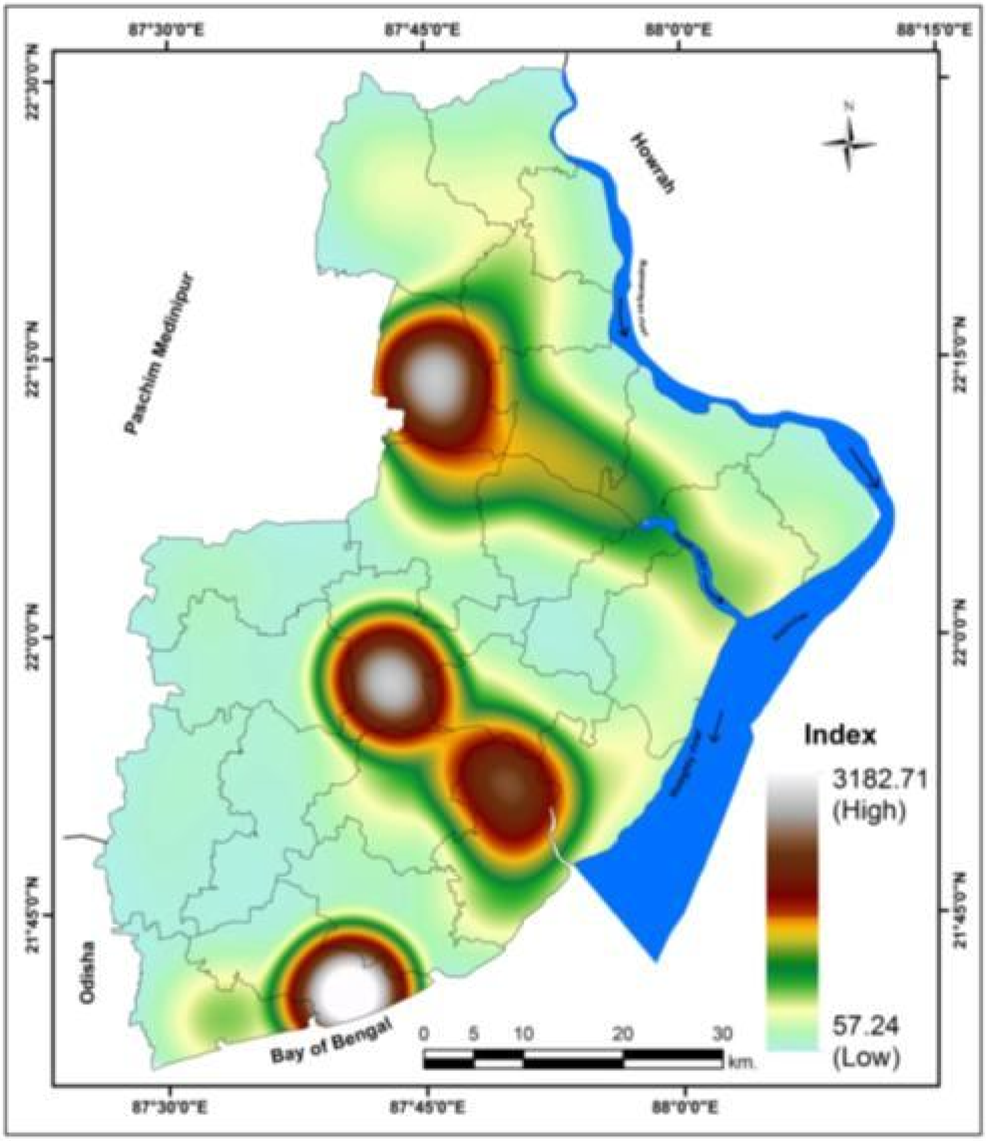

Figure 4.5 Density distribution of impounded water body, 2014

It is observed that Shannon's Entropy is the effective method for sprawled growth and identify the pattern of growth (Li and Yeh, 2004). The calculated absolute Shannon's entropy for the four zones (A, B, C and D) are shown in Table 4.3. The Shannon's entropy, represent the maximum possible value of log(10) is 1 that represents a totally dispersed distribution pattern. The absolute Shannon's entropy of zone A is 0.7459 in 2010 decreasing gradually 0.7442 in 2014 and 0.7323 in 2018. This type of growth pattern is indicating the compact distribution of water body from 2010 to 2018. Similarly, the compact growth pattern has also been observed in zone D, 0.7360, 0.7334, and 0.7318 in 2010, 2014 and 2018, respectively. On the other hand, the dispersed distribution pattern has been observed at zone B and C (Table 4.3). The comparison of entropies of four zones is presented in figure 4.8. On the other hand, the dispersed distribution pattern has been observed at zone B and C (Table 4.3). The comparative results of entropy analysis have been presented in figure 4.7. The graph (figure 4.8) is showing the gradually compact distribution of zone A (Moyna area), as the value of absolute entropy's are decreasing from 2010 to 2018 in respect to others zone.

