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RESEARCH ARTICLE

GIS AND REMOTE SENSINGBASED RECONNAISSANCE OF VEGETATION ANDAGROFORESTRY AREAS IN SOUTH 24 PARGANAS, WEST BENGAL, INDIA

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Abstract

Accessing the advantages of combining GIS with remote sensing could be better utilised for specifying vegetation cover including agroforestry systems in South 24 Parganas district with farm lands and ponds historically shaped out of mostly swampy lands covered with jungles and the Sundarbans crisscrossed with creeks and rivers in the south-easternmost part of West Bengal state in India by image processing based on updating of data or information in the form of maps or attributes. Such analysis for this district was performed mostly at the intervals of five years from 2005 to 2019.Changes in expanse of vegetation areas were classified in land coverage under deforestation and revegetation. Such changes are distinguishable through NDVI image values in the form of maps of the district and subdivisions, created on the Arc GIS 10.8 and ERDAS Imagine 2015 platforms by retrieving data of Landsat 4 - 5 TM Level 1 and Landsat 8 OLI/ TIRS Level 1 imageries as retrieved from USGS website. Healthy vegetation including agroforestry were sorted out through demarcation of highest indices of NDVI data. Areal extents of less than 10 ha of healthy vegetation were sorted out as areas either under new plantation or horti-agri or agroforestry. Individual agroforestry systems were found out with the help of Google Earth Pro. Monitoring of vegetation cover as well as agroforestry will be helpful to achieve SDG 15 and, thereby SDG 2 and 8 as defined by the UN for conservation of life on land as well as zero hunger including decent work and economic growth.

Introduction:-

Forests are vital resources in sustaining the livelihoods of millions of peoples. Provision of fuel wood, wildlife habitat and purification of air and overall maintenance of ecological balance on the land are all possible due to forests and woodlots covering about 40 per cent of the global land surface area [1], though interaction of waterbodies has great impact in this regard. Now, according to FAO and [2] forests are covering about 31 percent, reckoning to be about 4,617 million ha, of the world's land surface. However, year after year advancing trend of overexploitation of forest resources through deforestation is imposing a great challenge [1], while UNEP has pointed towards constantly increasing population in this regard [3]. Those activities are affecting nature's long-established balance in biodiversity, water, catchment and are also causing increase of greenhouse gases in atmosphere [4].

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Consequently, those are severely affecting biotic communities, soil resources, surface temperature, economic status of adjacent local community and, thereby, the economies of all the nations [5].

Geographic Information System (GIS) supported with remote sensing is the realistic approach to enumerate, to identify and to particularize a geomorphic feature including land use – land cover aspects. Denudation and degradation of forest cover change caused by natural and/ anthropogenic factors as enumerated by [6] can be effectively managed through growing of trees outside forests by application of various means of agroforestry technologies. Humans play the major role for exhausting natural resource reserve, e.g., forests to meet their basic needs. To overcome this situation agroforestry is potential enough in provisioning a variety of functions or benefits to farmers and communities. In this regard most easily, identifiable resources are the tree products including services provided by trees towards biodiversity and microclimate regulation. Additionally, like natural forests agroforestry serves for carbon sequestration, restoration of degraded land, and other ecosystem services as well [7,8,9,10,11,12]. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services admitted high potential of synergistic effect of agroforestry in conserving life on land, i.e., SDG 15 for which strong drivers could be SDG 2 (zero hunger) and goal 8 for decent work and economic growth [13]. Through dissemination of outcomes of agroforestry research farmers are now aware to follow various activities agroforestry systems in West Bengal [14, 9,15].

In the context of food security in changing climate in present times, use of remote sensing data has become a dependable tool for watching the variation in pattern of vegetation and its areal coverage in a given location over a period of time. For this purpose, vegetation indices (Normalized Difference Vegetation Index: NDVI) are widely used as well as reliable indicators [16]. The Visible, NIR and Mid-Infrared portions of the electromagnetic spectrum (EMS) bands all have the cumulative role in differentiating the ranges of these indices. The NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and the NIR has high reflectance because of the internal reflectance by the mesophyll spongy tissue of green leaf [17] and it can be calculated as a ratio of Red and NIR bands of a sensor system. NDVI values range from -1 to +1, where healthy vegetation shows NDVI values between the 0.3 to 1, besides the non-vegetated area like water body, open land shows NDVI values even lower values and near about zero due to high reflectance in both the visible and NIR portions of EMS [16].

Historically farm lands and ponds were carved out of the Sunderbans and jungle-studded lands mostly with swamps and low terrains crisscrossed with creeks and rivers through various types of land shaping [18] and clearing of jungles and reclamation of marshy lands in coastal areas in south 24 Parganas district of southernmost part of the state of West Bengal in India. This paper discusses recent changes in vegetation cover and present status of development of agroforestry systems in that district with the help of remotely sensed data.

Materials And Methods:-

Study Area

South 24 Parganas District (22°33'45" and 21°29'00" N Latitudes., 89°04'50" and 88°03'45" E Longitudes, covering an area of about 9960 km^2) is the selected study area in the south east corner of West Bengal State in India (Figure 1). It is the largest district in the state with Bangladesh border on the east, the Bay of Bengal on the south; the Bhagirathi-Hugli, the main branch of the Ganges in India and Howrah district in West Bengal on the west and Kolkata and North 24 Parganas district on the north [19]. Prevalent Coastal alluvial soils in the district with intermingled low, medium and high lands are conspicuously characterized by many small branches of rivers, creeks, estuarine areas with jungles and many islands with mangrove vegetation in the Sunderbans in the southern portions within which farm lands and ponds were carved out of by various forms of land shaping and raising of river banks and creeks from historical times [18].

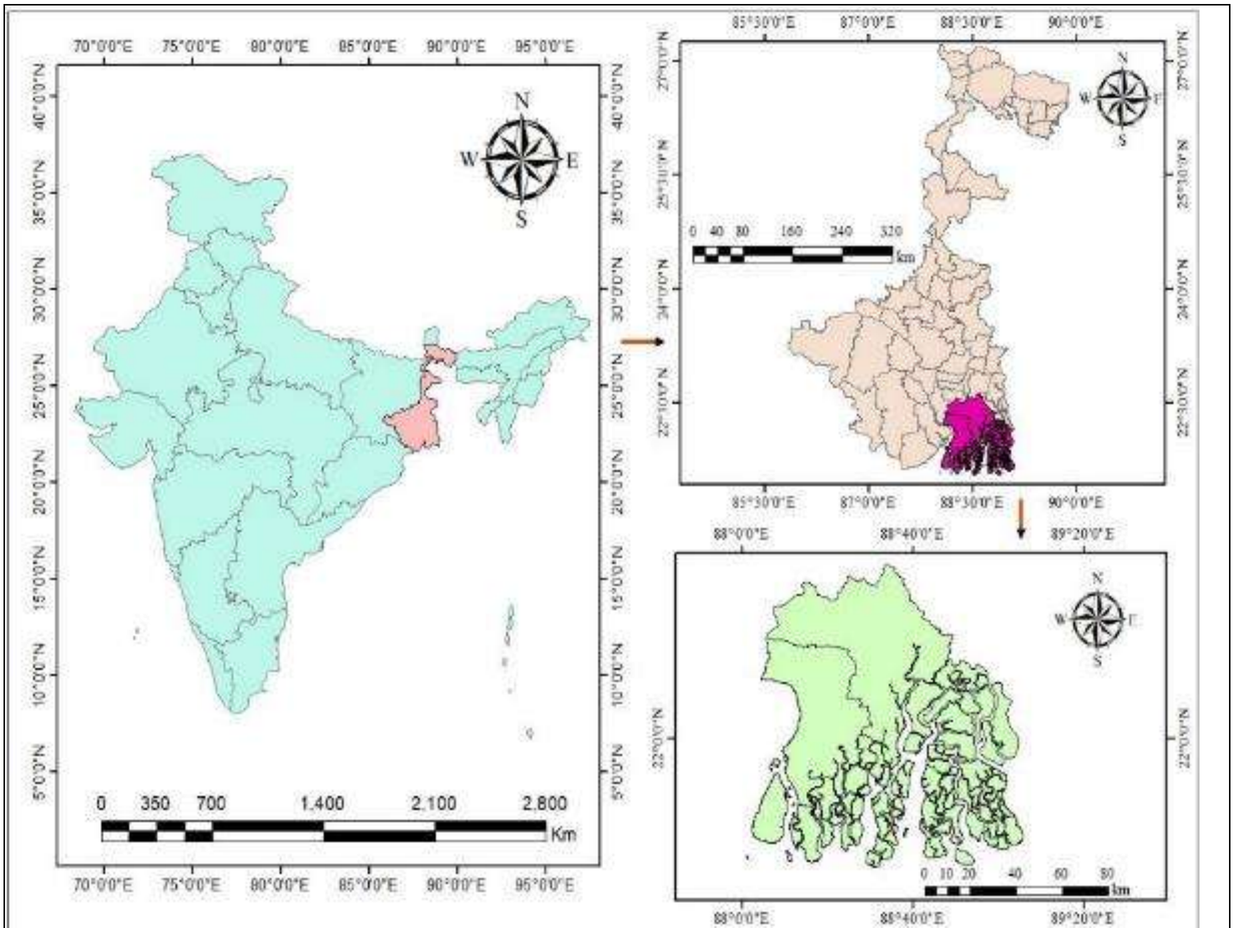

Figure 1:- Location map of the study area: South 24 Parganas District, West Bengal, India
Administrative boundary downloaded from: www.indiaremotesensing.com [20]

The district is comprised of five administrative subdivisions viz. Alipore Sadar, Baruipur, Diamond Harbour, Kakdwip and Canning [19]. More than 52 per cent of the total working population are engaged in agricultural operations. Due to lack of irrigation facilities the agriculture in the district is mainly dominated by mono-cropping of aman paddy with very little scope for diversification in cropping pattern. There are little variations in land slope, height of the flood plain, soil texture, structure and acidity in the district with wide presence of salinity in coastal soils. Owing to the deposits of river Ganges, the low-lying plains of the region are fertile and are full of halophytic mangrove forests. The southernmost places are the part of the world's largest delta – the Sundarbans; and indeed, this district, stretching from the Kolkata metropolitan areas to the remote villages up to the mouth of the Bay of Bengal, represents a complex geomorphic and physiographic feature [21].

Study Period

Expanding areal extent of human habitations with the growing population including impacts of numerous occurrences of cyclones like natural coastal hazards are characterised by change in land use pattern and so the changes in vegetation cover in the span of the study period (2005 – 2019) for the years of 2005, 2010, 2015 and 2019.

Data Sources

For the present study, both the primary and secondary data were assembled from various sources. Primary data were extracted from Landsat 4 - 5 Thematic Mapper (TM) and Landsat 8 OLI (Operational Land Imager)/ TIRS (Thermal Infrared Sensor) Level 1 satellite imageries, as downloaded from theUSGS Earth Explorer[22], of the study area for the years of 2005, 2010, 2015 and 2019 respectively (Table 1). To find out the elevation status of the study area, SRTM 1 Arc – Second Global (DEM) data (Table 1) were also collected from that [22]. The secondary data were collected from 2011 Census of India data of that district [19] and West Bengal Forest Report - Forest Survey of India [23]. Additionally, satellite imageries on vegetation cover in the district for different years of studies were collected from Google Earth Pro [24]and Global Forest Watch [25].

Table 1:- Details of Landsat data and SRTM data collected from USGS.

Date ofimage	**Satellite/ Sensor**	**Reference system / Path / Row**	**Year**	**Cloud cover (%)**
23.11.2005	Landsat 5 (TM) Level 1	WRS-2 138/44,138/45	2005	<10
23.12.2010	Landsat 5 (TM) Level 1	WRS-2 138/44,138/45	2010	<10
08.03.2015	Landsat 8 OLI/ TIRS Level 1	WRS-2 138/44,138/45	2015	<10
30.11.2019	Landsat 8 OLI/ TIRS Level 1	WRS-2 138/44, 138/45	2019	<10
23.09.2014	SRTM 1 Arc – Second Global	WRS – 2 Coordinates: 22, 89; 21, 89; 22, 88; 21, 88	2014	-

Details of band structure of our experiment

Landsat 5 (TM) Level 1 and Landsat 8 OLI/ TIRS Level 1 satellite imageries consist of 7 (Table 2) and 11 (Table 3) spectral bands respectively with different wave lengths. Out of those bands 3,4 and 4,5 with 30-meter resolutions respectively [26] were selected for analysis of vegetation cover through NDVI analysis on ArcGIS 10.8platform.

Table 2:- Band Structure of Landsat 4 - 5 (TM) Level 1 imageries.

Bands	**Wavelength(micrometres)**	**Resolution (meters)**
Band 1- Blue	0.45-0.52	30
Band 2 – Green	0.52-0.60	30
Band 3 – Red	0.63-0.69	30
Band 4 – Near Infrared (NIR)	0.76-0.90	30
Band 5 – SWIR 1	1.55-1.75	30
Band 6 - Thermal Infrared	10.40-12.50	120 (30)
Band 7 - SWIR 2	2.08-2.35	30

Sources: USGS [26]

Table 3:- Band Structure of Landsat 8 OLI/ TIRS Level 1 imageries.

Bands	**Wavelength (micrometres)**	**Resolution (meters)**
Band 1- Coastal aerosol	0.43 - 0.45	30
Band 2 – Blue	0.45 - 0.51	30
Band 3 – Green	0.53 - 0.59	30
Band 4 – Red	0.64 - 0.67	30
Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 – Panchromatic	0.50 - 0.68	15
Band 9 – Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6 - 11.19	100
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

Sources: USGS[26]

Satellite Data and Image Processing

The satellite imageries for the years of 2005, 2010, 2015, 2019 were geometrically corrected in the Datum WGS84 and projected coordinate system UTM zone N45 [27]. Some image improved techniques were applied to fix atmospheric error corrections to obtain improved image quality. The Red, Near Infrared (NIR) bands of Landsat 4 - 5 (TM) and Landsat 8 OLI/TIRS imageries having 30-meter resolutions were selected (Figure 2) for NDVI calculation through raster calculator with the help of ArcGIS 10.8 platform. After that mosaicking of different scenes were done to select geometry-based seamline generation option to make a single image to cover the study area, i.e., South 24 Parganas district on ERDAS Imagine 2015 platform [28].

