Satellite Image Transformation for mapping of aSingle Land / Land Cover of Meerut City,India

Saurabh Dubley*, Harendra Kumar*, Vikas Kumar* , Puneet Yadav*

*Undergraduate Scholars, Department of Civil Engineering, KIET Group of Institutions, Delhi-NCR, Ghaziabad

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Abstract- Maps and land use change monitoring now heavily rely on satellite photography. The goal of this work is to record changes in land cover and land use by transforming satellite pictures of Meerut, an Indian city in the Uttar Pradesh region. For this study , Meerut City (Uttar Pradesh,India) is selected.

Getting satellite pictures of the research region is the process's initial stage. The Landsat satellite, which takes pictures in the visible, near-infrared, and shortwave infrared bands, provided the photos utilised in this study, which were obtained from USGS. In order to adjust for atmospheric influences, the photos were pre-processed.

The study involved calculating various spectral indices from processed satellite images, including the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI). These indices are commonly utilized in remote sensing to highlight distinct land cover categories.

The NDVI was employed to detect vegetation cover, while the NDWI was used to identify water bodies. The NDBI served the purpose of identifying built-up areas. By applying these indices to the satellite images, land cover and land use change maps were generated.

The study findings demonstrated the accurate identification of vegetation cover through the NDVI and the successful identification of water bodies using the NDWI. The NDBI effectively highlighted built-up areas, enabling more precise mapping of land use changes.

Ultimately, the study concluded that incorporating spectral indices significantly enhances the accuracy of land cover and land use mapping with satellite imagery. Analyzing and interpreting transformed satellite images facilitates the creation of land-use maps, thereby supporting urban planning and management efforts. The results hold particular relevance for sustainable urban development, underscoring the importance of regularly updated land-use maps. Urban planners and policymakers can leverage these findings to make well-informed decisions regarding land use management in the study area.

Index Terms- Spectral indices, Land cover, Land use mapping, Remote sensing, Urban planning.

I. INTRODUCTION

Image transformation involves the manipulation of satellite images using mathematical operations on spectral bands. This process aims to extract or enhance specific features or characteristics within the images. Satellite imagery has emerged as a valuable tool for studying and monitoring changes occurring on the Earth's surface over time. Remote sensing technology, particularly in recent years, has found extensive applications in mapping and monitoring natural resources, vegetation, water bodies, urban development, and other environmental parameters.

Among the various applications of satellite imagery, calculating and analyzing vegetation indices such as NDWI, NDVI, and NDBI plays a vital role. These indices offer valuable insights into the vegetation, water content, and built-up areas of the land surface. In this research, we will focus on the utilization of NDWI, NDVI, and NDBI indices for mapping Meerut, a city situated in the northern Indian state of Uttar Pradesh.

Meerut, a rapidly growing city in Uttar Pradesh, has experienced notable changes in land use and land cover in recent years. The expansion of built-up areas and the reduction of vegetation cover have been prominent trends. Satellite imagery presents an opportunity to map and monitor these transformations, enabling a better understanding of their environmental and societal impacts.

II. STUDY AREA AND DATA USED

Meerut, situated in the state of Uttar Pradesh in India, is located approximately 70 kilometers northeast of the national capital, New Delhi. It is a historically significant city, tracing its roots back to the ancient Indus Valley Civilization. Presently, Meerut thrives as a commercial and industrial center, characterized by a diverse economy and a rapidly growing population.

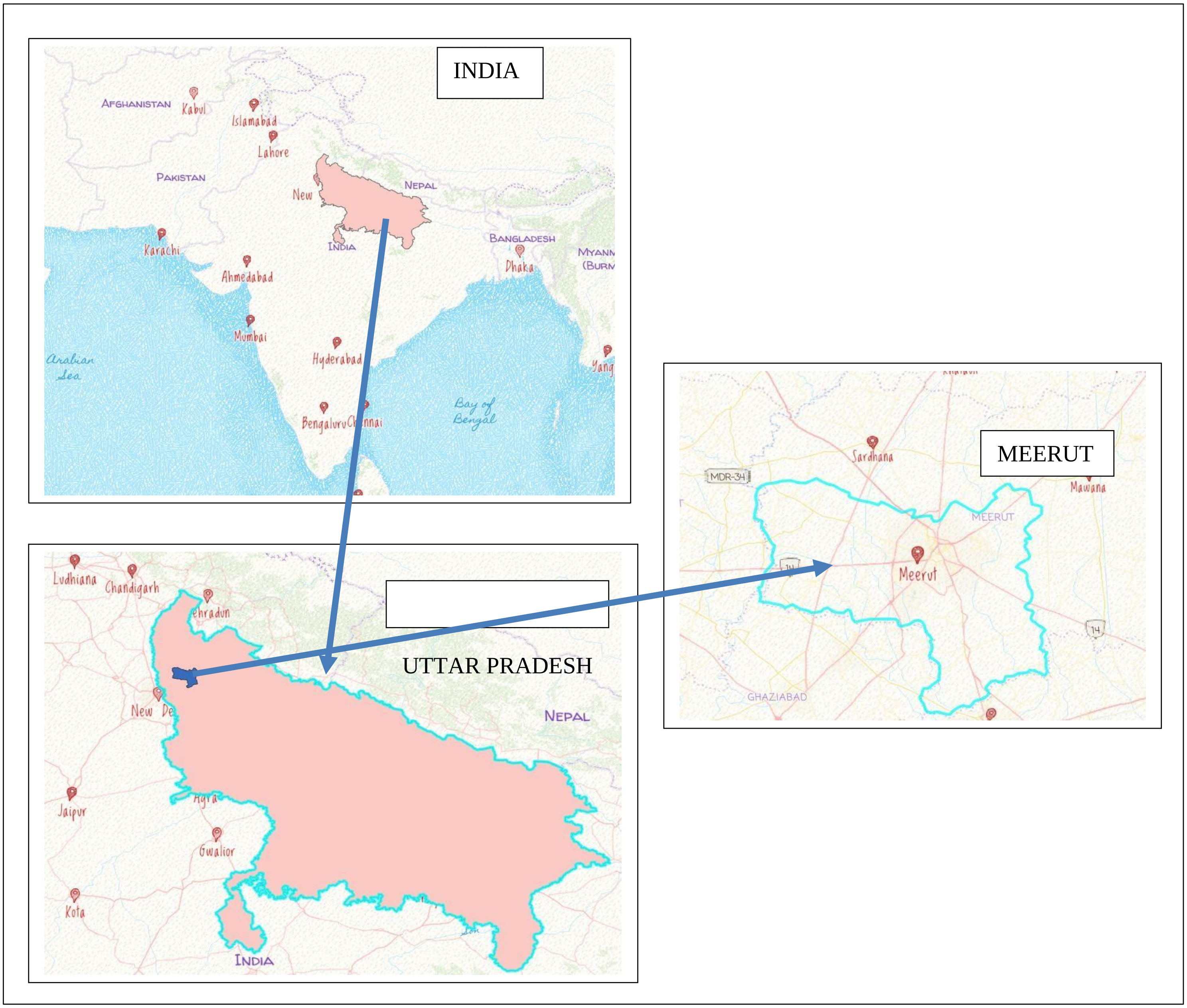


Figure 1. The study area of Meerut, India.

