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RESEARCH ARTICLE OPEN ACCESS

ASSESSING THE IMPACT OF CLIMATE CHANGE AND THE ENVIRONMENTAL DEGRADATION: A CASE STUDY ON PASCHIM MEDINIPUR, WESTBENGAL

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ABSTRACT

Climate change is recognized as a global crisis, marked by rising temperatures, shifting rainfall patterns, and frequent extreme events such as cyclones, floods, and droughts, all of which accelerate environmental degradation and threaten ecosystems and livelihoods. In Paschim Medinipur, a district with both sub-humid and tropical climates, spectral indices and machine learning were applied to satellite data across different seasons to assess land use and land cover changes. Findings revealed rapid urbanization, deforestation, and conversion of agricultural land into industrial and settlement areas, with low-lying terrains near non-perennial rivers facing the greatest vulnerability. Elevation was identified as a key factor in settlement pressure, while vegetation loss, soil degradation, and water logging were observed as recurring issues. The study predicts that degradation will intensify under modern livelihood patterns, leaving low-lying communities highly exposed to natural hazards. These results highlight the importance of district-level studies in supporting effective mitigation strategies aligned with UNFCCC guidelines.

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INTRODUCTION

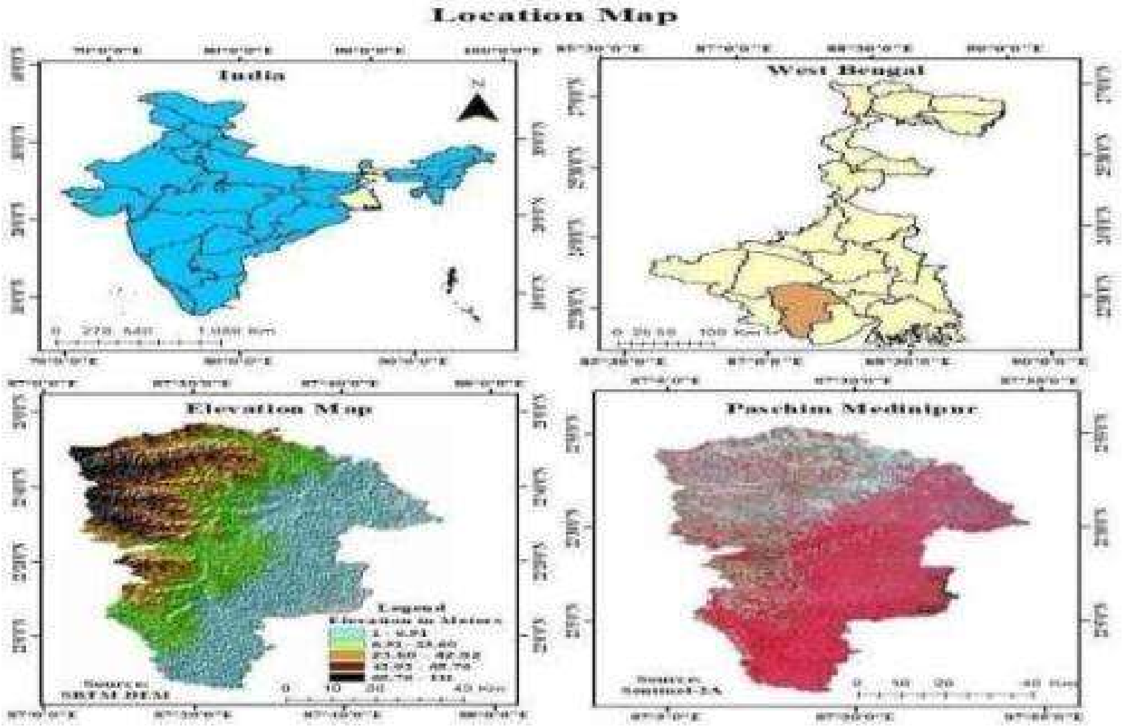
Climate is defined as the long-term average of weather conditions such as temperature, precipitation, and wind in a specific region. In the present era, climate change is acknowledged as one of the most pressing global crises, characterized by slow but noticeable alterations in climate systems. These changes have been associated with environmental degradation, affecting vegetation cover, built-up areas, soil properties, and ecosystems. Studies have indicated that nearly two billion people in arid, semi-arid, and sub-humid regions are highly vulnerable to the loss of ecosystem services (Warner, Hamza, Smith, & Renand, 2009). The impacts of climate change are being reflected in deforestation, soil depletion, and continuous land use modification, largely driven by rapid urban expansion. Settlements have increasingly been concentrated near industrial zones and riverbanks, resulting in shrinking vegetation cover and declining soil fertility. The present study was carried out in Paschim Medinipur district, located in the southernmost part of West Bengal, characterized by a tropical and sub-humid climate. The district experiences hot summers, moderate rainfall during the pre-monsoon, and heavy rainfall during the monsoon, with monthly precipitation ranging from 50–200 mm. While floods occur during heavy rains, dry conditions prevail in summers due to low humidity. Elevation varies between 1 and 111 m, with the western part highly elevated and the north-eastern and eastern areas low-lying. Several non-perennial rivers such as Rupnarayan, Kangsabati, and Silabati flow through the district, rendering it flood-prone. In the post-monsoon season of 2021, water bodies expanded by 11.74 ha owing to Cyclone Yash. Land degradation has been detected over time, with the total area decreasing from 1146.88 ha in 2018 to 1105.49 ha in 2025. Vegetation loss, soil depletion, and fluctuating water bodies were identified using six spectral indices, with bare soil and vegetation showing the most severe impacts. Post-monsoon rainfall was observed to support agricultural land expansion, though overall vegetation declined due to urbanization. Settlements expanded rapidly, increasing from 134.33 ha in 2018 to 241.4 ha in 2025, particularly in the western parts of the district.

