Impact of Rapid Urbanization and Changes Face of Landuse on Urban Wetland: Acase Study of Berhampore Municipality, Murshidabad, West Bengal (India)

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Research Article

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Abstract

Wetlands play a vital role in environmental protection. Wetland works not only as kidney of environment but also they provide us water storage, urban flood control, recharge of groundwater, water purifications, agricultural facilities, wildlife resource management, and recreation spots. In present day rapid unplanned urbanization process is shooting low risky high profitable zone wetland areas because of huge amount population pressure in urban sector and lack of awareness about environmental protection. Berhampore town is one of the important towns which is located in the Murshidabad district of West Bengal and express rapid urban growth. Because of the rapid unplanned urban growth land use and land cover are changing very rapidly within very short time gap which may impacts on the local land resources. Through this paper we want to show the present day scenario of Wetlands in municipality area, how wetlands are affected by unplanned urbanization directly or indirectly with the help of landuse landcover change, we are also using some indices to summarized present actual relation between wetland and built up area. To find out the present scenario wetland and built up area of Berhampore town Normalized Difference Wetland Index, Normalized Difference Built up Area Index, Modified Normalized Difference Wetland Index, Normalized Difference Pond Index and Normalized Difference Turbidity Index etc have been used with the help of Landsat Satellite images(TM and OLI-TIRS sensor) from 1991 to 2021 .This study express that amount area of wetland are continuous declining over time and amount areas of built up areas are continuous increased form urban core to fringe area. Water is most precious to all over the world but due to endless demands of people they forget the ethical manners of human beings. This study will throw a new enlighten on the study of urban wetland status.

Introduction

Wetlands are permanently or seasonally water-saturated on land areas with a fundamental hydrologic landscape unit where perennial water lies on shallow or deep trench. According to US Fish and Wildlife Service (1979) – Wetlands are lands transitional between terrestrial and aquatic systems where the water level is usually at or near the surface or the land is covered by shallow water. Wetlands not only maintain the ecological balance rather they also maintain flood control, increase the rate of ground water recharge, flourish aquaculture and also help to developed good recreational sector etc. Wetlands are one of the crucial natural resources on the earth surface which helps to support rich species diversity. Wetland is a generic term for water bodies of various types, and includes diverse hydrological entities, named as, marshes, swamps, bogs, wet meadows, potholes, and river overflow lands (Tiner, 1999). Somehow, wetland controls the surface run-off from moving swiftly or overflowing the river banks. Due to their massive or numerous functionality sometime wetlands are described as *"the kidneys of the landscape"* in hydrological and chemical cycle as the downstream section receives wastes from both natural and human sources (De & Jana, 1997). Now-a-days wetlands have been analyzed as *"biological supermarkets"* for their extensive food webs and rich biodiversity support **(**Mitsch & Gosselink, 1993). Wetlands also have an ecologically sensitive and adaptive system (Turner et al., 2000) it was the most productive ecosystem on the earth's surface (Ghermandi et al., 2008). Wetlands consist of diversity according to their geographical location, nature, dominated by flora and fauna species, soil and sediment properties (Space Application Centre, 2010). Lack of conformity among government policies and human awareness in the field of nature conservation, it is one of the most important reason for the deterioration of water bodies in the field of planning (Turner et al., 2000, Bassi et al., 2014). According to landscape approach that allows to consideration of the results of environmental, economic, and social systems in time and space and the more general process of "environ-mental bio-diversification" which are influences on up gradation of environmental resources (**Agnoletti 2015**).There are also people continue to depend on locally available bio-resources for their livelihoods, such population who are directly dependent on local biological resources. Through their keen sense of observation, practices, and experimentation developed and established a body of knowledge that is passed on from generation to generation. Some are widespread traditional knowledge like cultivation practices. Wetland ecosystems are triggered by the lack of good governance and management. T.V. Ramachandra, (2001) has worked on the issue of restoration and management strategies of wetlands in developing countries in the context of world and Indian scenario. Ritesh Kumar, (2010) has stressed upon the management plan for east Kolkata wetlands. Manojit Paul, Mukti Chanda and Supriya Sengupta have played a pioneering role in conducting a survey to assess the strategy and scenario for wetland conservation in India. The Ramsar Convention on wetlands in 1971(2010) has a definite mission as ―the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. In 2013, 163 nations have joined together to include another 2060 wetlands around the world in the Ramsar List of Wetlands of International Importance. The Ramsar Convention Manual, 6th edition has outlined the definition of wetlands, its values and conservation strategies. It has mentioned wetland as one of the most important ecosystem of world which is in the verge of degradation. So, we need to protect the wetlands at any cost. In India, the rapidly growing human population, land use alteration, improper use of watersheds has caused a substantial decline in wetlands resources throughout the country. Anthropogenic pressures are posing a serious threat to the survival of wetland ecosystem. A collaborated research involving natural, social, and inter-disciplinary study, which aims at understanding the various components, monitoring of water quality, economic valuation, biodiversity, and other activities as an indispensable tool for formulating an effective and long term conservation strategies on wetland management (Kiran et al. 1999). Those publications stressed a wide approach to wetlands conservation and suggested several desirable solutions, all of which have been taken into account for future wetland research in Berhampore municipality. The foregoing literature analysis clearly depicts the current state of wetlands in India and around the world. However, in the case of identifying research needs, micro-scale wetland-related research in the Murshidabad area has yet to be completed at a suitable scale. We classified inland wetland groups in our study region during the research process (Table 1.1).

Schuyt & Brander (2004) describe four types of functions performed by wetlands:

i. *Regulation function* - Wetlands regulate ecological processes that contribute to a healthy environment (recycling nutrients, ground water recharge etc.).
ii. *Carrier functions*- Wetlands provide space for activities such as cultivation, energy production and habitat for animals.
iii. *Production functions*- Wetlands also provide resources for people (food, water, raw materials etc.) to sustain their life.
iv. *Information functions*- Wetlands contribute to control mental stability by providing scientific and spiritual values.

According to **US Millennium Ecosystem Assessment** report says that the level of degradation of wetland is higher than the other ecosystem in the world, that's why society needs human awareness about wetland conversation and various necessary measures also had been taken to control present day scenario. Wetlands are classified in various category. Schoot are classified into five categories that's are -

- *Estuaries* – Where rivers meet the sea and salinity is intermediate between salt and freshwater, such as deltas, mudflats, salt marshes etc.
- *Marine* – It is influenced by river flows such as shorelines and coral reefs etc.
- *Riverine* – It is generally found along the perennial river such as oxbow lake, water meadows etc.
- *Lacustrine* – That areas covered with permanent water with slight flow such as pond, lakes etc.
- *Constructed* **–** That wetland is an artificial wetland to treat by local government or industrial waste water or storm water runoff. It may also be designed for land reclamation or use as a mitigation step for natural areas lost to changing landuse pattern.

Table 1.1: ***Classification of Wetland category in study area***

WETLAND CATEGORY	TYPE	EXAMPLE
INLAND WETLAND	NATURAL	LAKE , POND , OX BOW LAKE, CUT OFF MEANDER, WATER LOGGED,RIVER,RIVERINE WETLAND
	MANMADE	RESERVOIR,BARRAGE, TANK,POND, WATERLOGGED, RECREATIONAL SPOT

Source: Prepared by Authors, 2022

1.2 Objectives

- To evaluate how wetlands are affected by unplanned urbanization directly or indirectly with the help of spatio - temporal change.
- To show the major problems and some probable solutions for wetland conservation in study area.

1.3 Selection of study area

The area under study is Berhampore Municipality, under Berhampore block of Murshidabad District of West Bengal. Berhampore Municipality is one of the oldest municipalities in West Bengal. Berhampore municipality was established in 1876. Geographically the area extends from 88º14' 57" East to 88º15'50" East and from 24º04'39" North to 24º07'48" North (**Figure 1.1**). According to census 2011, Total area of Berhampore Municipality is 31.42 km² spread into 25 Wards. The Bhagirathi River flows across the entire west of the city from north to south. The N.H. 34 divides the city into two sections, and the Easter Railway running through the eastern section. Berhampore is the administrative, nodal, and district headquarters of the Murshidabad district. According to census of India , 2011 - Berhampore town categorized as class-1 municipality town and 7th largest city in West Bengal. This is perhaps the only municipality in the state of W.B, which is the member of IHCN (Indian Heritage Cities Network), (Sharma, 2012). It is a highly functional unit which plays a vital role to provide good urban services all over the urban territory and its surroundings.

Database And Methodology

1.4.1. Materials

This study leaned heavily on secondary data derived from multiple of official and non-government sources. Berhampore Municipality's ward map was obtained from the Berhampore Municipality. USGS Earth Explorer was used to retrieve Landsat images from 1991, 2001, 2011, and 2021 (**Table 1.2**). Those data have been processed in order to achieve the goals. To reduce the number of errors, cloud-free photos were used for the analysis. Ground truth verification was carried out in order to improve the study's correctness. Information on the growth and development of Berhampore town has been gathered from the Berhampore Municipality's various offices. The last matter was settled following a ground truth inspection of the wetland sites in Berhampore municipality to determine their current state.

Table 1.2
Details of used Landsat data

SL. NO.	DATE ACQUIRED	SATELLITE SENSOR	WRS- PATH/ROW	DATUM	MAP PROJECTION
1	1991-01-24	Landsat 5/ TM	139/43	WGS 84	UTM
2	2001-01-19	Landsat 5/ TM	139/43	WGS 84	UTM
3	2011-01-31	Landsat 5/ TM	139/43	WGS 84	UTM
4	2021-02-11	Landsat 8/ OLI-TIRS	139/43	WGS 84	UTM

Source: Prepared by Authors, 2022

1.4.2. Image processing

Pre-processing satellite images prior to change detection is critical in order to develop a more direct link between the acquired data and biophysical processes (Abd El-Kawya et al., 2011). Both remote sensing and GIS techniques were used in the assessment. Various cartographic techniques have been adopted for mapping purposes. Using MS Office Excel and SPSS software, numerous parametric statistical studies were performed to demonstrate demographic growth. Arc GIS 10.2 software has been used to derive the data and map preparation of the NDWI, NDBI, MNDWI, NDPI, and NDTI indexes.