The city of Meerut has a rich heritage spanning more than 5,000 years, having been governed by various dynasties such as the Mauryas, Guptas, Mughals, and British. During the Indian Rebellion of 1857, Meerut played a pivotal role in the uprising as Indian soldiers stationed there led a mutiny against British officers. Although the rebellion was ultimately unsuccessful, Meerut became a prominent center for British military operations in the region.

Meerut is geographically positioned in the western part of Uttar Pradesh, encompassing an area of around 142 square kilometers. It sits at an elevation of 219 meters above sea level and is bordered by the Ganges River to the east and the Yamuna River to the west. The city experiences a hot and dry climate during the summer months (May-July) with temperatures reaching up to 45°C, while winters (November-February) are mild, with temperatures dropping to around 5°C. The monsoon season (July-September) brings moderate to heavy rainfall to the area.

The economy of Meerut is primarily driven by a flourishing manufacturing industry, particularly in textiles, sports equipment, and musical instruments. The city is home to numerous small and medium-sized enterprises, as well as several large multinational companies. Benefitting from its central location and well-developed transportation infrastructure, Meerut serves as a significant commercial hub with convenient connectivity to major cities in the region.

Date Of acquisition	Platform	Sensor	Path/Row	Application
18 Sep 2013	Landsat 8	OLI/ TIRS	146/40	Indices
04 Feb 2018	Landsat 8	OLI/TIRS	146/40	Indices
26 Feb 2023	Landsat 9	OLI/TIRS	146/40	Indices

Table 1. Description of Landsat satellite data used.

Landsat images used were acquired using different sensors viz. TM, ETM+ and OLI/TIRS for different dates (Table 1). Total 3 multi-sensor Landsat images have been used in this study for computation of various spectral indices. The spatial resolution of the imagery is 30 meters, except for the panchromatic band which has a resolution of 15 meters. In order to get the shapefile designated for MEERUT boundaries, we used GADM. The Global Aviation Data Management (GADM) program is a data management platform which integrates multiple sources of operational data received from various channels. GADM provides maps and spatial data for all countries and their sub-divisions. For the MEERUT REGION, we utilised the GADM_IND41 shape file with the FID - 2203 third level border distribution.

III. METHODOLOGY

The following literature provides a full breakdown of the processes involved in the planned study.

A. FOR NDVI ANALYSIS:

To distinguish between the various land cover types in the research region, the Normalised Difference Vegetation Index (NDVI) is crucial. The NDVI scale goes from -1.0 to +1.0. The near-infrared (NIR) band in satellite imagery is highly sensitive to vegetation cover, while the red band is sensitive to chlorophyll absorption. NDVI values close to +1 indicate dense vegetation cover, while values near 0 indicate minimal or no vegetation cover. In the NDVI formula, the NIR represents the reflectance value in the near-infrared band, and the red represents the reflectance value in the red band.

NDVI has been widely used in various studies focused on monitoring vegetation and mapping land use. In the case of Meerut, NDVI can be employed to map different types of vegetation cover, including forests, crops, and grasslands. This information is valuable for applications such as land use planning and environmental monitoring. The normalised difference between the near infrared band (0.85-

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

0.88 m) and the red band (0.64- 0.67 m) of the pictures is used to compute NDVI on a per-pixel basis using the equation :

Where ,

NIR - near infrared band value of a pixel
RED - red band value of the same pixel.

For Landsat 8/9 :

Band 5 – NIR
Band 4 – RED

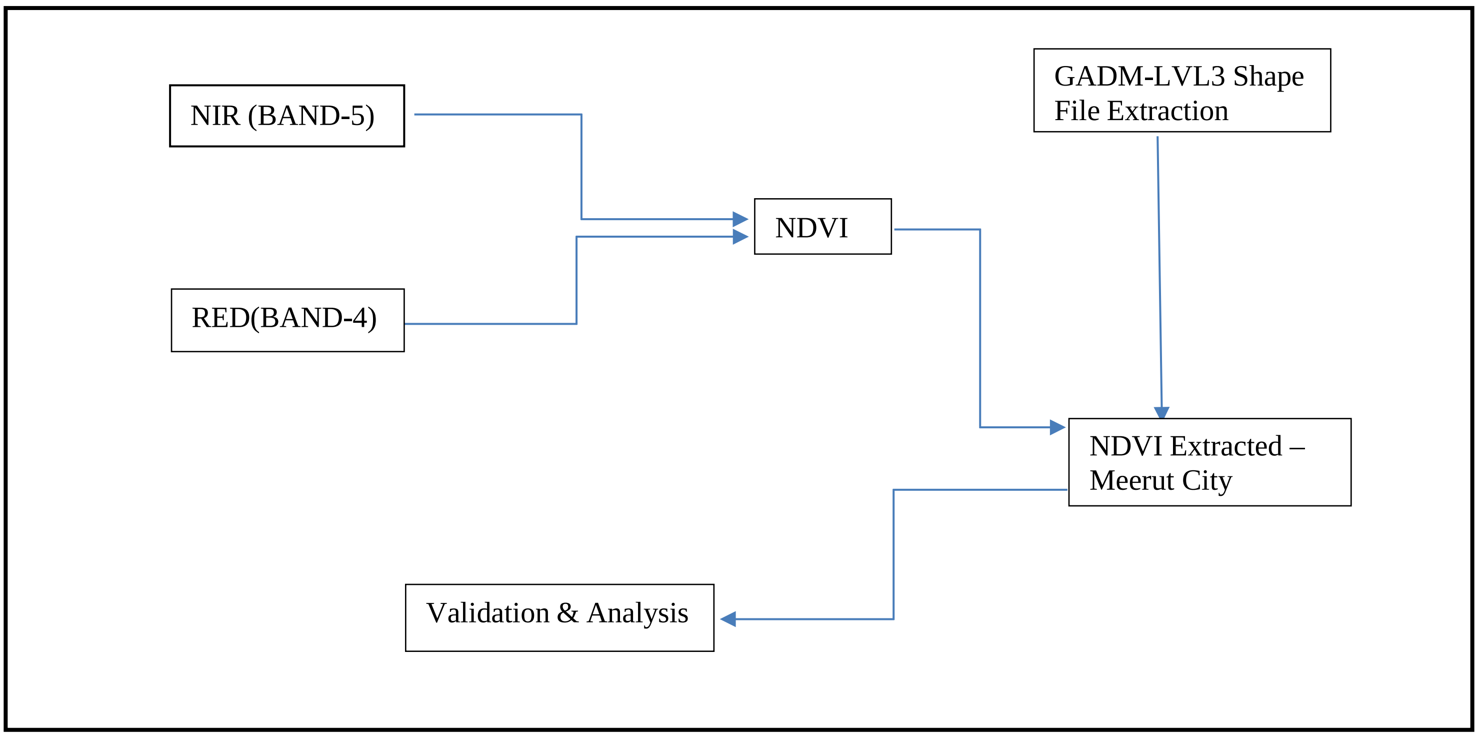


Figure 2 Flow diagram for NDVI retrieval

B. FOR NDWI ANALYSIS:

NDWI analysis, which stands for Normalized Difference Water Index analysis, is a commonly used method in remote sensing to identify and analyze water bodies and their characteristics. It involves calculating the NDWI values for different areas or regions of interest to assess the presence and extent of water content.