Extract of the study area

Extraction of the study area (Figure 2) by mask was done for South 24 Parganas district and subdivisions boundary shapefiles through ArcGIS software [29].

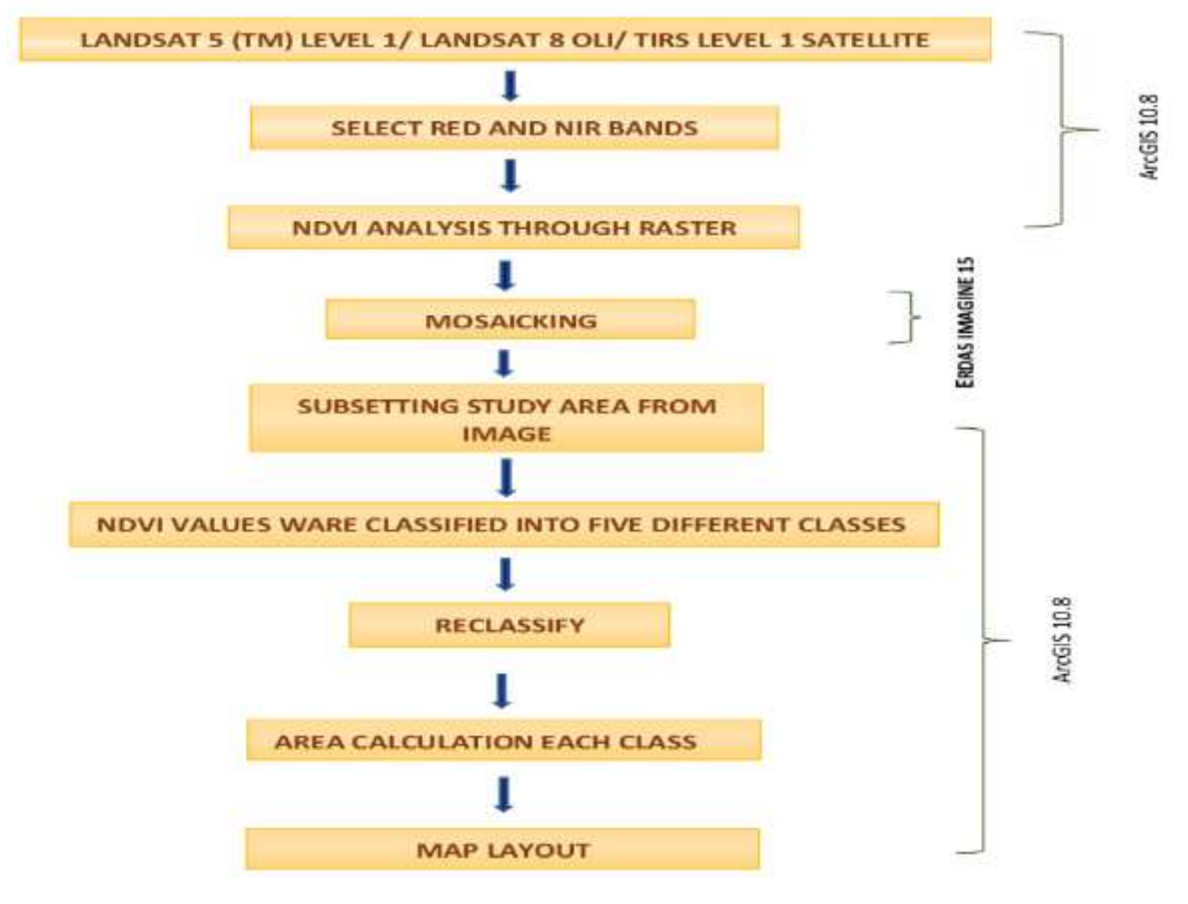

Figure 2:- Flow Chart on Techniques of Normalized Difference Vegetation Index (NDVI) Analysis.

NDVI (Normalized differences vegetation index)

The NDVI (normalized difference vegetation index) is most widely used to detect surface radiant temperature and vegetation/ forest cover changes in study area from satellite imageries [30]. NDVI values, ranging from (-1 to +1) were found out for the years of 2005, 2010, 2015 and 2019 satellite imageries. Higher NDVI number depicts greater crown density. The NDVI images are classified based on estimated values considering reflectance of visible (RED ≡ 0.64-0.67 µm) and near-infrared (i.e., NIR ≡ 0.85-0.88 µm) EM radiations by using Eq.1 [28].

$$NDVI = (NIR - RED) / (NIR + RED) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Those vegetation indices are mostly used in remote sensing for monitoring temporal changes in vegetation cover. Soil and open lands have broadly similar reflectance giving NDVI values close to 0. NDVI values, little higher than zero, is indicative of the presence of vegetation. High NDVI values imply the healthy vegetation while moderate NDVI values indicate the stressed vegetation. Negative and near zero NDVI values are the provenances of non-vegetation classes viz. water body, snow, built-up areas, etc. NDVI values typically between 0.1 to 0.6 or above and at this higher range signify increased chlorophyll content and high canopy density [16, 31].

Measured NDVI Values for crown density, i.e., healthy vegetation, were classified into five different classes that showed natural breaks (Jenks) interval of values with the help of ArcGIS software [29]. This technique is applied for analysis of NDVI in South 24 Parganas district to obtain the information on changes in vegetation cover through comparative studies of those values from one period to other.

Identification of agroforestry systems

In the study year of 2019, some clusters with dense pixel range (i.e., lower canopy) were identified for further identification of agroforestry systems in the farm lands (with the lowest to lower pixels in the highest pixel range for that year). Areal extents of less than 10 ha of healthy vegetation were sorted out as areas either under new plantation or horti-agri or agroforestry. With the help ofGoogle Earth Pro[24] structure of individual agroforestry systems were found out.

Digital elevation model (DEM)

From the shuttle Radar topography mission (SRTM) of NASA's Jet Propulsion Laboratory (JPL) [32] SRTM 1 Arc-Second Global (30 meters) digital elevation models were retrieved from USGS Earth explorer [22]of the present study area (Table 1) for assessing variability in land elevations status of South 24 Parganas district and each sub division with the help of ArcGIS 10.8 platform [33, 27].

Results and Discussion:-

Digital elevation model (DEM) Analysis

The DEM (Digital Elevation Model) analysis (Figure3) shows the entire area of the South 24 Parganas district with general land slope from north western to north eastern and to south eastern directions. Most of the high lands, intermingled with medium and low lands, are located in north western sides; and most of the low lands, intermingled with medium and high lands are found in north eastern sides to southern sides. Medium lands have created carpet like geomorphic feature criss-crossing either the high or low land situations covering the whole landscape including all islands, of the district. Such intermingling land situational features (w.r.t. m above m.s.l.) are reflected through the DEM models of five subdivisions.

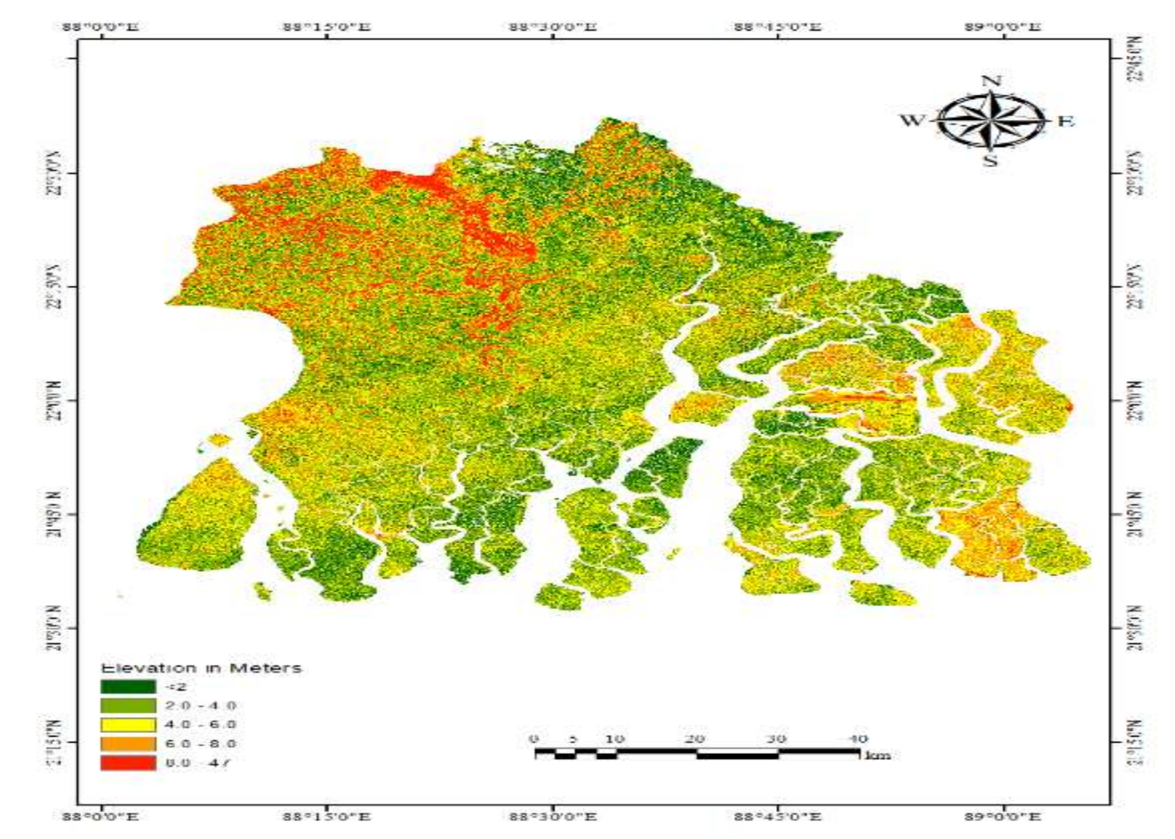

Figure 3:- DEM map of the District: South 24 Parganas (2014).

In Alipore Sadar subdivision (Figure 3a-1), such crisscrossing intermingling land situational features are also present. In that subdivision medium (6 – 9 m m.s.l.) and medium to high (9 – 20 m m.s.l.) lands borders the north-western boundary, and those land situations are present in south-western part while low (<3 m m.s.l.) and low to medium (3 – 6 m m.s.l.) lands are spread on north-eastern parts to south eastern parts and south-western parts. General land slope in Alipore Sadar is north-western to south-eastern direction and western to eastern side and western border areas from eastern to western direction.

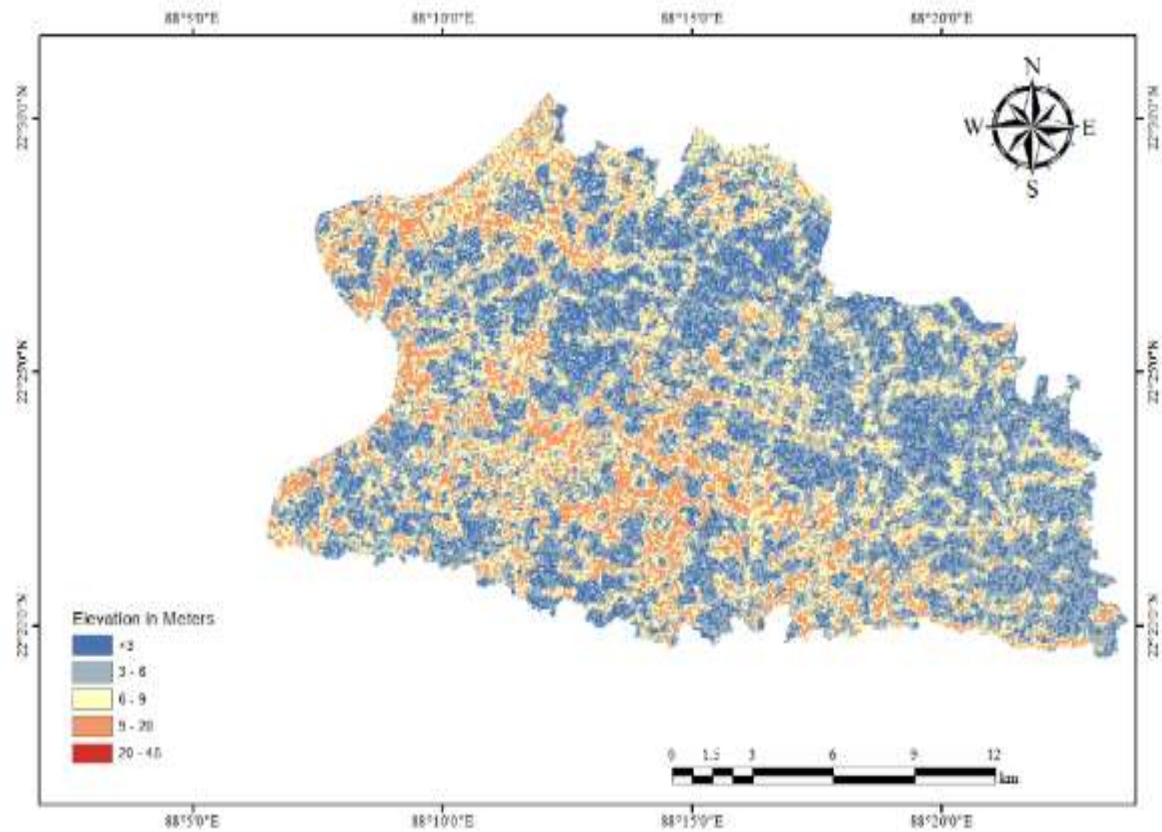

Figure 3a-1:- DEM map of the Subdivision: Alipore Sadar, South 24 Parganas (2014).

