ASSESSMENT OF URBAN DYNAMICS – A CASE STUDY ON BERHAMPORE MUNICIPALITY AND ITS SURROUNDINGS, WEST BENGAL, INDIA

ROY SUBHAM KUMAR*[1], KUMAR ANIRUDDH**

Key-word: Berhampore, Built-up Index, Normalized Difference Vegetation Index, Modified Normalized Difference Water Index, Normalized Difference Built-up Index, urban dynamics.

Abstract. Berhampore was a former Armenian-to-British colony and historic commercial centre, had steady expansion during the colonial era, a still-ongoing trend. The natural landscape is transforming from the centre to the periphery in an extremely unpredictable way due to rapid urbanization. The current study examines the urban growth of Berhampore town in West Bengal, India, using geospatial techniques. To understand the spatiotemporal dynamics of the urban landscape from remotely sensed data, four indices are used: the Normalized Difference Built-up Index (NDBI), the Normalized Difference Vegetation Index (NDVI), the Built-up Index (BUI), and the Modified Normalized Difference Water Index (MNDWI). The result of these indices shows the unsustainable urbanization in this region. Over the course of thirty years, the built-up area increased by nearly 7.80 percent, depleting the prime vegetative cover, water bodies and, in some cases, the barren land. According to the study, it is helpful to determine current urban growth and development so that local planning authorities may control growth and development in accordance with the ecological or environmental carrying capacity of the region.

1. INTRODUCTION

The landuse changes are almost global phenomena due to the rapid population growth and urbanization currently occurring. The natural landscape has been significantly impacted by the dynamics of land use/cover (LULC) pattern throughout time, which have been the outcome of the human civilization's existence and activities on the outermost layer of the planet (Lyon *et al.*, 1998; Cheruto *et al.*, 2016; Zha *et al.*, 2003; Xu *et al.*, 2019). The term "land cover" refers to an inherent feature of land, while land use is the process by which land is changed from one primary use to another. The rate of uncontrolled rapid urbanization is quite alarming, particularly in developing countries (Bose & Roychowdhury, 2020; Chen *et al.*, 2003; Cheruto *et al.*, 2016; Tah *et al.*, 2023; Roy & Mondal, 2023). Land use change and urban sprawl were two of the most important and significant issues in urban studies as cities expanded upward and outward. In most cases, city cores are extended from the centre to the urban fringe due to population increase and urbanization, which results in a fragmented urban morphology that negatively impacts the surrounding area and the local ecosystem (Ramachandra *et al.*, 2014; Naikoo *et al.*, 2020; Das *et al.*, 2021). Climate change, air pollution, water pollution and the degradation of the quality of life for both rural and urban areas are some of the most significant ecological issues associated with rapid urban expansion.

According to the United Nation report (2018 & 2019), the overall population of the world will increase to 8.5 billion in 2030, and nearly 55% of the total world population will live in urban areas (Tah *et al.*, 2023). By the end of April 2023, the United Nations Department of Economic and Social Affairs (UN DESA) predicted that India's population will exceed 1,425,775,850 based on the most recent UN predictions and estimations of the world's population. From 62 million in 1951 to 377.1 million in 2011,

* Research Scholar, Department of Geography, Tilka Manjhi Bhagalpur University, Bihar, India, skroy0003@gmail.com.

** Associate Professor, Head of Department of Geography, Tilka Manjhi Bhagalpur University, Bihar, India, akgeo11@gmail.com.

[1] Corresponding author

the number of people living in urban areas had dramatically increased in India and it is anticipated to reach 600 million by 2031(Mukherjee and Das, 2018; Das *et al.*, 2021; Roy & Mondal, 2023).

Remotely sensed images provide accurate, precise, spatio-temporal data covering large areas. In comparison to the conventional methodologies, Remote Sensing (RS) and Geographic Information Systems (GIS) provide a new tool for identifying, evaluating, mapping, and simulating the nature and extent of urban growth and its related changes. Using a variety of indices, matrices, and models, several studies have shown the value of remotely sensed data in monitoring land use and land cover change in urban environments (Yang and Lo, 2002; Xu *et al.*, 2019). Various local, regional & global level works have been undertaken on the basis of interrelationship among NDBI, NDVI, MNDWI and BUI by using modern GIS techniques (Das *et al.*, 2021; Roy & Kasemi, 2021; Roy & Mondal, 2023).

In India, urban expansion-related extensive research work has been done on various cities, like *Kolkata* (Bhatta, 2009; Das *et al.*, 2022), *Mumbai* (Kandpal and Saizen, 2019), *Delhi* (Naikoo *et al.*, 2020), *Chennai* (Vaani and Anand, 2018), *Bhubaneswar* (Das *et al.*, 2021), Durgapur Sub Division (Patra and Gavsker, 2021), *English Bazar* (Shaw and Das, 2018), Raiganj (Roy and Kasemi, 2021), Siliguri (Bose and Roy Chowdhury, 2020), Asansol Durgapur (Choudhury *et al.*, 2019) etc. Small and medium-sized cities and towns contribute significantly to urban growth, yet they are sometimes overlooked. In order to better understand the urban dynamic in small towns and cities in developing countries, Berhampore, a small city in West Bengal, has been selected as the study area, even though the nature of urban dynamics and the intensity of city growth depend on various factors and vary from area to area.

The current work aims to analyse and observe the spatiotemporal variation of the Berhampore urban agglomeration at a distance of about 6 km from its core to the outside boundary using NDVI, NDBI, BUI, and MNDWI indicators in the RS and GIS context.

2. STUDY AREA

In 1876, Berhampore municipality was set up. One of the oldest municipalities in West Bengal, it is located in the Berhampore block of the Murshidabad district. According to the "Bengal Municipal Act of 1876", the administration and management of Berhampore Municipality was eventually transferred to 14 elected and 5 government-nominated members in the year 1884. At that time, Berhampore Municipality was split into 6 wards, including Gorabazar, Cantonment, Berhampore, Khagra, Cossimbazar and Saidabad.

The latitudinal extension of the area is 24º04'39"N to 24º07'48"N and the longitudinal extension is from 88º14'57" E to 88º15'50" E (Fig. 1).