1.4.3. Image classification

After that, supervised image classification methods are used to classify the pre-processed images. The maximum likelihood algorithm incorporated into the Arc GIS application will classify according to the number of classes necessary and the digital number of pixels available in the supervised classification approach. The maximum likelihood algorithm will classify the image in the supervised classification technique based on the training sets (signatures) provided by the user based on his area knowledge. The user's training data instructs the software on which types of pixels should be used for certain land cover classes. Finally, the classification yields the area's land use/land cover image. The research area is divided into four land use and land cover classes: water bodies, vegetation areas, open space, and built-up areas.

1.4.4. Supervised image classification:

Supervised classification is a user-guided method that involves selecting training sites as category references (Campbell 1996 &Jensen 1996). In this technique, supervised image classification is a true procedure for recognizing spectrally comparable areas on satellite images by assigning training sites of known targets and then extracting those spectral fingerprints to other areas of unknown targets. The analyst's classifications are a three-stage procedure that includes training, classification, and output. The analyst selects training sites to reflect areas with known cover kinds during the training stage. Liveware identified links between different types of land and their spectral frequency of multiple wave lengths at this stage. The classification stage is the second step in the supervised classification process, and it involves categorizing a large number of spectral bands into precise land use and land cover categories. Maximum likelihood is the most extensively used classification algorithm. The output stage is the last step in the process. The results are presented, visualized, and interpreted using the output products. Finally, the analyst compresses the classified data into a specified group of classes and presents it in digital graphical and tabular form. The statistical parameters, accuracy assessment table, and other supporting information are included with the end product (Khorram et. al.2013). A supervised image classification system was employed in this study to demonstrate change detection across a 30-year period. In the supervised image classification, four land use and land cover (Table 1.3) units of the study region are represented by groups of training pixels. Using the Arc GIS (10.2) programme, each image is classified independently using the supervised image classification method with the help of maximum likelihood algorithm.

Table 1.3
Land use and Land cover classes of study area.

CLASSES OF IMAGE CLASSIFICATION	DESCRIPTION
WATERBODY	Natural and Manmade Lake, Ox-bow and Ponds.
VEGETATION AREA	Deciduous Forest Lands, Gardens, Mixed Forest Lands, Roadside or Riverside vegetation areas etc.
OPEN SPACE	Stadium, Play Ground, Park, Recreational spot and Project area under construction.
BUILTUP AREA	Residential, Commercial and Services lands.
Source: Prepared by Authors, 2022	

1.4.5. Accuracy assessment :

The term 'accuracy' is often used to indicate the measure of a derived map's (classification's) 'correctness,' which is tested using an error-matrix. A significant number of remote sensing studies have focused on accuracy assessment as a key component. The accuracy assessment of change detection procedures, on the other hand, is still in the experimental stage and entails concerns such as sampling strategies that aren't commonly recognized, image registration, boundary problems, and reference data. Error matrix analysis (Khorram et al.2013) is the most often used approach for assessing accuracy (Table 1.4). Individual classifications are critical in the change detection procedure. As a result, a comprehensive accuracy evaluation must contain a report on overall accuracy, user accuracy, and producer accuracy, all of which were studied using the Kappa coefficient.

Table 1.4
Kappa Statistics (Rwanga, 2017)

SL.NO.	VALUE OF K	STATUS
1	< 0.0	Poor
2	0.0–0.2	Slight
3	0.21–0.4	Fair
4	0.41–0.6	Moderate
5	0.61–0.8	Good
6	0.81–1	Very good
Source: Das & Sahu, 2020		

Overall Accuracy $= \frac{\text{TotalNumberofcorrectlyclassifiedpixcels}\ (\text{Diagonal})}{\text{TotalNumberofreferencepixcels}} \times 100$

In a comparable way to overall accuracy, the classification performance of distinct classes is assessed. There are two methods for achieving accuracy: user accuracy and producer accuracy. The producer's accuracy is derived by dividing the total number of pixels collected from the reference data by the number of accurate pixels in one categorization. Meanwhile, the user's accuracy is determined by dividing the total number of pixels categorized in each class by the number of accurately identified pixels in that class. The accuracy of the user assesses the commission error and shows the likelihood that a pixel categorized into a particular category represents that class on the ground. The following formula is used to calculate the accuracy of the user and the producer:

User Accuracy = $\frac{\text{Numberofcorrectlyclassifiedpixelsineachclass}}{\text{TotalNumberofclassifiedpixcelsinthatclass (TheRowTotal)}} \times 100$

Producer Accuracy = $\frac{\text{Numberofcorrectlyclassifiedpixcelsineachclass}}{\text{TotalNumberofclassifiedpixcelsinthatclass (TheColumnTotal)}} \times 100$

The Kappa coefficient (K) is another study indicator that is used to determine the study's level of relevance. Kappa has a value of 0 to 1, with 0 denoting agreement based only on chance. A number of 1 indicates that the two data sets are in full agreement. Although negative values are possible, they are erroneous. The Kappa statistic is a more complicated measure of classifier agreement that is better at differentiating between classes than total accuracy. The Kappa Coefficient equation was used to determine if the values in an error matrix represent a result that is significantly better than random (Congalton, 1991) or to determine if the values in an error matrix represent a result that is significantly better than random (Jensen and Cowen, 1999).

(K) = $\frac{(\text{Totalsample} - \text{Totalcorrectedsample}) - \Sigma(\text{ColumnTotal} \times \text{RowTotal})}{(\text{Totalsample})\,2 - \Sigma(\text{ColumnTotal} \times \text{RowTotal})} \times 100$

Table 1.5

Summary of Accuracy Assessment from 1991 to 2021

LAND USE / LAND COVER CLASS	1991		2001		2011		2021	
	USER'S ACCURACY	PRODUCER'S ACCURACY	USER'S ACCURACY	PRODUCER'S ACCURACY	USER'S ACCURACY	PRODUCER'S ACCURACY	USER'S ACCURACY	PRODUCER'S ACCURACY
WATERBODY	0.833	0.88	0.8	0.85	0.83	0.83	0.83	0.83
VEGETATION	0.8	0.75	0.81	0.76	0.8	0.85	0.8	0.85
OPEN AREA	0.83	0.76	0.87	0.82	0.88	0.88	0.88	0.88
BUILTUP AREA	0.76	0.81	0.83	0.86	0.9	0.85	0.9	0.85
OVERALL ACCURACY	0.8		0.95		0.85		0.85	
KAPPA	**0.74**		**0.92**		**0.81**		**0.81**	
Source: Prepared by Authors, 2022								

The overall accuracy of 1991, 2001, 2011, and 2021 (Table 1.5) was found to be 0.8, 0.95, 0.85, and 0.85, respectively. In this study, producer and user accuracy ranges from 0.75 to 0.88, 0.76 to 0.83 in 1991, 0.76 to 0.86 and 0.8 to 0.87 in 2001, 0.76 to 0.86 and 0.8 to 0.87 in 2011, producer and user accuracy ranges from 0.83 to 0.88 and 0.8 to 0.9 in 2011, and 0.83 to 0.88 and 0.8 to 0.9 in 2021. In 1991, 2001, 2011, and 2021, the classification's Kappa coefficients were 0.74, 0.92, 0.81, and 0.81, respectively. According to Rwanga's classification scale (Table 1.4), the classification ranges from good to very good from 1991 to 2021.

1.4.6. Method for calculating NDWI, NDBI, MNDWI,NDPI and NPTI statistical assessment:

To illustrate the relationship between built-up area and water content of different indices were calculated using Landsat data with the help of GIS software Arc GIS as NDWI (Normalized Difference Water Index), NDBI (Normalized Difference Built-up Index), MNDWI (Modified Normalized Difference Water Index),NDPI (Normalized Difference Pond Index) and NDTI (Normalized Difference Turbidity Index) respectively.

1.4.6.1. NDWI:

The NDWI Index (Normalized Difference Water Index) is a satellite image visual indicator that is primarily utilised for remote sensing measures, particularly open surface water body mapping. For the most part, two bands have been utilised to calculate the NDWI Index. Green Band and Near Infrared are the two options. It's constantly between − 1 and + 1. Table 1.6 assists in the classification of the study area's NDWI.

NDWI INDEX = $\frac{GREEN - NIR}{GREEN + NIR}$

Where, in Landsat 5 TM, the Green band indicates Band 2 (0.52–0.60 μm) and the NIR band indicates Band 4 (0.77–0.90 μm) and in Landsat 8 OLI - TIRS, the Green band indicates Band 3 (0.53–0.59 μm) and the NIR band indicates Band 5 (0.85–0.88 μm).That the positive values of NDWI are assumed to represent water surfaces, while the negative values are assumed to be non-water surfaces (McFeeters,1996).

Table 1.6
Index values for NDBI.

CATEGORIES	VALUE
LOW	< -0.16
MEDIUM	− 0.16 - -0.07
HIGH	-0.07- 0.01
VERY HIGH	> 0.01
Source: Prepared by Authors, 2022	

1.4.6.2. NDBI:

NDBI Index (Normalized Difference Builtup Index) is another useful graphical indicator, which is for measuring the urban areas specially built up areas or artificial structure. It ranges from − 1 to + 1, with negative values indicating water bodies and vegetation cover in the earth surface, low positive values indicating barren soil types and positive values indicating built-up areas. NDBI helps to measures that the rate of urbanization. Table 1.7 assists in the classification of the study area's NDBI.