In Baruipur subdivision (Figure 3a-2), high and medium to high lands are most prominent on a small portion of north-western part, and those geomorphic features spread from northern part towards south and low lands on middle portion of northern part and on a very small pocket in the middle portion of the subdivision towards south. Crisscrossing streams divided the southern part of that subdivision into small islands. In Baruipur land is generally flat with a pocket in the northern part the slope is from southern direction to northern direction and in the middle of the land in the southern half the slope in a pocket is from western died to eastern side.

In Diamond Harbour subdivision (Figure 3a-3), medium to high and high lands in a crisscross manner visibly divides the low land situations in northern portion to middle part of the land where such lands conspicuously surround low lands visibly in a triangularly land

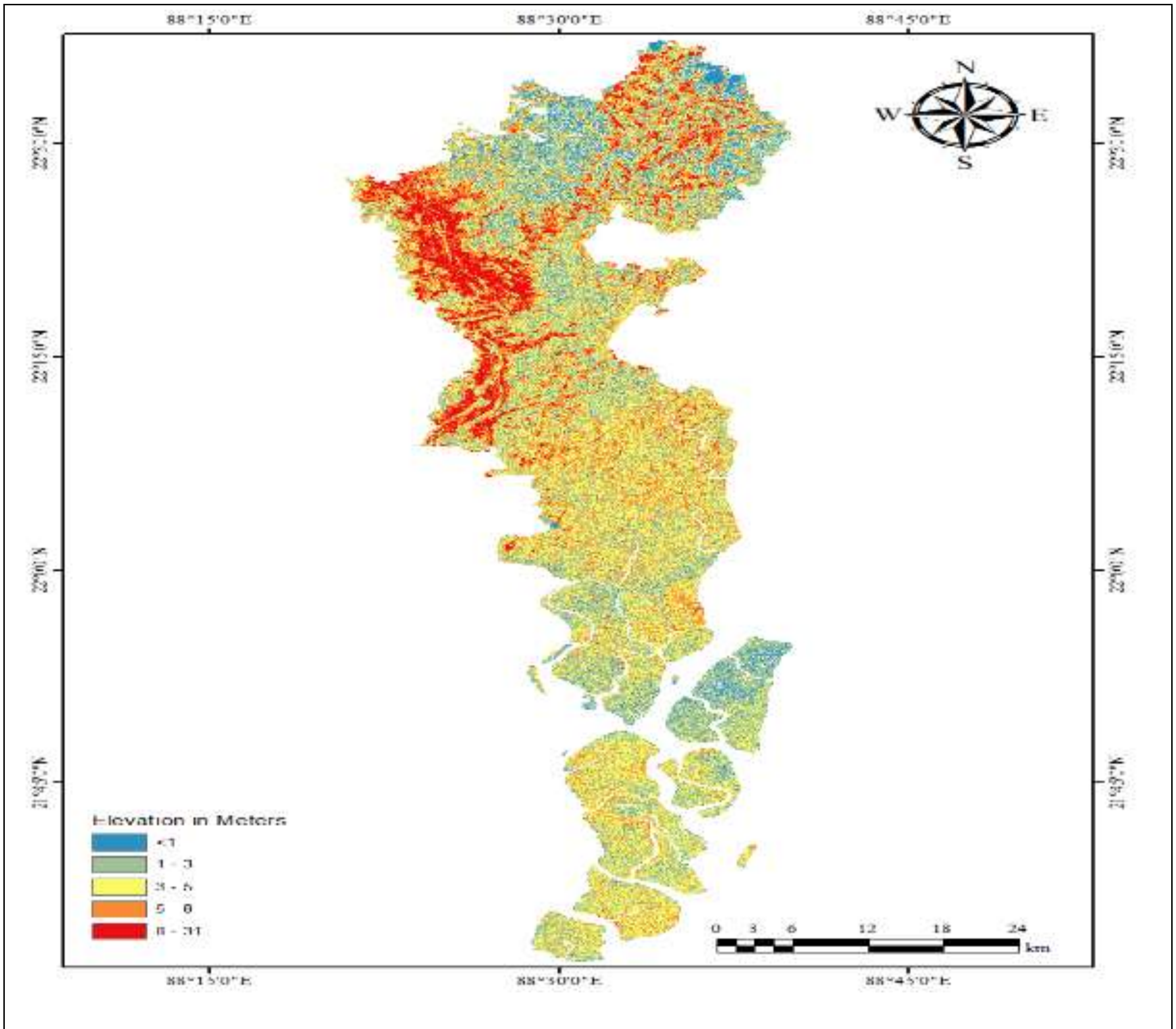

Figure 3a-2:- DEM map of the Subdivision: Baruipur, South 24 Parganas (2014).

locked situation. Then towards southern parts, presence of low lands resembling a stair-case look as intermingled by medium to high and high lands. Land slope in the northern half of Diamond Harbour is generally from north western to south eastern direction followed by similar slope in the southern half with alternate presence of low and medium to high lands.

In Kakdwip subdivision (Figure 3a-4), high lands are mostly in a pocket on the north western part and intermingling of high and medium lands with low lands in a crisscross manner are found in northern half of the subdivision while low lands are mostly in the southern half. The whole subdivision is divided into numerous small streams of distributaries of the Ganges among those. There is situated the biggest one, the Sagar Island on the western side of the subdivision with similar land situational condition as found throughout that subdivision. General land slope in Kakdwip subdivision is north to south and north western to south eastern directions.

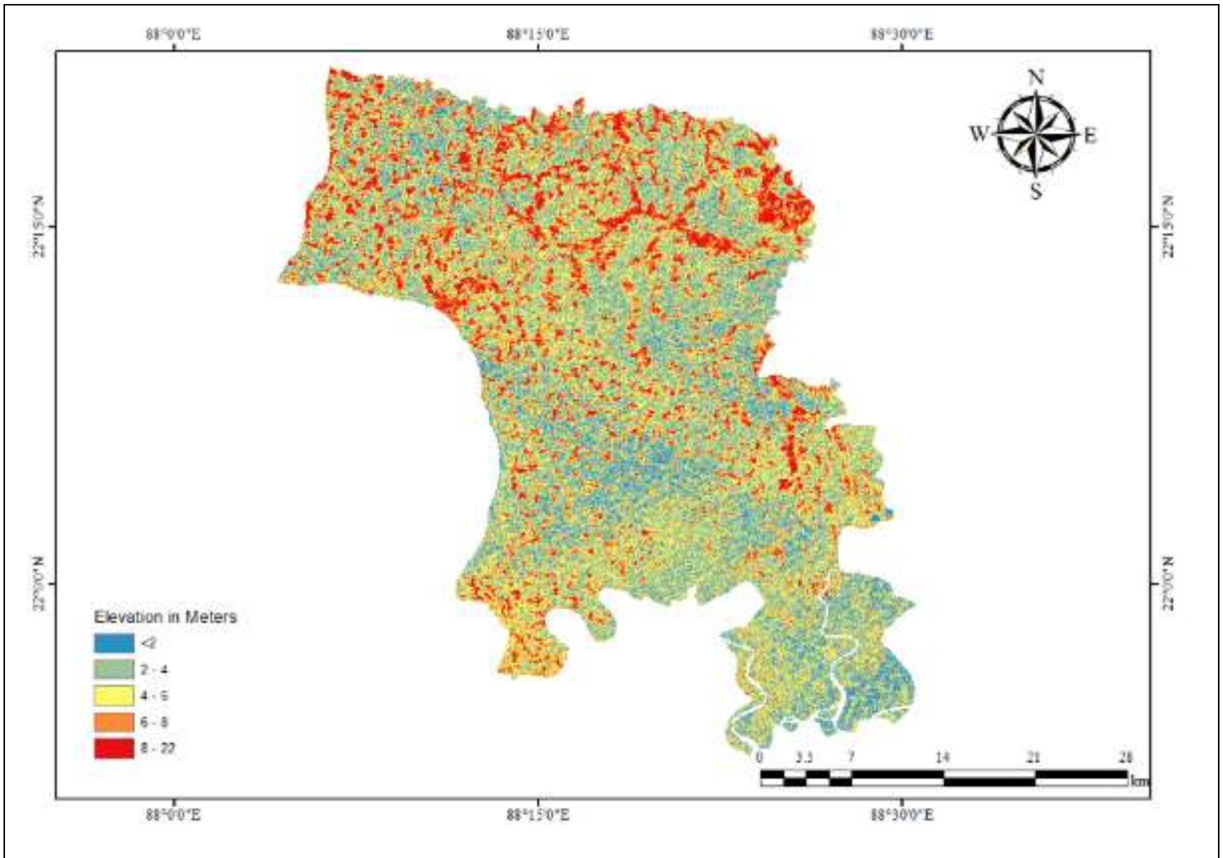

Figure 3a-3:- DEM map of the Subdivision: Diamond Harbour, South 24 Parganas(2014).

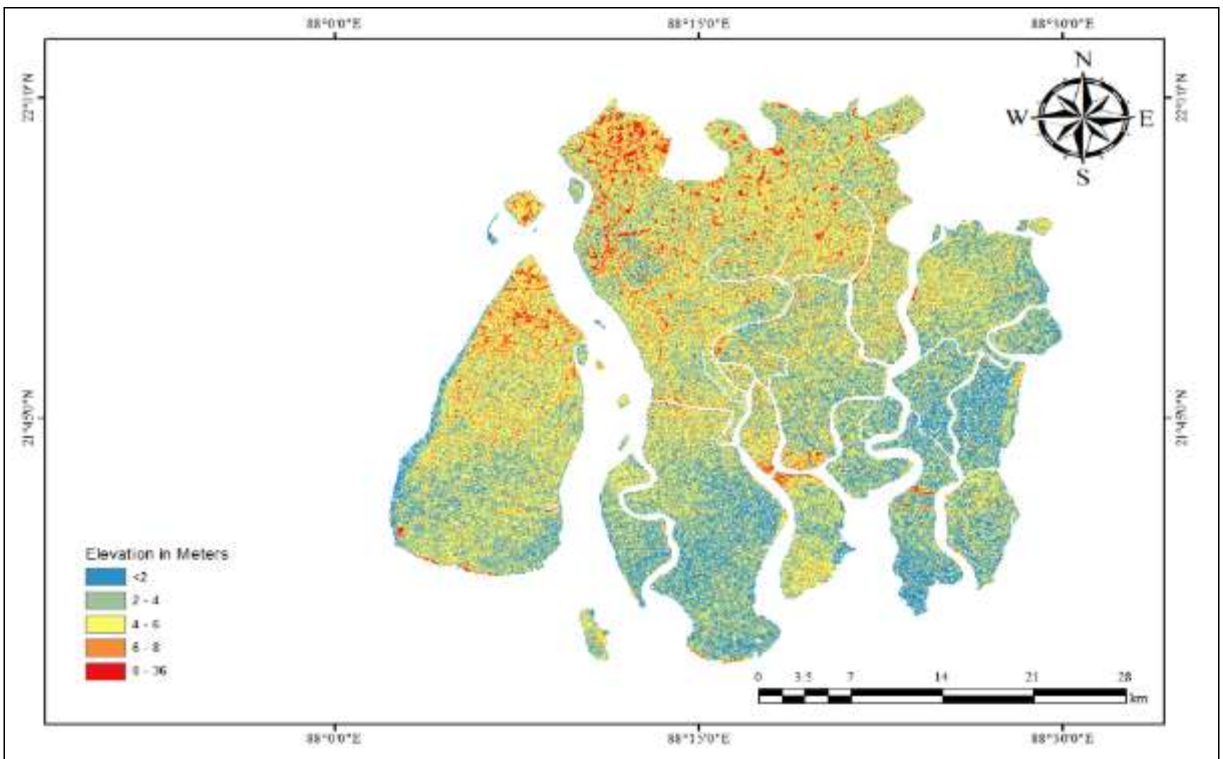

Figure 3a-4:- DEM map of the Subdivision: Kakdwip, South 24 Parganas (2014).

The Canning subdivision (Figure 3a-5) is remarkably divided into numerous islands where high to medium lands are present on middle portion and in a pocket in south eastern side. In the northern half in Canning subdivision land slope is south to north and in the southern half eastern to western direction while the middle part is with low lands.

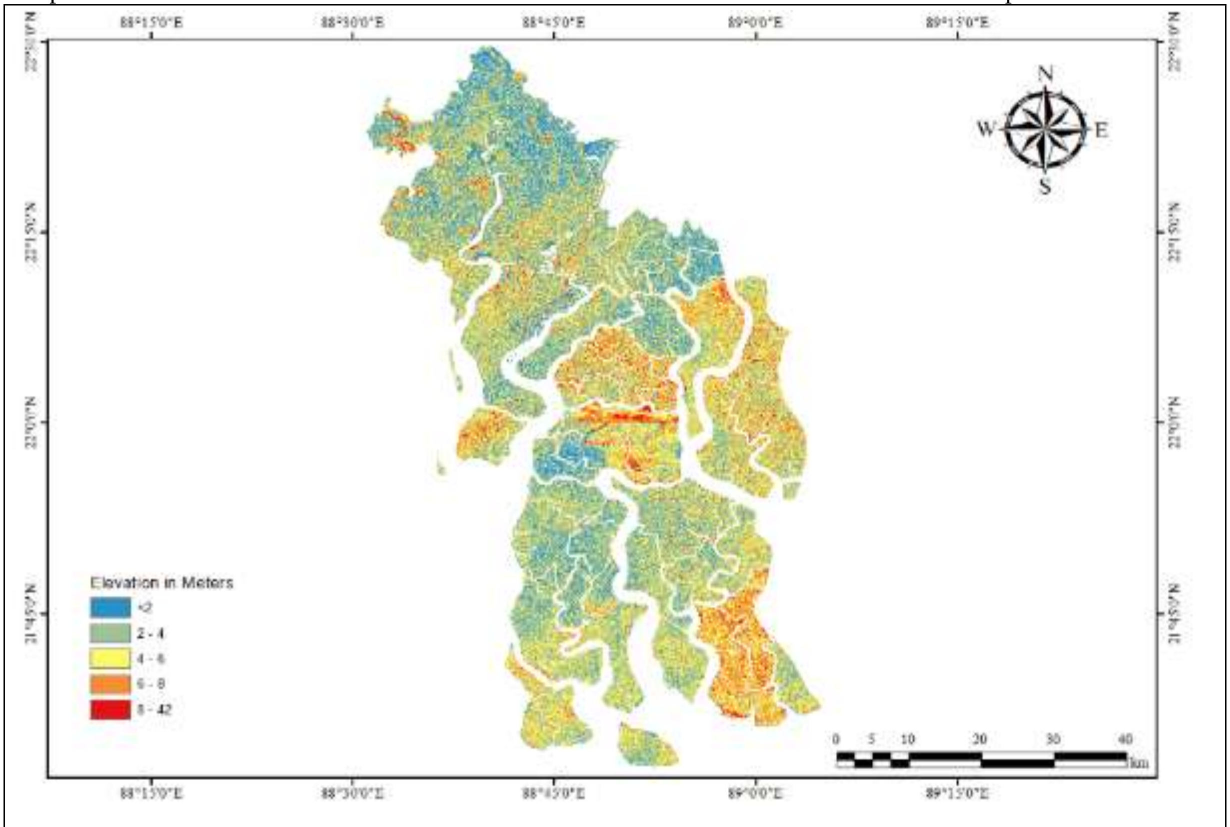

Figure 3a-5:- DEM map of the Subdivision: Canning, South 24 Parganas (2014).