RESEARCH OBJECTIVES

- To identify the environmental degraded areas due to seasonal climatic changes over a short period of time in Paschim Medinipur district.
- Implementation of spectral indices and machine learning algorithm over different time frames in a year to delineate the environmental changes

STUDY AREA

The focus of this study was Paschim Medinipur District of West Bengal, situated between 21°46′N–22°57′N latitude and 86°33′E–87°44′E longitude (Bhunia, Samanta, Pal, & Pal, 2012), with a total area of 1146.88 hectares. Both drought and flood conditions were recorded due to variations in elevation and the presence of major rivers such as Kansabati, Subarnarekha, Rupnarayan, Kelaghai, and Rasulpur (Bhunia & Shit, 2023). Elevation ranged from 1–111 meters, and the low-lying north-eastern and eastern regions were most affected by flooding. Limited navigability of non-perennial rivers and reduced soil infiltration, caused by continuous changes in land use and land cover, contributed to frequent waterlogging.



Climatically, the district exhibited both sub-humid and tropical characteristics (Das & Das, 2016). Elevated western and south-western regions experienced extreme dryness during pre- monsoon, whereas monsoon and post-monsoon seasons brought sufficient rainfall, averaging 50–200 mm monthly (Figure 8.f). Forest cover was dominated by Sal, Neem, Kendu, Mahua, Segun, and Simul, while agricultural land supported rice, potato, til, maize, pulses, and mustard (Pal, Samanta, & Maiti, 2010). Soils included loamy, silty clay loam, clay loam, and silty clay, generally acidic with pH values ranging from 6.5–7.5 (Pal, Samanta, & Maiti, 2010).

RESEARCH METHODOLOGY USED

Discussion of Used Materials and Methods

Secondary datasets were used for analysis. Sentinel-2A imagery (2018, 2021, 2025) from the Copernicus Data Space Ecosystem was employed to generate LULC maps and spectral indices (NDVI, NDBI, NDMI, MNDWI, DBSI). VIIRS Night-time Day/Night Band composite data (2018, 2021, 2025) were applied to identify luminous settlement growth. Climate Hazards Group Infrared Precipitation with Station Data (CHIRPS v2.0) was used to analyze rainfall distribution, while SRTM DEM (USGS, 2000) provided elevation mapping.

A season-wise assessment of changes was conducted. Spectral reflectance variations of vegetation, built-up areas, water, and soil were examined using indices. **Support Vector Machine (SVM)** classification in ArcGIS Pro (10.4) was implemented, with Google Earth Engine used for automation and cross-validation. Accuracy assessments validated classification outcomes.