NDBI INDEX = $\frac{\mathrm{SWIR} - \mathrm{NIR}}{\mathrm{SWIR} + \mathrm{NIR}}$

Where, in Landsat 5 TM, the SWIR band indicates Band 5 (1.55–1.75μm) and the NIR band indicates Band 4 (0.76–0.90 μm); in Landsat 8 OLI, the SWIR band indicates Band 6 (1.57–1.65 μm) and the NIR band indicates Band 5 (0.85–0.88 μm). This index is mainly used for the mapping of constructional area where a positive value indicates the presence of artificial structure or manmade structure and the lower value indicates the availability of natural features existing on earth surface.

Table 1.7
Index values for NDBI.

CATEGORIES	VALUE
LOW	< -0.07
MEDIUM	− 0.07 - -0.02
HIGH	-0.02–0.3
VERY HIGH	> 0.3
Source: Prepared by Authors, 2022	

1.4.6.3. MNDWI:

MNDBI Index (Modified Normalized Difference Water Index) is another pictorial representation, which is used for the enhancement of open water features. It also diminishes built-up area features that are often correlated with open water in other indices. It ranges from − 1 to + 1, (Xu, 2006) to reduce the urban noise in the delineation of water bodies. Table 1.8 assists in the classification of the study area's MNDWI.

MNDWI INDEX = $\frac{\mathrm{GREEN} - \mathrm{SWIR}}{\mathrm{GREEN} + \mathrm{SWIR}}$

Where, in Landsat 5 TM, the Green band indicates Band 2 (0.52–0.60 μm) and the SWIR band indicates Band 5 (1.55–1.75μm) and in Landsat 8 OLI - TIRS, the Green band indicates Band 3 (0.53–0.59 μm) and the SWIR band indicates Band 6 (1.57–1.65 μm). Due to growing values of water features and lowering values of built-up land from positive to negative, the MNDWI's contrast between water and built-upland will be significantly widened. Increased water enhancement in the MNDWI-image will result in more accurate extraction of open water features, as built-up land, soil, and vegetation all have negative values and are thus significantly muted, if not completely deleted (Xu,2006).

Table 1.8
Index values for MNDWI.

CATEGORIES	VALUE
LOW	< -0.15
MEDIUM	− 0.15 - -0.07
HIGH	-0.07–0.01
VERY HIGH	> 0.01
Source: Prepared by Authors, 2022	

1.4.6.4. NDPI:

NDPI Index (Normalized Difference Pond Index) is another graphical indicator, used for the enhancement of open water features. It also helps to the pond area features that are often correlated with open water in other indices. It ranges from − 1 to + 1. Table 1.9 assists in the classification of the study area's MNDWI.

NDPI INDEX = $\frac{\text{SWIR} - \text{GREEN}}{\text{SWIR} + \text{GREEN}}$

Where, in Landsat 5 TM, the SWIR band indicates Band 5 (1.55–1.75μm) and the Green band indicates Band 2 (0.52–0.60 μm) and Landsat 8 OLI – TIRS, the SWIR band indicates Band 6 (1.57–1.65 μm) and the Green band indicates Band 3 (0.53–0.59 μm). When combined with NDVI, the NDPI provides greater distinction between aquatic and wetland vegetation and typical vegetation than the NDVI alone. This representation has significantly improved the results, particularly for small and shallow water bodies, and it now contains all edge pixels of water bodies that can be visually distinguished from the image. The threshold values for various factors change depending on the soil background and are implemented as a set of conditions.

Table 1.9
Index values for NDPI

CATEGORIES	VALUE
LOW	< -0.05
MEDIUM	− 0.05–0.05
HIGH	0.05–0.1
VERY HIGH	> 0.1
Source: Prepared by Authors, 2022	

1.4.6.5. NDTI:

NDTI Index (Normalized Difference Turbidity Index) is another imagistic indicator, used for the enhancement of open water features. It also diminishes built-up area features that are often correlated with open water in other indices. It ranges from − 1 to + 1. Table 1.10 assists in the classification of the study area's MNDWI.

NDTI INDEX = $\frac{\text{RED} - \text{GREEN}}{\text{RED} + \text{GREEN}}$

Where, in Landsat 5 TM, the Red band indicates Band 3 (0.63–0.69 μm) and the Green band indicates Band 2 (0.52–0.60 μm) and Landsat 8 OLI – TIRS the Red band indicates Band 4 (0.64 – 0.67 μm) and the Green band indicates Band 3 (0.53–0.59 μm). The availability of suspended particles in the water has increased turbidity levels, with the red band reflecting more than the green band (Islam et.al., 2006). The NDTI allows for the identification of water with a high turbidity (poor clarity) (Lacaux et al., 2007). This spectral characteristic of turbid water has been captured in Lacaux's Normalized Difference Turbidity Index, which can be used to detect turbid water pixels. Based on a study of sensor data in the scenario of severely turbid water bodies when the value is larger than + 0.25.

Table 1.10
Index values for NDTI.

CATEGORIES	VALUE
LOW	< -0.04
MEDIUM	− 0.04–0
HIGH	0–0.02
VERY HIGH	> 0.02
Source: Prepared by Authors, 2022	

1.4.7. STATISTICAL MEASURES:

Correlation analysis is a form of statistical analysis which allows researchers to explore the degree of association between independent and dependent variables (Schober & Schwarte, 2018 ; Senthilnathan,2019).

$$r = \frac{\sum (Xi - \bar{x})(Yi - \bar{y})}{\sqrt{\left(Xi - \bar{x}\right)^2 \sum (Yi - \bar{y})^2}}$$

where, ‘r’ is the Pearson products moment correlation coefficient, ‘x_i’ is values of x variable in a sample, ‘$\bar{x}_i$’ 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.

To demonstrate the impacts of the NDWI, NDBI, MNDWI, NDPI, and NDTI, scatter plots were created using regression analysis with all time-points from 1991 to 2021. Pearson product-moment correlation coefficient (PPMCC) measures the direction and strength of the relationship between two variables, while regression analysis describes the functional relationship between variables independent (x) and dependent (y) (Härdle & Vieu, 1992; Zhao, 2013). Linear regression 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.

$y = \beta_0 + x_1 \beta_{1+\ldots} x_p \beta_p +$
Where, ‘β’ reflects how much of an effect x has on y, and ‘’ is the error term.

Result

1.5.1. Population growth:

In the latter half of Eighteenth century, for observing the *Nawabai* activity, a military camp was formed in ‘*Brahmapur mouza’*. *Mr. Beveridge* wrote about Brahmapur in his book *Old places of Murshidabad* ,Calcutta Reviewed,1892. Due to pronunciation this *Brahmapur* was later renamed as *Berhampore*. After the battle of *Palashi* ,1757 and the battle of *Mir Qashim,1763*, the construction of cantonment has started at Brahmapur mouza to keep an eye on Nawabi activities. According to *Hunter*, that cantonment was completed in 1767 and the chief architect was *A.Campbell.* The city of Berhampore was formed around this cantonment. As per *State Paper Report* 1858 by *Sir Frederick James Haliday* (British Civil Servant & first Lieutenant Governor of Bengal) – states that the Sipoy revolt, 1857 that started across all over India started in Brahmapur Cantonment. After that the cantonment was demolished in 1870. *King Thibaut* of *Burma* was defeated and taken prisoner during the third *Ingo – Burmese war.* This old town was famous for silk production due to these factor Armenian merchants was come to this famous town nearly 1665. The *French mansion* was built in 1668. Due to *Bhagharathi River* course shifting that area remarked as a famous trading center and nodal point for business purposes. Berhampore Municipality was established in 1876 which had 16.19 sq.km occupied area (Roy et al., 2021). In the very beginning, the British Government did not leave the governance of this municipality completely in the hand of Non Government folks as after Sipoy Mutiny in 1857, a large number British army people stayed at Berhamopore Cantonment area. Therefore the Municipality was constituted with both the government and non government peoples. The municipal board was constituted by, 14 non-governmental members and 5 government nominated members, total 19 members. This trend was continued up to 1884.The District Magistrate acted as the President of the Municipality during this tenure. In the year 1884, according to “Bengal Municipal Act 1876”, finally the Administration and management of Berhampore Municipality was handed over to 14 elected and 5 governments nominated members. The first Chairman of Berhampore Municipality was Ray Bahadur Baikunthanath Sen, who was a reputed Advocate and the President of District Bar Association as well. That time the area of Berhampore Municipality was divided into 6 wards i.e. 1) Gorabazar 2) Cantonment 3) Berhampore 4) Khagra 5) Saidabad and 6) Cossimbazar. The numbers of elected members from each ward were as follows, 3 from Gorabazar,1 from Cantonment,4 from Berhampore ,3 from Khagra,2 from Saidabad and 1 member from Cossimbazar ward. It is the district head quarter of Murshidabad (http://www.berhamporemunicipality.org.in/). Figure 1.2 showing the continuous population growth in Berhampore municipality from 1901 to 2011 with R^2 value demarked as highly positive population growth. Now the Municipality is comprised of 25 wards and one elected member from each ward. Total area of this municipality is 31.42 sq.km. and it has a population of 1,95,223 (Census,2011). In year 1901 the population was 24397 and it becomes 55613 in year 1951. But after 1971, the population growth rate of this municipality is going higher. The town is primarily a service town having a population of 1,95,223 as per 2011 census, with an overall population density 6213 persons per sq km. The decadal growth rate over the last five decades varies from 16.51 to 36.12. Highest decadal growth had been founded in 2001 census which was recorded as 36.12 and present decadal growth is 21.91 in 2011 census. In that case we found a negative decadal growth according to their value because high price of land in municipal area, trafficking as a common problem, so lots of people come and settled down surrounding the municipal area to ensure the uses of all urban services from their locality. Within a decade numbers of census towns are increased from 3 to 9 surrounding Berhampore municipality in 2001 census we found that Kasim Bazar, Gora Bazar and Goaljan but in 2011 rest of three more six census town has been added those are Banjetia, Sibdanga badarpur, Gopjan, Chaltia, Haridasmati and Ajodhyanagar. Those nine census towns are well bonded the municipality allover direction. Surrounded villages are converted into urban space within a very short time.