DEM analysis of the district (Figure.3) shows that the areas covered by low lands (between 1m to 5m), medium lands (between 5m to 8m) and high lands (above 8m) are about 4,76,027 ha, 4,21,677 ha and 98,296 ha respectively (Table4).

Table 4:- Elevation Status in South 24 Parganas District.

Elevation in Meters(above m.s.l.)	Area (Ha)	Low(ha)	Medium (ha)	High(ha)	Total land (ha)
<2	85,208.64	4,76,027.052	-	-	9,96,000
2 – 4	3,90,818.40				
4 – 6	2,78,782.44	-	4,21,676.952		
6 -8	1,42,894.50				
8 - 47	98,295.99		-	98,296	

NDVI (Normalized differences vegetation index) Analysis

NDVI Analysis for the year 2005

In 2005, the NDVI values are estimated in the pixel range of - 0.50 to 0.70 (i.e., NDVI values) having mean and standard deviation of 0.395 and 0.166 respectively (Table 5). The higher NDVI values in the range of 0.47 – 0.70 are found in most of the middle portions and south eastern parts and some areas of north western corner in the district. The south eastern part is covered with the mighty dense mangrove forest. Lower NDVI values outside mangrove areas show the presence of arable lands, built-up areas, waterbodies, etc. (Figure 4).

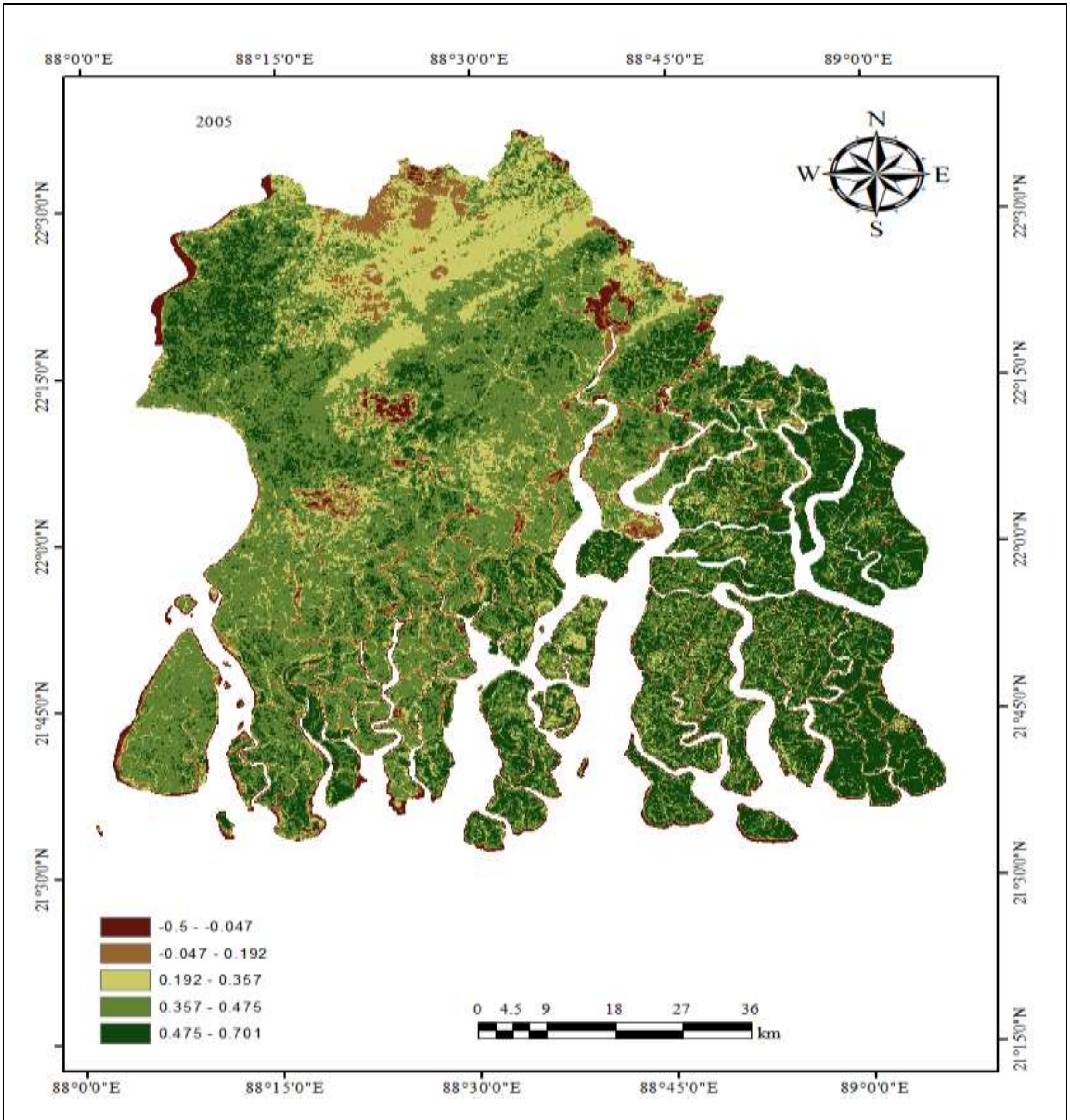

Figure 4:- NDVI map of South 24 Parganas District in the year 2005.

Table 5:- Year-wise Normalized Difference Vegetation Index (NDVI) status of South 24 Parganas District.

Year	Highest pixel values (range)	Mean	Standard Deviation	Area (Ha) with Highest pixel range
2005	0.47-0.70	0.395	0.166	3,13,019.70
2010	0.29-0.50	0.171	0.143	2,25,809.52
2015	0.30-0.54	0.224	0.092	1,70,118.33
2019	0.26-0.47	0.205	0.087	2,38,235.28

Comparing DEM features with NDVI mapping revealed that there was presence of more vegetations on comparatively high land situations than on the surrounding comparatively low land situations (Figure 3 and Figure 4). So, accordingly more vegetations were present in the north western corner, western side and from middle part

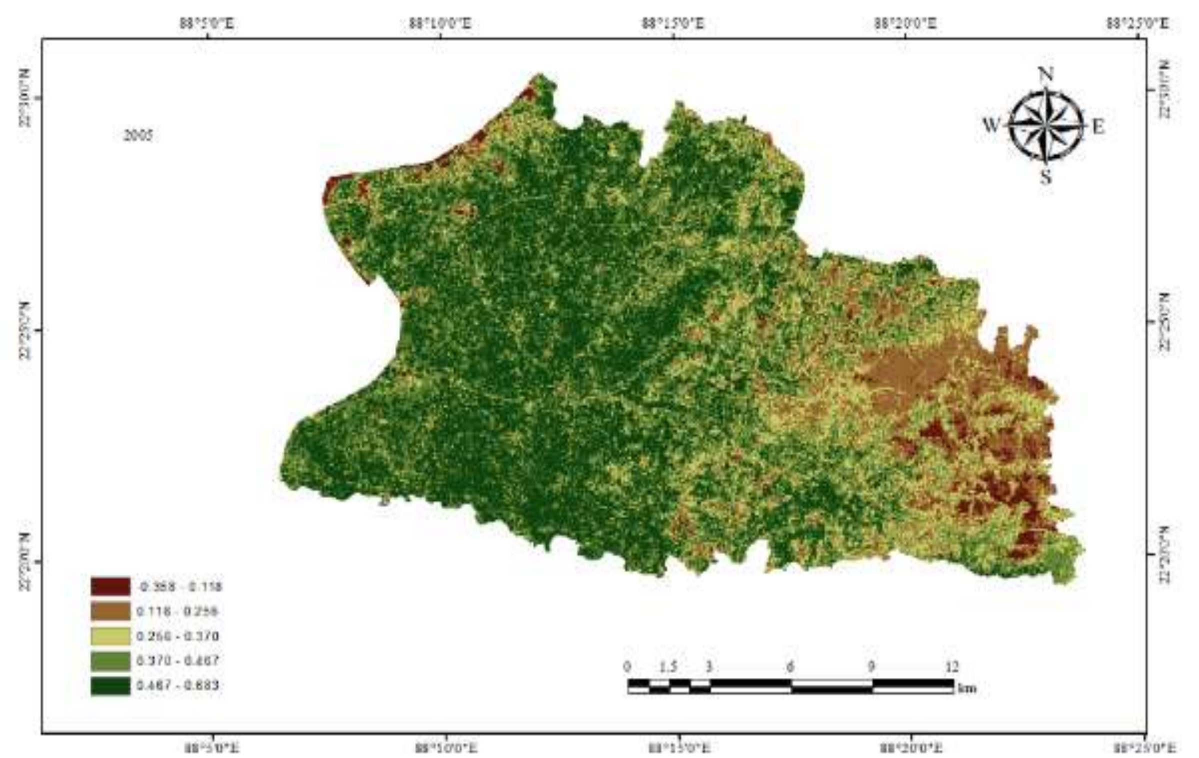

Figure 4a-1:- NDVI map of the Subdivision: Alipore Sadar, South 24 Parganas (2005).

dense vegetations increased from north western to south eastern direction, though at the same clearing of vegetation on the northern border part could be ascertained due to presence very low vegetation on comparatively higher land situations (Figure 3). General vegetational geomorphic features in the district manifested natural trends of terrestrial plant succession gradually on higher land situations.

In the year of 2005, such NDVI features were prominent in all five subdivisions, with no prominence of mangroves with very high NDVI values in three subdivisions of Alipore Sadar, Baruipur and Diamond Harbour.

In accordance with DEM features vegetational characteristics in Alipore Sadar subdivision revealed the signatures of higher NDVI values on the western half of the subdivision, though clearing of vegetation cover could be ascertained through presence of low vegetation comparatively on similar land situations with higher vegetations (Figure 4a-1). In Baruipur similar vegetational features as per land situation were found with distinct manifestation of clearing of vegetation on most of the northern part (Figure 4a-2). In Diamond Harbour similar vegetational feature with clearing of vegetation in some pockets on the eastern side and on the middle part could be found (Figure 4a-3). Better vegetation cover In Kakdwip showed with very meagre presence of plant cover on sea side boundaries in few spots and those were might be due to storm-damage or anthropogenic factors (Figure 4a-4). Similar to Kakdwip subdivision better vegetation cover was found in Canning in the year of 2005 with prominent anthropogenic cause of clearing of vegetation bordering the stream banks also (Figure 4a-5).

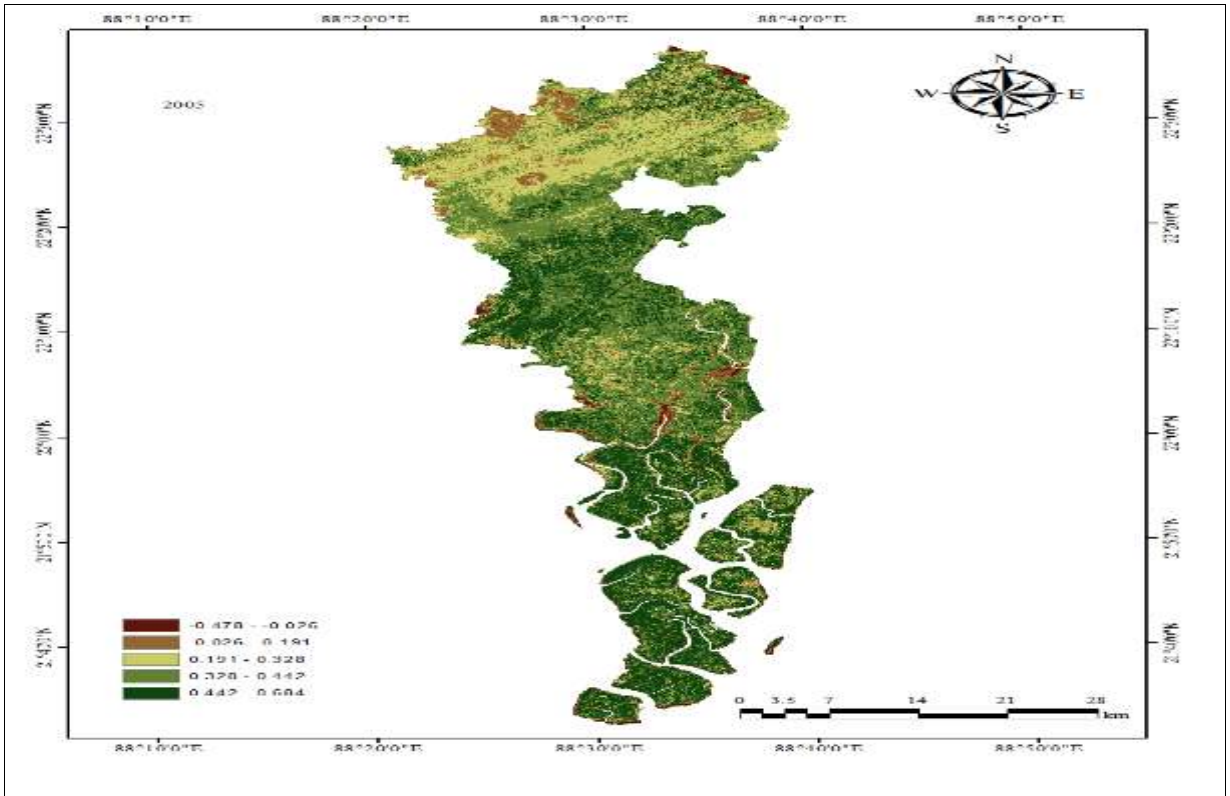

Figure 4a-2:- NDVI map of the Subdivision: Baruipur, South 24 Parganas (2005).

