IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

Environmental Change in Coastal Region of West Bengal: A District Level Study

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Abstract: *The 21st century experiences a rapid pace of urbanization in the world and especially in the developing countries like- India. More than half of the world's population lives in cities and towns that symbolize the unprecedented growth of urbanization. This very urbanization is coupled with social, economic, spatial and environmental impacts and challenges. Though higher rate of urbanization seems to be positive sign for economic development and overall prosperity of the regions. Contemporary urbanization in developing regions means inadequate basic infrastructural amenities, substandard housing, overcrowding, depletion of green spaces, inadequate transport facilities, and non-compliance with building bye-laws and planning regulations. This leads to multiple and serious environmental problems in the form of pollution, deforestation, wet land destruction, erosion and flooding, urban sprawl, slums and squatter settlements, and aesthetic degradation which all have adverse impacts on human's well-being. Similar kinds of impacts are visible not only in the interior parts of the country but also in the coastal zones where urban places are facing multiple challenges and ecological crisis as well. The present study focuses on the development and environment in the coastal region (including districts East Medinipur and South 24-Parganas) of West Bengal, a state with 31.87 percent level of urbanization as per Census of India 2011. Since this study is in preliminary phase, there has been made an attempt to provide an overview on the quality of life and environmental conditions in the coastal region. Present study is based on secondary source of data and information, and tries to address the following objectives: a) to examine the urbanization- environment relationships and its consequences in the coastal areas, and b) to identify and explore the emerging issue areas and concerns in the coastal region of the state.*

Keywords: Urbanization, development, environmental, substandard, human's well-being, pollution, overcrowding, deforestation

I. INTRODUCTION

In the last two hundred years the world has witnessed rapid growth in urban population form 2 percent to nearly 50 percent. The most peculiar aspect of this urbanization is the increase in the number of megacities comprising 10 million or more people. From 4 megacities in 1975 to 18 megacities in year 2000. According to an estimate of the United Nations (UN), there would be 22 megacities by year 2015. Urbanization in the contemporary world is directed towards a growth of small to medium size cities deviating from its familiar track of creation of huge urban agglomerations. However, with little change in criteria of *urban,* migration from rural areas contributes to an increase in urban population. The reason for migration of rural people to urban areas is associated with availability of greater opportunities in urban areas such as livelihoods, education, healthcare and services. People living in urban areas are comparatively better off than the people who reside in rural areas in terms of having access to better health, education, culture and other physical and material comforts that upgrade the quality of human life.

Coastal regions which provide shelter to a large proportion of worlds' population are now found to be under pressure of environmental degradation. In developing countries this problem is the most serious and one of the reasons for environmental degradation is the growth in the density of population. People are found highly concentrated in coastal region. These features are in connection to many economic benefits such as industrial development, urbanization, revenue from tourism, advanced transportation and food processing activities located thereon. But such growth in

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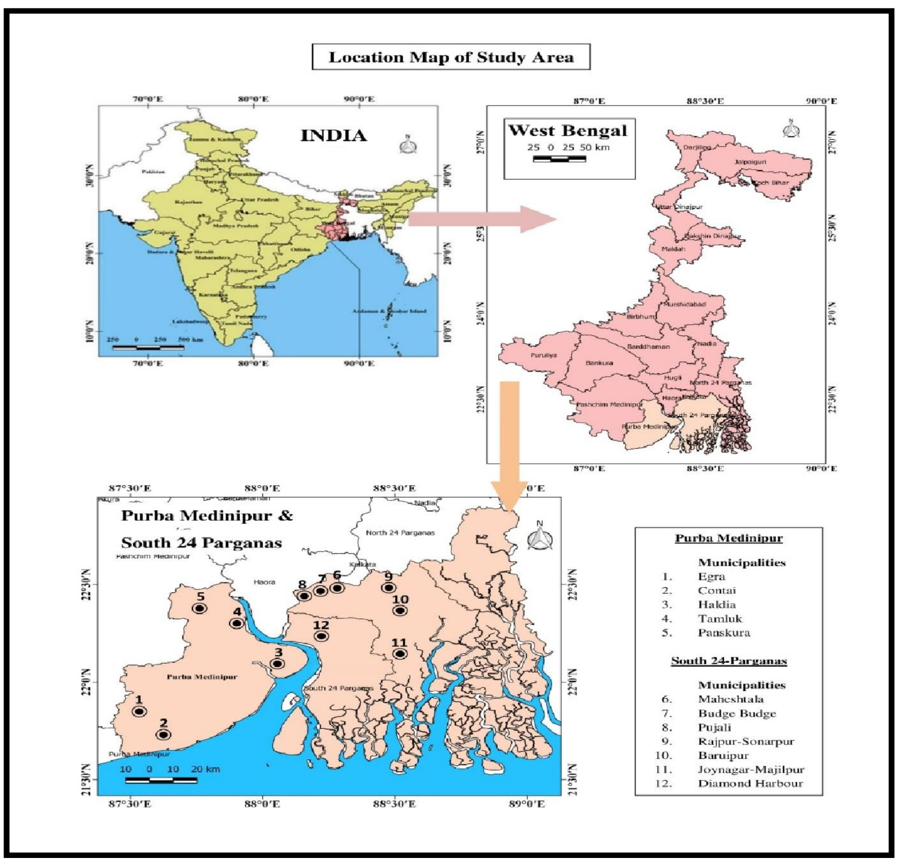
population accompanied by economic and technological development actually puts ecosystems of the region under threats and perils. Many international agencies like United Nations Development Programme (UNDP) through their strategy and activities look for effective governance of water that ensures equitable access to water supply and sanitation in these areas. They actively raise the concerns like access to sustainable energy services. To combat desertification and land degradation, they propose for sustainable land management. These activities include a creation of favorable situation by which bio-diversity can be conserved and used sustainably. Priority areas of The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) include, among others; social issues; environment and sustainable development. The World Urban Forum (formed in 2001) is an international conference dedicated to urban issues. It is organized by UN-Habitat to examine two important issues of the contemporary world such as rapid urbanization and sustainable urban development. Focus areas of Asian Development Bank (ADB) are environment, climate change, disaster risk management, education, finance sector development, infrastructure including transport and communications, energy, urban development, water supply and sanitation, regional cooperation and integration, private sector lending. In the recent years, ADB advocated and highlighted the importance of keeping a proper balance between the creation and development of basic amenities in the urban sectors for the well-being of population integral to it and maintaining the safety and well-being of environment. These studies stress on initiatives and regulations, norms and standards to maintain the standard of living without causing environmental degradation.

II. THE STUDY AREA



Source: Prepared by the Author

The coastal region of West Bengal consists of two districts of the State which is located in the eastern part of India. The state of West Bengal is geographically located in the east with its southern part being one of the ecologically sensitive zones of the country, world over known for the *Sundarbans*, the mangrove forest. As the focus of the study, two districts of West Bengal namely Purba Medinipur and South 24-Parganas are selected to study the urbanization, human development and environmental conditions of the municipalities located in the region, as shown in the Map 1.

The coastal districts Purba Medinipur and South 24-Parganas have 11.65 percent and 25.61 percent of the total population in urban areas. There are five Municipalities in Purba Medinipur and seven Municipalities in the South 24-Parganas.

Purba Medinipur district is a segment of the Lower Ganga Plain (Coastal Belt on the Bay of Bengal), West Bengal, India. Its geographical location lies between 21° 36' 35"N to 22° 02' 23"N and 87° 22' 48"E to 88° 01' 12"E, and it covers an area of 4295.00 sq. km. Purba Medinipur district is surrounded by Paschim Medinipur and Howrah in north, Bay of Bengal in the south, South24-Parganas and Howrah in east and also Odisha state in the west.

South 24-Parganas is the southernmost district of the State occupying southern part of the Bengal Delta. The district lies between 21°29'0" north and 22°33'45"north latitudes and 88°3'45" east and 89°4'50" east longitudes. The district peripheries 9,960 sq. km. Map 1 Showing the Location Map of Coastal Region of West Bengal (Study Area)

III. REVIEW OF LITERATURE

For the purpose of present research several studies are reviewed and their major findings are discussed in the following sections. Most of these works focus on urbanization, urban development and environmental conditions in the coastal region at different scales. Mavris, C. (2011) studied threat of destruction of Cyprus coastal resources and an evolution of future management towards their sustainable use. The present concern is to revive and revitalize the environment that had long been affected by tourism development through the process measures and undertaken project. Study finds that an Integrated Coastal Zone Management can keep a balance between sustainable environmental tourism and sustainable coastal zone management. Kara, B., Esbah, H. and Deniz, B. (2013) study analyzed changes in land use and land cover (LULC) in the Kusadasi coastal areas during 1993-2006. Aerial photographs, high resolution IKONOS and Quick Bird satellite images have been taken for the present research. Attention is paid to the effects of urban fabric, industrial, commercial and transport units and advocated for using non-agricultural vegetation and permanent crops in the area. Mohanty, P.K., Panda, U.S., Pal, S.R. and Mishra, P. (2008) studied the Coastal Zone of Odisha which runs for 480 km on the eastern side of India. Study acknowledges that in last few decades there has been tremendous pressure on the coastal zone for the development of fisheries, aquaculture, ports, harbours and urban settlements. These all activities have led to rapid environmental changes in the region. They have become issue of concern for public as well as state government. Remote Sensing observations and field survey are taken for the measurement the nature of change. Findings suggest for an outline of coastal zone management programmes. Hemantkumar A.C., Parthasarathy, D. and Pattanaik, S. (2017) examined the effects of CRZ rules and contravention in Mumbai Metropolitan Region. This urban region is the expertise of remarkable growth of fast industrialization and urbanisation. Mangrove destruction, hamper to coastal ecology and urban biodiversity; high population density; inverse environmental quality as well as socio-economic termination are common problem exhibited in the region. After analysis it is said that urban biodiversity management needs to clear valuation of the long-term ecological and socioeconomic benefits of sustenance of coastal ecology and related livelihoods. Bera, A. (2013) highlighted various developmental activities gradually affected the coastal eco-system. As a main coastal tourist spot Digha, in the North East India, and how to protect this requires a comprehensive attention. Both primary and secondary data, thematic map, cartographic technique and some statistical techniques are applied in study. Tarafder, S and Jana, N.C. (2014) assessed the stresses on nature, scope and extension of tourism development with the environmental perspective and through the sustainable eco-tourism in the coastal region of West Bengal. Secondary and primary data source has been taken into consideration to analysis the phenomenon. After analysis it is observed that without compromising the coastal environment, new focus should on development of eco-friendly eco-tourism in regions of state of West Bengal. Roy, M. (2020) highlighted that one of the very important factors behind economic growth is coastal tourism in Digha of West Bengal. There is an imbalance between tourism functions and natural environmental activities and that is the main query of this study. The SWOT analysis has been taken for the methodology devised for this concern. The findings suggested that to avoid the current problem, public awareness on the matter of adverse effects of huge pressure of mass tourism and the practices of sustainable eco-tourism is urgently needed. This will contribute towards a better tourism space to develop and attract more number of tourist in the area. Efforts should be made to make Digha a sound place from tourism and environment and economic point of views.