1.5.1.2. Degree of urbanization:

The degree of urbanization generally refers to the relative or absolute number of people who live in places defined as urban (Kundu, 2013).

Degree of Urbanization = $\frac{UrbanPopulation}{TotalPopulation} * 100$

= (195223 / 446887)*100

= 43.68

1.5.1.3. Speed of Urbanization:

This index shows the annual rate of change in the number of population in the town (Kundu, 2013).

Speed of Urbanization = $\frac{(X-Y)}{Y}$ * 100

[where, X = Present Census year Population

= {(195223 – 160143)/160143}*100 Y = Previous Census year Population]

= 21.90

1.5.1.4. Population Projection:

It is an estimate of a future population. It is fraught with uncertainties as there is no fixed law of population increment and various techniques of projections are to give a generalized result (Mandal, 2000). It is a sign of economic development and cultural advancement of an urban center (Roy et al.,2021).

Population Projection:

2011 census = 195223, 2001 census = 160143

r = (195223–160143) = 35080

P.2021 = 2011 + (r* 10)

= 546023

P.2031 = 896823

P.2041 = 1052400

1.5.2. LULC

One of the most significant processes related to the deterioration of the earth's natural ecosystem have been regarded by Land use and land cover (LULC) dynamics. Rapid urbanization has become a key challenge for the future urban sustainability. LULC maps of Berhampore town highlighting the spatial distribution of land use and land cover areas based on the images from 1991 to 2021. The below figures (Fig. 1.3)illustrate the fact that there was a significant difference in the land use and land cover among the North-Western, South, and South Western parts of the Berhampore municipality area. Changing land characteristics from one to over time due to human-induced transformation activities were referred to as land use and land cover transformation. Land features are in a constant state of transition from one type to another, based on local environmental suitability and local people's requirements.

Table 1.11

Area under different LULC in Berhampore Municipality from 1991 to 2021

LULC CLASSIFICATION	AREA COVER								LULC CHANGE				
	1991		2001		2011		2021		1991–2001		2001–2011		2011–2
	Area (Sq.Km.)	%	Area (Sq.Km.)	%	Area (Sq.Km.)	%	Area (Sq.Km.)	%	Area (Sq.Km.)	%	Area (Sq.Km.)	%	Area (Sq.Km.
WATERBODY	3.64	11.58	1.72	5.47	0.78	2.48	0.62	1.97	-1.92	-6.11	-0.94	-2.99	-0.16
VEGETATION	15.18	48.31	9.48	30.17	8.7	27.68	6.18	19.69	-5.7	-18.14	-0.78	-2.49	-2.52
OPEN AREA	2.14	6.81	1.34	4.26	0.95	3.02	2.02	6.42	-0.8	-2.55	-0.39	-1.24	1.07
BUILTUP AREA	10.46	33.29	18.88	60.08	20.99	66.8	22.6	71.92	8.42	26.79	2.11	6.72	1.61
Source: Prepared by Authors, 2022													

LULC types (vegetation cover, and water body) shows decreasing trends, and rest of two other LULC types built up area show increasing trends but in case of open area highlight the feature continuous decreasing trend from 1991 to 2011 but in 2021 it becomes positive change (Table 1.11). The statistical result indicates that the most land in Berhampore municipality was covered by built up area; 33.29% in 1991, 60.08% in 2001, 66.8% in 2011 and 71.92% in 2021 followed and vegetation 48.31% in 1991, 30.17% in 2001, 27.68% in 2011and 19.69% in 2021, another special land cover feature of lulc map is waterbody 11.58% in 1991, 5.47%in 2001,2.48% in 2011 and 1.97% in 2021. The greatest decline was found for vegetation; a total number of 28.62% of area of vegetation cover loss after that waterbody also decline with 9.61% of its own area and maximum agglomeration of built up area nearly 38.63% of area were observed in Berhampore municipality area during the study period.

Land use land cover classification was done in the study area under the supervised classification method using maximum likelihood algorithm. On the basis of the number of pixels, the area of each class was calculated. Based on the land use land cover map of 1991(Table 1.11) the area and percentage of areas as classified are water body 11.58% (3.64 sq.km.), vegetation cover 48.31% (15.18 sq.km.), open area 6.81% (2.14 sq.km.) and built up area 33.29% (10.46 sq.km.). In the land use land cover map of 2001 the area and percentage of areas as classified are water body 5.47% (1.72 sq.km.), vegetation cover 30.17% (9.48 sq.km.), open area 4.26% (1.34 sq.km.) and built up area 60.08% (18.88 sq.km.). In the land use land cover map of 2011 the area and percentage of areas as classified are water body 2.48% (0.78sq.km.), vegetation cover 27.68% (8.7 sq.km.), open area 3.02% (0.95 sq.km.) and built up area 66.8% (20.99sq.km.) and the final land use land cover map of 2021 the area and percentage of areas as classified are water body 1.97% (0.62 sq.km.), vegetation cover 19.69% (6.18 sq.km.), open area 6.42% (2.02 sq.km.) and built up area 71.92% (22.6sq.km.). The dominant land use class was defined as built up area, and the land cover type was classified as vegetation cover in (Fig. 1.4), which carried out the part of the dominant landuse and landcover type of the study area.

1.5.2.1. Water body

In the study area water bodies mainly consists of lakes, ponds and tanks, etc. One major river Bhagirathi which is flows towards the western boundary of Berhampore municipality from north to south direction. Many tanks and ponds are also found in the region (Fig. 1.5). The area included in this category, 1991 was 3.64 km^2which accounts for 11.58 % f the total area, 1.72km^2which accounts for 5.47 % in 201, 0.78 km^2which accounts for 2.48 % in 2011of the total area and 0.62km^2, 2021 which accounts for 1.97% of total area receptively. So, it is clearly indicate that from 1991 to 2021 amount of water body continuous decreases according to time nearly 3.02 km^2 or 9.61 percentage of area and according to R^2 value of waterbody is 0.865. As a result, it indicates the level of significance of the rate of gradually decreasing waterbody over time (Table 1.11).

1.5.2.2. Vegetation cover

Dense vegetation can be observed in the East, North East and South-East parts of the region (Fig. 1.6). Some patches of forest cover seen in the Central and North-West parts. The area included in this category, 1991 was 15.18 km^2which accounts for 48.31 % f the total area, 9.48km^2which accounts for 30.17 % in 201, 8.7 km^2which accounts for 27.68 % in 2011of the total area and 6.18km^2, in 2021 which accounts for 19.69% of total area receptively. So, it is clearly indicate that from 1991 to 2021 amount of vegetation cover continuous decreases according to time nearly 9 km^2 or 28.62 percentage of area and according to R^2 value of vegetation cover is 0.89. It indicates the rate of extensive decreasement about vegetation cover within study time (Table 1.11).

1.5.2.3. Open area

In urban sector open space mainly identified as Stadium, Play Ground, Park, Recreational spot and Project area under construction. The area included in this category, 1991 was 2.14 km^2which accounts for 6.81 % f the total area, 1.34km^2which accounts for 4.26 % in 201, 0.95 km^2which accounts for 3.02 % in 2011of the total area and 2.02km^2, in 2021 which accounts for 6.42% of total area receptively. So, it is clearly indicate that from 1991 to 2021 amount of open area continuous decreases according to time from 1991 to 2011 but in the year of 2021 it turns on positive growth (Table 1.11). Generally natural open area mainly helps for recreational and ground water infiltration process but the passage of times this natural open area also converted urban sector and few of them remain static (Fig. 1.7). According to R^2 value of open area is 0.03. So it is indicate the low positive value and show its significant level of complexness of open area within study time.

1.5.2.4. Built-up area

In urban sector builtup area mainly identify as Residential, Commercial and Services lands etc. Accordingly, the area included in this category in 1991 is 10.46 km^2, which accounts for 33.29 % o the total area, 18.88 km^2 which accounts for 60.08 % in 201, 20.99 km^2 which accounts for 66.8 % of the otal area, and 22.6 km^2 in 2021, which accounts for 71.92% of the total area receptively. So, it is clearly indicate that from 1991 to 2021 amount of vegetation cover continuous increase according to time nearly 12.14 km^2 or 38.63 percentage of area respectively (Table 1.11). The growth of Builtup area mainly transform from western part to all round the municipal area (Fig. 1.8). According to R^2 value of open area is 0.84. So it is indicate the highly positive value and show significant level of development of builtup area within study time.

1.5.3. NDWI:

Among the natural Land Use and Land Cover (LULC), water body is a major feature of Berhampore municipal area. Water body is mainly high in the core areas of the city which is gradually decreases towards periphery of town.