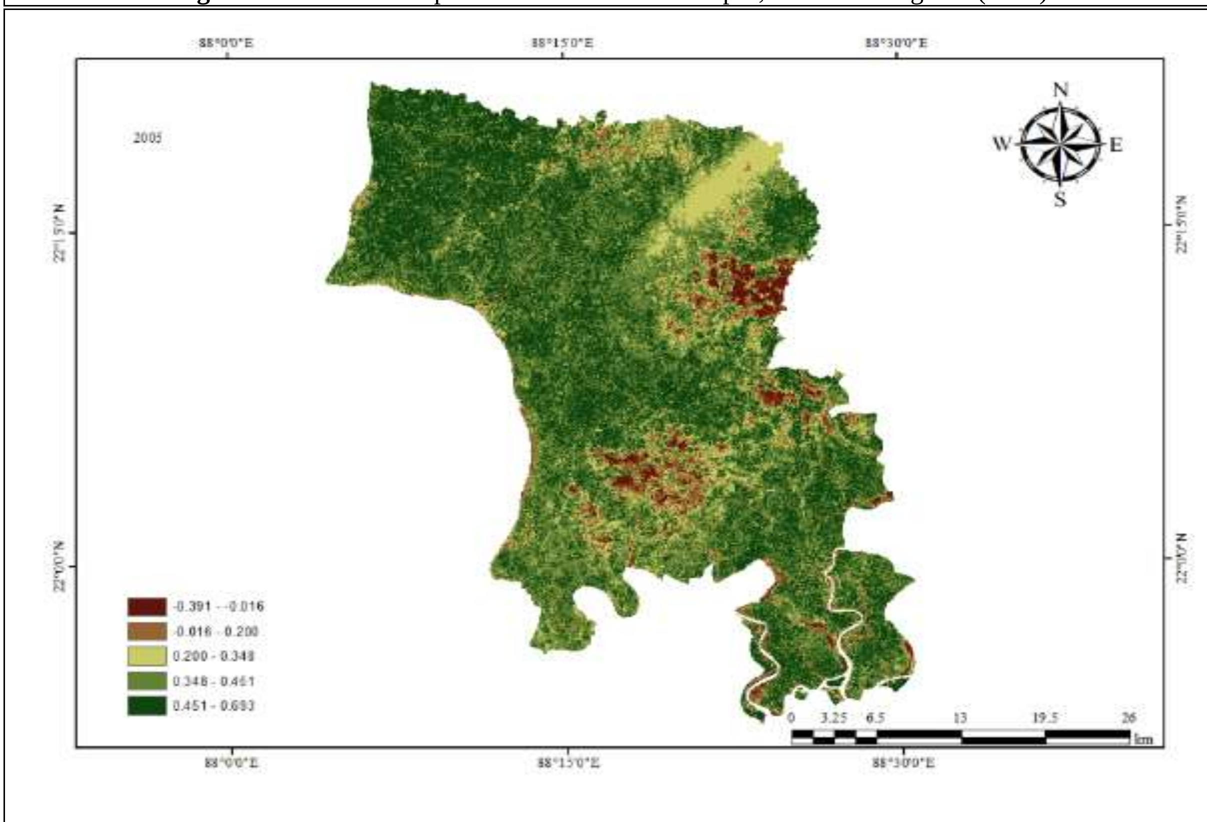

Figure 4a-3:- NDVI map of the Subdivision: Diamond Harbour, South 24 Parganas(2005).

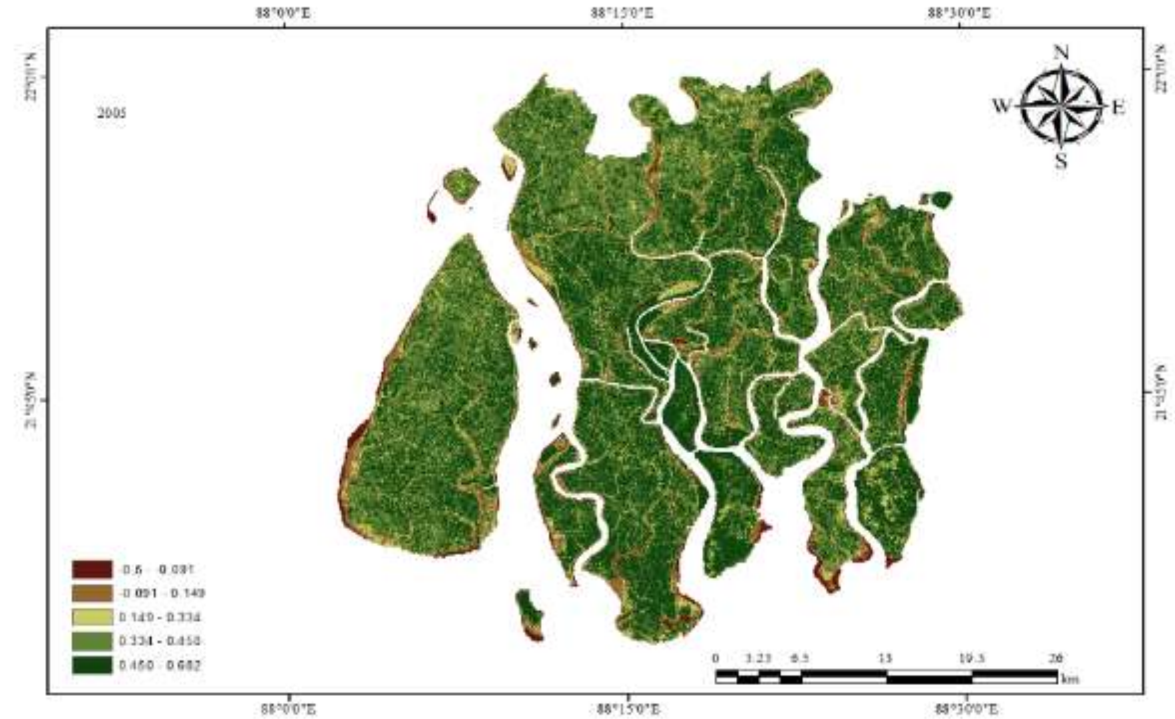

Figure 4a-4:- NDVI map of the Subdivision: Kakdwip, South 24 Parganas (2005).

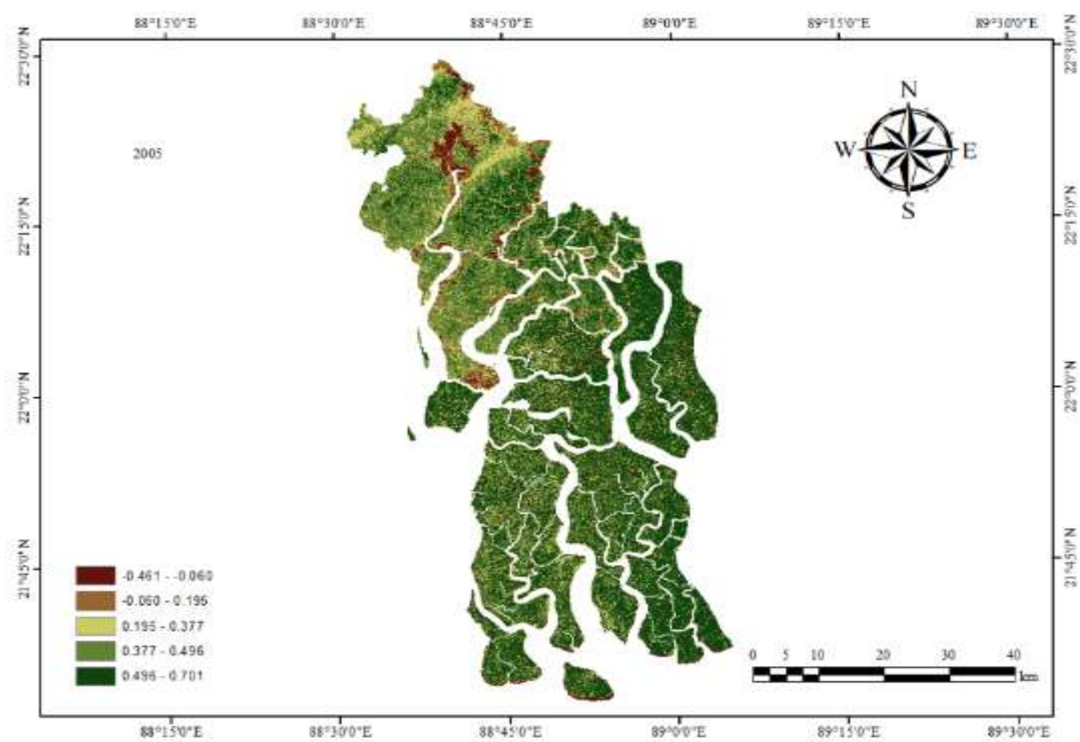

Figure 4a-5:-NDVI map of the Subdivision: Canning, South 24 Parganas (2005).

NDVI Analysis for the year 2010

In 2010, the NDVI values were estimated in the range of -0.41 to 0.50, unique from the previous year of studies, i.e., 2005, having mean and standard deviation of 0.171 and 0.143 respectively. NDVI values of 0.29 to 0.50 showed healthy vegetation whereas waterbodies, built-up areas showed lower values (Table 5, Figure 5).

NDVI Analysis for the year 2015

In 2015, the NDVI values were reckoned in the range of -0.21 to 0.54 (Figure 6), distinctive from both the previous years of studies of 2005 and 2010 and having mean and standard deviation of 0.224 and 0.092 respectively. The NDVI values of pixel range 0.30-0.54 showed high crown density (Table 5).

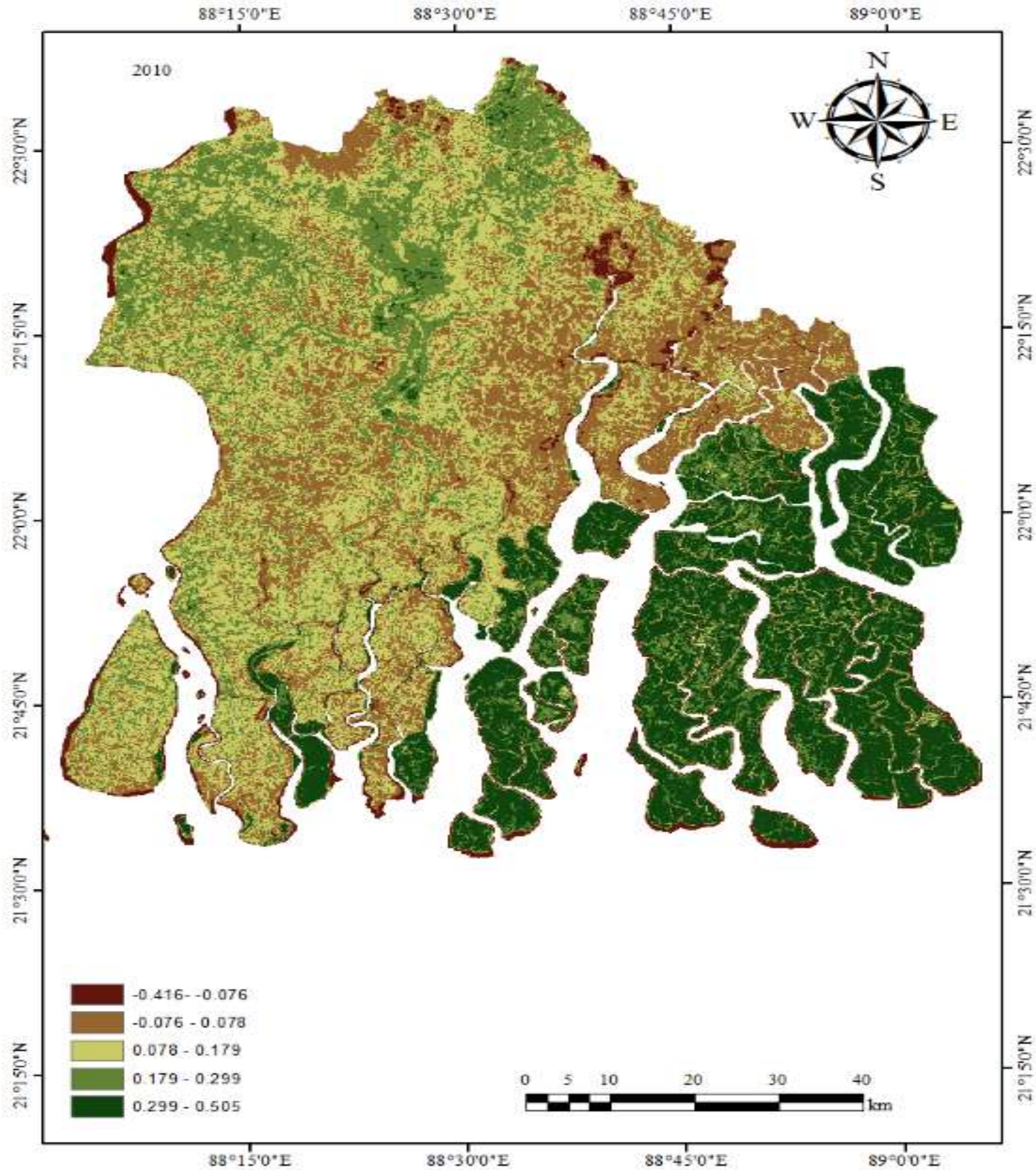

Figure 5:- NDVI map of the South 24 Parganas district (2010).