The NDWI is derived by calculating the normalized difference between the reflectance values of the green and near-infrared (NIR) bands. The formula is as follows:

NDWI = (Green - NIR) / (Green + NIR)

The green band is sensitive to water content, while the NIR band is sensitive to vegetation. By taking the difference between the green and NIR reflectance values and normalizing it, the NDWI can highlight areas with high water content.

NDWI values range from -1 to 1, where values close to 1 indicate the presence of water, while values close to -1 indicate the absence of water. A threshold value can be set to classify the pixels as water or non-water based on the NDWI values. This classification can be further used to generate water maps, delineate water bodies, monitor changes in water extent, and analyze water-related parameters such as water quality, vegetation health in wetlands, and flood mapping.

NDWI analysis is widely applied in various fields, including hydrology, environmental monitoring, agriculture, and urban planning. It provides valuable information for understanding and managing water resources, assessing ecosystem health, and supporting decision-making processes related to water management and land use planning.

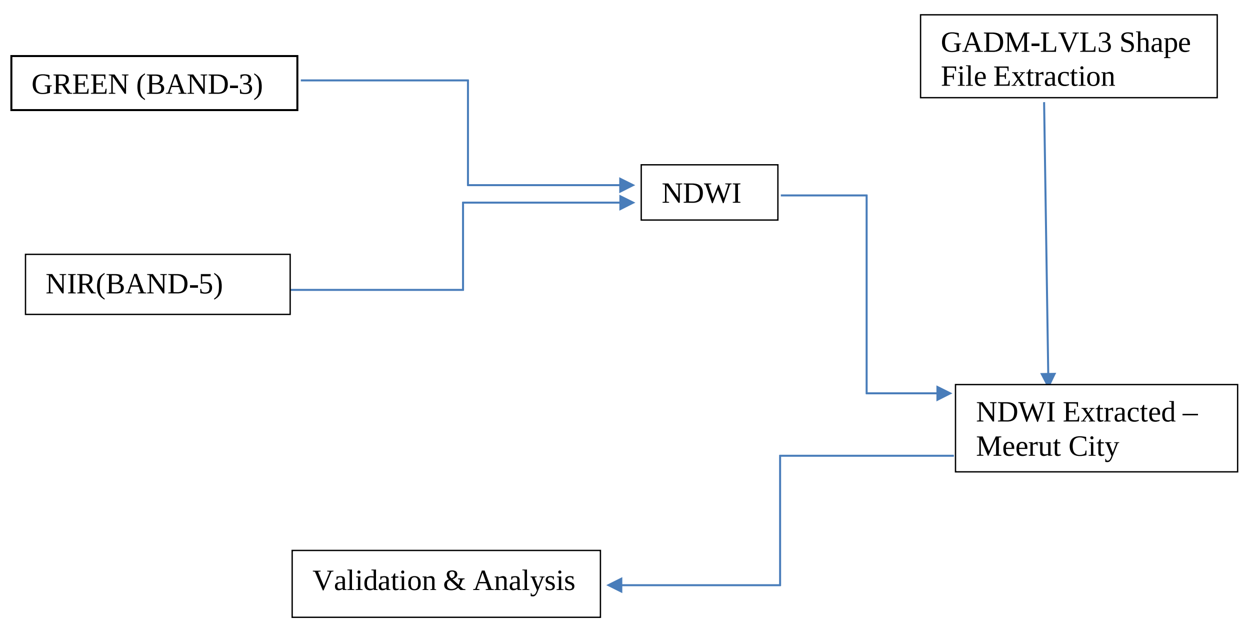


Figure 3 Flow diagram for NDWI retrieval

C. FOR NDBI ANALYSIS:

NDWI analysis, NDBI stands for Normalized Difference Built-Up Index. It is a remote sensing index used to assess urbanization and built-up areas in satellite imagery. The index is calculated by taking the normalized difference between the near-infrared (NIR) and shortwave infrared (SWIR) bands of the imagery.
The calculation of NDBI involves the subtraction of the reflectance values of the shortwave infrared (SWIR) and near-infrared (NIR) bands, divided by their sum:
NDBI = (SWIR - NIR) / (NIR + SWIR)

The NDBI is particularly useful for monitoring and analyzing urban growth, land use changes, and the expansion of built-up areas over time. It helps distinguish between built-up and non-built-up areas by highlighting the presence of man-made structures and impervious surfaces.
In the NDBI calculation, the NIR band is sensitive to vegetation, while the SWIR band is sensitive to the thermal radiation emitted by buildings and paved surfaces. By subtracting the SWIR value from the NIR value and normalizing the result, the NDBI emphasizes the built-up areas and minimizes the influence of vegetation.
The output of NDBI is a grayscale image or a range of values where high positive values represent built-up areas, while low or negative values indicate non-built-up areas such as vegetation or water bodies. The index can be further processed or classified to identify and map urban areas accurately.

NDBI is widely used in urban planning, land management, environmental monitoring, and other applications where understanding urbanization patterns and changes is essential. It provides valuable information for policymakers, researchers, and urban planners to make informed decisions regarding urban development, infrastructure planning, and resource management in Meerut.