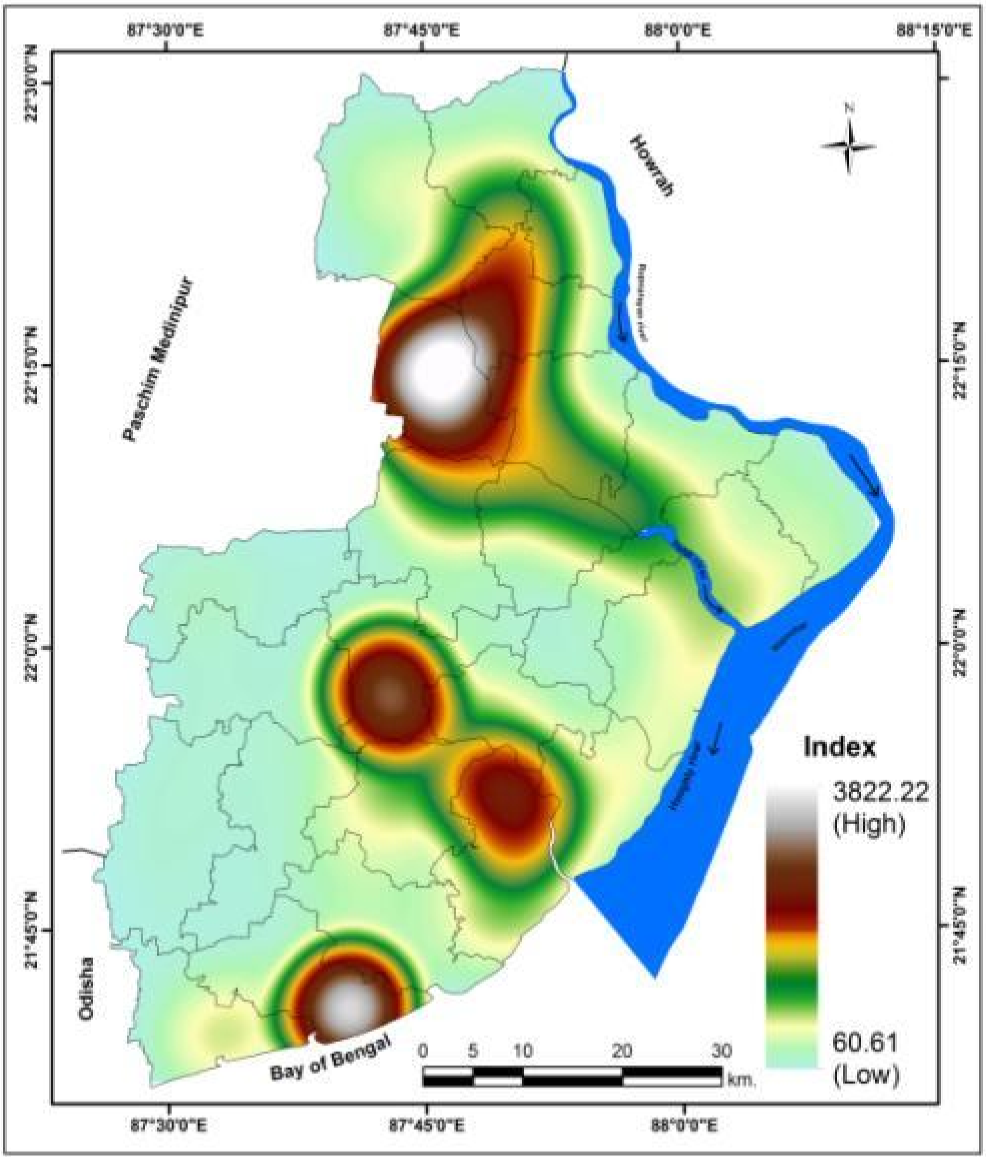

Figure 4.6 Density distribution of impounded water body, 2018

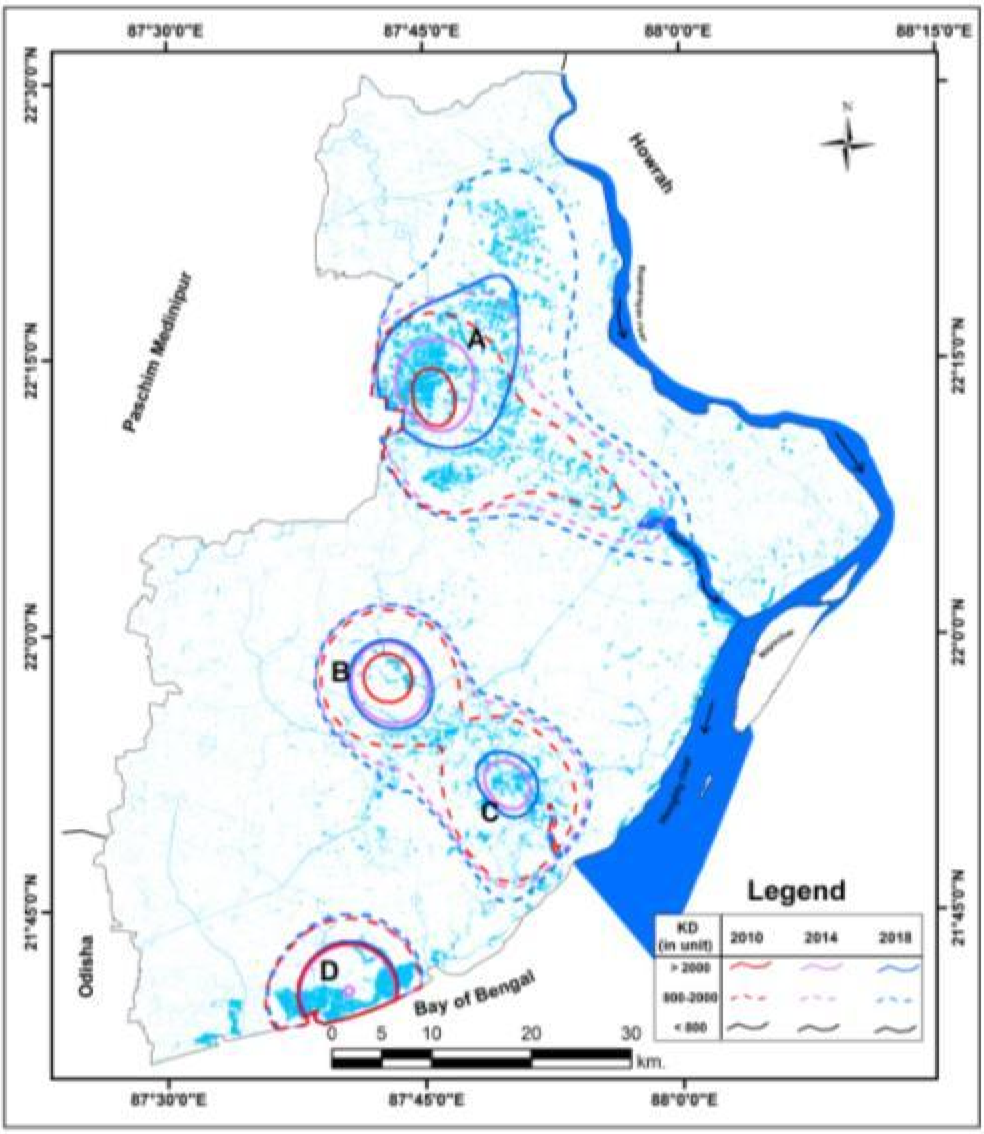

Figure 4.7 Simultaneously change of water body density, 2010, 2014 and 2018

Figure 4.8 Comparison of absolute entropy of each zone (A, B, C and D)