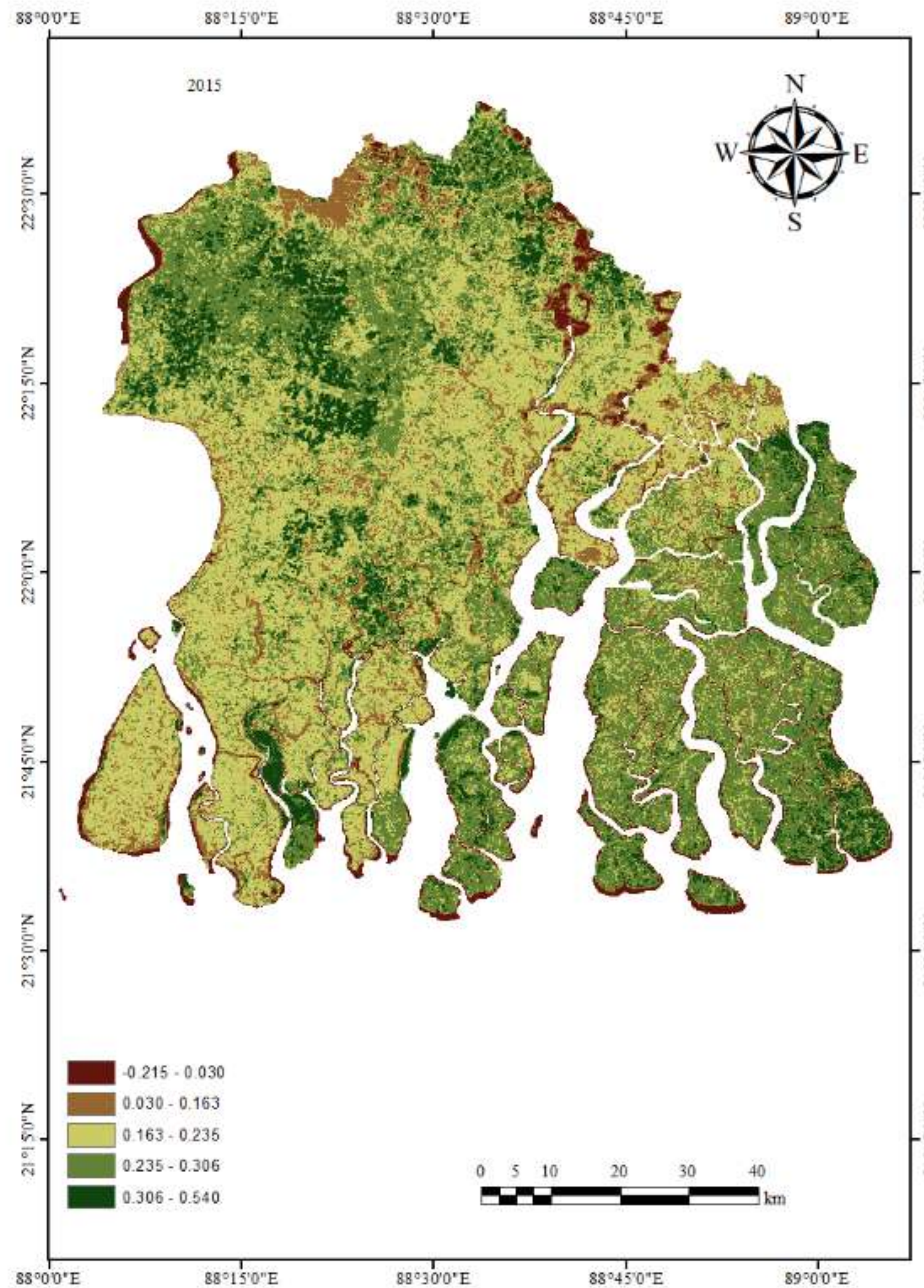

Figure 6:- NDVI map of South 24 Parganas district (2015).

NDVI Analysis for the year 2019

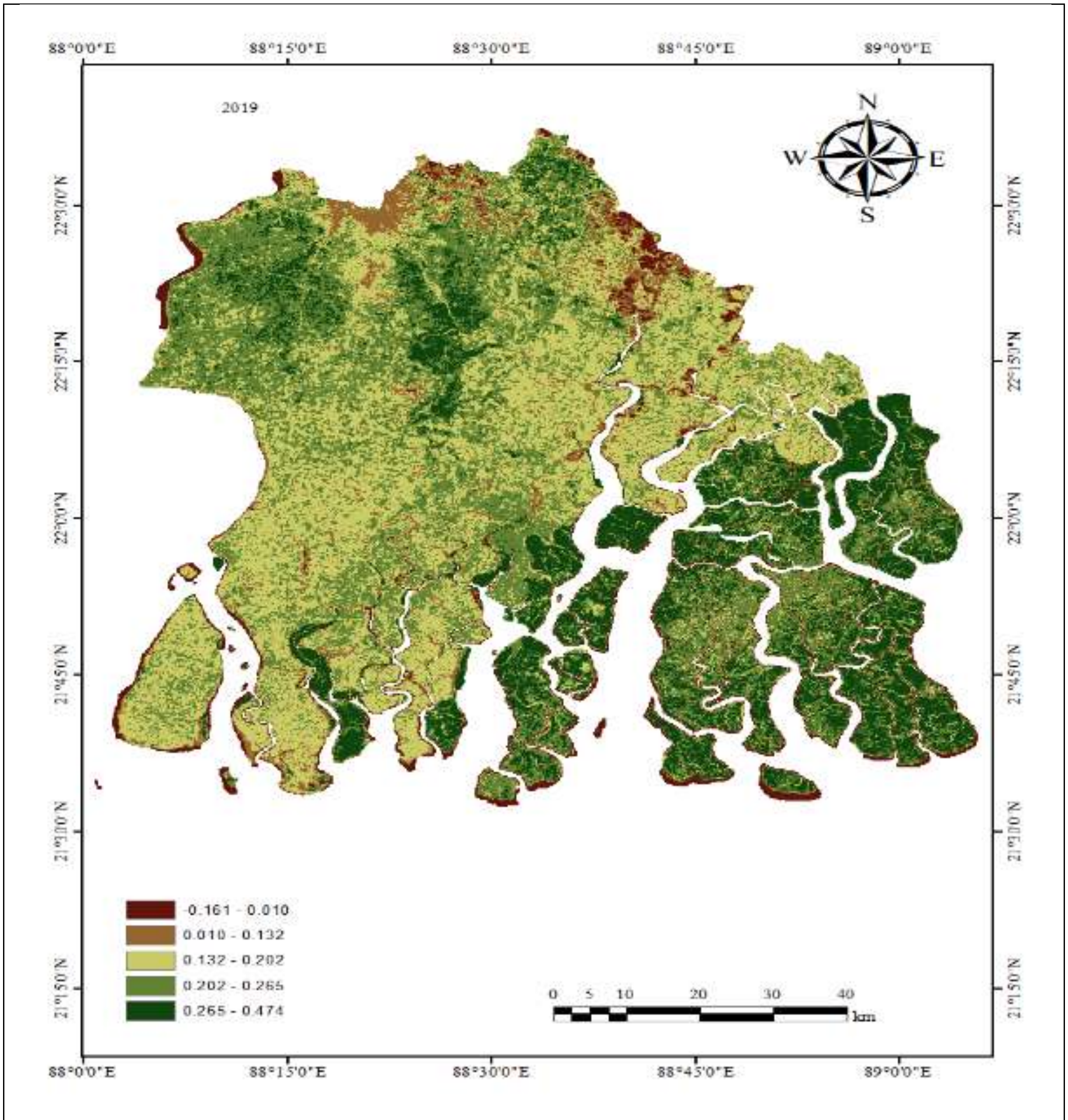

Figure 7:- NDVI map of South 24 Parganas district (2019).

In 2019, the NDVI values are observed in an especially different range of -0.16 to 0.47 (from all three previous years of studies of 2005, 2010 and 2015, with mean and standard deviation of 0.205 and 0. 087 (Table 5). Higher NDVI values are observed only over small parts of northern side and south eastern region in the district. Lowest NDVI values are seen over waterbodies as well as highly built-up areas (Figure 7). Such contrasting NDVI features were reflected in all five subdivisions of the district (Figure 7a-1, Figure 7a-2, Figure 7a-3, Figure 7a-4, Figure 7a-5).

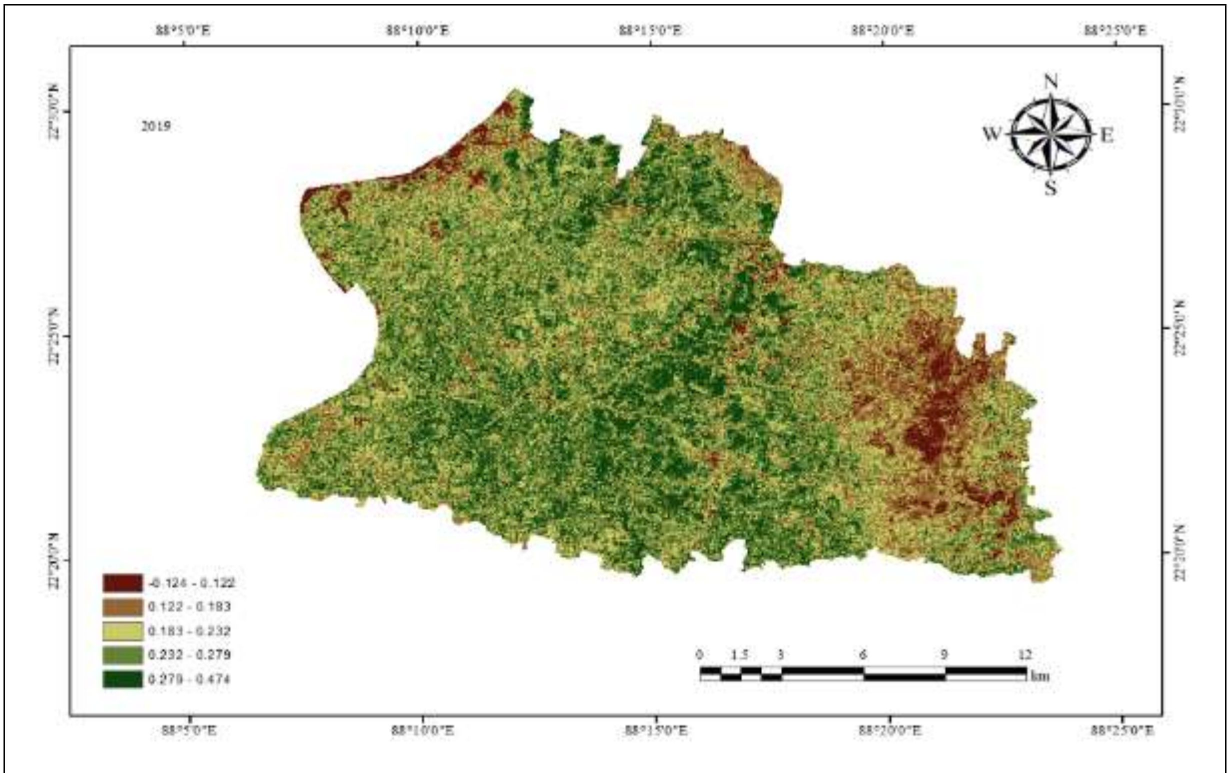

Figure 7a-1:- NDVI map of the Subdivision: Alipore Sadar, South 24 Parganas (2019).

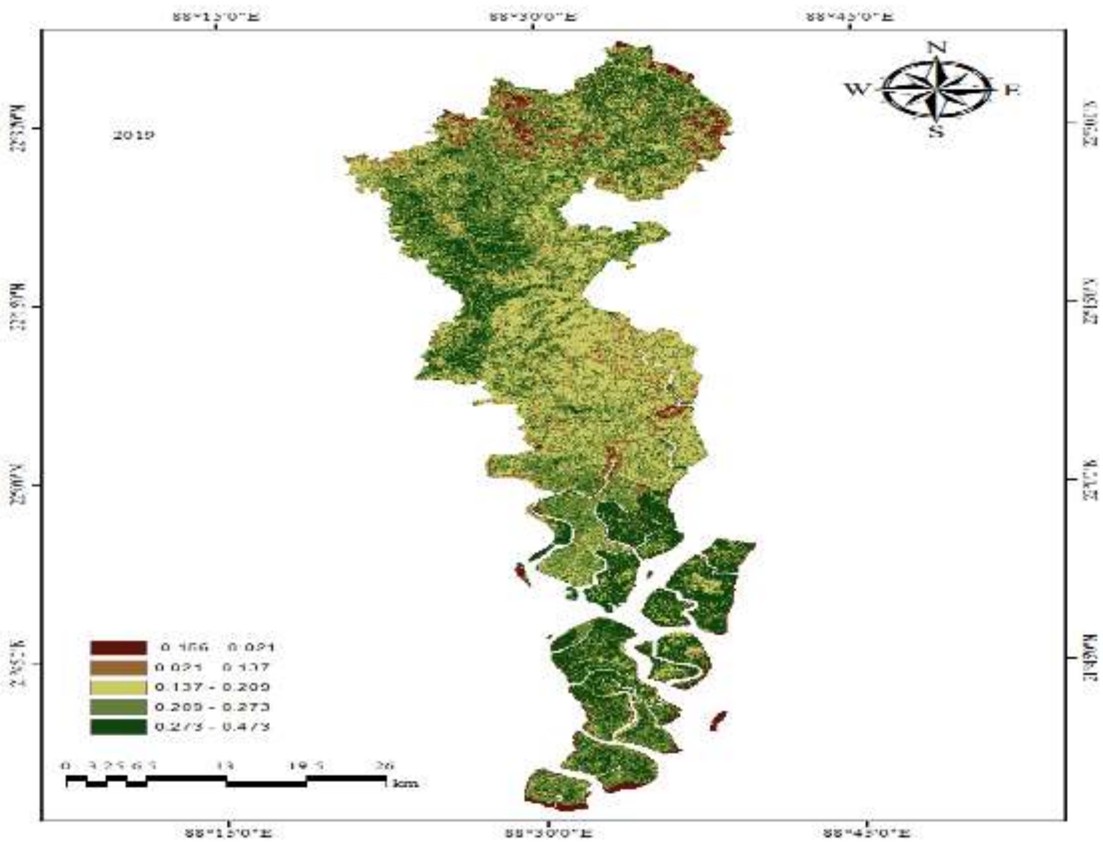

Figure 7a-2:- NDVI map of the Subdivision: Baruipur, South 24 Parganas (2019).