The Bhagirathi River passes the middle portion of the town. National Highway 12 (Previous National Highway34) divides the study area into two parts and the Eastern Railway runs through the Eastern side. Berhampore is the administrative, nodal, and district headquarters of the Murshidabad district. According to the 2011 census of India, the total population of Berhampore town was 195, 223, allowing it to be categorized as a class-1 municipality town in West Bengal. Berhampore is located as the middle part of the State, which is why it acts as an active nodal centre between North Bengal and South Bengal. According to the 2011 Census, Berhampore Municipality was surrounded by nine census towns such as – Banjetia, a part of Kasim Bazar, Sibdanga Badarpur, Chaltia, a part of Gora Bazar Ajodhyanagar, Haridasmati, Goaljan and Gopjan etc. The whole study area is roughly 113.02 sq. km. This study area consists of one municipality, nine census towns, and numerous villages. A buffer of 6 km was created from the District magistrate office of Berhampore to select our study area to show the urban – peri–urban landscape transformation. The Berhampore Urban Agglomeration (UA) has grown rapidly in the past two decades. The process of concentrating a population in a certain region over a relatively short period of time is known as urbanization. The existing literature study (Roy & Biswas, 2021; Roy & Mondal, 2023) points out that the surroundings of Berhampore are changing quite rapidly. The western side of the area of study does not have a quicker pace of urbanization due to the river. Moreover, the pattern of urban growth and the shape of urban sprawl have never been investigated. This is why through this research we add to the existing literature on the area, and expand the knowledge on land use change in urban areas in India.

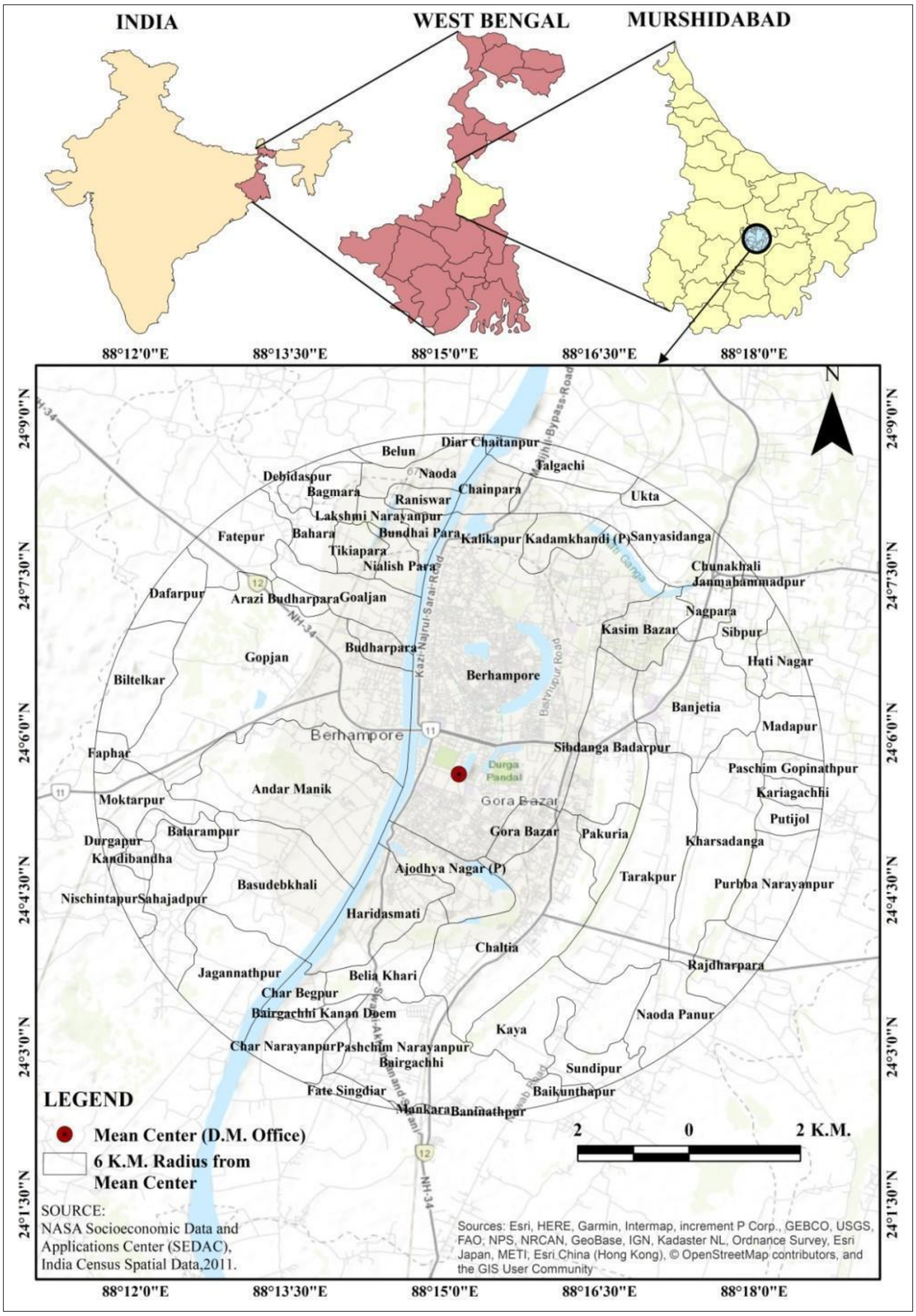

Fig. 1 – Location of the study area.

3. DATABASE AND METHODOLOGY

The present study has been undertaken with the help of geospatial data, due to a lack of official data at micro-level. The images from Landsat 5 TM, 8 OLI and TIRS are used in the index-based classification method to find changes for the years 1991, 2001, 2011, and 2021. The images were downloaded from the United States Geological Survey (USGS) of different dates (Table 1). The ArcGIS 10.2 and QGIS 2.18 software have been used to create a location map, a NDVI map, a NDBI map, a BUI map and a MNDWI map. MS-Excel (07) is used for the statistical calculation and for the representation of the calculated data.

Table 1

Details of used secondary data

Data Type	Date	Sensor	Path Row	Data Source	Datum & Projection
Spatial data	1991-01-24	Landsat 5/ TM	139/43	USGS earth explorer	WGS 84 UTM
	2001-01-19	Landsat 5/ TM	139/43		
	2011-01-31	Landsat 5/ TM	139/43		
	2021-02-11	Landsat 8/ OLI-TIRS	139/43		
Non-spatial data	Murshidabad District Census HandBook, 2001 & 2011				
	District Statistical Hand Book, Murshidabad 2010,2011,2013 & 2014				

3.1. Normalized Difference Vegetation Index (NDVI)

NDVI is frequently used to determine the health of the greenery that has been changed over a period of time in a large area (Lyon *et al.*, 1998). The Normalized Difference Vegetation Index is mainly used to identify the vegetation cover by using satellite images. Near-infrared (NIR) and RED bands are used to calculate the NDVI.

$$\mathbf{NDVI} = \frac{NIR-RED}{NIR+RED}$$

The NDVI value ranges from -1 to +1. A positive value indicates healthy vegetation and a negative value indicates water bodies, artificial structures or a lower vegetation cover. NDVI values are classified into three categories, such as <0 (low), 0–0.2 (medium) and >0.2 (high), according to this study area. These values are selected based on the previous study which was suitable for that location (Roy & Mondal, 2023).