IV. OBJECTIVES

The present study attempts to address the following major objectives:

- To assess and measure development, quality of life and liveability in municipal urban centres of coastal region of West Bengal;
- To analyze environmental quality and detrimental factors in the study area of coastal region;
- To examine environmental changes in select municipalities of the coastal region;
- To suggest policy measures to create sustainable coastal environment;

V. METHODOLOGY

The secondary source of data is collected from various sources books, research articles, Census of India 2011, District Statistical Handbook 2011, Central Pollution Control Board of India (CPCB) and the West Bengal State Pollution Control Board (WBSPCB), Kolkata and others.

(i) Satellite Data

The dataset used in the study is multi-temporal Landsat remotely sensed data, with data covering the period from 2001 to 2021; which were acquired from USGS (https://earthexplorer.usgs.gov/). Landsat data have been commonly used for tracking Land Use and Land Cover Changes (LULCCs) or Urban Heat Island (UHI), but few studies have attempted to map and integrate the long-term dynamics of LULCCs and UHI for environmental quality assessment (EQA). The Global Land 30 dataset, which are used as a reference point and it is the secondary dataset, are used (http://www.globallandcover.com/).

Normalized Difference Vegetation Index (NDVI)

The NDVI is the most extensively used vegetation index in urban heat island (UHI) research as an indication of vegetation abundance (Aburas et al. 2015; Ghaleb and Mohammed 2015; Nasser Mohamed Eid et al. 2020; Sarp 2012; Sruthi and Aslam 2015). And is computed with the red and near-infrared band in multispectral satellite images using Eq. 1.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \qquad (1)$$

Normalized Difference Built up Index (NDBI)

For the mapping of urban constructed areas or impervious surface, NDBI is extremely helpful (Malik et al. 2019), and has been computed using the Eq. 2 expressed as follows:

$$NDBI = \frac{(MIR - NIR)}{(MIR + NIR)} \qquad (2)$$

Where, MIR (Band 5 for Landsat TM, and Band 6 for Landsat 8) and NIR (Band 4 and 5 for Landsat TM and Landsat 8 respectively) are middle infrared and near-infrared respectively. A negative NDBI score often denotes a body of water, whereas values around zero suggest vegetation and positive ones indicate built-up (Liu, X. et al. 2020; Rahdary et al. 2008; Tzavali et al. 2015; Yuan, F. 2008).

Normalized Difference Water Index (NDWI)

Monitor changes in water content of leaves, using near-infrared (NIR) and short-wave infrared (SWIR) wavelengths, proposed by Gao in 1996 and has been computed using the Eq. 3 expressed as follows:

$$\mathrm{NDWI} = \frac{(\mathrm{Green} - \mathrm{NIR})}{(\mathrm{Green} + \mathrm{NIR})} \qquad (3)$$

Retrieval of Land Surface Temperature (LST)

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To calculate land surface temperature (LST), raw thermal band data (band 6 in Landsat 5 (TM) and Landsat 7 (ETM+), and band 10 in Landsat 8 (TIRS) were converted into spectral radiance using the following formula (Eq. 4):

$$L_\lambda = M_L * Q_{CAL} + A_L \quad (4)$$

Where, L_λ is the top of atmospheric spectral radiance $(Watts/(m^2 * srad * \mu m)$, M_L is the band-specific multiplicative rescaling factor from the metadata, and A_L is the band-specific additive rescaling factor from the metadata.

To obtain at sensor temperature (brightness) was evaluated (Firoozi et al. 2020; Kayet et al. 2016; Kumar et al. 2018; Meng et al. 2019; Ning et al. 2018) by Eq. 5.

$$BT = \frac{K_2}{Ln\left(\frac{K_1}{L_\lambda} + 1\right)} - 273.15 \quad (5)$$

Where, BT is at-Satellite Brightness Temperature (°C), $L_\lambda$is TOA Spectral Radiance$(Watts/(m^2 * srad * \mu m))$, K_1 is calibration Constant$(Watts/(m^2 * srad * \mu m))$, and K_2 is Calibration Constant (K). For LANDSAT-5 TM value of K 1 for band 6 is 607.76 and K 2 for band 6 is 1260.56 respectively. For LANDSAT-8 TIRS values of K 1 for band 10 and 11 are 774.8853 and 480.8883 respectively and K 2 for band 10 and 11 are 1321.0789 and 1201.1442 respectively.

One of the most key considerations for determining vegetation cover is the normalized difference vegetation index (NDVI) (Xue and Su 2017). Since the index is calculated through a normalization procedure, the NDVI value range is 0 to 1, with a resilient response to green vegetation even in areas with little vegetation (Gandhi et al. 2015; Sruthi and Aslam 2015). NDVI was calculated from the red and near-infrared bands (Eq. 6):

$$NDVI = \frac{NIR - R}{NIR + R} \quad (6)$$

Where, NIR means near-infrared band and R means red band. The proportion of Vegetation (PV) is derived (Basara et al. 2010; Unger et al. 2011) by the following formula (Eq. 7).

$$P_V = \left[\frac{NDVI - NDVI_{Min}}{NDVI_{Max} - NDVI_{Min}}\right]^2 \quad (7)$$

In the next step, calculate the land surface emissivity ($\mathcal{E}$) (Eq. 8) according to **Dissanayake et al. 2019** is given below.

$$\mathcal{E} = 0.004 * P_V + 0.986 \quad (8)$$

Where, p_v is the proportion of vegetation. Finally, land surface temperature (LST) in °C is estimated by the following formula (Eq. 9).

$$LST = \frac{BT}{1 + \left(\frac{W_\lambda * BT}{\rho}\right) * Ln(E)} - 273.1 \quad (9)$$

Where, BT-satellite brightness temperature (°C), $\mathcal{E}$ is the land surface emissivity, ρ is h*c/σ $(1.4388 * 10^{-2}$ m * K) = 14388µmK, h *is* Planck's constant$(6.626 * 10^{-34}\, J * s)$, σ is Boltzmann constant$(1.38 * 10^{-23}\, J/K)$, c is the light velocity$(2.998 * 10^8\, m/s)$, and W_λ is the wavelength of emitted radiance, for LANDSAT-5 TM value of W_λ for band 6 is 11.45µm, for LANDSAT-8 TIRS value of W_λ for band 10 and band 11 are 10.8 µm and 12 µm respectively.

(ii) Correlation Analysis

Pearson Product-Moment Correlation Coefficient (PPMCC)

Correlation analysis (Eq. 10) is a quantitative analytical technique, thus becoming useful to explore the degree of association between independent and dependent variables (Schober & Schwarte, 2018; Senthilnathan, 2019). Here, to study the relationship between independent and dependent variables i.e. Normalized Difference Water Index (NDWI), Normalized Difference Build up Index (NDBI), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) and Spatial Pattern of Precipitation Index (PCI) of land use/land cover classes of the earth surface has been taken in to consideration.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (10)$$

Where, 'r' is the Pearson products moment correlation coefficient, 'x_i' is values of x variable in a sample, $\bar{x_i}$ is mean of values of x variable, y_i is the value of y variable in the sample, and $\bar{y_i}$ is mean values of y variable.

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Linear Regression Model

The Pearson product-moment correlation coefficient (PPMCC) which measures the direction and strength of the relationship between two variable, while regression analysis estimates the functional relationship between the variable independent (x) and dependent (y) (Hardle & Vieu, 1992; Mathieu & Zajac, 1990; Zhao, 2013). Multiple linear regression (MLR) is used to ascertain the impact of several numbers of independent variables, X_1, X_2, X_3…X_i on a single dependent variable y Symbolically (Eq. 11). In this study, Land Surface Temperature (LST) is dependent variable and independent variables are Normalized Difference Water Index (NDWI), Normalized Difference Build up Index (NDBI), Normalized Difference Vegetation Index (NDVI).

$$y = \beta_o + x_1\beta_1 + \cdots x_p\beta_p + \varepsilon \quad (11)$$

Where, 'β' reflects how much of an effect x has on y, and '€' is the error term.

Environmental Stresses of Coastal Region

With the increasing pressure of population in the coastal areas the environment has come under unprecedented stress. The associated activities with human population are urbanization, industries, and tourism all of them influence the land and environment in the region. The coastal region of West Bengal is too experiencing uncontrolled expansion of urban centres and growing tourism which together affects the area. Equally important is change in the land use and land cover of the region due to various factors.

Land Use and Land Cover Statistics

Land cover describes surface cover on the ground such as vegetation, urban infrastructure, water, bare soil etc. Identification of land cover begins with the baseline details for activities for example- thematic mapping along with change detection analysis. Land use indicates to the motivation that the land serves for instance, pleasure, wildlife dwelling or cultivation. When used jointly with the phrase Land Use/ Land Cover (LULC) generally mentions the classification or categorization of human activities and natural elements on the environment within a certain time based on set up scientific and statistical systems of analysis of suitable source materials.