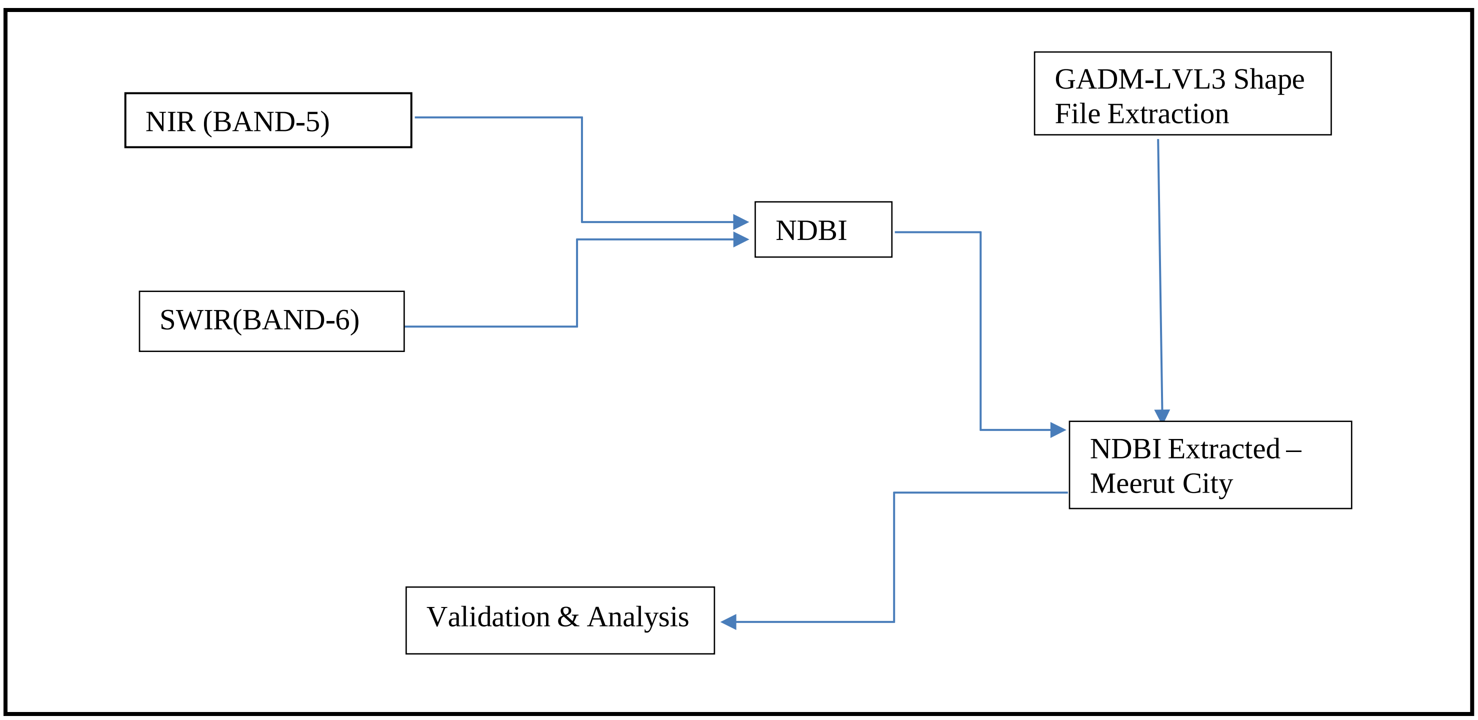


Figure 4 Flow diagram for NDBI retrieval

Band Designations	Wavelength (µm)	Resolution (m)
Band 1 (Coastal Aerosol)	0.43 - 0.45	30
Band 2 (Blue)	0.45 - 0.51	30
Band 3 (Green)	0.53 - 0.59	30
Band 4 (Red)	0.64 - 0.67	30
Band 5 (Infrared)	0.85 - 0.88	30
Band 6 (Short wave infrared)	1.57 - 1.65	30
Band 7 (Short wave infrared)	2.11 - 2.29	30
Band 8 (Panchromatic)	0.50 - 0.68	15
Band 9 (Cirrus)	1.36 - 1.39	30
Band 10 (Thermal infrared)	10.6 - 11.19	100
Band 11 (Thermal infrared)	11.50 - 12.51	100

Table 2. LANDSAT 8/9 OLI and TIRS

IV. RESULTS AND ANALYSIS

A. NDVI ANALYSIS:

Based on the analysis of NDVI (Normalized Difference Vegetation Index) in Meerut, Uttar Pradesh, using data from Landsat 8 and 9 satellites, the following results can be drawn:

I. Vegetation dynamics: The NDVI values provide insights into the vegetation dynamics in Meerut. The positive NDVI values indicate the presence of healthy vegetation, while negative values indicate non-vegetated areas or areas with limited vegetation cover.

II. Vegetation changes over time: The comparison of NDVI values across different years (2013, 2018, and 2023) reveals changes in vegetation cover. In 2013, the NDVI ranged from -0.12 to 0.61, indicating a wide variation in vegetation density. In 2018, the NDVI ranged from -0.11 to 0.5, and in 2023, it ranged from -0.07 to 0.49. These changes suggest potential shifts in vegetation patterns, including changes in vegetation extent and density.

III. Vegetation response to urbanization: The observed NDVI patterns may reflect the influence of urbanization and land use changes in Meerut. As urban areas expand, they often lead to a reduction in vegetation cover and fragmentation of green spaces. The declining NDVI values over time might indicate the encroachment of urban areas into previously vegetated regions.

IV. Environmental monitoring: NDVI serves as an effective tool for environmental monitoring and assessing the health of vegetation. The analysis of NDVI in Meerut provides valuable information for monitoring the impact of urbanization, identifying areas of vegetation loss, and highlighting the need for green infrastructure planning and conservation efforts.

V. Importance of remote sensing: The utilization of Landsat 8 and 9 satellite data demonstrates the significance of remote sensing technology in studying urban environments and monitoring changes in vegetation indices. Remote sensing enables large-scale and long-term observations, facilitating comprehensive analysis of land cover dynamics.

VI. Policy implications: The findings from the NDVI analysis can inform urban planning and land management strategies in Meerut. The identification of areas with declining NDVI values can guide decisions on urban greening initiatives, restoration of vegetation, and preservation of green spaces.

VII. Further research directions: To enhance the understanding of the factors influencing the observed changes in NDVI, future research can focus on investigating the specific drivers of vegetation change in Meerut, such as urban expansion, agricultural practices, and climate variability.