3.2. Normalized Difference Built up Index (NDBI)

The NDBI helps to detect the changes in built-up areas over a period of time in a vast area. Shortwave Infrared (SWIR) and Near Infrared (NIR) are used to calculate the NDBI (Zha *et al*., 2003).

$$\mathbf{NDBI} = \frac{SWIR-NIR}{SWIR+NIR}$$

The NDBI value ranges from -1 to +1. A positive value indicates the high density of a built-up area, and a negative value indicates the low density of a built-up area. NDBI values are classified into three categories, such as <0 (low), 0–0.2 (medium) and >0.2 (high), according to this study area from literature review (Roy & Mondal, 2023).

3.3. Built Up Index (BUI)

The built-up Index is calculated using the revised method developed by Chen *et al.* (2003) to distinguish urban areas and barren land to some extent based on their value of reflectance in the GIS environment. It is mainly used to identify new artificial structures of urban landscape.

$$\textbf{BUI} = \text{NDBI} - \text{NDVI}$$

The BUI value varies from -1 to +1, and the higher the BUI is, the greater the possibility that the pixel is a built-up area.

3.4. Modified Normalized Difference Water Index (MNDWI)

MNDWI is more appropriate than the Normalized Difference Water Index (NDWI), established by McFeeters (1996) for acquiring water information from urban environments by reducing, or even deleting, vegetation, land, and soil noise. Green and Shortwave Infrared (SWIR) are used to calculate the MNDWI (Xu, 2006).

$$\textbf{MNDWI} = \frac{GREEN - SWIR}{GREEN + SWIR}$$

The value ranges from -1 to +1. A higher degree of water enhancement in the MNDWI-image means that open water features may be extracted more precisely, since built-up areas, soil, and vegetation all have negative values and are thus more easily identified and removed from the analysis. MNDWI values are classified into three categories, such as < 0 (low), 0–0.2 (medium) and >0.2 (high), according to this study area from literature review (Roy & Mondal, 2023).

4. RESULTS AND DISCUSSION

4.1. NDBI

The nature of the artificial structure of the urban and peri-urban sector has been explained by the NDBI from 1991 to 2021 with a 10-year gap. The NDBI maps have been classified into three categories (Table 2), such as <0 (low), 0–0.2 (medium) and >0.2, which applies to areas with high values of the index. The class of high values of NDBI was not represented in the 1991 and 2001 images of the study area. However, in the years of 2011 and 2021 the value increased from 4.81 to 7.80 % of the area. It clearly indicates that the values of the NDBI have gradually increased over time. Therefore, it is clear that, from 1991 to 2021, the highest NDBI value increased over nearly 8% of the total area.

Table 2

Area under different NDBI values within the study area (1991 to 2021)

NDBI	1991		2001		2011		2021		Area Change(%)			
	Area Sq. km.	**%**	**Area Sq. km.**	**%**	**Area Sq. km.**	**%**	**Area Sq. km.**	**%**	**1991–2001**	**2001–2011**	**2011–2021**	**1991–2021**
<0	93.58	82.80	90.31	79.91	85.49	75.64	79.02	69.92	-2.89	-4.27	-5.72	-12.88
0-0.2	19.44	17.20	22.71	20.09	22.09	19.55	25.19	22.29	2.89	-0.54	3.35	5.7
>0.2	0	0.00	0	0.00	5.44	4.81	8.81	7.80	0	4.81	2.99	7.80
Total	113.02	100	113.02	100	113.02	100	113.02	100				