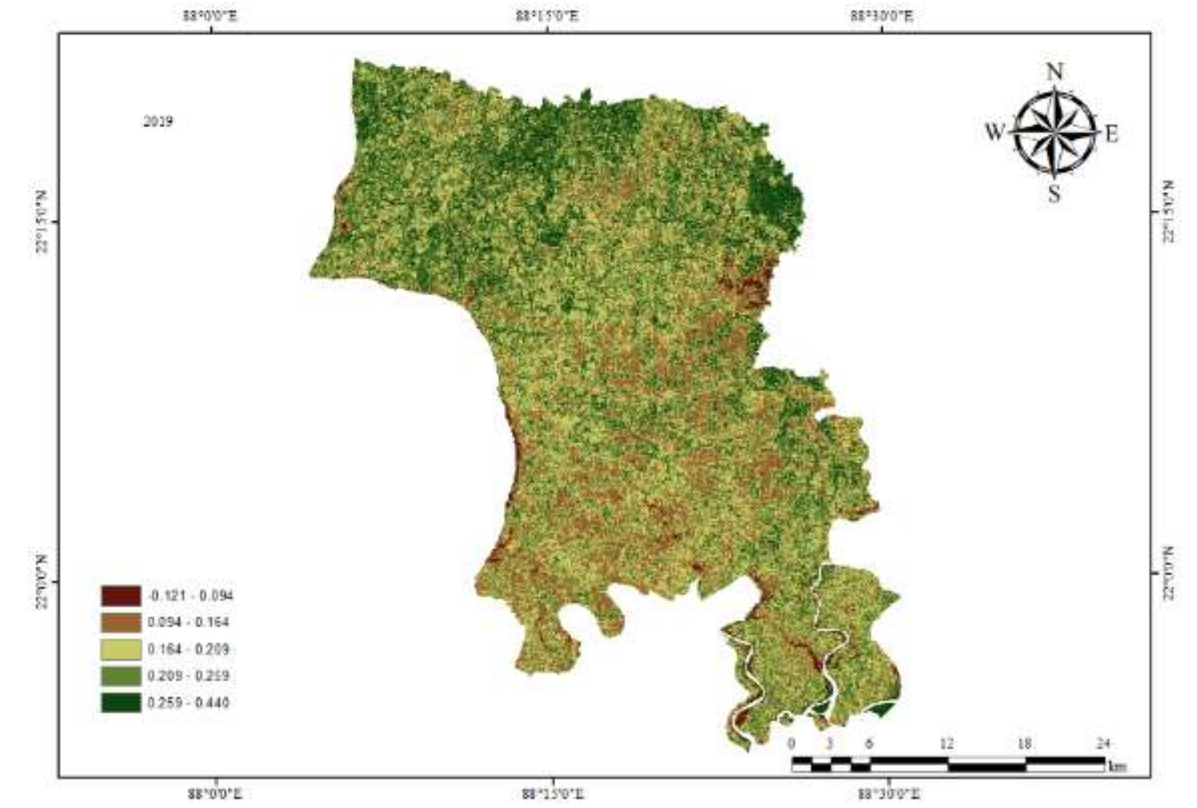

Figure 7a-3:- NDVI map of the Subdivision: Diamond Harbour, South 24 Parganas (2019).

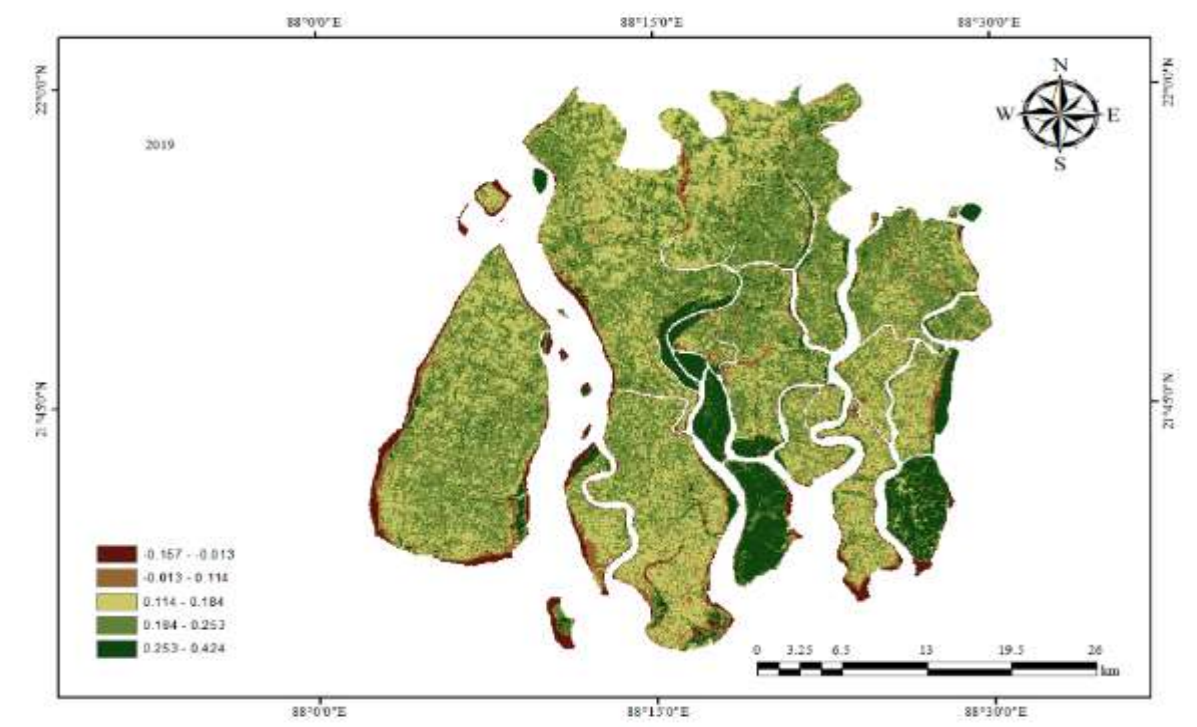

Figure 7a-4:- NDVI map of the Subdivision: Kakdwip, South 24 Parganas (2019).

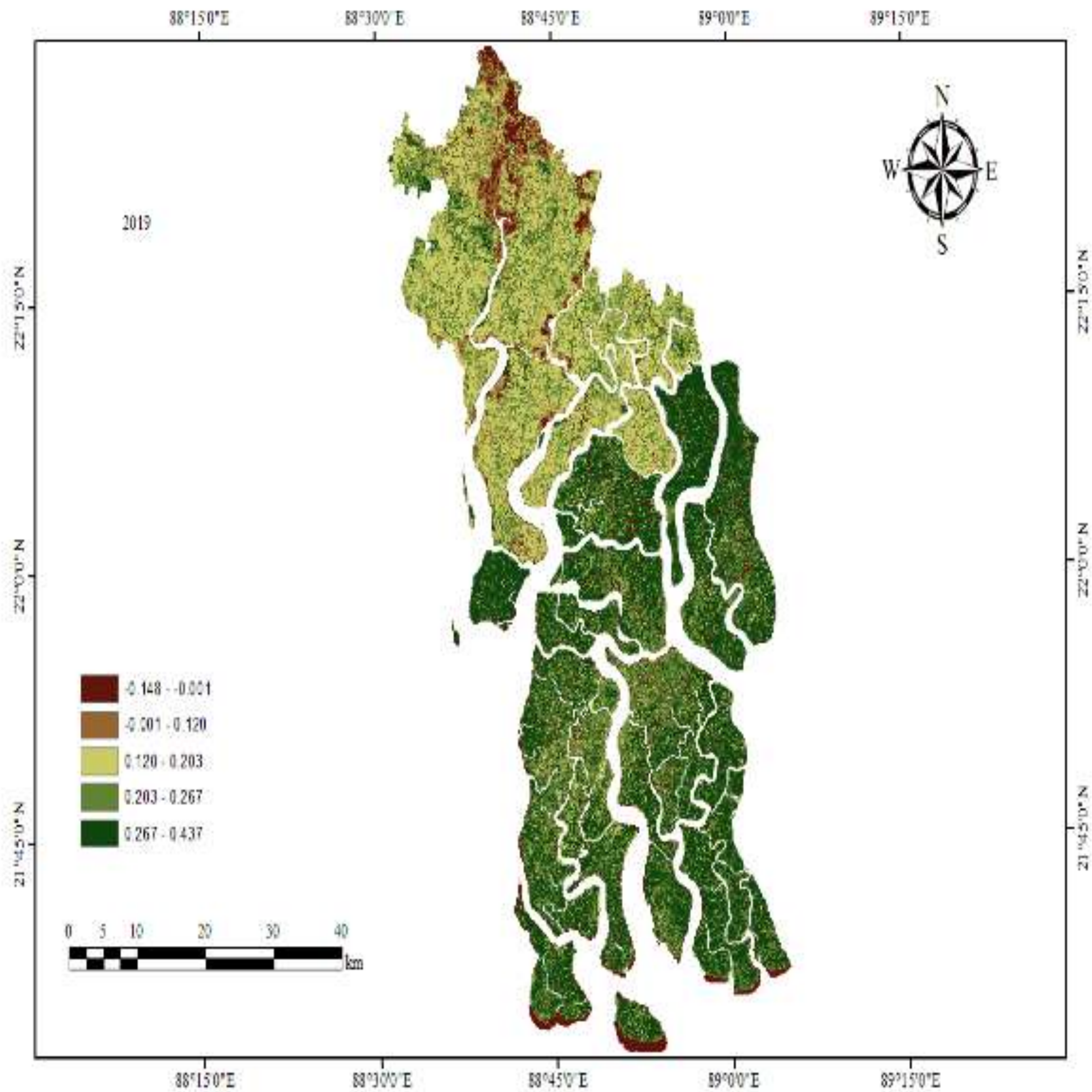

Figure 7a-5:- NDVI map of the Subdivision: Canning, South 24 Parganas (2019).

Identification of agroforestry systems

It was found that areal extents with higher NDVI values decreased year after year during 2005-2015 as estimated to be 3,13,019.70 ha; 2,25,809.52 ha and 1,70,118.33 ha for the years of 2005, 2010 and 2015 respectively. But those areas increased to 2,38,235.28 ha in 2019 which was more than those in the years of 2010 and 2015. That increased area might be due to a good contribution from development of various types of agroforestry systems, having boundary plantations in common, on moderate areas of arable land (Table 5, Figure 8) on high and medium land situations as were evidenced from Baruipur and Canning subdivisions (Figure 8a-1, Figure 8a-2).

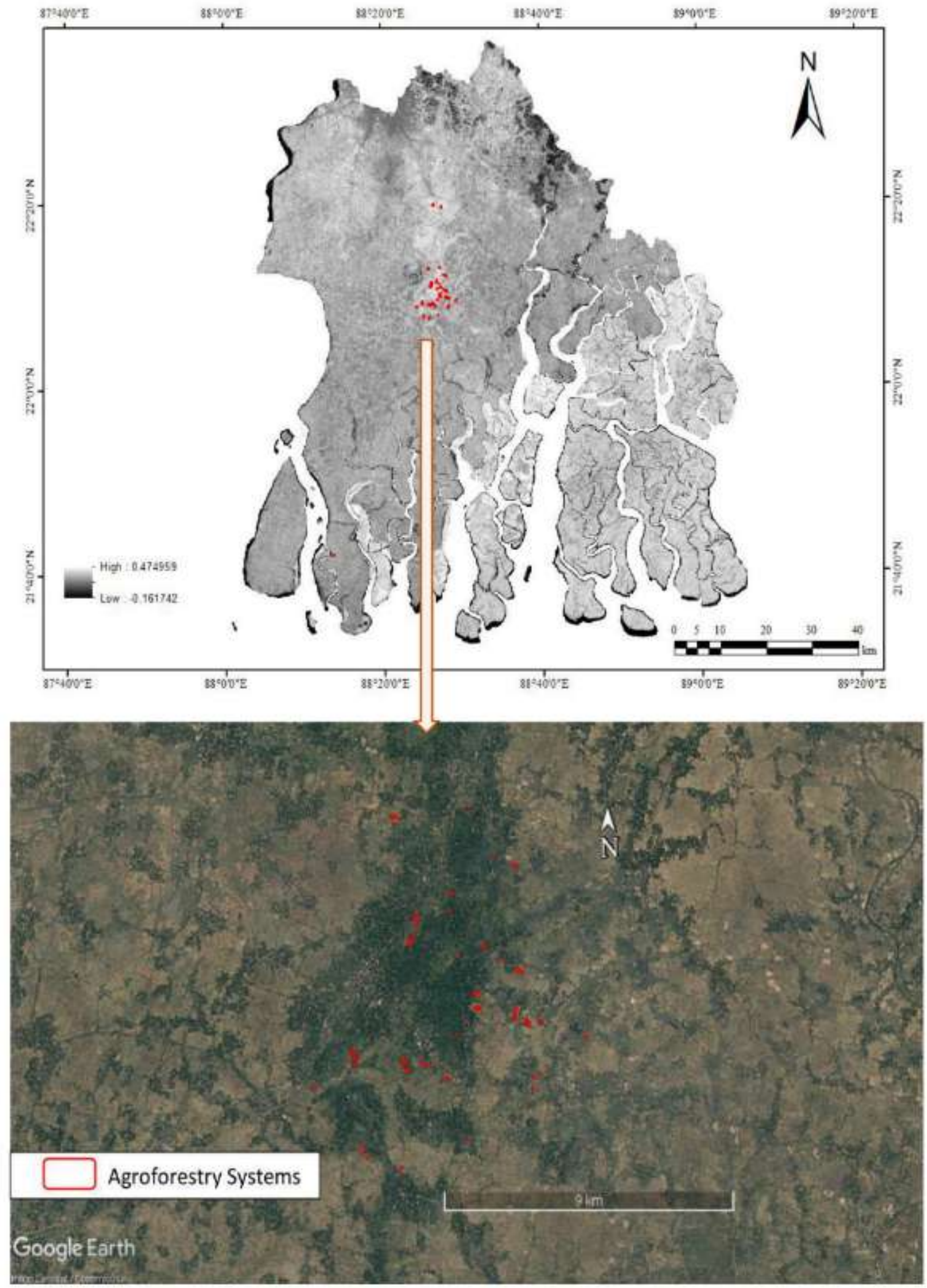

Figure 8:- Agroforestry systems clusters development in South 24 Parganas (2019).