Table 1 depicts about Land use and land cover statistics of Purba Medinipur district from Figure 1. Among various attributes of land use land cover of earth surface, water body gradually has decreased from the year 2001 to 2011 from 11.40 percent to 10.38 percent and it further decreased in the year 2021 to 9.91 percent. The field of vegetation has decreased too. In the year 2001, it was 21.76 percent and it decreased by -3.76 percent became in 2011. It further declined to 14.29 percent in the year 2021. If one can see difference from 2001 to 2021, it is found at 7.47 percent. In terms of Crop and, a little change is reported. It has been seen that 51.48 percent was reported in 2001 and that increased slightly by 2011 to 51.58 percent and it further grew in 2021 to 52.11 percent. Share of fallow land also declined over the study period in the coastal region. In the year 2001, 2011 and 2021, its pattern has been 1.15 percent, 0.80 percent and 0.55 percent reduction respectively. Due to the population increase in the region the data regarding built up land has shown an unprecedented increase being 14.22 percent in 2001, which grew to 19.25 percent in 2011 and further to 23.13 percent in 2021. In terms of change in percentage, water body share declined considerably being -1.02 percent in 2001-11 and -0.47 percent in 2011-21. A higher decrease is reported in vegetation cover the years being -3.76 percent in 2001-11 to -3.71 in 2011-2021. Slightly percent share of crop land is reported increasing. Fallow land has also declined. Built up land share has shown a drastic change in the last twenty years in the region. Having increased to 5.03 percent in 2001-11, it grew at 3.88 percent during 2011-21.

Figure 1 (a), (b) & (c) shows the graphical presentation of land use and land cover statistics of Purba Medinipur district.

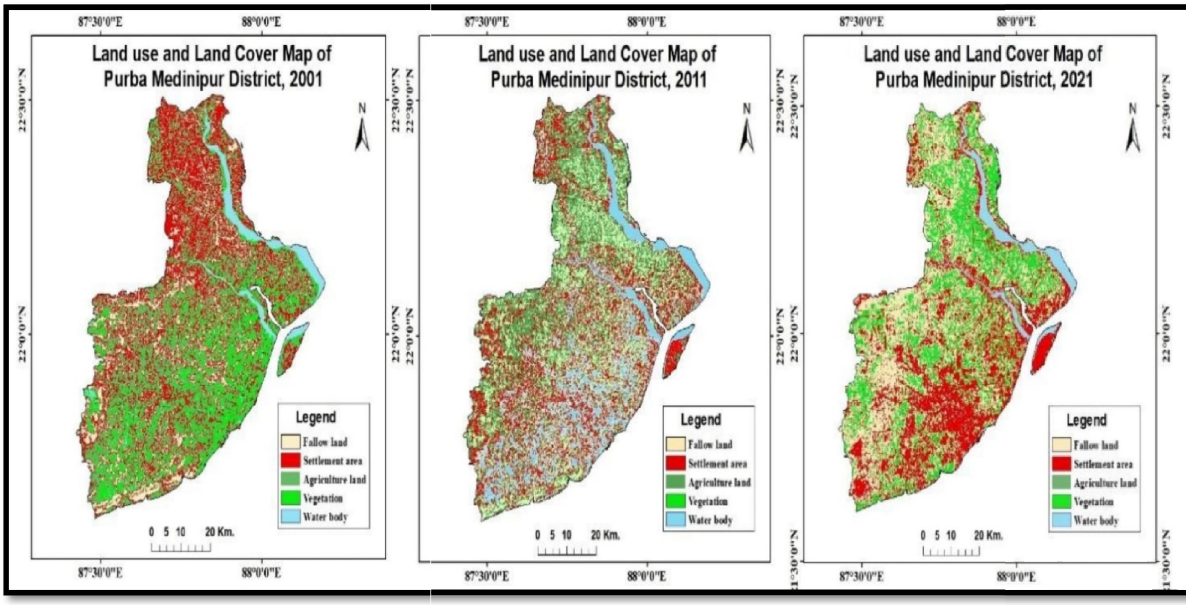
Table 1 Land Use and Land Cover Statistics of Purba Medinipur District

Land Use and Land Cover Class	Absolute Area Cover (Sq. km.)						LULC Changes (Percent)		
	2001		2011		2021		2001-2011	2011-2021	2001-2021
	Area	Percent	Area	Percent	Area	Percent			
Waterbody	453.350	11.40	412.880	10.38	394.224	9.91	-1.02	-0.47	-1.49
Vegetation	865.450	21.76	715.860	18.00	568.750	14.29	-3.76	-3.71	-7.47

Crop land	2047.660	51.48	2051.630	51.58	2073.501	52.11	0.1	0.53	0.63
Fallow land	45.760	1.15	31.850	0.80	22.008	0.55	-0.35	-0.25	-0.6
Built up land	565.780	14.22	765.750	19.25	920.480	23.13	5.03	3.88	8.91

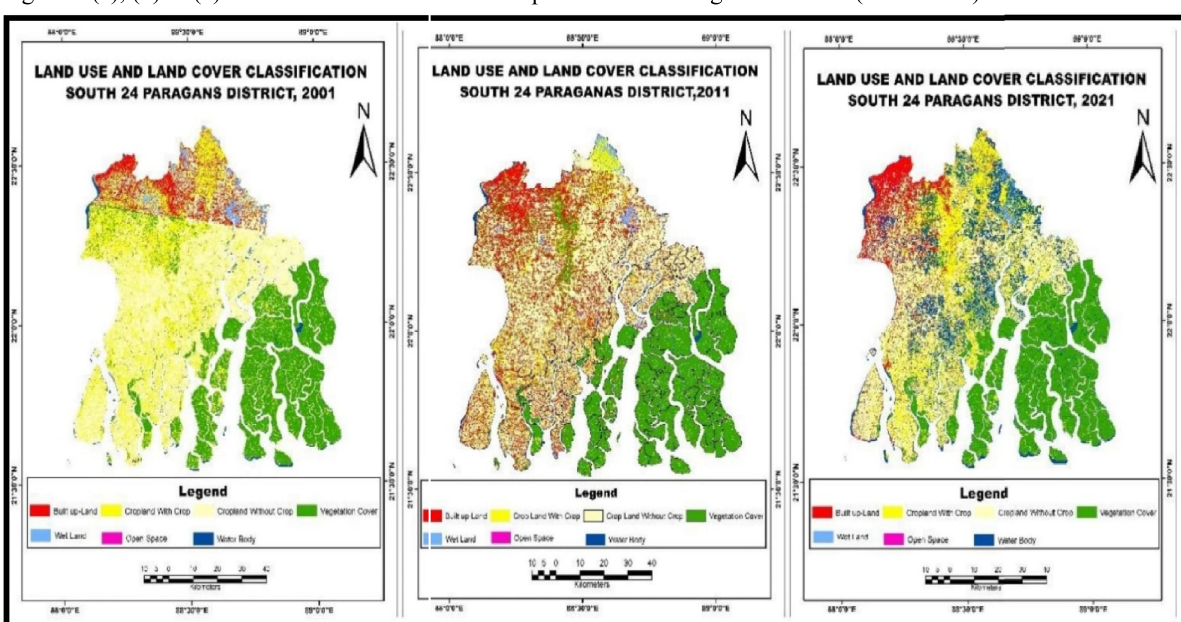
Source: Landsat Images Calculation by the Author

Figure 1 (a), (b) & (c) Land Use and Land Cover Map of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

Figure 2 (a), (b) & (c) Land Use and Land Cover Map of South 24-Parganas District (2001-2021)



Source: Landsat Images, Earth Explorer

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Table 2 shows about land use and land cover statistics of South 24-Parganas district in sq. km. from Figure 2. In terms of built-up land attribute temporally increases since 2001 when it was 6.18 percent, and by 2011 and 2021 it became 19.94 percent and 29.93 percent respectively. In case of cropland with crop area has been suddenly decreased 23.91 percent - 8.09 percent during 2001 and 2011and in 2021 it is 6.92 percent. Cropland without crop attribute has been decreased proportionally i.e. 39.38 percent, 36.72 percent and 23.36 percent in 2001, 2011 and 2021 respectively. Regarding vegetation cover in 2001 it was 27.15 percent and it reduced 24.47 percent and 21.82 percent in 2011 and 2021 respectively. In case of wet land attribute which had 1.62 percent in 2001, then it increased 2.37 percent in 2011 and in 2021 it reduced 1.67 percent. Open space is one of the major important features of land use and land cover whose data had been increased temporarily. It is seen that, the data was 0.14 percent, 0.18 percent and 0.78 percent in 2001, 2011 and 2021 respectively. In terms of water body, the data shows an increase being 1.62 percent in the year 2001, it became 8.245 in 2011. It is further increased by 15.52 percent in 2021. Figure 2 (a), (b) & (c) shows the graphical presentation of Land use and land cover change of Purba Medinipur district.

Table 2 Land Use and Land Cover Statistics of South 24-Parganas District

Land Use and Land Cover Class	Absolute Area Cover (Square km.)						LULC Changes (Percent)		
	2001		2011		2021		2001-2011	2011-2021	2001-2021
	Area	Percent	Area	Percent	Area	Percent			
Built up land	452.64	6.18	1461.23	19.94	2194.05	29.93	13.76	9.99	23.75
Cropland with crop	1752.73	23.91	592.98	8.09	507.25	6.92	-15.82	-1.17	-16.92
Cropland without crop	2886.39	39.38	2691.62	36.72	1712.42	23.36	-2.66	-13.36	-16.02
Vegetation cover	1990.16	27.15	1793.51	24.47	1599.08	21.82	-2.68	-2.65	-5.33
Wet land	118.93	1.62	173.42	2.37	122.69	1.67	0.75	-0.7	0.05
Open space	10.15	0.14	13.16	0.18	56.95	0.78	0.04	0.6	0.64
Water body	118.97	1.62	604.06	8.24	1137.54	15.52	6.32	7.08	13.90

Source: Landsat Images Calculation by the Author

Normalized Difference Vegetation Index (NDVI)

Table 3 shows the features of Normalized Difference Vegetation Index (NDVI) in the district of Purba Medinipur. The mean value was 0.188462 in the year 2001, in 2011, it was decreased by 0.179152 and it is again slightly increased by 0.179478 in the year 2021 (Figure 3 & Figure 4 (a), (b), & (c)).

Table 3 Summary Statistics for NDVI of Purba Medinipur District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
Purba Medinipur	2001	-1	1	0.188462	0.157635
	2011	-1	1	0.179152	0.206258
	2021	-0.182763	1	0.179478	0.11476

Source: Landsat Images Calculation by the Author

Table 4 represents the summary statistics of South 24-Parganas district in the field of Normalized Difference Vegetation Index (NDVI). In the year of 2001, the mean value was 0.175896. It has increased by 0.198953 in 2011 and it is further tremendously increased by 0.455836 in the year 2021 (Figure 5 & Figure 6 (a), (b) & (c)).