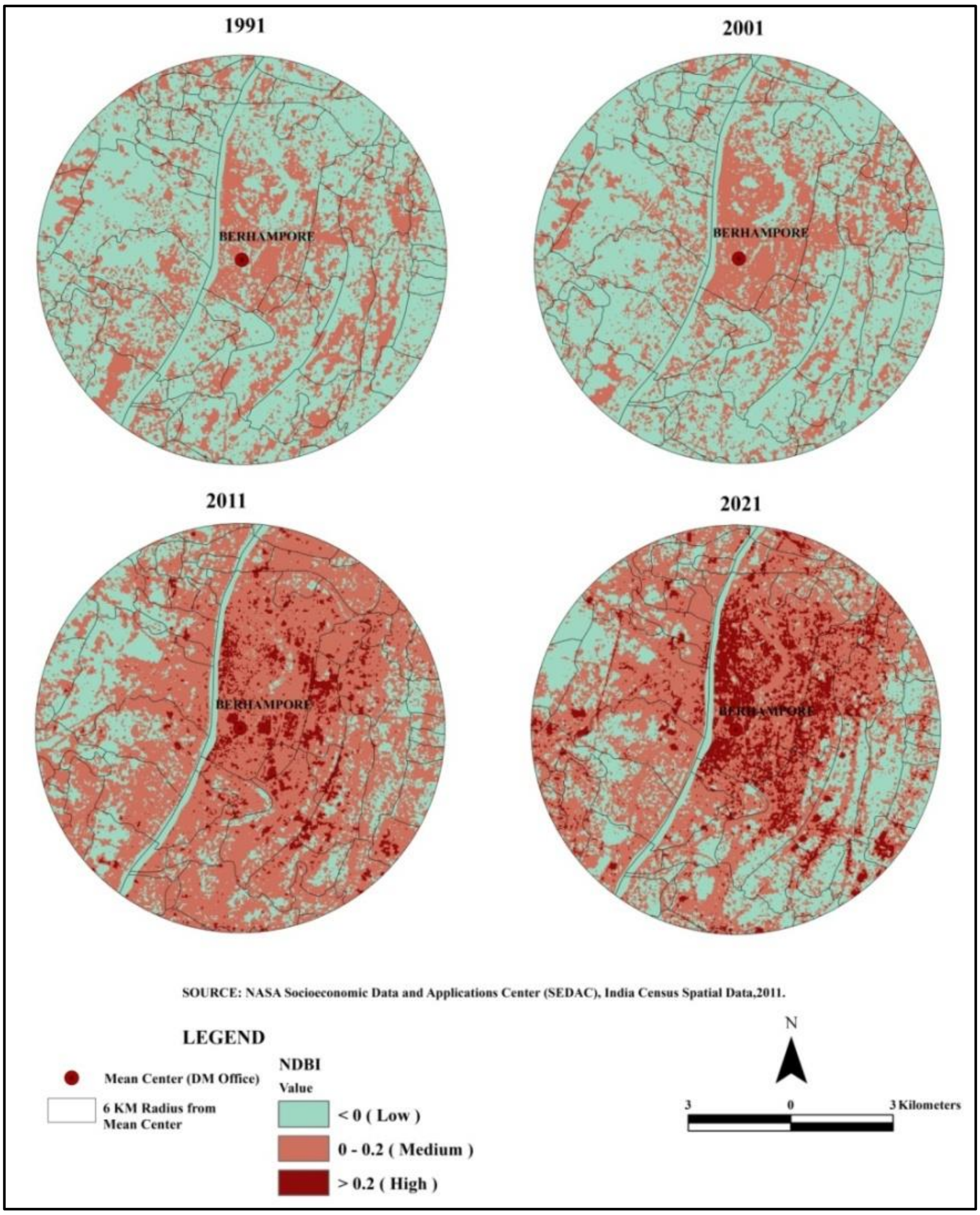

Fig. 2 – The Normalized Difference Built up Index of the study area from 1991 to 2021.

The NDBI values in the study area in 1991, 2001, 2011 and 2021 varied between +0.12 to –0.27, 0.15 to -0.28, 0.31 to -0.24 and 0.39 to -0.23, respectively. The highest value of NDBI is found mainly in the central part of town. These parts consist primarily of Khagra, Saidabad, Gorabazar, Indropostha, Dayanagar, Cossimbazar and Kadai etc. The rate of urbanization of Berhampore town and its surroundings is very dynamic from 2001 to 2011. In India, a census town is one which is not statutorily notified and administered as a town, but whose population has nevertheless attained urban characteristics. They are characterized by the following population exceeding 5000. At least 75% of the main male working population is employed outside the agriculture sector and population density is greater than 400 persons per square kilometre.

According to the Census Handbook (2011) it was clearly observed that:

- Phase 1: Kossimbazar was one census town from 1971 in the North-Eastern part of the city;
- Phase 2 (the middle phase): Two new census towns were added in the North-Western portion of the city Gorabazar and the Western part of the city Goaljan from 1991 to 2001;
- Phase 3: Six additional census towns were added to the area around the Berhampore municipality during this phase, which lasted from 2001 to 2011. These census towns are Gopjan (Western part), Sibdanga Badarpur (Eastern part), Banjetia (North-Eastern part), Chaltia (North-Western), Ajodhayanagar, and Haridasmati (Southern part).

All directions are calculated using the quadrant method of the District Magistrate office as the mean location inside the Berhampore municipality. The low value of NDBI is mainly found in the fringe region and in the Western and Eastern parts of the study area. According to Roy & Biswas (2021). It is clearly observed that National Highway 34 and State Highway 11 play a vital role in the urbanization process. Additionally, it has been noted that the census towns, a part of Gorabazar, Ajodhyanagar, Chaltia, Sidbanga and Badarpur, and a part of Kasimbazar fall under the inner region of urban expansion, with the mean centre of three of these towns (Gorabazar, Sidbanga Badarpur, and Chaltia) shifting from the core to a transitional zone. According to a hotspot study, Chaltia Census Town is 95% significant to enhancing the increasing functionality of the functioning area and it has been demonstrated that the functional centre shifted from the core to Chaltia because of its location, which offers reduced traffic and easy access to all urban amenities (Roy & Biswas, 2021).

4.2. NDVI

The changes to the tropical deciduous forest cover (the natural vegetation in the area) between 1991 and 2021 have been investigated using the NDVI index. The NDVI maps have been classified into three categories (Table 3), such as <0 (low), 0–0.2 (medium), and > 0.2, which represents areas with high values of the index. The threshold value 0.2 basically indicates the shrub type of vegetation cover. The class of high values represents NDVI values for 1991, 2001, 2011 and 2021, which are, respectively, 20.91, 19.48, 15.95 and 14.87 percent in the total area. So, it can be clearly noted that the values of NDVI gradually decrease over time because of unplanned rapid urbanization. Therefore, it is apparent that the highest NDVI value from 1991 to 2021 has dropped by over 6 percent of the entire area due to the process of illegal unplanned urbanization, or some vegetated area being converted into agricultural fields or any kind of construction activity.

Table 3

Area under different NDVI in the study area from 1991 to 2021

NDVI	**1991**		**2001**		**2011**		**2021**		**Area Change (%)**			
	Area Sq. km.	**%**	**Area Sq. km.**	**%**	**Area Sq. km.**	**%**	**Area Sq. km.**	**%**	**1991–2001**	**2001–2011**	**2011–2021**	**1991–2021**
<0	3.59	3.18	3.5	3.15	3.12	2.76	3	2.65	-0.03	-0.39	-0.11	-0.53
0–0.2	85.8	75.92	87.89	77.36	91.87	81.29	93.21	82.47	1.44	3.93	1.18	6.55
>0.2	23.63	20.91	21.63	19.48	18.03	15.95	16.81	14.87	-1.43	-3.53	-1.08	-6.04
Total	113.02	100	113.02	100	113.02	100	113.02	100				