Table 1.12

Area under different NDWI in Berhampore Municipality from 1991 to 2021

NDWI	AREA								AREA CHANGE			
	1991		2001		2011		2021		1991–2001	2001–2011	2011–2021	1991–2021
	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	%	%	%	%
< -0.16(LOW)	3.18	10.12	2.99	9.51	2.4	7.63	2.05	6.52	0.6	1.87	1.11	3.59
-0.16 - -0.07 (MEDIUM)	7.98	25.39	8.17	26	8.99	28.61	9.45	30.07	-0.6	-2.6	-1.46	-4.67
-0.07- 0.01(HIGH)	12.6	40.1	13.68	45.53	14.55	46.3	14.88	47.35	-3.43	-2.7	-1.05	-7.25
> 0.01(VERY HIGH)	7.66	24.37	6.58	20.94	5.48	17.41	5.04	16.04	3.43	3.5	1.4	8.33
Source: Prepared by Authors, 2022												

To investigate the nature and patterns of Water body in Berhampore town, NDWI indices have been done. NDWI indices have been done over the years from 1991 to 2021. Distribution of the NDWI index in Berhampore between 1991 and 2021 (Table 1.12) are classified into four categories such as < -0.16 is low, -0.16 – -0.07 is medium, -0.07–0.01 is high and > 0.01 is very high zone. In 1991,2001,2011 and 2021; 10.12, 9.51, 7.63 and 6.52 percent of the total Berhampore experiences very low NDWI values and 24.37,20.94,17.14 and 16.04 percent experiences very high NDWI values. It is clearly indicated the value of NDWI are gradually decrease over the time.

Table 1.13

Dispersion of NDWI in Berhampore Municipality from 1991 to 2021

YEAR	MAXIMUM	MINIMUM	MEAN	SD
1991	0.05	-0.28	-0.11	0.23
2001	0.04	-0.29	-0.12	0.23
2011	0.02	-0.3	-0.14	0.22
2021	0.01	-0.33	-0.16	0.24
Source: Prepared by Authors, 2022				

From the NDWI images (Fig. 1.9) of Berhampore town of 1991, 2001, 2011 and 2021 (Table 1.13), it has been found that values for NDWI ranges from + 0.05 to − 0.28, 0.04 to -0.29, 0.02 to -0.3 and 0.01 to -0.33 respectively. Highest value of NDWI are mainly found in central part of the town such lakes area available here those are Bishnupur bill, Chatrar bill, Laldighi, Dhobighat, Minbhaban, and Shilpo taluk etc. In another hand amount of low value of NDWI are mainly found in the area of core urban space and West, North West, South West part of town (Fig. 1.9).

It indicates that the proportion of waterbody in the city area has decreased from their mean value − 0.11 in 1991 while it decreased by − 0.16 in 2021(Fig. 1.10). This diagram mainly plot of mean value of NDWI and r^2 value is 0.979 that means it's highly correlated the matter according to time decreasing the water cover of town.

1.5.4. NDBI

Among the manmade Land Use and Land Cover (LULC), builtup area is a major feature of Berhampore municipal area. Builtup is mainly high in the core areas of the city which is gradually increases towards periphery of town in an even distribution.

Table 1.14

Area under different NDBI in Berhampore Municipality from 1991 to 2021

NDBI	AREA								AREA CHANGE			
	1991		2001		2011		2021		1991–2001	2001–2011	2011–2021	1991–2021
	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	%	%	%	%
< -0.07(LOW)	11.25	35.80522	9.18	29.21706	8.05	25.62062	7.1	22.59707	6.58	3.59	3.02	13.2
-0.07 - -0.02(MEDIUM)	7.88	25.07957	8.38	26.67091	9.07	28.86696	9.47	30.14004	-1.59	-2.19	-1.27	-5.06
-0.02-0.03(HIGH)	6.3	20.05092	7.84	24.95226	8.2	26.09803	8.35	26.57543	-4.9	-1.14	-0.47	-6.52
> 0.03 (VERY HIGH)	5.99	19.06429	6.02	19.15977	6.1	19.41439	6.5	20.68746	-0.09	-0.25	-1.27	-1.62
Source: Prepared by Authors, 2022												

To investigate the nature and patterns of Builtup area in Berhampore town, NDBI indices have been done. NDBI indices have been done over the years from 1991 to 2021. Distribution of the NDBI index in Berhampore between 1991 and 2021 (Table 1.14) are classified into four categories such as < -0.07 is low, -0.07 – -0.02 is medium, -0.02–0.03 is high and > 0.03 is very high zone. In 1991,2001,2011 and 2021; 35.80, 29.21, 25.62 and 22.59 percent of the total Berhampore experiences very low NDBI values and 19.06,19.15,19.41 and 20.68 percent experiences very high NDBI values. It is clearly indicated the value of NDBI are gradually increase over the time due to their functionality.

Table 1.15

Dispersion of NDBI in Berhampore Municipality from 1991 to 2021

YEAR	MAXIMUM	MINIMUM	MEAN	SD
1991	0.12	-0.22	-0.05	0.2404163
2001	0.15	-0.25	-0.05	0.2828427
2011	0.3	-0.28	0.01	0.4101219
2021	0.38	-0.3	0.04	0.4808326
Source: Prepared by Authors, 2022				

From the NDBI images (Fig. 1.11) of Berhampore town of 1991, 2001, 2011 and 2021 (Table 1.15), it has been found that values for NDBI ranges from + 0.12 to − 0.22, 0.15 to -0.25, 0.3 to -0.28 and 0.38 to -0.3 respectively. Highest value of NDBI are mainly found in central part of the town such urban area available here those are Khagra, Saidabad, Gorabazar, Indropostha, Dayanagar, Cossimbazar and Kadai etc. In another hand amount of low value of NDBI are mainly found in the area of periphery urban space and East and South East part of town (Fig. 1.11).

It indicates that the proportion of buildup area in the city area has increased from their mean value − 0.05 in 1991 while it increased by 0.04 in 2021(Fig. 1.12). This diagram mainly plot of mean value of NDBI and r^2 value is 0.896 that means it's highly correlated the matter according to time increasing the rate of urban space of town.

1.5.5. MNDWI

It is used for the enhancement of open water features. It also diminishes built-up area features that are often correlated with open water in other indices.

Table 1.16

Area under different MNDWI in Berhampore Municipality from 1991 to 2021

MNDWI	AREA								AREA CHANGE			
	1991		2001		2011		2021		1991–2001	2001–2011	2011–2021	1991–2021
	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	%	%	%	%
< -0.15(LOW)	4.68	14.89	4.8	15.27	4	12.73	3.45	10.98	-0.38	2.54	1.75	3.91
-0.15 - -0.07(MEDIUM)	14.42	45.89	19.8	63.01	21.42	68.17	23.22	73.9	-17.12	-5.16	-5.73	-28.01
-0.07- 0.01(HIGH)	9.68	30.8	4.88	15.53	4.54	14.44	3.73	11.87	15.27	1.09	2.57	18.93
> 0.01(VERY HIGH)	2.64	8.4	1.94	6.17	1.46	4.64	1.02	3.24	2.23	1.53	1.4	5.16
Source: Prepared by Authors, 2022												

To examine the nature, patterns and accuracy of Water body in Berhampore town, MNDWI indices have been done. MNDWI indices have been done over the years from 1991 to 2021. Distribution of the MNDWI index in Berhampore between 1991 and 2021 (Table 1.16) are classified into four categories such as < -0.15 is low, -0.15 – -0.07 is medium, -0.07–0.01 is high and > 0.01 is very high zone. In 1991,2001,2011 and 2021; 14.89, 15.27, 12.73 and 10.98 percent of the total Berhampore experiences very low MNDWI values and 8.4, 6.17, 4.64 and 3.24 percent experiences very high MNDWI values. It is clearly indicated the value of MNDWI are gradually decrease over the time because of main water body are remain static under supervision by Berhampore Municipality but others bill fall in a great danger because of promoting raj those wetland converted into a vertical residential project.

Table 1.17

Dispersion of MNDWI in Berhampore Municipality from 1991 to 2021

YEAR	MAXIMUM	MINIMUM	MEAN	SD
1991	0.16	-0.26	-0.05	0.29
2001	0.15	-0.28	-0.065	0.3
2011	0.09	-0.29	-0.1	0.26
2021	0.07	-0.25	-0.09	0.22
Source: Prepared by Authors, 2022				

From the MNDWI images (Fig. 1.13) of Berhampore town of 1991, 2001, 2011 and 2021 (Table 1.17), it have been found that values for MNDWI ranges from 0.16 to − 0.26, 0.15 to -0.28, 0.09 to -0.29 and 0.07 to -0.25 respectively. Highest value of MNDWI are mainly found in central part of the town such lakes area available here those are Bishnupur bill, Chatrar bill, Laldighi, Dhobighat, Minbhaban, and Shilpo taluk etc(Fig. 1.13).

It indicates that the proportion of modified water body in the city area has decreased from their mean value − 0.05 in 1991 while it increased by − 0.09 in 2021(Fig. 1.14). This diagram mainly plot of mean value of MNDWI and r^2 value is 0.765 that means it's highly correlated the matter according to time decreasing the rate of water body in town.

1.5.6. NDPI

It is used for the enhancement of open water features. It also diminishes the pond area features that are often correlated with open water.

Table 1.18

Area under different NDPI in Berhampore Municipality from 1991 to 2021

NDPI	AREA								AREA CHANGE			
	1991		2001		2011		2021		1991–2001	2001–2011	2011–2021	1991–2021
	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	%	%	%	%
< -0.05(LOW)	3.02	9.61	3.68	11.71	5.01	15.94	6.2	19.73	-2.1	-4.23	-3.79	-10.12
-0.05–0.05(MEDIUM)	3.84	12.21	4.94	15.72	5.41	17.21	5.88	18.71	-3.51	-1.49	-1.5	-6.5
0.05–0.1(HIGH)	15.6	49.64	14.7	46.78	13.54	43.09	12.33	39.24	2.86	3.69	3.85	10.4
> 0.1(VERY HIGH)	8.96	28.51	8.1	25.77	7.46	23.74	7.01	22.31	2.74	2.03	1.43	6.2
Source: Prepared by Authors, 2022												

To evaluate the nature, patterns of Pond or Stagnant water content in Berhampore town, NDPI indices have been done. NDPI indices have been done over the years from 1991 to 2021. Distribution of the NDPI I index in Berhampore between 1991 and 2021 (Table 1.18)are classified into four categories such as < -0.05 is low, -0.05–0.05 is medium, 0.05–0.1 is high and > 0.1 is very high zone. In 1991,2001,2011 and 2021; 9.61, 11.71, 15.94 and 19.73 percent of the total Berhampore experiences very low NDPI values and 28.51, 25.77, 23.74 and 22.31 percent experiences very high NDPI values. It is clearly indicated the value of NDPI are gradually decrease over the time because unplanned rapid urbanization.