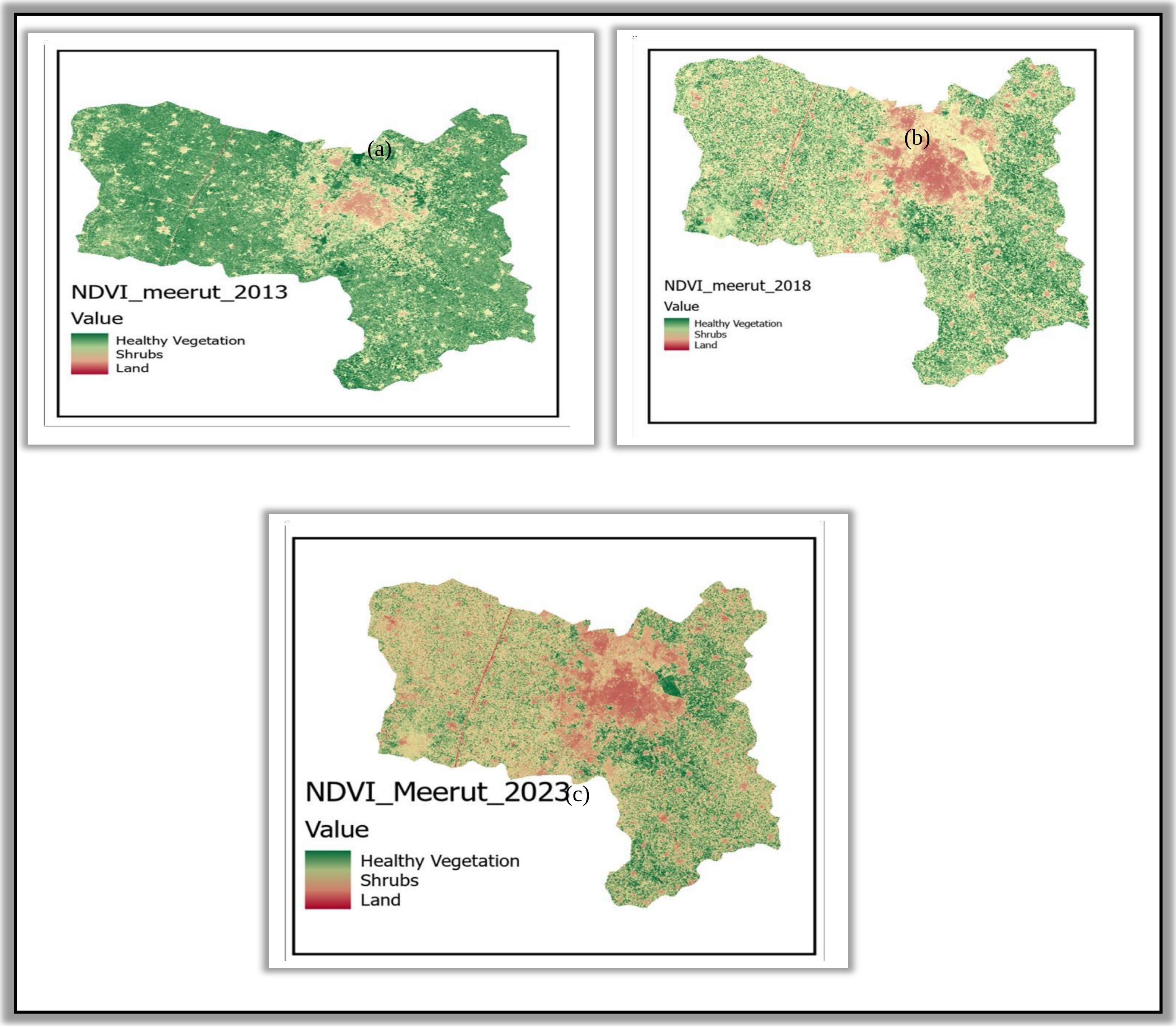


Figure 5. NDVI images for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

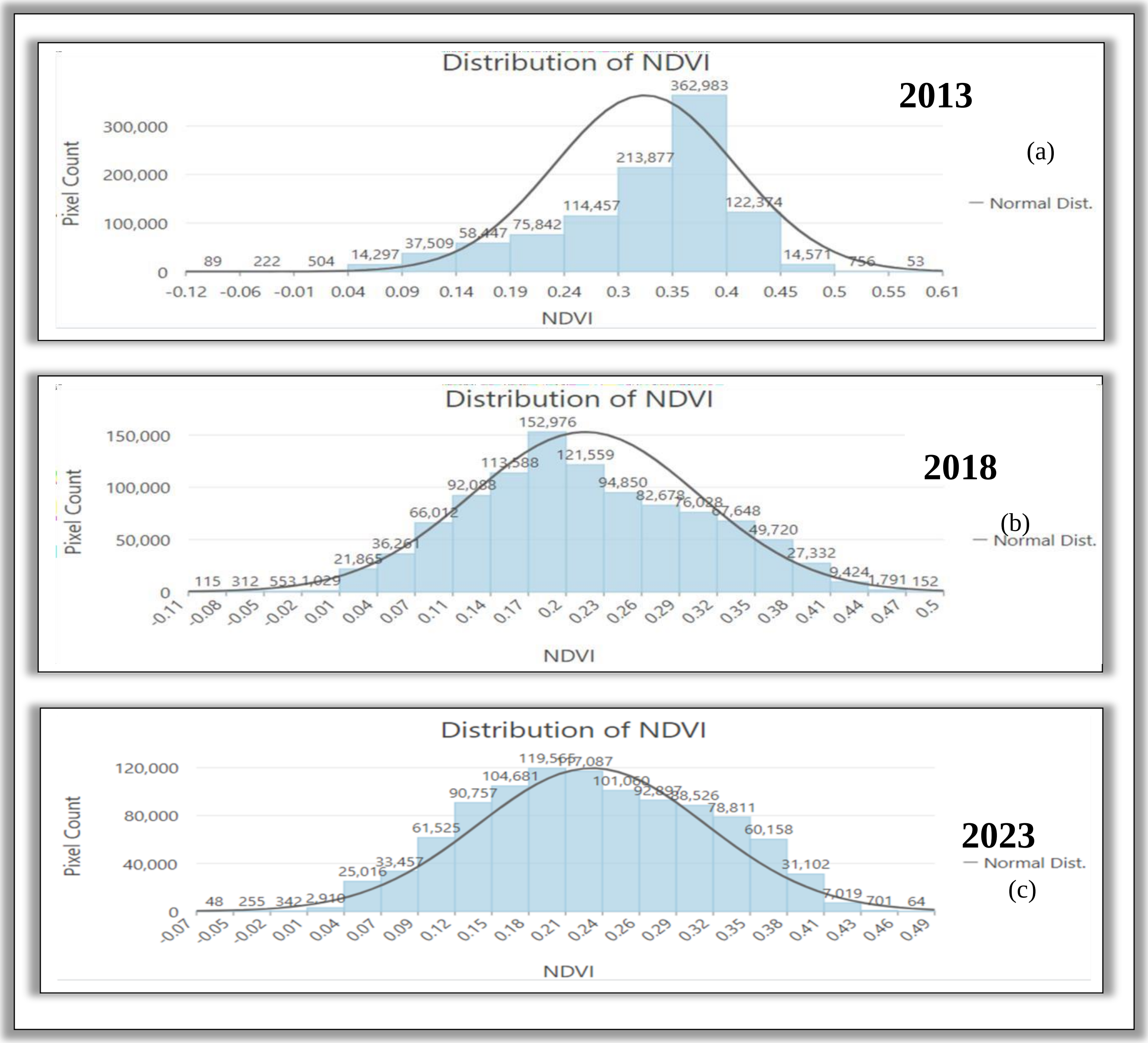


Figure 6. Data of NDVI for for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

B. NDBI ANALYSIS:

Based on the analysis of NDBI (Normalized Difference Built-Up Index) in Meerut, Uttar Pradesh, using data from Landsat 8 and 9 satellites, the following results can be drawn:

I. Built-up area dynamics: The NDBI values provide insights into the dynamics of built-up areas in Meerut. NDBI quantifies the presence and extent of built-up structures, such as buildings and paved surfaces, within the study area.

II. Built-up changes over time: The comparison of NDBI values across different years (2013, 2018, and 2023) reveals changes in the extent and density of built-up areas. In 2013, the NDBI ranged from -0.44 to 0.17, indicating a variation in the presence of built-up structures. In 2018, the NDBI ranged from -0.43 to 0.47, and in 2023, it ranged from -0.39 to 0.62. These changes suggest potential shifts in urban development and expansion.

III. Urbanization and land use: The observed NDBI patterns reflect the impact of urbanization and changes in land use in Meerut. The increasing NDBI values over time indicate the expansion of built-up areas, as well as changes in land use patterns from natural or agricultural areas to urbanized regions.

IV. Urban heat island effect: The changes in NDBI can contribute to the urban heat island effect, where built-up areas experience higher temperatures compared to surrounding vegetated or non-built-up areas. The increasing NDBI values may indicate a rise in surface temperatures due to increased impervious surfaces and reduced vegetation cover.