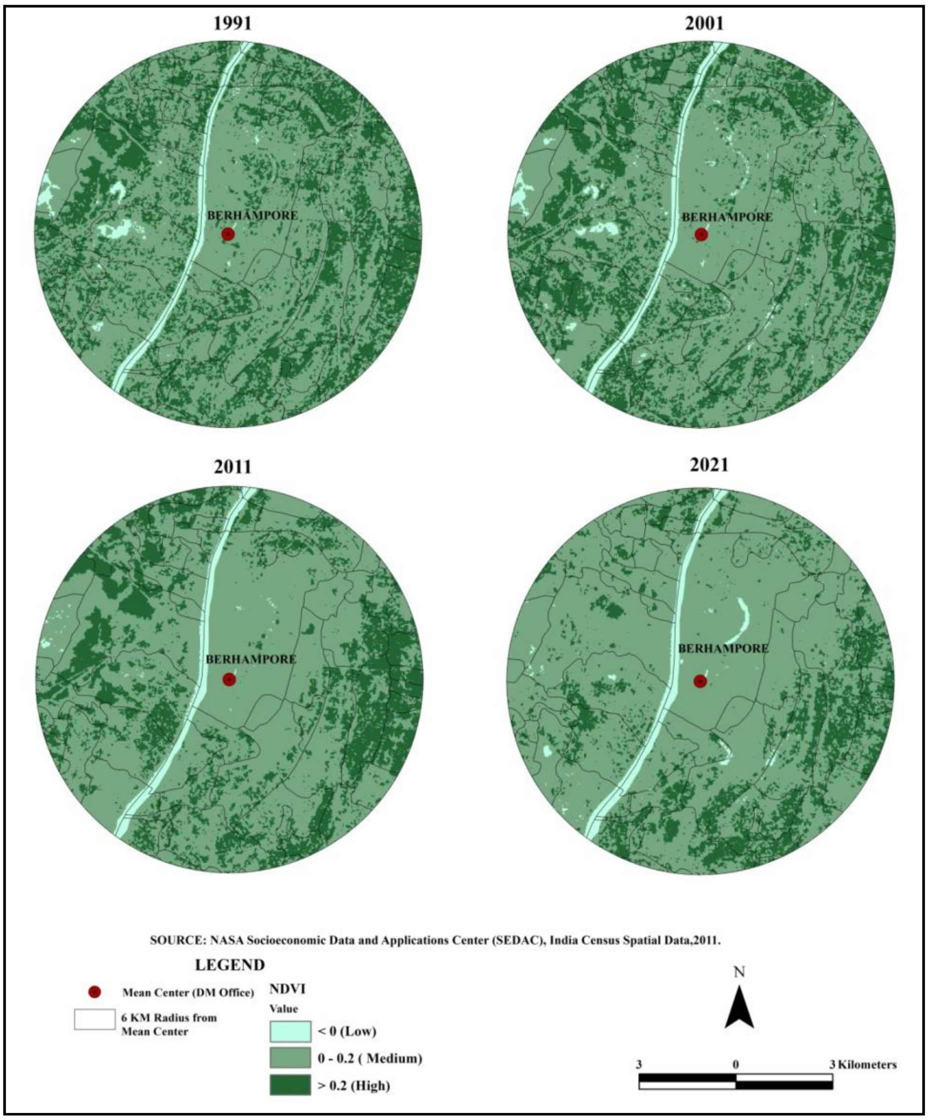

Fig. 3 – The Normalized Difference Vegetation Index of the study area from 1991 to 2021.

The NDVI values in the study area in 1991, 2001, 2011 and 2021 varied from+0.37 to -0.07, from 0.40 to -0.09, from 0.42 to -0.01 and from 0.28 to -0.02, respectively. The highest value of NDVI is mainly found at the outer part of the town, and the lowest value is recorded at the town's core and its surroundings. The core area of the city acts mainly as the central business district or main urbanized sector, but the surrounding sector of the city is not very well developed in comparison to the core. The city's Western and Eastern areas had the highest vegetation cover; however, owing to unplanned urbanization, peri-urban areas quickly became urban sectors, and, as a result, all of the study area would see major vegetation loss in 2021.

4.3. MNDWI

MNDWI is another extremely important indicator that shows the water component of the city and its periphery from 1991 to 2021 within a 10-year temporal gap. The MNDWI maps have been classified into three categories (Table 4) such as <0 (low), 0–0.2 (medium), and >0.2 which represents areas with high values of the index. The threshold value 0.2 basically indicates the healthy body of water. The areas with high values of MNDWI in 1991 and 2001 registered 3.03 and 1.77 percent, respectively, for the entire study area. Most of the healthy water bodies are missing from the study area due to unplanned rapid urbanization. The main urban centre relocated to the Southeast, and it is evident from the maps of 2011 and 2021 that darker blue regions are absent during this time period (Roy & Biswas, 2021; Roy & Mondal, 2023). Therefore, it is clear that the maximum MNDWI value for the whole area from 1991 to 2021 has decreased by more than 3%.

Table 4

Area under different MNDWI in the study area from 1991 to 2021

MNDWI	1991		2001		2011		2021		Area Change (%)			
	Area Sq.km.	%	Area Sq.km.	%	Area Sq.km.	%	Area Sq.km.	%	1991–2001	2001–2011	2011–2021	1991–2021
<0	88.27	78.10	89.01	78.76	91.2	80.69	95.01	84.06	0.66	1.93	3.37	5.96
0–0.2	21.33	18.87	22.01	19.47	21.82	19.31	18.01	15.94	0.6	-0.16	-3.37	-2.93
>0.2	3.42	3.03	2	1.77	0	0.00	0	0.00	-1.26	-1.77	0.00	-3.03
Total	113.02	100	113.02	100	113.02	100	113.02	100				

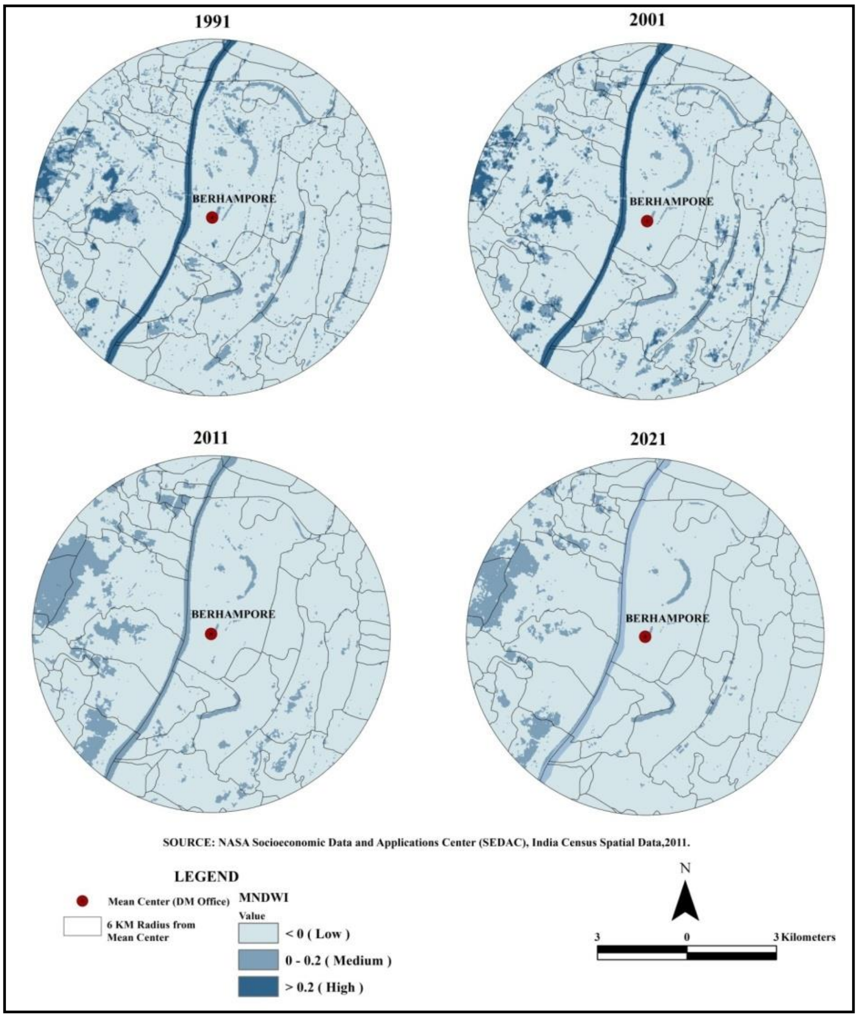

Fig. 4 – The Modified Normalized Difference Water Index of the study area from 1991 to 2021.