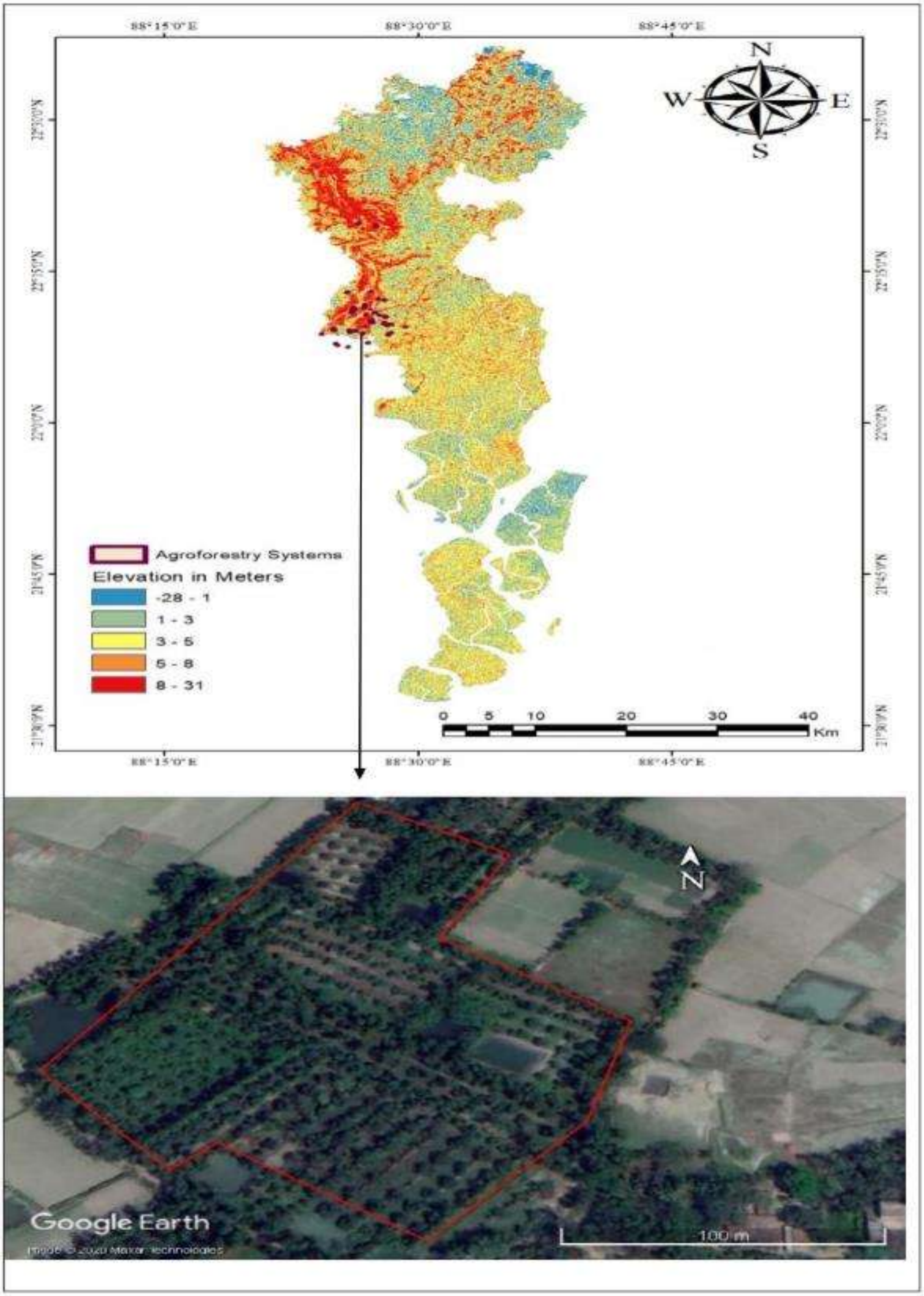

Figure 8a-1:- Agroforestry systems development: Baruipur subdivision, South 24 Parganas (2019)

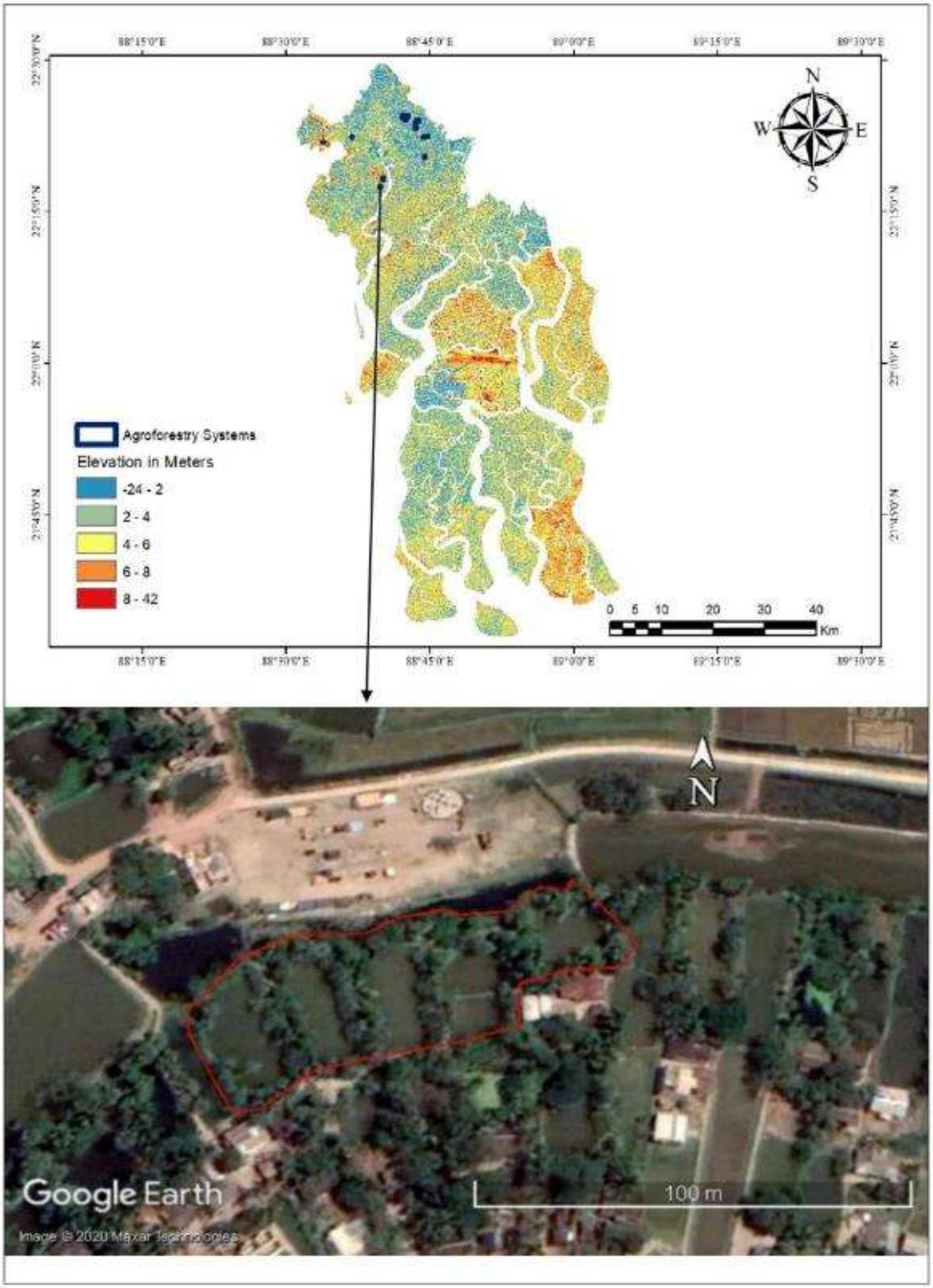

Figure 8a-2:- Agroforestry systems clusters development: Canning subdivision, South 24 Parganas (2019).

Generalised observations from NDVI analysis during 2005 - 2019

The South 24 Parganas district consists of five subdivisions of Alipore Sadar, Baruipur, Diamond Harbour, Kakdwip and Canning with geographical areas of about 39,822.74 ha, 2,15,503.5 ha, 1,32,439.9 ha, 2,14,022.4 ha and 3,94,211.5 ha respectively. During the period of studies from 2005 to 2019 the areal extents of healthy vegetation decreased in all those five subdivisions (Table 6, Figure 4a-1, Figure 4a-2, Figure 4a-3, Figure 4a-4, Figure 4a-5 and Figure 7a-1, Figure 7a-2, Figure 7a-3, Figure 7a-4, Figure 7a-5). Among those Kakdwip showed highest loss of healthy vegetation of about 2196 ha/year followed by Diamond Harbour, Canning, Alipore Sadar and Baruipur due to increase in built-up areas throughout the district (Table 6).

Table 6:- Changes in healthy vegetation area in subdivisions of South 24 Parganas district (2005 to 2019).

Subdivisions of South24 Parganas	**Total Area (ha)**	**AreaofHealthy Vegetation Cover (2005) (ha)**	**Area of Healthy Vegetation Cover (2019)(ha)**	**Decrease in Healthy Vegetation Cover (2005 to 2019)(ha)**	**Vegetation Loss/Year (ha)**
Alipore Sadar	39,822.74	22,115.38	19,525.79	2589.58	172.63
Baruipur	2,15,503.5	54,758.28	52,565.97	2192.31	146.15
Diamond Harbour	1,32,439.9	54,127.83	30,729.71	23,398.11	1559.87
Kakdwip	2,14,022.4	61,278.50	28,336.88	32,941.62	2196.10
Canning	3,94,211.5	1,20,739.70	1,07,076.89	13,662.81	910.85
Total	9,96,000	3,13,019.70	2,38,235.25	74,784.43	4985.62

From the studies (2005 – 2019) it was revealed that overall changes in healthy vegetation cover increased to the tune of about 81,557 ha due to increase in deforestation (i.e., decrease in Higher Dense vegetation) mainly in mangrove areas and increase in built-up areas (i.e.,non-Vegetation). During that period. During that period areas under habitation and farm lands (Lowest Dense and Lower Dense NDVI classes) increased which were compounded with decrease in dense vegetation class (i.e., lower canopy) of traditional trees in habitat areas and around crop lands due to supply towards day-to day wood demand of the inhabited population (Table 7).

Table 7:- NDVI values over South 24 Parganas District during 2005 – 2019.

NDVI Class	**2005**		**2019**		**Changes in area during 2005 -2019**	
	NDVI Range (pixel)	**Area (ha)**	**NDVI Range (pixel)**	**Area (ha)**	**Increased (ha)**	**Decreased (ha)**
Non-Vegetation	0.5 – 0.047	75,236.5	0.161 – 0.010	82,009.2	6772.7	-
Lowest Dense	0.047 – 0.192	1,00,522.5	0.010 – 0.132	1,15,838.0	15,315.5	-
Lower Dense	0.019 – 0.357	1,80,886.7	0.132 – 0.202	2,86,473.7	1,05,587.0	-
Dense	0.357 – 0.475	3,26,334.7	0.202 – 0.265	2,73,443.9	-	52,890.8
Higher Dense	0.475 – 0.701	3,13,019.7	0.265 – 0.474	2,38,235.3	-	74,784.4
Total	-	9,96,000	-	9,96,000	-	
OVER ALL DECREASE IN HEALTHY VEGETATION DURING 2005 – 2019				(Increase in Non-vegetation + Decrease in Higher Density) = (74,784.4 + 6772.7) = 81,557.1 ha		

Within such desolate scenes of loss of vegetation cover (Table 6) and loss of healthy vegetation (Table 7), the year 2019 showed a ray of hope of highest areas under vegetation w.r.t. the unique highest pixel range for that year

(Table 5) after a long gap since 2005. That fact was evidenced from the development of various types of agroforestry systems on farm lands (Figure 8, Figure 8a-1, Figure 8a-2). In that way agroforestry systems were proved to be potential to increase overall increase in NDVI values i.e., increase in vegetation cover in the concerned subdivisions. Thus, putting agroforestry systems on more farm lands, as obtained in the year of 2019, is the better means for resilience to get back higher NDVI values resembling the past, as in the year of 2005, with higher vegetation cover.

Conclusion:-

1) Intermingling features of low, medium and high land situations in South 24 Parganas district, are with maximum areal coverage under low lands followed by medium and high lands.
2) Highest NDVI pixel range has decreased from 0.70 to 0.47 during the period of 2005 - 2019.
3) Comparative analysis of DEM features and NDVI mapping revealed natural trend of terrestrial plant succession and gradually higher NDVI values on relatively higher land situations.
4) Areal extents with higher NDVI values decreased year after year during 2005-2015 and thereby increased in the year of 2019.
5) Recent increase in healthy vegetation during 2015 – 2019 due to raising of various types of agroforestry systems on high and medium arable lands.
6) Such GIS based NDVI maps are potentially helpful in monitoring of vegetation covers in remote areas as well as areal coverage of arable lands under agroforestry systems, and thereby promoting attainment of the objectives of the UN SDG 15 (i.e., conserving life on land) as well as assuring food security (SDG 2), decent life and economic growth (SDG 2).

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Conflicts of Interest:
The authors declare no conflicts of interest.

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