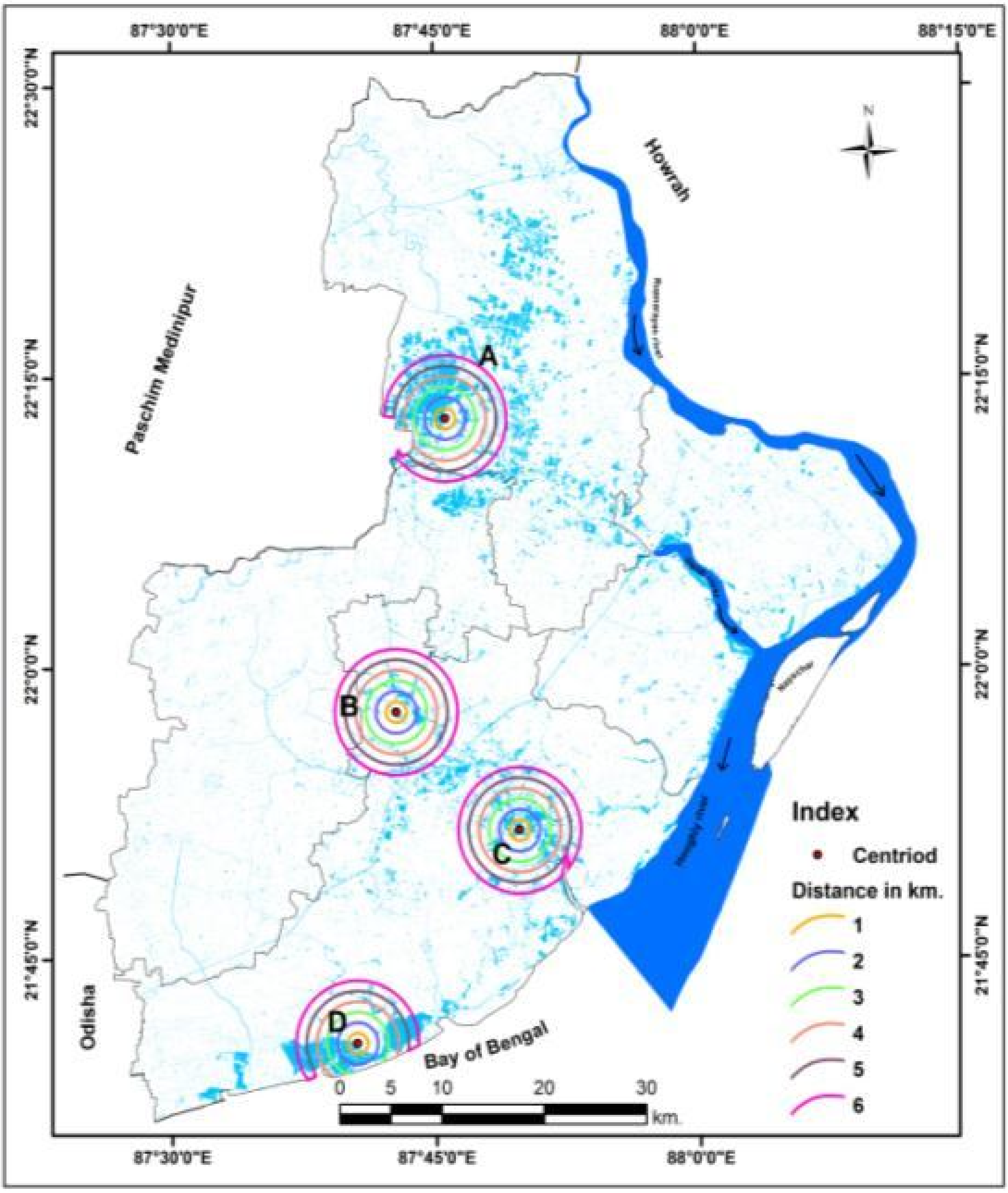

Figure 4.9 Distribution four zones with sub-zone (1-6 km.)

Other than the Google Earth imagery, there is not an option to extracting real-life status of the earth features (Dutta et al., 2016). Existing pond and aquaculture farms are not properly identified from Landsat or Sentinel-2B images. Therefore, existing pond and aquaculture have been identified from temporal high resolution Google Earth imagery. The newly created or rapid growing farms and ponds are prevalent in the area which leads to massive change in the land use pattern (Figure 4.10, 4.11).