The MNDWI values in the study area in 1991, 2001, 2011 and 2021 varied from0.21 to –0.26, from0.21 to -0.29, from0.16 to -0.29, and from0.12 to -0.27, respectively. The highest value of MNDWI is mainly found at the Western boundary of Berhampore municipality, due to the river Bhagirathi and the city core, as well as important lakes such as Chaltia, Bishnupur, Chatrar, Dhobighat, Minbhaban, and Shilpo taluk etc. The remaining lakes, including Biltekar (in the extreme West), Nischintapur Lake (South-West), Sahajadpur (South), Kalaberia Lake (South-East), Pakuria Lake (East) and Katiganga (North) are scattered within the study area. According to Roy and Mondal (2023), it is clear that the process of urbanization has destroyed roughly 3.02 sq. km of water bodies within the boundaries of the Berhampore Municipality, while from 1991 to 2021 the number of ponds decreased and the turbidity of water bodies increased steadily.

4.4. BUI

Another significant graphical indicator is the built-up index (BUI), which is widely used for identifying among built-up land and urban regions. As a result, the geographical distribution of the built-up index for the area of study is shown in (Fig. 5). In the city's urban and densely populated sections in early 1991, built-up index (BUI) values were high at the city core. As a result, the highly populated and constructed zones in the centre of a city act as its core, having a very high built-up index, while the outermost regions of the city with high vegetation cover were where the low value of built-up index was most frequently observed. Even higher BUI values were calculated at the core of the city in 2021 (the maximum values calculated for that year reached 0.53, compared with the maximum of 0.05 in 1991).

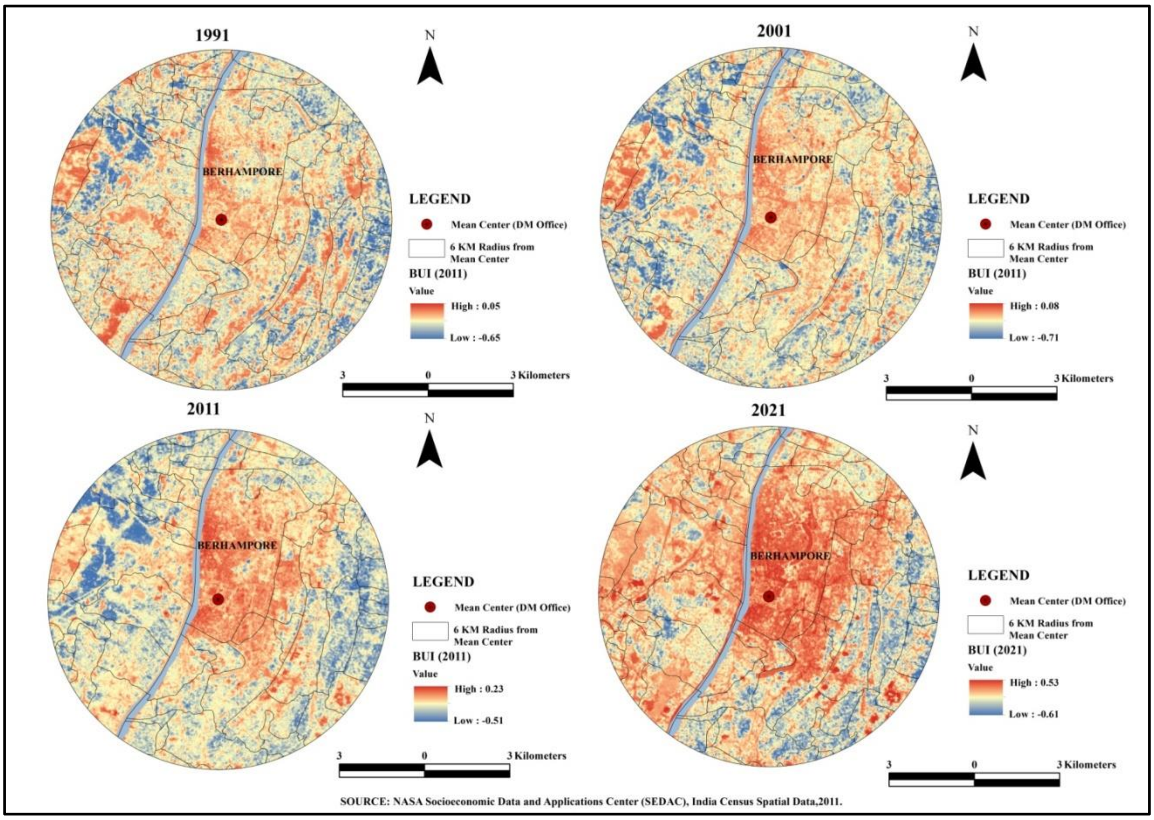

Fig. 5 – The Built up Index of the study area from 1991 to 2021.

However, after 30 years, a significant transition happened with a rising tendency of BUI values towards the city's North, North-Eastern, Eastern, South-Eastern and Southern outskirts. As a result, the spatial patterns of built-up areas show an increasing built-up index (BUI) trend towards the North, North-Eastern, Eastern, South-Eastern, and Southern outskirts, as they are covered with less vegetation. However, the Western portion of the Berhampore municipality has not been expanded due to the natural barrier of the river Bhagirathi. This trend is indicative of the rapid growth of the city towards the periphery as a result of extreme population pressure and the rising cost of land at the city core.

The correlation between indicators of urban dynamics and the change rate of urban landscape is presented in Fig. 6. Urban dynamics has rapidly increased within the study time. It is obvious that NDBI and NDVI, as well as NDBI and MNDWI have low to significant negative relationships due to a rapidly increasing trend of the built up area within the study frame.