Table 4 Summary Statistics for NDVI of South 24-Parganas District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
South 24-Parganas	2001	-0.416667	1	0.175896	0.150736
	2011	-0.461538	1	0.198953	0.149689
	2021	-0.156852	1	0.455836	0.157094

Source: Landsat Images Calculation by the Author

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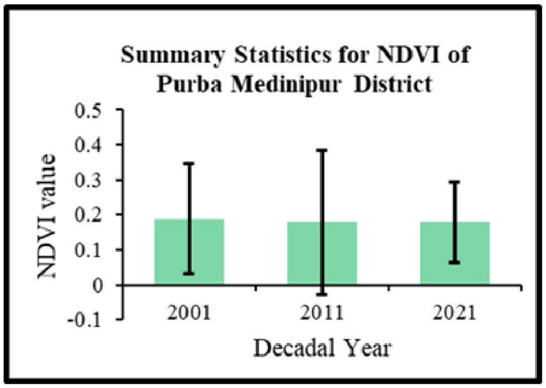
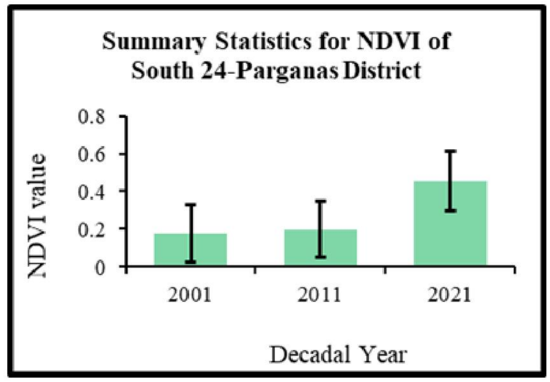
Figure 3 Summary Statistics for NDVI of Purba Medinipur District (2001-2021)



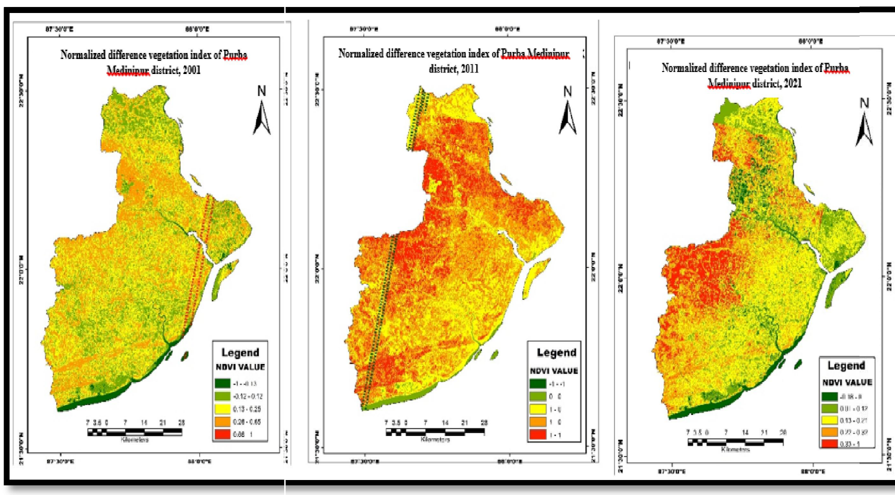
Source: Landsat Images Calculation by the Author Table 3

Figure 5 Summary Statistics for NDVI of South 24-Parganas District (2001-2021)



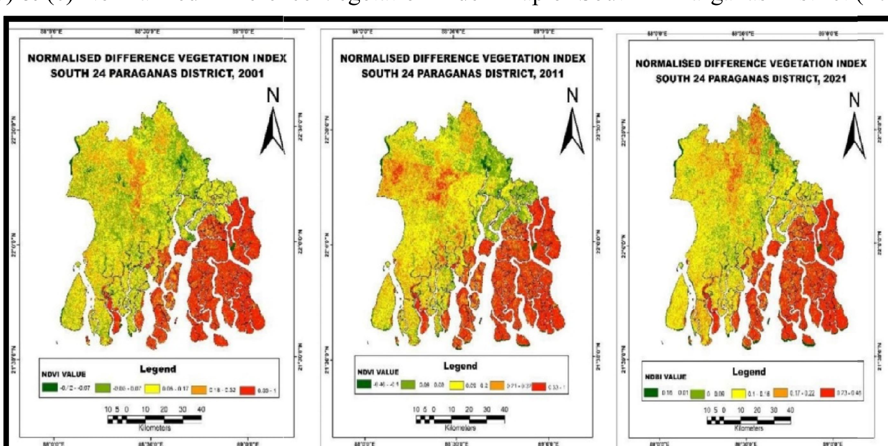
Source: Landsat Images Calculation by the Author Table 4

Figure 4 (a), (b) & (c) Normalized Difference Vegetation Index Map of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

Figure 6 (a), (b) & (c) Normalized Difference Vegetation Index Map of South 24-Parganas District (2001-2021)



Source: Landsat Images, Earth Explorer

Normalized Difference Build up Index (NDBI)

Table 5 highlights the statistics of Normalized Difference Build up Index (NDBI) in the district of Purba Medinipur. It is seen that, the mean data were increased in the year 2001, 2011 and in 2021 it has decreased. The value was 0. 073539 in 2001, 0.076338 in 2011 and -0.084437 in 2021 (Figure 7 & Figure 8 (a), (b) & (c)).

Table 5 Summary Statistics for NDBI of Purba Medinipur District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
Purba Medinipur	2001	-1	1	0.073539	0.217984
	2011	-1	1	0.076338	0.213488
	2021	-0.336411	1	-0.084437	0.08

Source: Landsat Images Calculation by the Author

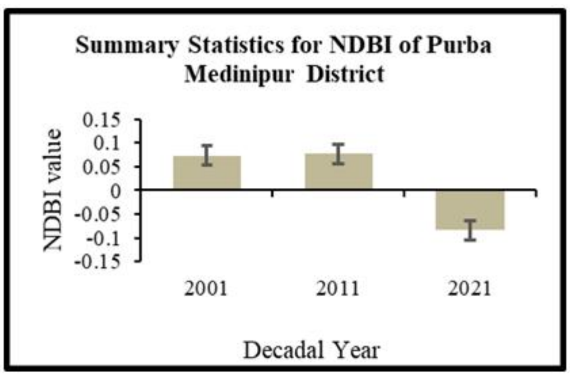
Table 6 presents the temporal changes of Normalised Difference Build up Index (NDBI) of South 24-Parganas district between 2001 and 2021. The mean value has increased from 2001 (0.02238) to 2011 (0.02472) and then decreased -0.11206 in 2021 (Figure 9 & Figure 10 (a), (b) & (c)).

Table 6 Summary Statistics for NDBI of South 24-Parganas District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
South 24-Parganas	2001	0.714286	1	0.02238	0.231317
	2011	-0.72093	1	0.02472	0.190168
	2021	-0.387717	0.237952	-0.11206	0.096075

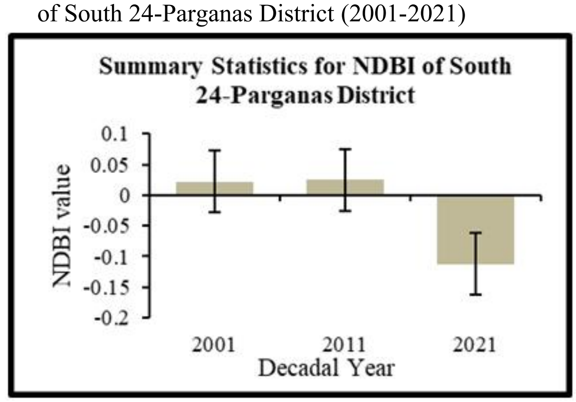
Source: Landsat Images Calculation by the Author

Figure 7 Summary Statistics for NDBI of Purba Medinipur District (2001-2021)



Source: Landsat Images Calculation by the Author Table 5

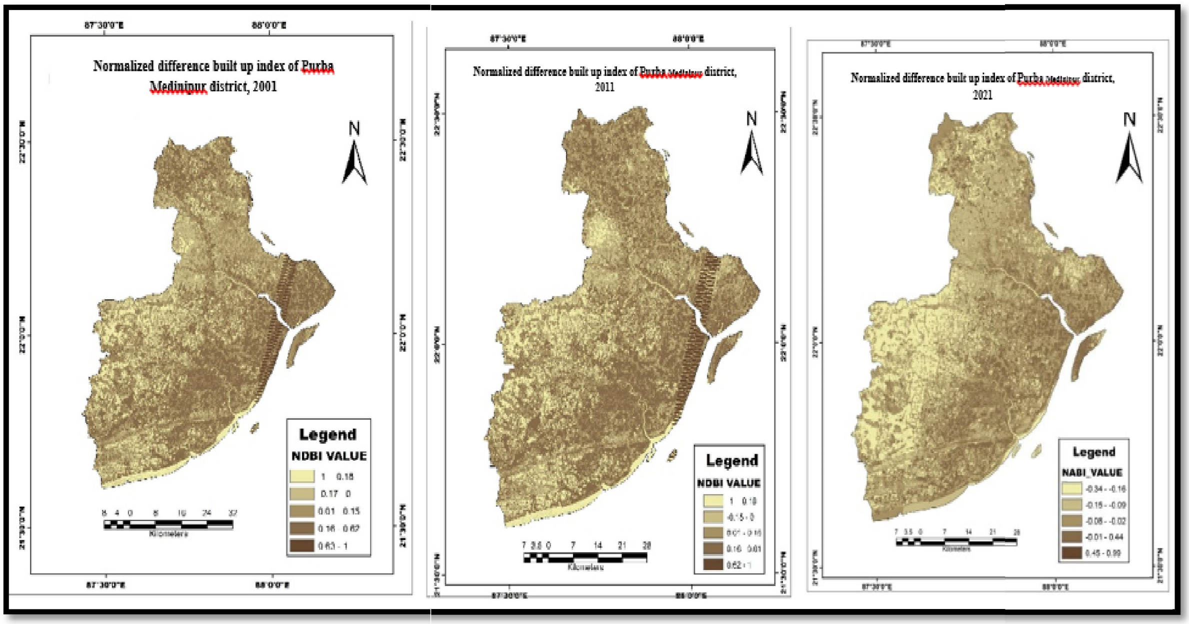
Figure 9 Summary Statistics for NDBI of South 24-Parganas District (2001-2021)