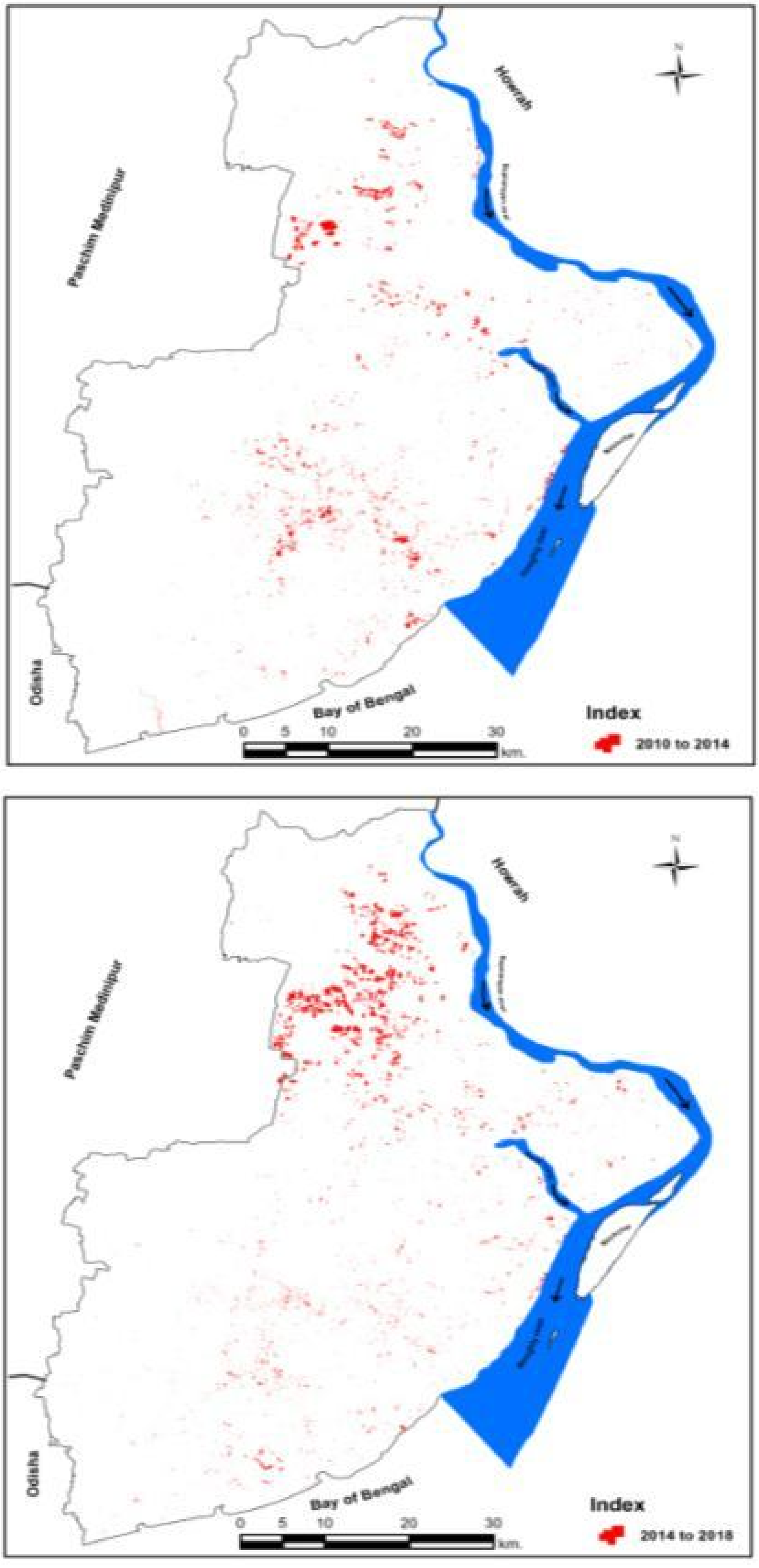

Figure 4.10 Water changing scenario of 2010 to 2014 to 2018

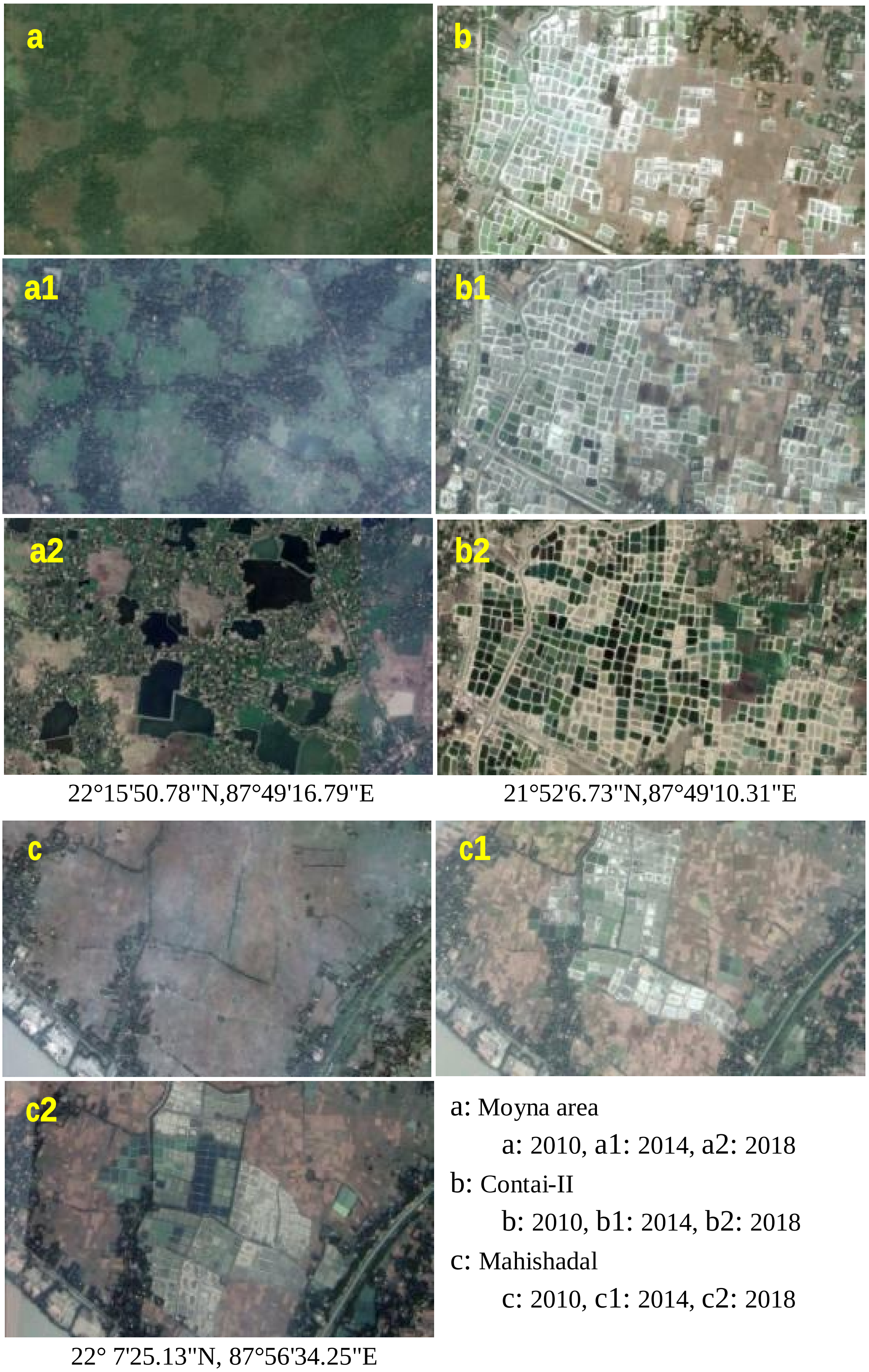

Figure 4.11 Google Earth map showing the spatio-temporal changes in water bodies of 2010, 2014 and 2018

4.4.1 Relationship between geomorphology and concentration of water bodies

On the basis of topographic characters of Purba Medinipur district following areas of geomorphic significance are categorized into following ways:

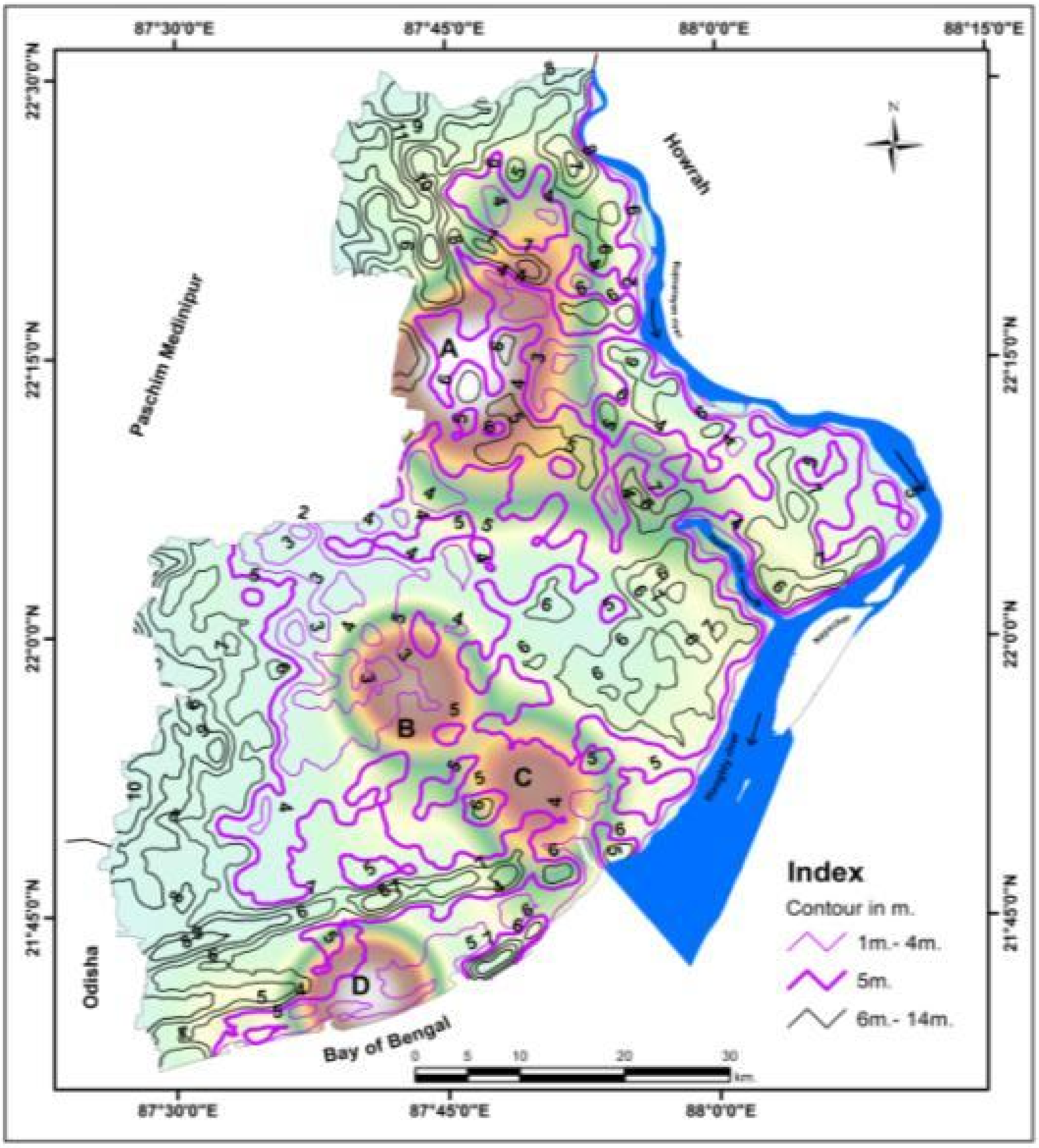

Figure 4.12 Relationship between geomorphology and concentration of water bodies

A. Moyna Basin (North eastern part of Haldi River estuary)

B. Patashpur Bhagawanpur Basin, drained by Kaliaghai River (Along the Rasulpur Kaliaghai confluence)

C. Hizili Rasulpur Basin (Along the downstream section of Rasulpur River)

D. Dubda Basin (Upstream section of Champa River and Paniparul areas)

The elevation of above basin surfaces is ranging from 2.5 to 3.5 mt. Remaining areas of the district is lying above 5mt contour from the MSL.

Most of the surface water bodies are situated around the basins or in the topographic depressions.

2.4 Summary

This chapter summarized the chronological 'impounded water bodies' distribution status of Purba Medinipur district. This chapter also discussed about the area wise classification, growth rate, density measurement and characteristic concentration pattern analysis of impounded water bodies. It has been observed that from 2010 to 2018 the total overall water body is increasing enormously. The result shows that the area of pond water bodies in 2010 was 22790.02 ha. increased to 27006.71 ha. in 2014 and reached a peak at 34202.88 ha. in 2018. The present water body density shows high density at four places in Moyna, Bhagwanpur-II, Contai-II and Ramnagar-II blocks across the district. A distinct difference in water density can be observed from 2010 to 2018 data. The absolute Shannon's entropy for the four zones (A, B, C and D) have been calculated and the result indicating the compact distribution of water body from 2010 to 2018 in the zone A and D. Conversely, the dispersed distribution pattern has been observed in case of zone B and C. The gradually highest compact distribution pattern observed at zone A (Moyna area), as the values of absolute entropy's are decreasing from 2010 to 2018 in respect to others zone. Relationship between geomorphology and concentration of water bodies of entire study area was also analyzed and it has been observed and it might be concluded that most of the surface water bodies are situated around the basins or in the topographic depressions.