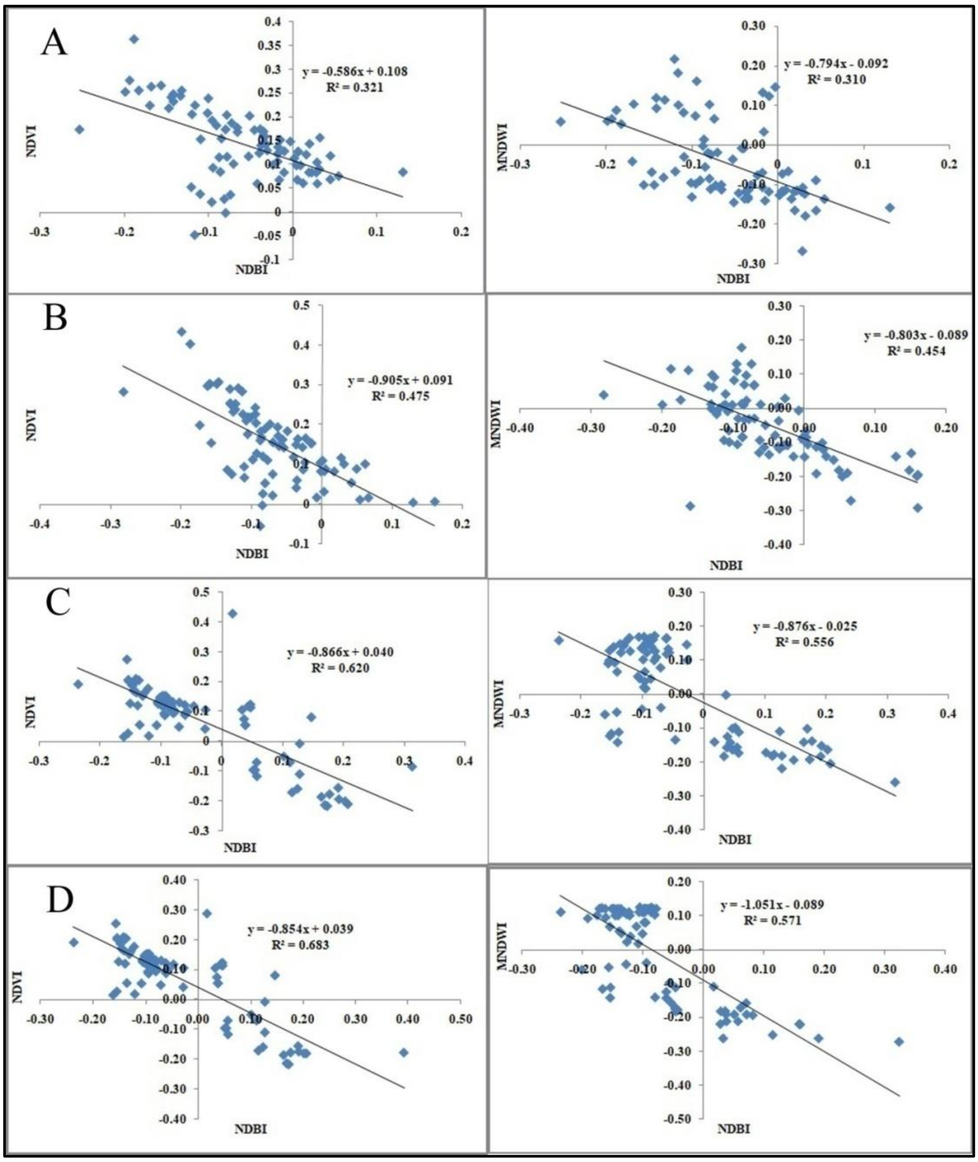

Fig. 6 – **A**. The correlation between NDBI-NDVI & NDBI-MNDWI in1991**; B.** The correlation between NDBI-NDVI & NDBI-MNDWI in 2001**; C.** The correlation between NDBI-NDVI & NDBI-MNDWI in year 2011; **D.** The correlation between NDBI-NDVI & NDBI-MNDWI in year 2021.

5. CONCLUSIONS

Urbanization is associated with the modification of land use, economic activity and cultural characteristics in addition to the gradual increase in the urban population. Since the beginning of the Armenian colonial setup, the town of Berhampore has gradually experienced morphological transformations as a result of urbanization. Early in the 18th century, commercial enrichment and British colonialism accelerated the progress of urbanization, and the city began expanding in the North and North-Eastern directions. Although there were just 24,397 urban residents in Berhampore municipality in 1901, there are now 195,223 according to the 2011 census. At present, it is a Class I municipality town, which means a city is an urban centre with a population of more than 100,000 inhabitants. The growth of urban buildings is accelerated by the increase in population, but the amount of green and blue space is simultaneously reduced. During the investigated period (1991–2021), the natural landscape in the study area has been heavily impacted by urbanization and urban sprawl. The most rapid changes took place between 2001 and 2011.The amount of shrub green cover has recorded the maximum value 20.91 percent in 1991, as the second phase (2001–2011) displays the highest changes. Due to significant development in residential projects and artificial structures, the healthy water bodies suffered significant changes in 1991 and 2001, and did not recover in the following decades. On the other hand, the highest built-up area happened between 2011 and 2021. The study found that the expansion of the town over time was unplanned and sluggish, and that its structure had significantly shifted from the centre to the periphery. The health of the town may not be supported by the current green and blue areas. The living conditions, social and bio-psychosocial wellness and way of life of the city inhabitants may be affected due to the removal of the vegetative cover and water bodies. The scientific and sustainable urban land use by local administrators, as well as people’s awareness are urgently needed in order to support environmental sustainability and prevent the future deterioration of the city environment. Urban planners and the town leaders may benefit from the current research in adopting long-term planning in the near future.

Acknowledgments: This study is not supported by any Government, Non-Government or NGO’s funding.

REFERENCES

Bhatta, B. (2009), *Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India*. International Journal of Remote Sensing. **30** (*18*), pp. 4733–4746. https://doi.org/10.1080/01431160802651967.

Bose, A., Roy Chowdhury, I. (2020), *Monitoring and modeling of spatio-temporal urban expansion and land-use/land-cover change using markov chain model: a case study in Siliguri Metropolitan area, West Bengal, India*. Modeling Earth Systems and Environment, **6**, pp. 2235–2249. https://doi.org/10.1007/s40808-020-00842-6.

Chen, J., Gong, P., He, C., Pu, R., Shi, P. (2003), *Land use/land cover change detection usin gimproved change vector analysis*. Photogrammetric Engineering & Remote Sensing, **69**(*4*), pp. 369–379.

Cheruto, M. C., Kauti, M. K., Kisangau, P. D., Kariuki, P. (2016), *Assessment of land use and land cover change using GIS and Remote Sensing techniques: A case study of Makueni County, Kenya*, Journal of Remote Sensing and GIS, **5**(*4*). DOI: 10.4175/2469-4134.1000175.