Table 1.19

Dispersion of NDPI in Berhampore Municipality from 1991 to 2021

YEAR	MAXIMUM	MINIMUM	MEAN	SD
1991	0.29	-0.09	0.1	0.26
2001	0.25	-0.07	0.09	0.22
2011	0.28	-0.15	0.065	0.3
2021	0.27	-0.16	0.055	0.3
Source: Prepared by Authors, 2022				

From the NDPI images (Fig. 1.15) of Berhampore town of 1991, 2001, 2011 and 2021 (Table 1.19), it have been found that values for NDPI ranges from 0.29 to − 0.09, 0.25 to -0.07, 0.28 to -0.15 and 0.27 to -0.16 respectively. Highest value of NDPI are mainly found in central part of the town such lakes area available here those are Bishnupur bill, Chatrar bill, Laldighi, Dhobighat, Minbhaban, and Shilpo taluk etc (Fig. 1.15). Rest of those pond or lakes remain in great danger. Due to purpose proper urban management municipality are working with important lakes to maintain their health.

It indicates that the proportion of open pond in the city area has decreased from their mean value 0.1 in 1991 while it decreased by 0.05 in 2021(Fig. 1.16). This diagram mainly plot of mean value of NDPI and r^2 value is 0.96 that means it's highly correlated the matter according to time decreasing the rate of water body and it's health in town because of improper management of water body all over the town.

1.5.7. NDTI

As turbidity level of water increases due the increase in the suspended particles in the water, the reflectance of the red band more than that of the green band (Islam et.al., 2006).The NDTI allows the detection of high turbidity (low clarity) water cover (Lacaux et al., 2007).

Table 1.20

Area under different NDTI in Berhampore Municipality from 1991 to 2021

NDTI	AREA								AREA CHANGE			
	1991		2001		2011		2021		1991–2001	2001–2011	2011–2021	1991–2021
	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	AREA (Sq.Km.)	%	%	%	%	%
< -0.03(LOW)	1.02	3.24	1.94	6.17	2.95	9.38	3.24	10.31	-2.93	-3.21	-0.93	-7.07
-0.03–0(MEDIUM)	17.18	54.67	16.95	53.94	16.42	52.25	16.3	51.87	0.73	1.69	0.38	2.8
0–0.03(HIGH)	11.5	36.6	10.88	34.62	10.53	33.51	10.48	33.35	1.98	1.11	0.16	3.25
> 0.03(VERY HIGH)	1.72	5.47	1.65	5.25	1.52	4.83	1.4	4.45	0.22	0.42	0.38	1.02
Source: Prepared by Authors, 2022												

To find out the turbidity nature of Pond or Stagnant water content in Berhampore town, NDTI indices have been done. NDTI indices have been done over the years from 1991 to 2021. Distribution of the NDTI I index in Berhampore between 1991 and 2021 (Table 1.20) are classified into four categories such as < -0.03 is low, -0.03–0 is medium, 0–0.03 is high and > 0.03 is very high zone. In 1991,2001,2011 and 2021; 3.24,6.17,9.38 and 10.13percent of the total Berhampore experiences very low NDTI values and 5.47,5.25,4.83 and 4.45 percent experiences very high NDTI values. It is clearly indicated the value of NDTI are gradually decrease over the time because of implementation of various scheme to modification drainage system. Due to this turbidity rate of main lake remain minimize.

Table 1.21

Dispersion of NDTI in Berhampore Municipality from 1991 to 2021

YEAR	MAXIMUM	MINIMUM	MEAN	SD
1991	0.03	-0.09	-0.03	0.22
2001	0.03	-0.05	-0.01	0.3
2011	0.05	-0.06	-0.005	0.26
2021	0.04	-0.04	0	0.3
Source: Prepared by Authors, 2022				

From the NDTI images (Fig. 1.17) of Berhampore town of 1991, 2001, 2011 and 2021 (**Table 1.21**), it has been found that values for NDTI ranges from 0.03 to − 0.09, 0.03 to -0.05, 0.05 to -0.06 and 0.04 to -0.04 respectively. Highest value of NDTI are mainly found in central part of the town such lakes area and open space land available here those are Bishnupur bill, Chatrar bill, Laldighi, Dhobighat, Minbhaban, Shilpo taluk and open land surface area etc (Fig. 1.17).

It indicates that the proportion of open pond in the city area has decreased from their mean value − 0.03 in 1991 while it increased by 0 in 2021(Fig. 1.18). This diagram mainly plot of mean value of NDTI and r^2 value is 0.869 that means it’s correlated the matter according to time increasing the rate of turbidity in water body and open surface in town because of improper management of water body and open surface by the process of illegal dumping of solid waste and modification of drainage system it may accelerate the process of eutrophication and environmental degradation in particular features of earth all over the town.

Conclusion

'Urbanization' was defined as the dynamic growth of people in urban areas over a specific period of time. Total population of Berhampore municipality was 195223 according to census of India, 2011 and municipal area nearly was 31.42 sq.km. From the study, it has been found that water body has been decreased very fast and another path of landuse rapidly increases in urban area. NDWI maps shows that water body area is high in the peripheral areas than the central part of town areas or urban areas in 1991but due to process of human encroachments of the urban area over the waterbody. In the core of urban area some major wetland remain static which is controlled by municipality. On the other hand, NDBI index is higher towards the city areas than the outwards of city center. Loss of wetland nearly 3.02 sq.km area and 9.61 percentage of area during the study time (Table 1.11).According to Fig. 1.20 showing the rate of transformation land from waterbody to builtup area according to time, in 1991–2001 0.9sq.km.area, in 2001–2011 0.4sq.km. area and in 2011–2021 0.2 sq.km. area rapidly changed during the process of unplanned urbanization and R^2 value is 0.97 which is highly support that the event. Which was remarkable change within small city town it also triggered urban flood, ground water depletion risk in the city.

Table 1.22
Pearson's Correlations among NDWI, NDBI, NDTI, NDPI & MNDWI

YEAR	VARIABLE	NDWI	NDBI	NDTI	NDPI	MNDWI
1991	**NDWI**	**1**				
	NDBI	0.17	**1**			
	NDTI	-0.09	0.35	**1**		
	NDPI	-0.67	0.61	0.54	**1**	
	MNDWI	0.67	-0.61	-0.54	-1	**1**
2001	**NDWI**	**1**				
	NDBI	0.14	**1**			
	NDTI	-0.08	0.62	**1**		
	NDPI	-0.68	0.64	0.59	**1**	
	MNDWI	0.68	-0.61	-0.59	-1	**1**
2011	**NDWI**	**1**				
	NDBI	0.1	**1**			
	NDTI	0.15	0.65	**1**		
	NDPI	-0.66	0.55	0.36	**1**	
	MNDWI	0.66	-0.55	-0.36	-1	**1**
2021	**NDWI**	**1**				
	NDBI	0.5	**1**			
	NDTI	-0.01	0.73	**1**		
	NDPI	-0.73	0.18	0.3	**1**	
	MNDWI	0.73	-0.18	-0.3	-1	**1**

Source: Prepared by Authors, 2022

Table 1.23
Linear regression model of study variables

YEAR	VARIABLE	R SQUARE	ADJUSTED R SQUARE	STANDARD ERROR	F	STANDARD COFFICIENT	t	p
1991	**NDBI**	0.27	0.26	0.44	33.47	0.165	5.786	0.9
	NDTI	0.1	0.09	0.11	11.49	-0.98	-3.39	0.1
	NDPI	0.457	0.457	0.44	107.66	-0.1	-2.8	0.5
	MNDWI	0.457	0.457	0.41	106.66	0.676	31.74	0.75
2001	**NDBI**	0.21	0.2	0.46	25.77	0.146	5.07	0.8
	NDTI	0.6	0.6	0.12	7.69	-0.8	-2.77	0.6
	NDPI	0.47	0.46	0.45	102.54	-0.69	-0.17	0.9
	MNDWI	0.476	0.475	0.456	100.52	0.69	32.75	0.987
2011	**NDBI**	0.12	0.11	0.35	14.44	0.18	3.787	0.6
	NDTI	0.24	0.23	0.12	30.235	0.156	3.053	0.2
	NDPI	0.443	0.443	0.37	96.28	-0.66	-31.01	0.46
	MNDWI	0.44	0.44	0.37	96.3	0.66	31.01	0.56
2021	**NDBI**	0.25	0.25	0.32	42.86	0.506	20.51	0.575
	NDTI	0.26	0.26	0.1	44.82	0.8	21	2.2
	NDPI	0.54	0.54	0.28	143.77	-0.736	-0.78	0.47
	MNDWI	0.54	0.54	0.28	143.72	0.736	0.78	0.47

Source: Prepared by Authors, 2022

Summarizes the results of the bi variate correlations and linear regression model (**Table1.22 & 1.23**) among study variables in the observed period of 30 years (1991–2021). In this diagram mainly identify the relationship among study variables in the observed period of 30 years (1991–2021) (**Figure 1.19**). It is clearly identified that Built up and waterbody represent an inverse relationship. During the time of 1991 correlation value was 0.17 (low positive) because this phase identify the first footmark of outgrowth of city and within 30years time span that relationship dramatically changed was 0.53 (medium to high positive) so that value identify the massive change or transformation of city from waterbody to builtup area. In case of NDPI and NDBI shows the actual condition urban growth and stagnant waterbody of the city, correlation value was 0.61 in 1991 which was converted into 0.18 in 2021. In another sense the inter relationship between NDBI and NDTI also increases from1991 to 2021, in 1991 value was 0.35 and in 2021 value was 0.73. So, all the indicators are helps to correlate our objectives the growth of urban space hamper the number and health of stagnant water body in Berhampore town.