Source: Landsat Images Calculation by the Author Table 5.6

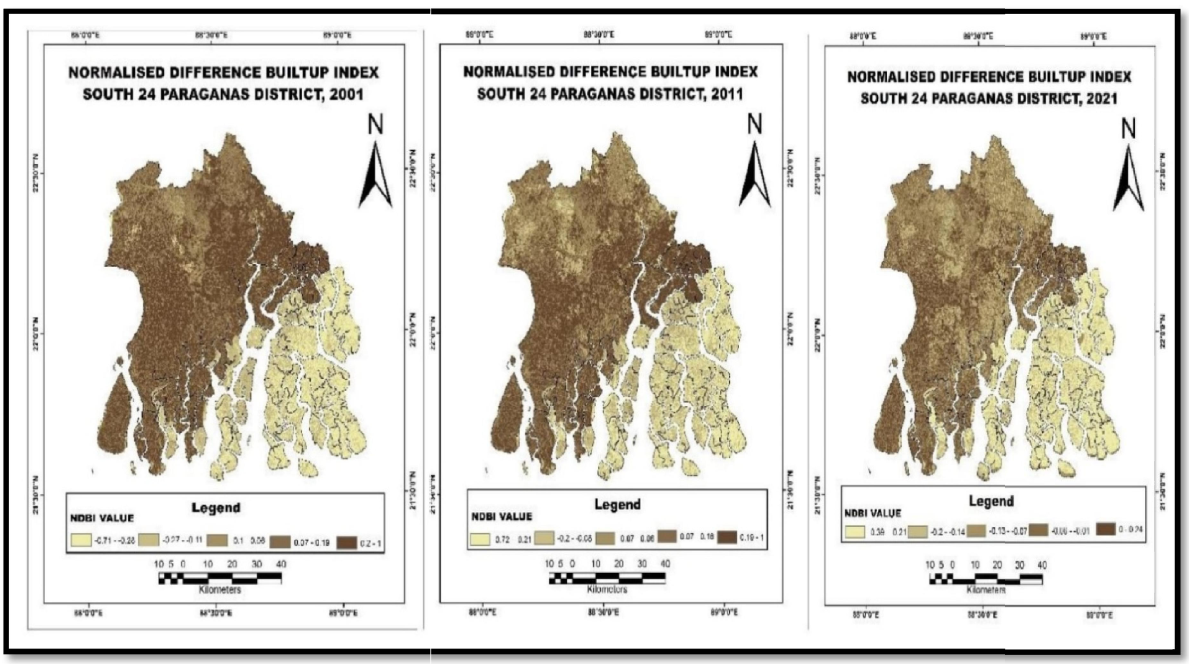
IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

Figure 8 (a), (b) & (c) Normalized Difference Build up Index Map of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

Figure 10 (a), (b) & (c) Normalized Difference Build up Index Map of South 24-Parganas District (2001-2021)



Source: Landsat Images, Earth Explorer

Normalized Difference Water Index (NDWI)

Table 7 explores the summary data of Normalized Difference Water Index (NDWI) in the district, Purba Medinipur. The mean value was -0.191652 in 2001 and has increased by -0.16751 in 2011. It is further increased by -0.1463191 in the year 2021 2021 (Figure 11 & Figure 12 (a), (b) & (c)).

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 1, February 2024

Table 7 Summary Statistics for NDWI of Purba Medinipur District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
Purba Medinipur	2001	-1	1	-0.191652	0.157779
	2011	-1	1	-0.16751	0.16371
	2021	-1	0.242716	-0.1463191	0.104809

Source: Landsat Images Calculation by the Author

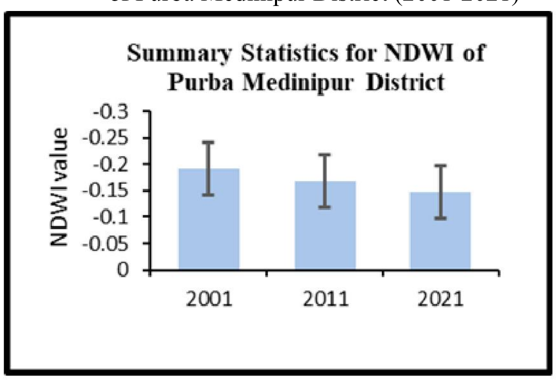
Table 8 denotes the features of the term Normalized Difference Water Index (NDWI) of South 24-Parganas district. It was seen that in the year 2001 the mean value was -0.174733 and -0.18532 in 2011. It has increased in the year 2021 and resulted in -0.124744 (Figure 13 & Figure 14 (a), (b) & (c)).

Table 8 Summary Statistics for NDWI of South 24-Parganas District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
South 24-Parganas	2001	-0.486726	1	-0.174733	0.115963
	2011	-0.578231	1	-0.18532	0.119906
	2021	-0.398847	0.203396	-0.124744	0.07429

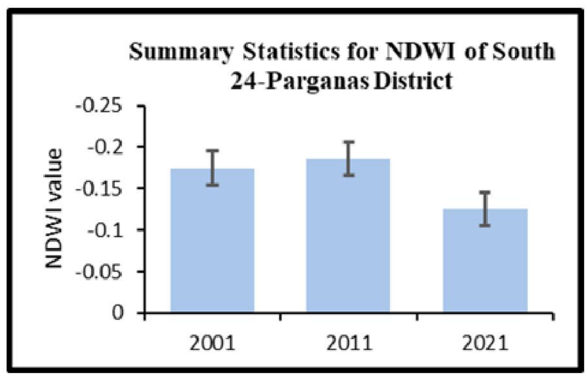
Source: Landsat Images Calculation by the Author

Figure 11 Summary Statistics for NDWI of Purba Medinipur District (2001-2021)



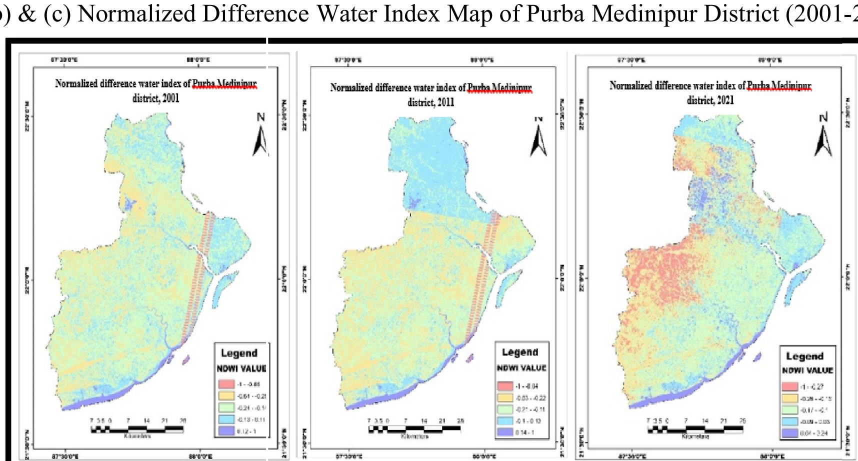
Source: Landsat Images Calculation by the Author Table 7

Figure 13 Summary Statistics for NDWI of South 24-Parganas District (2001-2021)



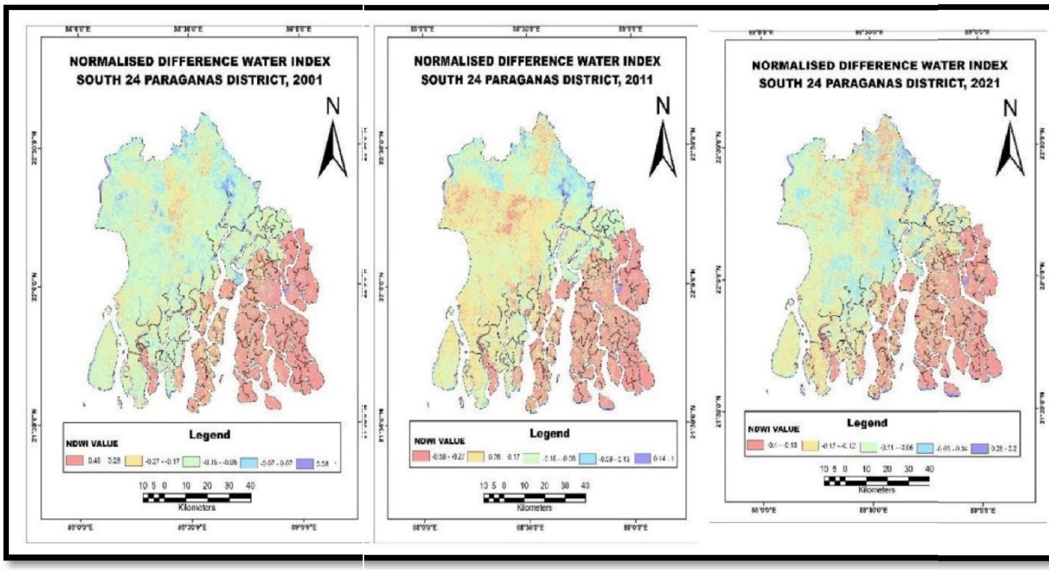
Source: Landsat Images Calculation by the Author Table 8

Figure 12 (a), (b) & (c) Normalized Difference Water Index Map of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

Figure 14 (a), (b) & (c) Normalized Difference Water Index Map of South 24-Parganas District (2001-2021)



Source: Landsat Images, Earth Explorer

Land Surface Temperature (LST)

Table 9 represents the summary statistics of Land Surface Temperature (LST) of the district of Purba Medinipur. It is seen that the data is increased temporarily. In 2001, the mean value was 17.54 (˚C) and the data has increased by 26.41 (˚C) in the year 2011 and it has further increased by 26.66 (˚C) in 2021 (Figure 15 & Figure 16 (a), (b) & (c)).