Choudhury, D., Das, K., Das, A. (2019), *Assessment of land use land cover changes and its impact on variations*. The Egyptian Journal of Remote Sensing and Space Sciences, **22**, pp. 203–218. https://doi.org/10.1016/j.ejrs.2018.05.004.

Das, T., Jana, A., Mandal, B., Sutradhar, A. (2021), *Spatio-temporal pattern of land use and land cover and its effects on land surface temperature using remote sensing and GIS techniques: a case study of Bhubaneswar city, Eastern India (1991–2021)*. GeoJournal. DOI:10.1007/s10708-021-10541-z.

Das, M., Mandal, A., Das, A., Pereira, P. (2022), *Land use and land cover change future projection in Kolkata Metropolitan Area, Eastern India.* (P. Pereira, E. Gomes, & J. Rocha, Eds.) Mapping and Forecasting Land Use, Elsevier. https://doi.org/10.1016/B978-0-323-90947-1.00011-9.

Kandpal, R., Saizen, I. (2019), *An evaluation of the relative urbanisation in peri-urban villages affected by industrialization: the case study of Bhiwandi in the Mumbai Metropolitan Region, India*. Spatial Information Research, **27** (*2*), pp. 137–149. https://doi.org/10.1007/s41324-018-0221-z.

Lyon, J. G., Yuan, D., Lunetta, R. S., Elvidg, C. D. (1998), *A change detection experiment using vegetation indices*. Photogrammetric Engineering and Remote Sensing, **64** (*2*), pp. 143–150.

McFeeters, S. K. (1996), *The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features*. International Journal of Remote Sensing, **17**(*7*), pp. 1425–1432.

Mukherjee, K., Das, P. (2018), *Modelling the Relationship between Urban Growth Modes and the Thermal Environment – A Case Study of the Barasat Municipality, West Bengal*. Journal of Geography, Environment and Earth Science International, **17**(*2*), pp. 1–19. https://doi.org/10.9734/JGEESI/2018/44047.

Naikoo, M. W., Rihan, M., Ishtiaque, M., Shahfahad (2020), *Analyses of land use land cover (LULC) change and built-up expansion in the suburb of a metropolitan city: Spatio-temporal analysis of Delhi NCR using landsat dataset*. Journal of Urban Management, **9** (*3*), pp. 347–359. https://doi.org/10.1016/j.jum.2020.05.004.

Patra, S., Gavsker, K. K. (2021), *Land use and land cover change-induced landscape dynamics: a geospatial study of Durgapur Sub-Division, West Bengal (India)*. AUC Geographica, **56**(*1*), pp. 79–94. https://doi.org/10.14712/23361980.2021.3.

Ramachandra, T.V., Aithal, B.H., Sowmyashree, M.V. (2014), *Urban structure in Kolkata: metrics and modelling through geo-informatics*. Applied Geomatics, **6**(*4*), pp. 229–244. DOI:10.1007/s12518-014-0135-y.

Roy, S. K., Biswas, S. (2021), *Transformation of Berhampore Municipal Surrounding Area from Concentric Zone to Multiple Nuclei Zones*. Territorio della ricerca su in sediamenti e ambiente international journal of urban planning. **26** (*1*/2021), pp. 97–112. DOI 10.6092/2281-4574/8267.

Roy, B., Kasemi, N. (2021), *Monitoring urban growth dynamics using remote sensing and GIS techniques of Raiganj Urban Agglomeration, India*. The Egyptian Journal of Remote Sensing and Space Sciences, **24**, pp. 221–230. https://doi.org/10.1016/j.ejrs.2021.02.001.

Roy, S.K., Mondal, C. (2023), *Impact of Rapid Urbanization and Changing Face of Wetland: A Case Study of Berhampore Municipality, Murshidabad, West Bengal (India)*. In: Chatterjee, U., Antipova, A., Ghosh, S., Majumdar, S., Setiawati, M.D. (eds) *Urban Environment and Smart Cities in Asian Countries. Human Dynamics in Smart Cities*. Springer, Cham. pp. 23–59. https://doi.org/10.1007/978-3-031-25914-2_2.

Shaw, R., Das, A. (2018), *Identifying peri-urban growth in small and medium towns using GIS and remote sensing technique: A case study of English Bazar Urban Agglomeration, West Bengal, India*. The Egyptian Journal of Remote Sensing and Space Sciences, **21**, pp. 159–172. http://dx.doi.org/10.1016/j.ejrs.2017.01.002.

Tah, S., Roy, S.K., Mondal, C. (2023), *Assessment of Land Surface Temperature Using Landsat Images: A Case Study on Durgapur Municipal Corporation, West Bengal, India*. In: Chatterjee, U., Antipova, A., Ghosh, S., Majumdar, S., Setiawati, M.D. (eds) *Urban Environment and Smart Cities in Asian Countries. Human Dynamics in Smart Cities*. Springer, Cham. https://doi.org/10.1007/978-3-031-25914-2_9.

Vaani, N., Anand, A. (2018), *Land use / Landcover Mapping and Sustainability ANALYSIS of Chennai City, Tamilnadu, India*. International Journal of Civil Engineering and Technology, **9**(*13*), pp. 1201–1210.

Xu, H. (2006), *Modification of Normalised Difference Water Index (NDWI) to enhance open water features in remotely sensed imagery*. International Journal of Remote Sensing, **27**(*14*), pp. 3025–3033.

Xu, G., Jiao, L., Liu, J., Shi, Z., Zeng, C., Liu, Y. (2019), *Understanding urban expansion combining macro patterns and micro dynamics in three Southeast Asian megacities*. Science of the Total Environment, **660**, pp. 375-383. https://doi.org/10.1016/j.scitotenv.2019.01.039.

Yang, X., Lo, C. P. (2002), *Using a time series of satellite imagery to detect land use and land cover changes in the Atlanta, Georgia metropolitan area*. International Journal of Remote Sensing, **23**(*9*), pp. 1775–1798.

Zha, Y., Gao, J., Ni, S. (2003), *Use of Normalized Difference Built-up Index in automatically mapping urban areas from TM imagery*. International Journal of Remote Sensing, **24**, pp. 583–594.

United Nation (2018), *World urbanization prospects: The 2018 revision*. New York, United Nations.

United Nation (2019), *World population prospects 2019 highlights*. New York, United Nations.

District Census Handbook: Murshidabad (2001&2011). West Bengal. India. (https://censusindia.gov.in).

District Statistical Handbook: Murshidabad (2010, 2011, 2013 & 2014), West Bengal. India. (http://wbpspm.gov.in).

Received July 18, 2023