The study examined the impact of LULC on NDBI,NDWI,NDPI, NDTI and MNDWI in Berhampore town , from 1991 to 2021.In order to determine the association between study variables and the four land cover indices, a linear regression model (LRM) was applied where NDWI consider as constant. During the study periods, Berhampore experienced significant LULC changes; the built-up area, which has expanded by 12.14 sq.km. as a result of population growth and urbanization. In contrast, waterbody were showed a decreasing trend and decreased by 3.02 sq.km. during the study period respectively. Additionally, during the studies 30 year period the study variables had a statistically significant relationship with rapid urbanization.

In Berhampore town wetlands constitute a special ecosystem nurturing a large variety of flora and fauna and it is used as multiple systems. Peripheral households directly and indirectly are utilized the wetlands.

Local habitats surrounding the wetlands are classified into two categories according to their uses, such as - (a) *Bed village* and (b) *Belt village*. *Bed villages* are located at the immediate vicinity around the wetlands whose are intimately linked with the wetland functions. On the other, *Belt villages* are located a away from locality, who exploit wetlands especially for major commercial purpose *(Seshavatharam, 1992)*. Generally wetlands have lots of functionality in urban space of Berhampore town such as recycle nutrients, purify water, control storm water and floods, maintain stream flow, recharge ground water, providing drinking water, fish culture , control rate of runoff in urban area, Green-blue infrastructures (GBI) is presented as a strategy to deal with climate change in urban areas, Bishnupur Bill has a spiritual value and recreational center of the society.

The interaction between man and wetlands during the last few decades has been of disturb largely due to the rapid population growth in Berhampore. So, domestic and industrial wastes are leading pollutant of wetlands in town (commercial and residential site). Presently, we are overlooked the values of wetland and we are belonging in a particular profit maximum state of mind as a result wetlands remain in a great danger. Lots of problem are arise due to unplanned urbanization such as – quality of water decrease as well as biodiversity loss, the aquatic or lentic ecosystem, are hamper by solid waste disposal, sewerage ,waste water disposal and plays of various religious and cultural activities along the wetland zone, ground water depletion, removal of water bodies has led to the decline in water table due encroachment of natural drains, by construction of vertical residential project, removal of vegetative cover, reclamation of wetlands are the prime reasons for frequent flooding even during normal rainfall post 2000.

Wetlands are not delineated under any specific administrative jurisdiction of central as well as state government . The primary responsibility for the management of these ecosystems is in the hands of the Ministry of Environment and Forests. Although some wetlands are protected after the formulation of the Water (Prevention and Control of Pollution) Act – 1974 & 1977 but this is not enough to protect the urban wetland. We must need of Government cooperation along with the local community and corporate sector to come together for an effective management plan to control promoting raj in urban sector. To ensure sustainable success in the protection of wetlands, awareness among the general public, educational and corporate institutions must be created with strict legislation and environment impact assessment needed for major development projects highlighting threats to wetlands need to be formulated. To minimize these problems city administrative authorities should take immediate measures. The findings suggest that policymakers in Berhampore town should be worried about future urban expansion and develop a comprehensive plan for environmentally friendly constriction. The study also revealed that urban wetland can help in improving the overall urban life and sustainable environment.

Declarations

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Conflict of interest - The authors declare that they have no competing interests.

Data availability Data of the study were collected from the following sources –

https://earthexplorer.usgs.gov, https://censusindia.gov.in, http://www.berhamporemunicipality.org.in/