Table 9 Summary Statistics for LST (˚C) of Purba Medinipur District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
Purba Medinipur	2001	15.15	19.93	17.54	3.37
	2011	25.68	27.14	26.41	1.03
	2021	26.20	27.12	26.66	0.65

Source: Landsat Images Calculation by the Author

Table 10 highlights the statistical data on Land Surface Temperature (LST) of the district of South 24-Parganas. The mean value was 17.975 (˚C) in 2001. It has increased and resulted in 26.545 (˚C) in 2011 and it has further increased in 2021 and became 26.735 (˚C) (Figure 17 & Figure 18 (a), (b) & (c)).

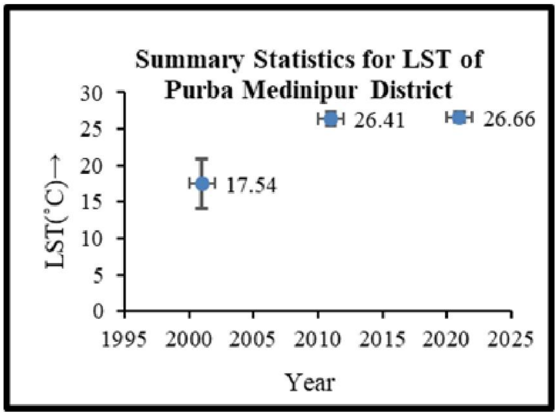
Table 10 Summary Statistics for LST (˚C) of South 24-Parganas District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
South 24-Parganas	2001	15.35	20.60	17.975	3.71
	2011	25.83	27.26	26.545	1.01
	2021	26.28	27.19	26.735	0.64

Source: Landsat Images Calculation by the Author

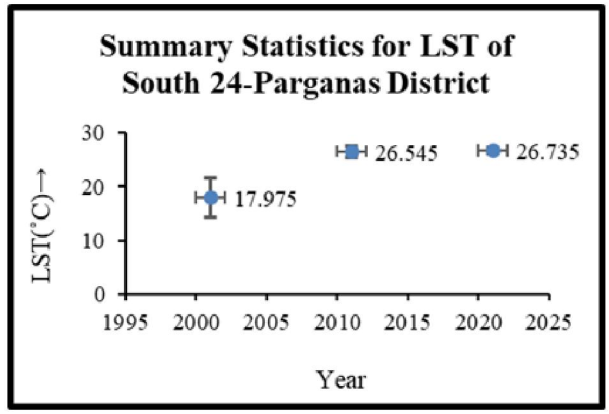
IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

Figure 15 Summary Statistics for LST of Purba Medinipur District (2001-2021)



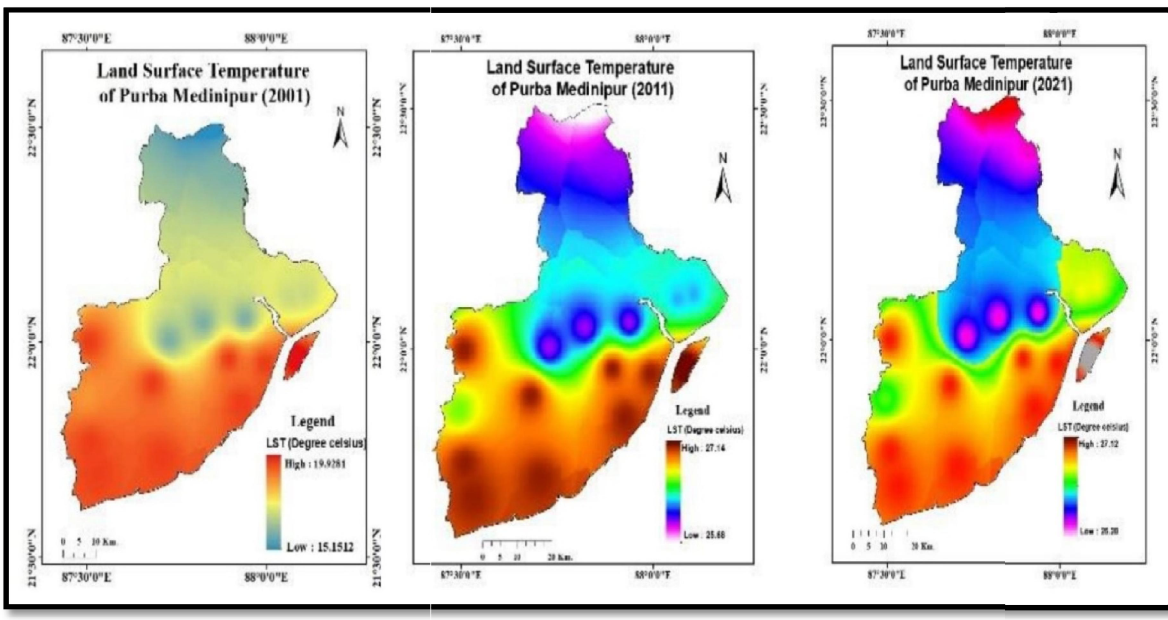
Source: Landsat Images Calculation by the Author Table 9

Figure 17 Summary Statistics for LST of South 24-Parganas District (2001-2021)



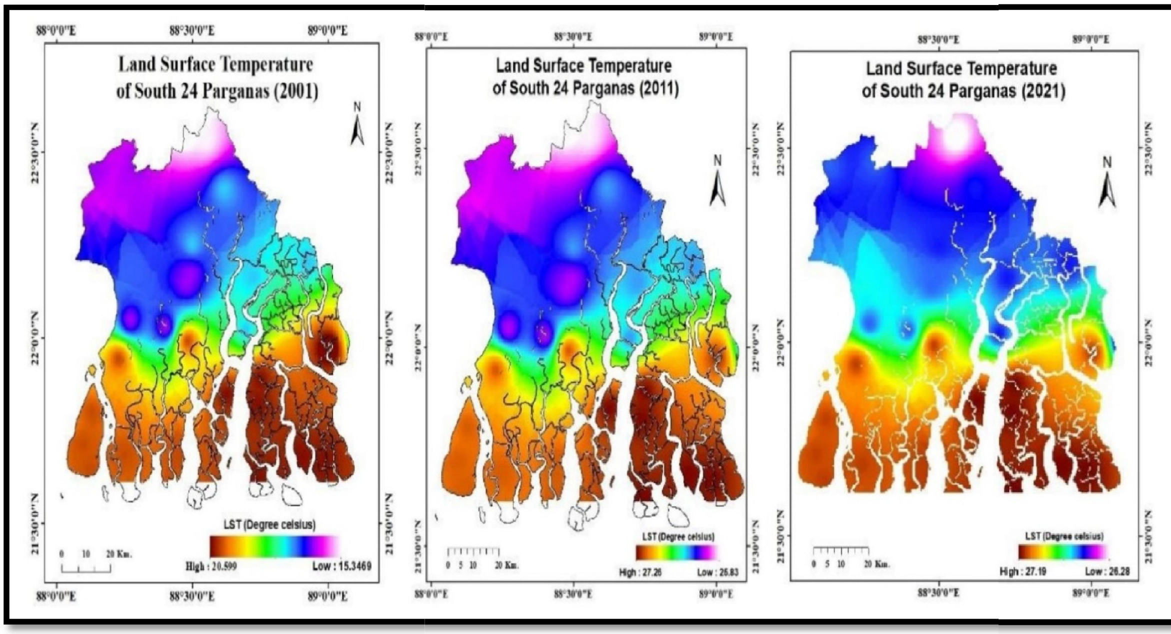
Source: Landsat Images Calculation by the Author Table 10

Figure 16 (a), (b) & (c) Retrieval of Land Surface Temperature Map of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

Figure 18 (a), (b) & (c) Retrieval of Land Surface Temperature Map of South 24-Parganas District (2001-2021)



Source: Landsat Images, Earth Explorer

Spatial Pattern of Precipitation (PCI)

Table 11 explores the temporal changes of spatial pattern of precipitation of Purba Medinipur district. The mean value was 1664.23 mm in 2001 and it has increased in the year 2011 by 1733.175 mm. But it is decreased in 2021 by 1414.23 mm (Figure 19 & Figure 20 (a), (b) & (c)).

Table 11 Summary Statistics for Spatial Pattern of Precipitation (mm) of Purba Medinipur District (2001-2021)

District	Year	Minimum	Maximum	Mean	Standard deviation
Purba Medinipur	2001	1536.58	1791.88	1664.23	180.52
	2011	1656.78	1809.57	1733.175	108.03
	2021	1236.58	1591.88	1414.23	251.23

Source: Landsat Images Calculation by the Author

Table 12 presents the changes on spatial pattern of precipitation in the district of South 24-Parganas. It had changed a lot. The mean value was 16.70.485 mm in 2001, increased and became 1835.965 mm in 2011. It has then decreased in the year 2021 and resulted in 1482.73 mm (Figure 21 & Figure 22 (a), (b) & (c)).