Table 4.3 Calculated values for absolute entropy

Zone	Distance (km.)	X_i			P_i			$1/P_i$			$\log(1/P_i)$			$P_i * \log(1/P_i)$		
		2010	**2014**	**2018**	**2010**	**2014**	**2018**	**2010**	**2014**	**2018**	**2010**	**2014**	**2018**	**2010**	**2014**	**2018**
	1	156.39	156.39	153.38	0.064006	0.052747	0.038772	15.6236	18.95856	25.79199	1.193781	1.277805	1.411485	0.076409	0.0674	0.054726
	2	428.35	428.35	449.29	0.175304	0.144467	0.113569	5.704368	6.922002	8.805225	0.756208	0.840232	0.94474	0.132566	0.121386	0.107293
	3	597.88	674.98	751.15	0.244686	0.227648	0.18987	4.08687	4.392753	5.266751	0.611391	0.642737	0.721543	0.149599	0.146318	0.137
A	4	571.01	650.44	842.98	0.23369	0.219372	0.213083	4.279176	4.558469	4.693002	0.63136	0.658819	0.671451	0.147542	0.144526	0.143075
	5	324.53	615.45	908.42	0.132815	0.207571	0.229626	7.529284	4.817634	4.354915	0.876754	0.682834	0.63898	0.116446	0.141736	0.146726
	6	365.29	439.41	850.88	0.149499	0.148197	0.21508	6.688988	6.747754	4.649429	0.82536	0.829159	0.6674	0.123391	0.122879	0.143544
	Sum	**2443.45**	**2965.02**	**3956.10**							**Absolute entropy (H_n)**			**0.745953**	**0.744245**	**0.732364**
	1	1.87	38.62	37.84	0.002764	0.036785	0.033297	361.8093	27.18464	30.03313	2.55848	1.434324	1.477601	0.007071	0.052762	0.049199
	2	139.15	160.24	158.40	0.206011	0.152634	0.139391	4.85411	6.551621	7.174089	0.68611	0.816349	0.855767	0.141346	0.124603	0.119286
	3	130.38	213.69	225.13	0.193022	0.203544	0.198105	5.18075	4.912953	5.04783	0.714393	0.691343	0.703105	0.137894	0.140718	0.139289
B	4	98.92	205.30	224.78	0.146449	0.195553	0.197801	6.828308	5.113702	5.055578	0.834313	0.708735	0.703771	0.122184	0.138595	0.139207
	5	126.03	191.21	211.71	0.186589	0.182129	0.186297	5.359365	5.490605	5.36778	0.729113	0.73962	0.729795	0.136045	0.134707	0.135958
	6	179.11	240.79	278.55	0.265167	0.229356	0.245113	3.771207	4.360039	4.079757	0.57648	0.63949	0.610634	0.152864	0.146671	0.149674
	Sum	**675.46**	**1049.85**	**1136.40**							**Absolute entropy (H_n)**			**0.697404**	**0.738056**	**0.732613**
	1	100.10	122.96	127.57	0.050353	0.051653	0.050337	19.85981	19.35988	19.86627	1.297975	1.286903	1.298116	0.065357	0.066473	0.065343
	2	282.52	337.15	349.36	0.142113	0.141626	0.137851	7.036635	7.060866	7.254235	0.847365	0.848858	0.860592	0.120422	0.12022	0.118633
	3	369.85	444.40	466.80	0.18604	0.186679	0.184191	5.375192	5.356783	5.429144	0.730394	0.728904	0.734731	0.135882	0.136071	0.135331
C	4	498.18	580.21	607.12	0.250591	0.24373	0.239558	3.990561	4.102904	4.174346	0.601034	0.613091	0.620588	0.150614	0.149429	0.148667
	5	340.67	387.59	417.94	0.171361	0.162817	0.164911	5.835634	6.14185	6.063884	0.766088	0.788299	0.782751	0.131278	0.128349	0.129084
	6	396.69	508.23	565.54	0.199541	0.213494	0.223152	5.011489	4.683966	4.481258	0.699967	0.670614	0.6514	0.139672	0.143172	0.145361
	Sum	**1988.01**	**2380.54**	**2534.33**							**Absolute entropy (H_n)**			**0.743225**	**0.743714**	**0.742419**
	1	100.24	89.66	92.84	0.035428	0.0325	0.031661	28.2264	30.76933	31.58457	1.450656	1.488118	1.499475	0.051394	0.048364	0.047475
	2	397.76	385.10	395.24	0.14058	0.139586	0.134781	7.1134	7.16405	7.419452	0.852077	0.855159	0.870372	0.119785	0.119368	0.117309
	3	567.26	538.77	562.93	0.200486	0.195288	0.191969	4.987874	5.12063	5.209186	0.697915	0.709323	0.71677	0.139922	0.138523	0.137597
D	4	628.38	613.45	652.44	0.222088	0.222357	0.22249	4.502718	4.497276	4.494589	0.653475	0.65295	0.65269	0.145129	0.145188	0.145217
	5	591.05	595.20	641.12	0.208894	0.215743	0.218631	4.78712	4.635135	4.573916	0.680074	0.666062	0.660288	0.142063	0.143699	0.144359
	6	544.73	536.67	587.87	0.192523	0.194526	0.20047	5.194179	5.140695	4.988268	0.715517	0.711022	0.69795	0.137754	0.138312	0.139918
	Sum	**2829.41**	**2758.84**	**2932.43**							**Absolute entropy (H_n)**			**0.736047**	**0.733453**	**0.731876**