V. Urban planning implications: The findings from the NDBI analysis have implications for urban planning and land management strategies in Meerut. The identification of areas with higher NDBI values can guide decisions on infrastructure development, land use zoning, and the promotion of sustainable urban design practices.

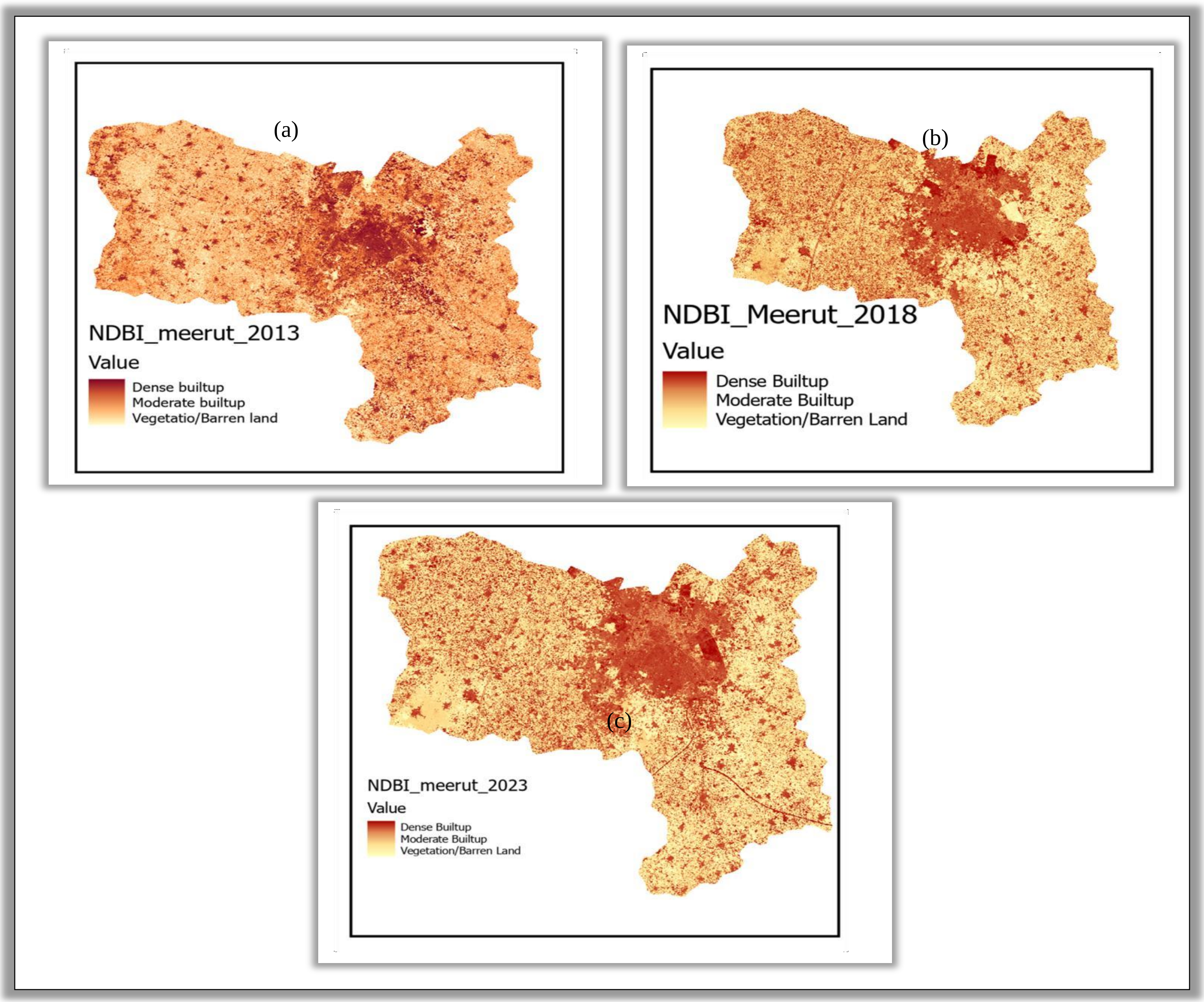


Figure 7. NDBI images for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

VI. Remote sensing application: The utilization of Landsat 8 and 9 satellite data demonstrates the importance of remote sensing in assessing built-up areas and monitoring urbanization processes. Remote sensing provides a valuable tool for monitoring and managing urban growth and land use changes.

VII. Future research directions: Further research can explore the underlying drivers of the observed changes in NDBI, such as population growth, economic activities, and policy interventions. Additionally, investigations into the socioeconomic and environmental impacts of urban expansion can provide valuable insights for sustainable urban development.