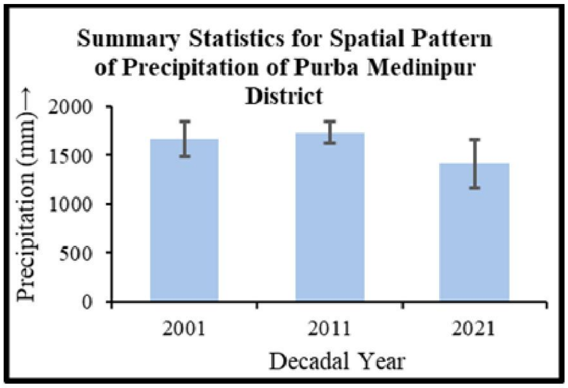
Table 12 Summary Statistics for Spatial Pattern of Precipitation (mm) of South 24-Parganas District (2001-21)

District	Year	Minimum	Maximum	Mean	Standard deviation
South 24-Parganas	2001	1536.28	1804.69	1670.485	189.79
	2011	1701.42	1970.51	1835.965	190.27
	2021	1285.33	1680.13	1482.73	279.16

Source: Landsat Images Calculation by the Author

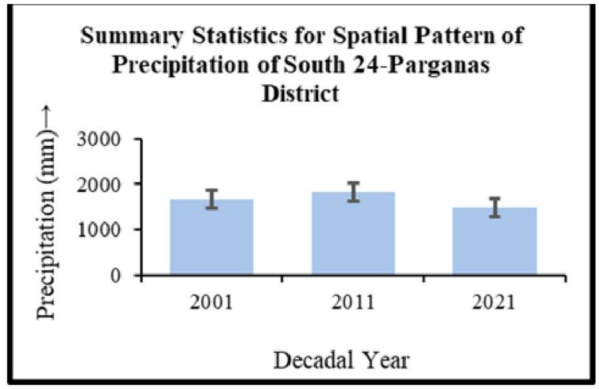
IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

Figure 19 Summary Statistics for Spatial Pattern of Precipitation of Purba Medinipur District (2001-21)



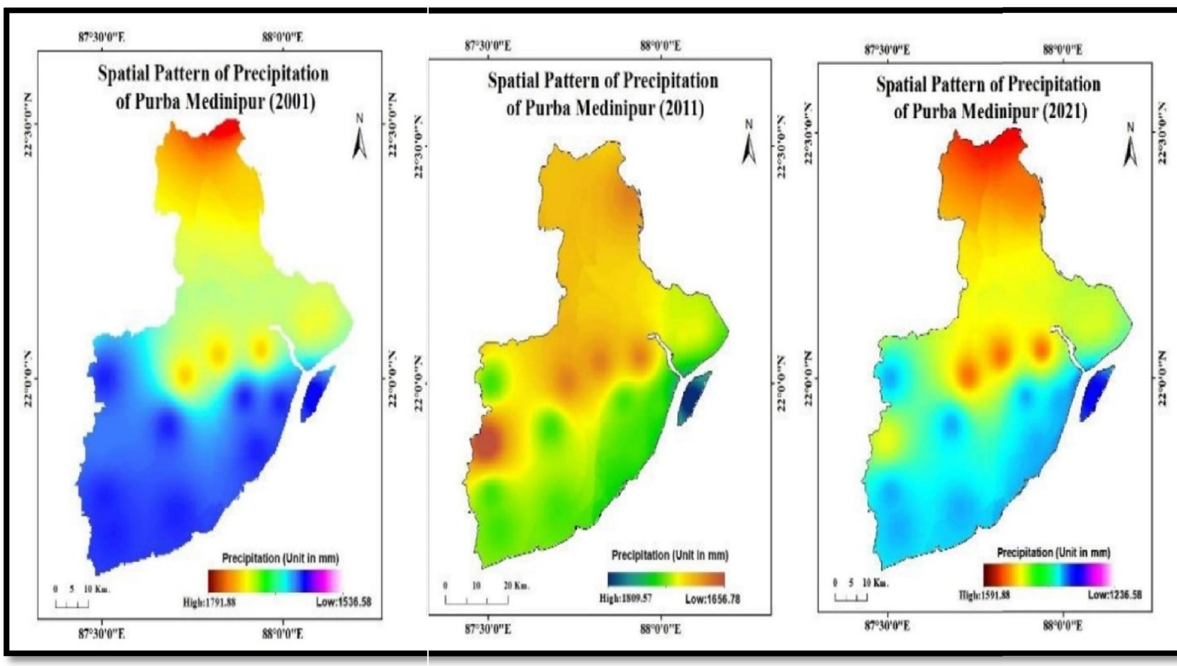
Source: Landsat Images Calculation by the Author Table 11

Figure 21 Summary Statistics for Spatial Pattern of Precipitation of South 24-Parganas District (2001-21)



Source: Landsat Images Calculation by the Author Table 12

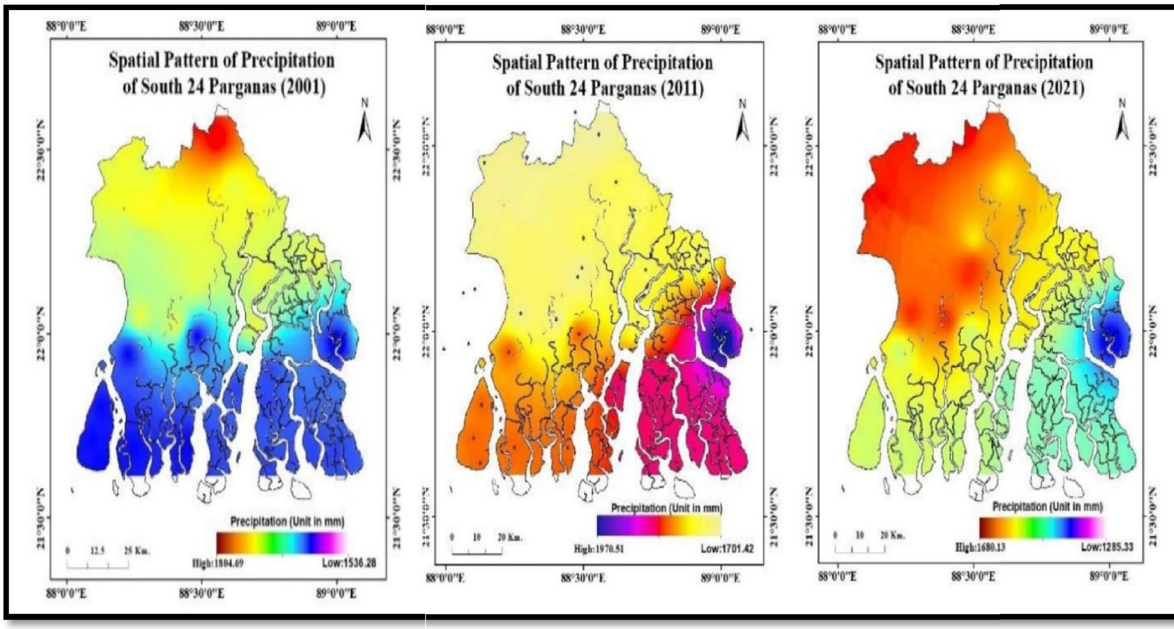
Figure 20 (a), (b) & (c) Spatial Pattern of Precipitation of Purba Medinipur District (2001-2021)



Source: Landsat Images, Earth Explorer

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

Figure 22 Spatial Pattern of Precipitation of South 24-Parganas District (2001-2021) (a), (b) & (c)



Source: Landsat Images, Earth Explorer

Pearson's Correlations, and Linear Regression Model among LST, PCI, NDWI, NDBI, and NDVI

Table 13 and Table 14 depicts the bivariate correlations and linear regression model (LRM) among study variables in the observed period of 20 years (2001-2021). The result shows that LST had a significant negative relationship (p < .001) with NDVI (β coefficient -0.03, -0.13, and -0.06 in 2001, 2011, and 2021 respectively) and NDLI (β coefficient -0.396, -0.386 and -0.385 in 2001, 2011 and 2021 respectively) for all time steps.

Table: 13 Pearson's Correlations among LST, PCI, NDWI, NDBI, and NDVI

Variable			LST		PCI		NDWI		NDBI		NDVI
2001	LST	Pearson's r									
	PCI	Pearson's r	-0.488	***							
	NDWI	Pearson's r	0.261	***	-0.389	***					
	NDBI	Pearson's r	0.4	***	-0.528	***	0.587	***			
	NDVI	Pearson's r	-0.264	***	0.558	***	-0.553	***	-0.329	***	
Variable			LST		PCI		NDWI		NDBI		NDVI
2011	LST	Pearson's r									
	PCI	Pearson's r	-0.501	***							
	NDWI	Pearson's r	0.085	**	-0.188	***					
	NDBI	Pearson's r	0.284	***	-0.508	***	0.616	***			
	NDVI	Pearson's r	-0.418	***	0.745	***	-0.413	***	-0.538	***	
Variable			LST		PCI		NDWI		NDBI		NDVI

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, February 2024

	LST	Pearson's r								
	PCI	Pearson's r	-0.361	***						
	NDWI	Pearson's r	0.007		-0.015					
	NDBI	Pearson's r	0.162	***	-0.257	***	0.012			
2021	NDVI	Pearson's r	-0.19	***	0.644	***	-0.04		-0.063	*

* p < .05, ** p < .01, *** p < .001

Source: Calculated by the Author

Where, LST- Land Surface Temperature, PCI- Spatial Pattern of Precipitation Index, NDWI- Normalized Difference Water Index, NDBI- Normalized Difference Build up Index, NDVI- Normalized Difference Vegetation Index

Table 14 Linear Regression Model (LRM) of Study Variables

		Unstandardized Coefficients		Standardized Coefficients	t	p
2001 **		B	Std. Error	Beta		
	(Constant)	22.68418	0.363634		62.38188	0
	NDWI	0.275622	1.303233	0.006971	0.211491	0.83
	NDBI	5.413116	0.893868	0.194776	6.055832	0
	NDVI	-0.754268	0.931853	-0.025891	-0.809428	0.42
		Unstandardized Coefficients		Standardized Coefficients	t	p
		B	Std. Error	Beta		
2011 ***	(Constant)	29.84358	0.255975		116.5877	0
	NDWI	-2.79438	1.081908	-0.08271	-2.58283	0.01
	NDBI	2.040408	1.001292	0.070411	2.037776	0.04
	NDVI	-2.7906	0.858675	-0.12571	-3.24989	0
		Unstandardized Coefficients		Standardized Coefficients	t	p
		B	Std. Error	Beta		
2021 ****	(Constant)	31.55199	0.327674		96.29084	0
	NDWI	0.133572	0.996825	0.003423	0.133998	0.89
	NDBI	1.545597	0.632403	0.065168	2.444008	0.01
	NDVI	-1.966341	1.017582	-0.065209	-1.932367	0.05

R=0.516, R^2=0.267, F=117.94, p=0.00**; R=0.509, R^2=0.259, F=117.94, p=0.00***; R=0.370, R^2=0.137, F=52.60, p=0.00****

Dependent variable (LST)

Source: Calculated by the Author

There is a positive correlation between LST and NDBI for all time steps, where correlation coefficient (r) values were 0.573, 0.400, and 0.162 in 2001, 2011, and 2021 respectively. Depending on the positive correlation, an expansion in the built-up areas may be predicted to raise the temperature of the surface of the land (R square ranged between 0.386 and 0.137).