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Figures

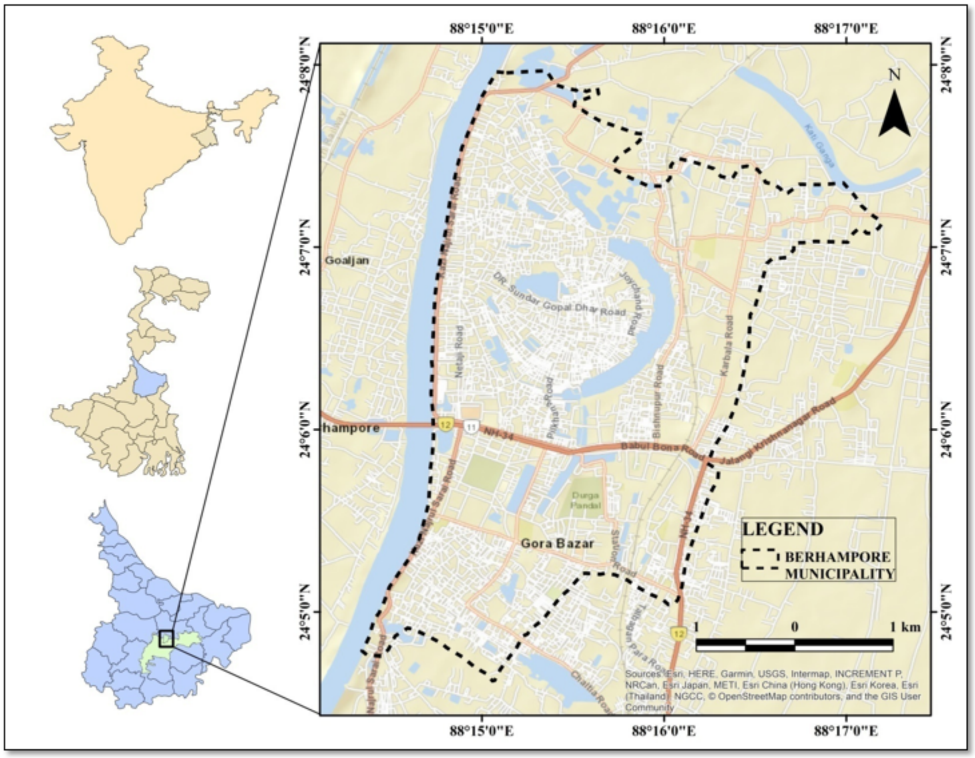

Figure 1

Location Map of Study Area

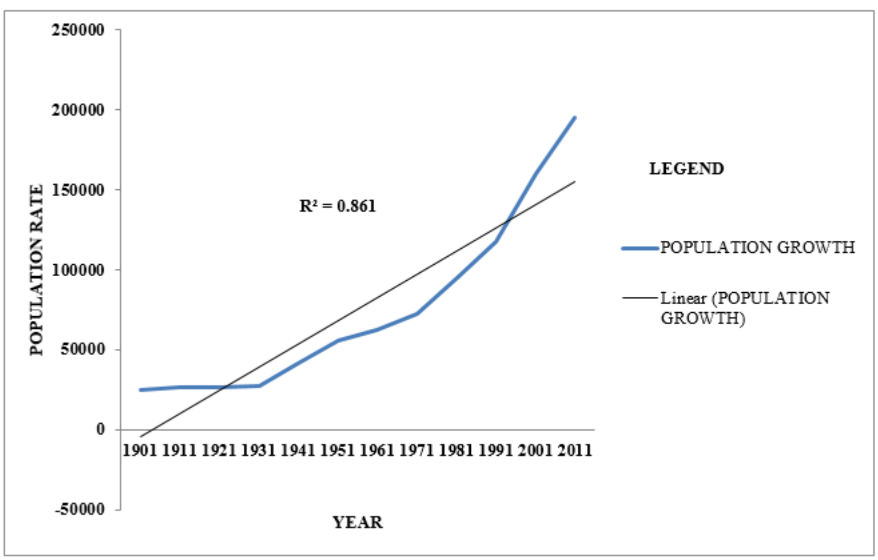

Figure 2

Population Growth of Study Area from 1901 to 2011

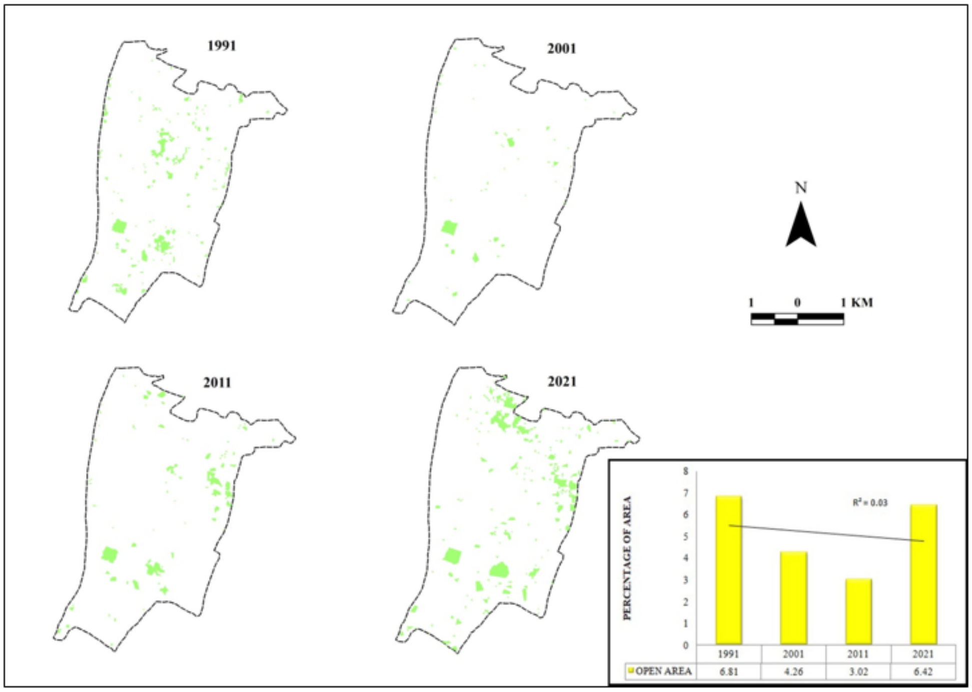

Figure 7

Spatial distributions of Open Area from 1991 to 2021

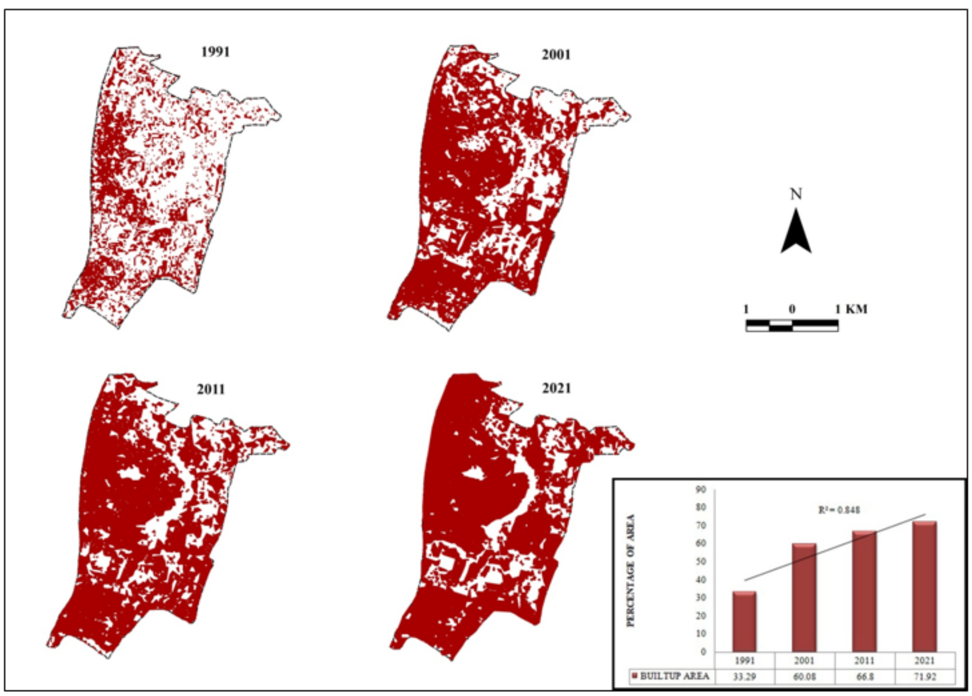

Figure 8

Spatial distributions of Builtup Area from 1991 to 2021

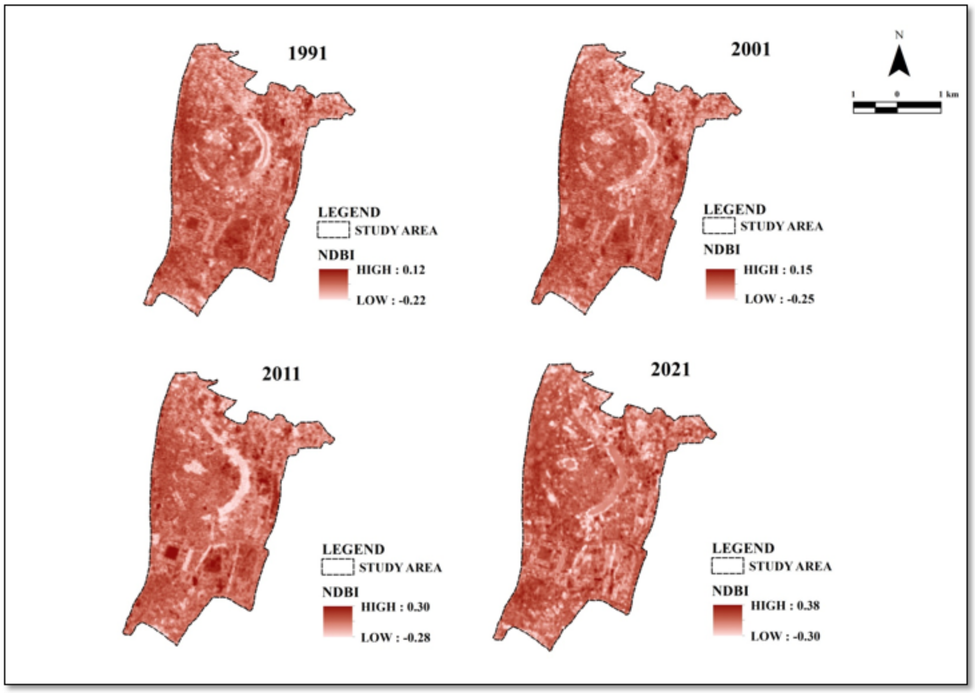

Figure 11

Normalized Difference Buildup Index (NDBI)from 1991 to 2021

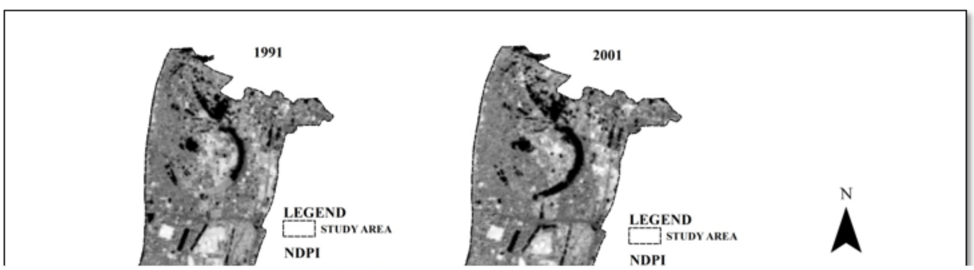

Figure 15

Normalized Difference Pond Index (NDPI)from 1991 to 2021

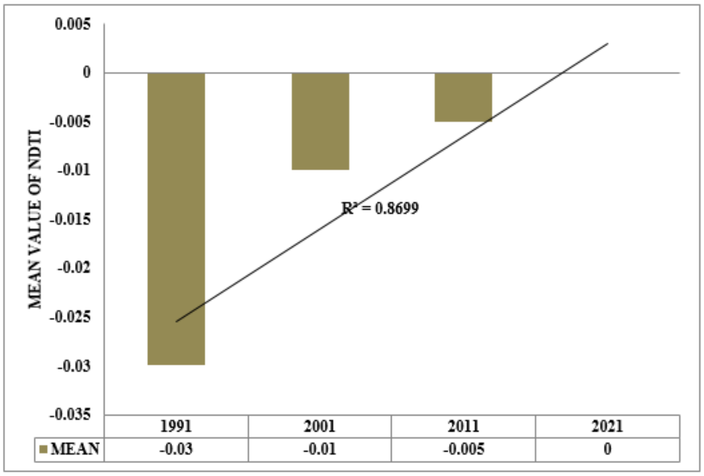

Figure 18

Temporal Change of NDTI 1991 to 2021

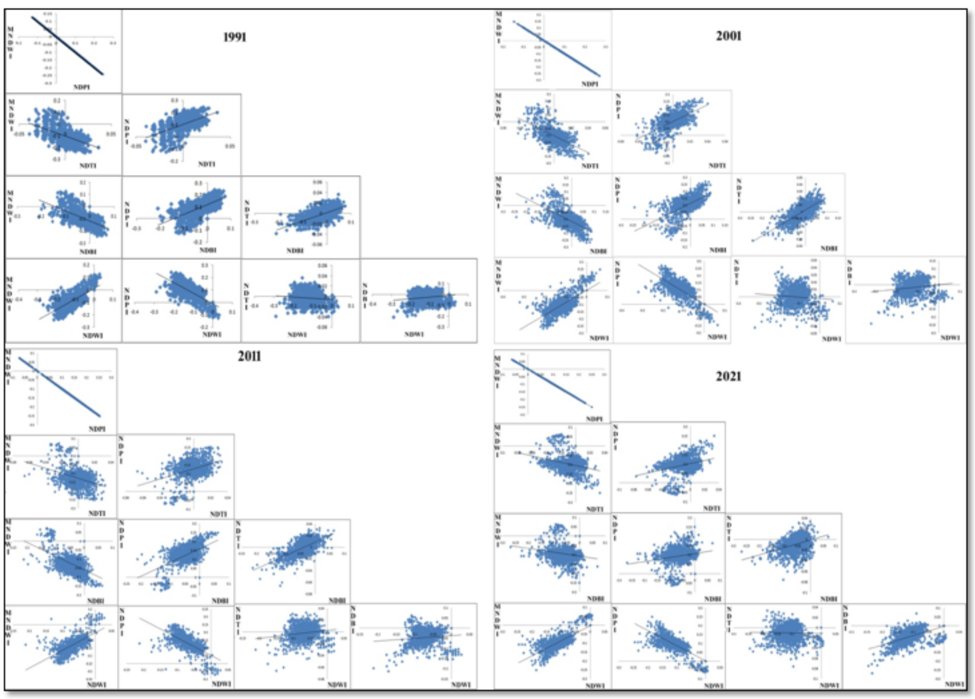

Figure 19

Correlation among study variables in 1991, 2001, 2011 and 2021