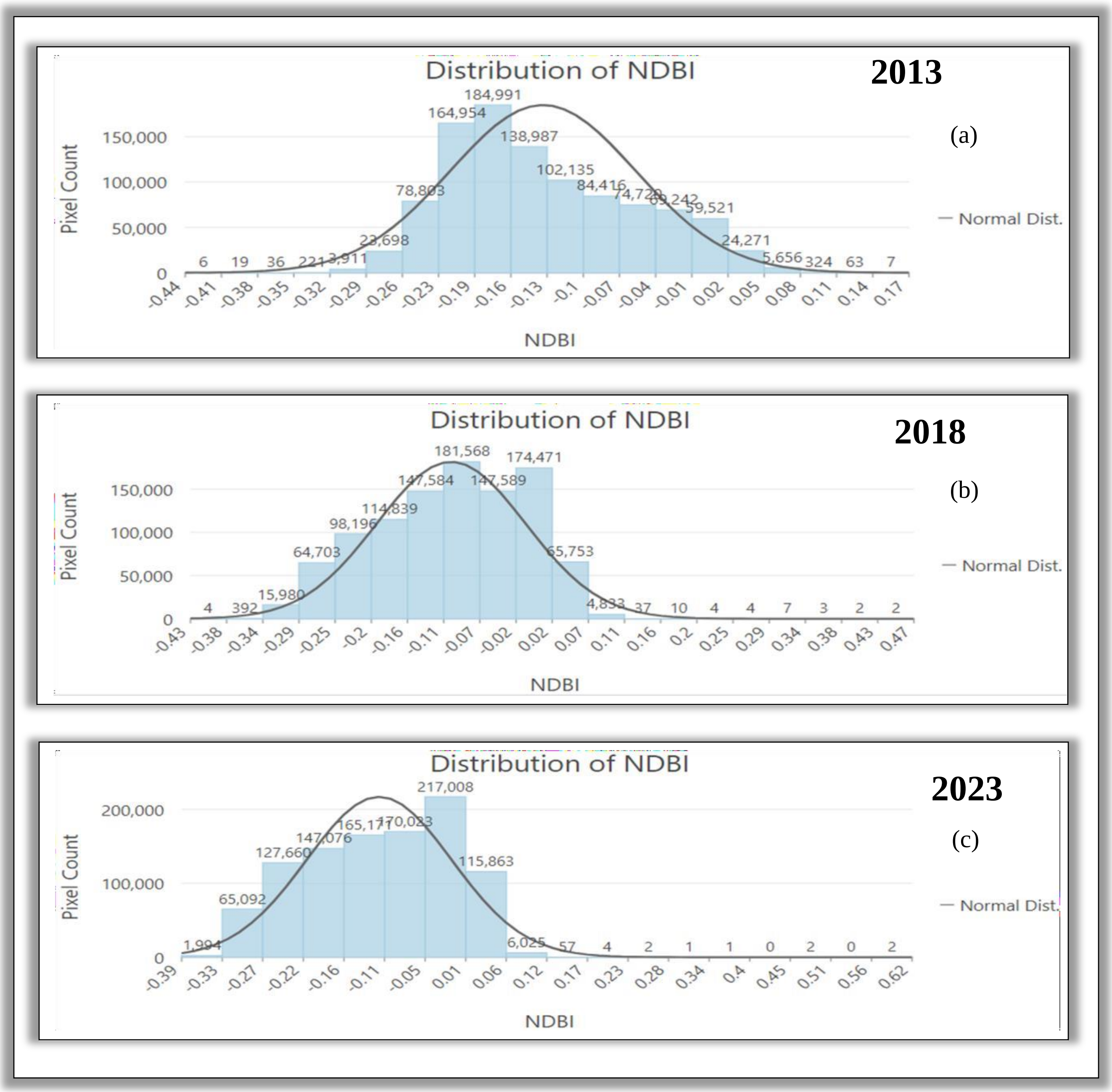


Figure 8. Data of NDBI for for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

C. NDWI ANALYSIS:

Based on the analysis of NDWI (Normalized Difference Water Index) in Meerut, Uttar Pradesh, using data from Landsat 8 and 9 satellites, the following results can be drawn:

I. Water body dynamics: The NDWI values provide insights into the dynamics of water bodies in Meerut. NDWI is a reliable indicator of the presence and extent of water within the study area.

II. Changes in water bodies over time: The comparison of NDWI values across different years (2013, 2018, and 2023) reveals changes in the extent and condition of water bodies. In 2013, the NDWI ranged from -0.52 to 0.13, indicating a variation in water coverage. In 2018, the NDWI ranged from -0.45 to 0.16, and in 2023, it ranged from -0.43 to 0.12. These changes suggest potential alterations in water availability, such as changes in surface water bodies, wetland areas, or groundwater levels.