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 1, February 2024

VI. ENVIRONMENTAL CHANGES IN THE COASTAL REGION

The urbanization process and the concept of development is closely related to each other. At present, haphazard spread of tourism industry, industrialization and associate urbanization often leads to the deterioration of the environment. So, there is an inverse relation between developmental process and degree of environmental quality. That's why the study areas thereby bring various kind of environmental degradation issues. Essential sectors of coastal belt of West Bengal states that the existent land use patterns like agriculture constitute about 1348 square km.; coastal aquaculture impoundment 267 square km., mud flats and beach cover about 200 square km., saltpans and salt marsh 28.6 and 22.13 square km, respectively. The forest area covers 1952 square km. of actual dense mangrove zone within the Coastal Regulation Zone I of 4164 square km. [Integrated Coastal Zone Management (ICZM) Project, 2010]. Wastewater is emerged from domestic, agricultural and industrial activities in the coast of West Bengal and that is the main source of pollution. The estimation of discharges and their entry in to coastal waters are stated below [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010].

Maximum discharge of domestic waste in the busy coastal towns and tourist resorts namely Digha, Haldia and near the coastal region the Tamluk river bank towns in Purba Medinipur district as well as Kakdwip, Bakkhali, Diamond Harbour, Canning and near the coastal region as a river bank towns Budge-Budge, Pujali from which a large amount of untreated municipal waste load into coastal water either directly or indirectly through creeks/canals and estuaries years after years. It is estimated that CPCB around 785.4 MLD (Millions of Liter Per Day) sewage is originated from cities and town in coastal region of West Bengal of which only around 141.7 MLD (Millions of Liter Per Day) is treated and the rest is loaded into coastal waters untreated and also transfer into discharge of around 146 and 378 TPD (Tons Per Day) of BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) accordingly into the coastal waters.

An estimation shows that every day near about 400 tonnes of sewage of the municipal waste from Kolkata metropolis is loaded into West Bengal coastal waters [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010]. Several functions done at port industry like loading and unloading of materials, materials discharge from major fish centres- Digha-Mohana, Sankarpur, Namkhana and Kakdwip and also rejection of solid, excess oil and grease. Pollution in Sundarbans as well as coastal region of West Bengal is mainly occurred due to burnt oil and grease from mechanized boats [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010].

The coast of West Bengal is not directly hampered by the influence of industries. But coastal pollution is observed in Haldia industrial region on the bank of Hooghly River about 20 nautical miles upstream. Apart from that discharges from about 62 large and medium industries are carried away by the Hooghly River from upstream. As per report, around 22 million of liter per day of industrial water is threw down into coastal waters in West Bengal. [State Project Management Unit (SPMU), W. B, Integrated Coastal Zone Management (ICZM) Project, 2010].

In Purba Medinipur District with respect to major pollution source the tourist resort is the Digha, Sankarpur, Mandarmani region and minor degree the Bakkhali (Fraserganj) and within the Sundarbans area include Sajnekhali, Pakhiralay, etc. area in South 24-Parganas mainly. It is said that near about 400 hotels, holiday homes and other various shops in Digha-Sankarpur areas but there are few such facilities are present in Bakkhali area. The wastes originated from these resources are also directly loaded into the coastal waters though there is no treatment inventory and also creates pollution. The analysis of water sample from Digha-Sankarpur coastal area, clearly shows that the considerable amount of biological pollution is seen at New Digha and Old Digha beach. Especially in the New Digha and Old Digha the coliform counts are also undoubtedly high [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010].

Oil spills are one kind of either accidental or natural process. Accidental oil spills processes are very much prominent consisting of collision, grounding and other accidents by ships and especially tankers that carry petroleum products to the Haldia and Kolkata ports. Again, in case of coastal pipelines that carry petroleum crude from Haldia to Barauni and Paradeep to Haldia, during carrying the accidental leakage creates hazardous pollution in coastal area. Sundarbans as well as off-shore areas of West Bengal coast are responsible in minor oil spills that involves fishing, mechanized boats and other activities from accidents concerning fishing trawlers, ferry launches carrying passengers and ships/barges carrying various cargos. In the inhabited areas of Sundarbans and the different tourist spot in the coastal areas of the both districts there are remarkable riverine traffic for various in transport and economic activities. [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010].

Geological Survey of India express in a report (1995) that in the district of Purba Medinipur, Digha coastal belt has been suffering an active process of erosion and accretion and here the influence of man-made activity involving removal of sand dunes and built the construction near the coast, and also continuous dumping of solid waste and raw sewage in the coastal water. The extension of beach from Digha to Dadanpatrabar is under very crucial erosional threat due to cyclonic storms, waves, tides and long-shore drifts and also human activities as construction of hotels-lodge reducing the sand dune and transfer of dunes for open sea visitor. The construction of embankment in Digha coastal belt has strong injurious effects on the coast as it rapid the erosive power of the waves. The backwash returns with more power that eroding the embankment much faster and lowering portion of the beach profile. The reducing of sand dune is caused mainly by anthropogenic activities like development of tourism, road construction, recreational activity, human trampling, off road vehicles and large-scale urban development at different coastal parts of Purba Medinipur [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010].

The shoreline of Purba Medinipur district changed restlessly due to cause of erosion and deposition and the erosion rate is higher than deposition rate. It is estimated that the 837.03 ha coastal surface eroded in the year 1950 to 2005 where only 33.77 ha deposition of coastal surface was found (see, Mitra et. al., 2013). It may be said that the sea level rise near about 1.06 – 1.75 mm per year in near to Digha–Sankarpur coast that helps to rapid the coastal erosion (see, Mitra et. al., 2013). Construction activities also have strong negative effects on the coast which also impacts upon the erosive energy that increases erosion.

The management problems are associated with the erosion of sand dune at Digha, an unthinkable instance that began around 1950 along with beach lowering. Prior to 1960s, New Digha and Sankarpur, Dadanpatrabar were considered to be depositional zone and old Digha to be an erosional zone. A present study highlights a discovery of along Digha-Sankarpur coast six contrasting deposition and erosional segments. Being a unique resort and tourist spot coastal erosion at this place is a serious issue in coastal zone management in this sector of West Bengal coast. [State Project Management Unit (SPMU), W.B, Integrated Coastal Zone Management (ICZM) Project, 2010]. On the study of researchers from School of Oceanography, Jadavpur University took up a time series explanation of the changes in the shape, size and geomorphic features of the island over a period of 32 years (1969-2001). The erosion and deposition array of the island [as the coastal portion of the concern district (South 24-Parganas) are composed with different island system can be summed up as follows:

a) 162.879 sq. km. is considered to be an account of total erosion over the 30 years. 6.212 sq. km. of some of the islands, such as, Lohachara and Bedford have already been departed from the physical map.

b) Out of 12 sea-facing southern islands from the shoreline of west to east coast, erosion zone saves the most prominent in the district of South 24-Parganas. Along the sea facing shore-line which is curved to the incoming waves, erosion can be observed.

c) The shoreline of the concerned district represents the status that eastern banks are less detrimental to erosion than the western banks of the inner islands. Deposition is seen at large at the mouth of estuary particularly along eastern and northern margins. 82.505 sq.km. is roughly calculated to be the amount of land deposition over the last 30 years.

VII. SUSTAINABILITY OF DEVELOPMENT IN COASTAL REGION

Sustainable development can be defined as the development sustaining Human Development Goals and keeping in view the natural systems to render natural resources and ecosystem on which the economy and society established. *"The concept of sustainable development does imply limits—not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities"* [World Commission on Environment and Development (WCED), note 3, page 8]. "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: The concept of 'needs', in particular, the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." — *World Commission on Environment and Development, Our Common Future (1987).*

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 1, February 2024

According to the United Nations sustainable development is not only the land development but also the improvement of standard of living, education and public health. Beaches, shorelines and coastal zones are the assets of great economic value and also having great recreational value and holiday making places all over the world. Its floral and faunal diversity makes the area as a great economic importance. So, it is necessary to conserve the environment of the coast. Sustainable economic activities are a conservative tool for the coastal environment. To ensure the conservation of the coast, Govt. of India has taken up a regulation, i.e. Coastal Zone Regulation Act for the necessary action. Here, Coastal Zone Management Status have presented for the sustainability of the concerned coastal region.

With a view to defensing of environment including coastal region The Environment Protection Act, 1986 was enacted. The notification no. 114 (E) of 1991 by Ministry of Environment and Forests, Government of India under section 3(1), 3(2) of the Act and Rules 5(3) (D) of Environment (Protection) rules, 1986 announcing coastal expansion as Coastal Regulation Zones (CRZ) and regulating activities in the CRZ was the primary remarkable attempt on legislation on coastal issues. This notification along with various legislation as discussed below gives broad frame work regulating activities in coastal zones (ICZM, 2010). The Water Prevention and Control of Pollution Act, 1974: This act is one of the most significant environment related legislation in terms of all basic aspects, means and mechanisms related to monitor of water pollution in the country up to 5 km into the sea. Coastal Regulation Zone Notification, 1991: Ministry of Environment and Forests, Govt. of India, 1991 through this notification announced the coastal stretches of seas, bays, estuaries, creaks, rivers and backwater which are controlled by tidal action up to 500 metres as coastal regulation zone between high tide line (HTL) and low tide line (LTL). These are four in type, like CRZ - I, CRZ - II, CRZ - III and CRZ - IV. Coastal Zone Management (CZM) Notification, 2008: This notification recommends setting up supporting of prevalent rules and institutional structures and fulfil the lack for preservation and enhancing the management of the coastal resources by increasing the resources of the coastal zone. Central government has issued instead of Coastal Regulation Zone (CRZ) a new Coastal Zone Management (CZM) Notification based on the above recommendations.

VIII. CONCLUSION

Present paper offers details about unavoidable and detrimental effects of the development on environment of the region. It shows that developmental process has led to environmental changes as pollution, coastal erosion, deforestation, and overall impact on larger coastal ecology. In the course of analyzing the relationship between the process of development and environment, it has been lying the areas of the Sundarbans as a point of reference in this study area. This area has also witnessed a steady decline in ecology. The picture of ecology viz. destruction of mangrove forest, erosion, tidal inundation, water pollution and destruction of aquatic bio-diversity being impacted by human effort to enhance the quality of life has been studied with reference to the indices related to environmental condition.

In the light of these facts and phenomena, it has been shown how the government and others responsible authorities related to the coastal zone need to come forward with plans and projects of the sustainable development of the region. The mission of sustainable development is to be put into practice in the region with involvement of communities and people.

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