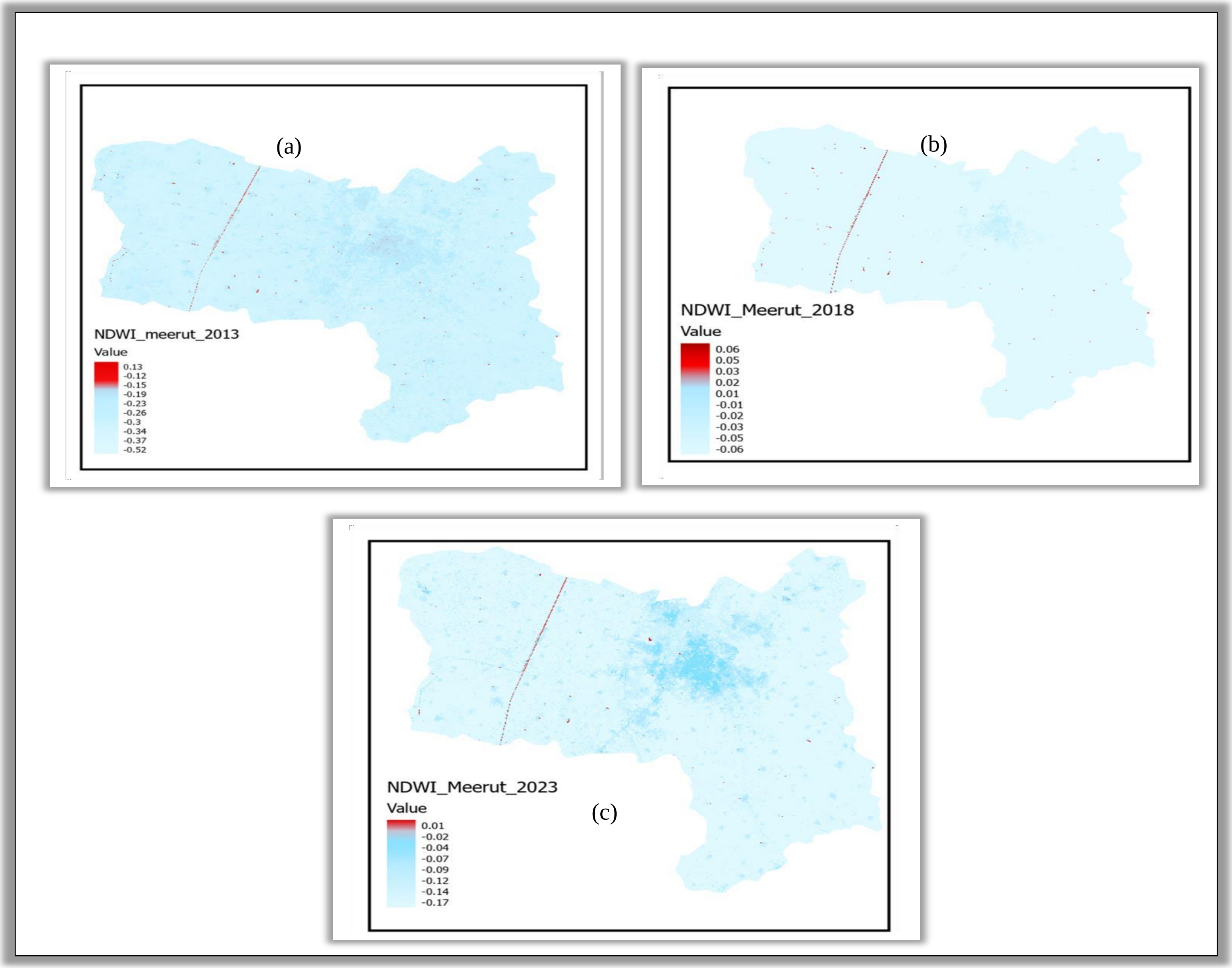


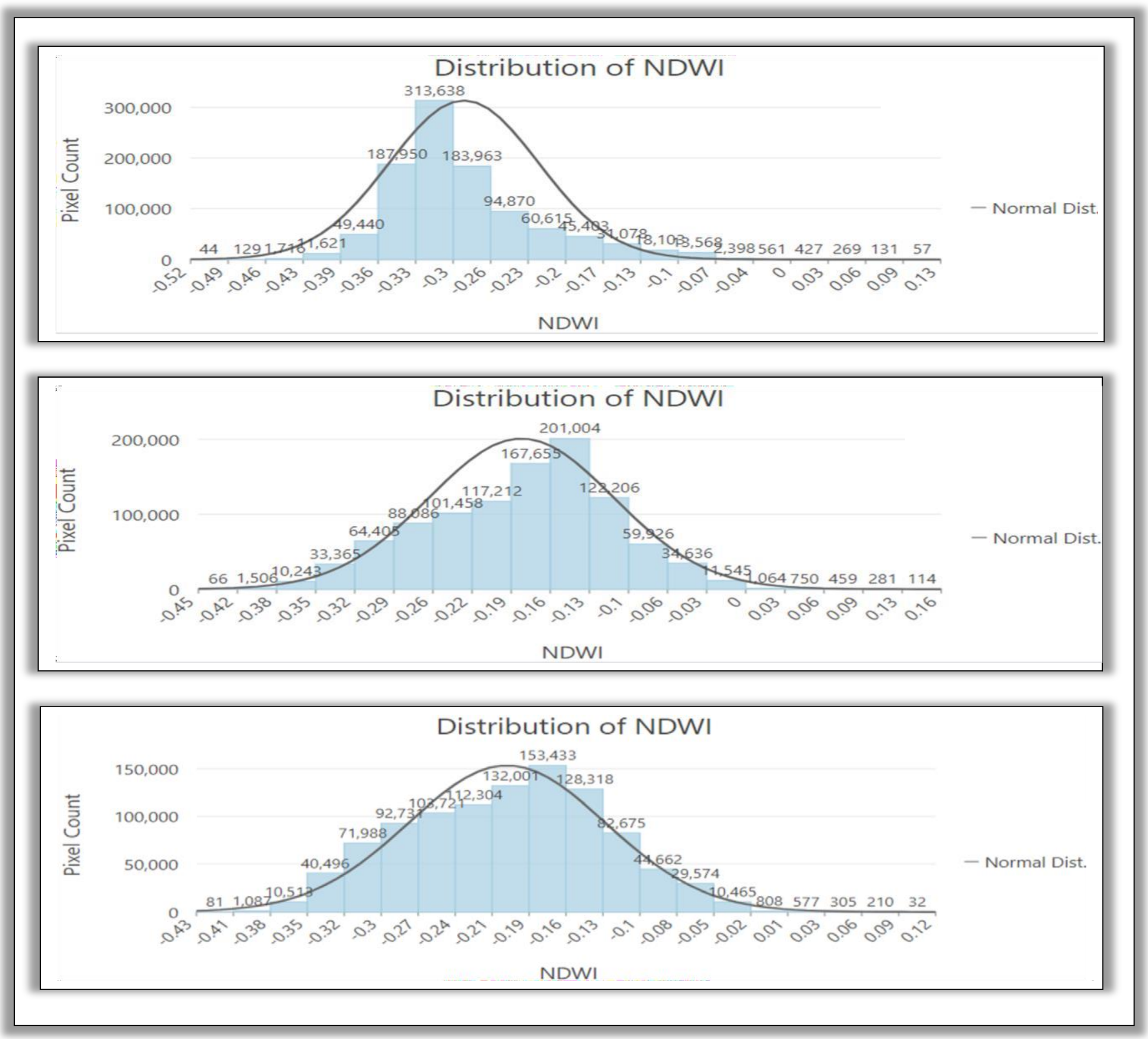
Figure 9. NDWI images for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

III. Hydrological changes: The observed NDWI patterns reflect the impact of natural and human-induced factors on the hydrological regime of Meerut. These factors may include climate variations, land use changes, and water management practices.

IV. Water resource management: The changes in NDWI values can provide useful information for water resource management and planning. Monitoring variations in water bodies helps in assessing the availability and distribution of water resources, which is crucial for sustainable water management practices.

V. Ecological implications: The fluctuations in NDWI values also have ecological implications. Changes in water bodies can impact local ecosystems, affecting flora, fauna, and biodiversity. Understanding these variations is essential for conservation efforts and the preservation of valuable ecosystems.

VI. Remote sensing application: The utilization of Landsat 8 and 9 satellite data demonstrates the significance of remote sensing in monitoring and analyzing water bodies. Remote sensing offers an efficient and cost-effective approach to assess changes in water resources over large spatial areas.



2013

(a)

2018

(b)

2023

(c)

Figure 10. Data of NDWI for for (a) 18/09 /2023 (b) 04/02/2018 (c) 26/02/2023

VII. Future research directions: Further research can focus on investigating the factors driving the observed changes in NDWI, including climate patterns, land use changes, and human activities. Additionally, research can explore the consequences of water body alterations on various sectors, such as agriculture, ecology, and water supply.

Built-up Area: The findings reveal a substantial increase in the built-up area of the city over the past few decades. The rate of urbanization has been particularly high in the outskirts, leading to the conversion of agricultural lands and natural resources into developed areas.
Agricultural Land: The results demonstrate a significant reduction in agricultural lands within and around the city. The conversion of agricultural areas into built-up spaces and other non-agricultural uses has been the primary driver of this decline.
Water Bodies: The analysis also highlights a notable decrease in water bodies such as lakes, ponds, and wetlands in the vicinity of the city. The conversion of these water features into built-up areas and other land uses has been the primary factor contributing to this decline.
Forest Cover: The findings suggest a substantial decrease in forest cover in the region over time. This decline can be attributed to the conversion of forests into agricultural lands and built-up areas.

Overall, the results indicate significant changes in the land use patterns of the studied area, characterized by urban expansion, loss of agricultural lands, depletion of water bodies, and decline in forest cover. These findings emphasize the need for sustainable land management practices and effective urban planning strategies to mitigate the adverse impacts of urbanization on natural resources and ecological.

V. CONCLUSION

The analysis of NDVI in Meerut reveals temporal variations in vegetation cover and indicates the potential impact of urbanization on vegetation dynamics. These findings underscore the importance of sustainable urban development and emphasize the need for proactive measures to preserve and enhance vegetation in urban environments.
The analysis of NDBI in Meerut highlights changes in built-up areas and urbanization dynamics. The findings underscore the need for effective urban planning strategies, considering the implications of land use changes on the urban environment, temperature patterns, and overall urban sustainability.
The analysis of NDWI in Meerut provides valuable insights into the dynamics of water bodies and hydrological changes. The findings have implications for water resource management, ecological conservation, and sustainable development in the region. The remote sensing approach employed in this study demonstrates the potential of satellite data in monitoring and managing water resources in urban and peri-urban areas.
In summary, the combined analysis of NDVI, NDBI, and NDWI in Meerut provides insights into the urbanization process, changes in vegetation cover, built-up areas, and water bodies. These findings contribute to a better understanding of the urban environment and support evidence-based decision-making for sustainable urban planning and management practices.

VI. ACKNOWLEDGMENT

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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AUTHORS

Saurabh Dubley – Department of Civil Engineering, KIET Group of Institutions, Ghaziabad, India;

Harendra Kumar– Department of Civil Engineering, KIET Group of Institutions, Ghaziabad, India;
Vikash Kumar– Department of Civil Engineering, KIET Group of Institutions, Ghaziabad, India;
Puneet Yadav – Department of Civil Engineering, KIET Group of Institutions, Ghaziabad, India;