- **NDVI** was used to assess vegetation health (Pal, Samanta, & Maiti, 2010).
- **NDBI** was applied to detect urban expansion.
- **NDMI** estimated vegetation and soil moisture.
- **MNDWI** was used to identify water availability influenced by the south-west monsoon (Das & Das, 2016).
- **DBSI** quantified bare soil and fallow land.

Night Light maps highlighted settlement distribution along road networks and riverbanks. **Land Surface Temperature (LST) maps** were prepared to assess climate-induced temperature variations, while rainfall distribution was mapped to evaluate the impact of the monsoon system.

Assessment Criteria: Season-wise assessment of the changes has taken place in this study. Changes in spectral reflectance of different natural phenomena are shown by different maps. The consequences of the climate change are havoc on the precipitation pattern, temperature changes, built-up pattern also lastly on the land use and land cover of the district. Machine learning algorithm like Support Vector Machine performed in ARC GIS PRO (10.4) along with that Google Earth Engine platform has been used to automate the works also to cross validate and access the real time datasets.

Selection Criteria

Table 2. Selection Criteria Listed in Tabular Form

Name	Formula
Normalized Difference Vegetation Index (NDVI)	$\frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$
Normalized Difference Built-Up Index (NDBI)	$\frac{\text{SWIR} - \text{NIR}}{\text{SWIR} + \text{NIR}}$
Normalized Difference Moisture Index (NDMI)	$\frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$
Modified Normalized Difference Water Index (MNDWI)	$\frac{\text{Green} - \text{SWIR}}{\text{Green} + \text{SWIR}}$
Dry Bare Soil Index (DBSI)	$(\frac{((\text{SWIR1}-\text{Green})/(\text{SWIR1}+\text{Green}))}{((\text{NIR}-\text{Red})/(\text{NIR}+\text{Red}))})$

Land use and land cover (LULC) maps were prepared to analyze temporal changes using supervised classification with a Support Vector Machine algorithm. Accuracy assessment was conducted to validate the classification. Vegetation dynamics were evaluated through NDVI, derived from the NIR and Red bands, to indicate vegetation health. Settlement expansion was detected using NDBI, calculated from SWIR and NIR bands. Night Light maps were generated to identify settlement distribution and road networks. Land Surface Temperature (LST) maps were produced to assess climate-induced temperature variations, while rainfall distribution was examined through seasonal rainfall maps to evaluate the role of the south-west monsoon. Water availability was analyzed using MNDWI, based on SWIR and Green bands, to capture seasonal water fluctuations in rivers and tributaries. DBSI was used to detect bare and fallow lands, showing that areas left uncultivated in pre-monsoon became productive after rainfall in the post-monsoon season.

RESULTS AND DISCUSSION

The study was conducted to examine the impact of climate change and environmental degradation in Paschim Medinipur district, using a machine learning approach based on Support Vector Machine (SVM). Satellite datasets and indices were applied to delineate temporal variations during pre- and post-monsoon seasons across 2018, 2021, and 2025. Maps and indices such as LULC, NDVI, NDBI, MNDWI, NDMI, DBSI, luminous values, and Land Surface Temperature (LST) were prepared to identify changes in land cover, vegetation, settlement, water resources, and soil.

Land Use and Land Cover (LULC) - LULC classifications revealed seven categories: river, water body, settlement, barren land, vegetation, grassland, and sediment. Accuracy assessments (kappa values 69–88%) confirmed reliable classifications. In 2018, barren land was dominant in pre-monsoon, whereas vegetation and grassland expanded post-monsoon due to rainfall. In 2021, vegetation cover increased post-monsoon following Cyclone Yash, which also expanded water bodies while reducing settlement cover. In 2025, vegetation and grassland expanded in the monsoon, though settlements continued to grow in pre-monsoon. Overall, land area degraded from 1146.88 ha (2018) to 1105.49 ha (2025) due to urban expansion and climate variability. Vegetation Dynamics (NDVI) - NDVI values indicated a decline in vegetation cover from 2018 to 2025. In 2018, the highest pre-monsoon NDVI was 0.7273, but this decreased to 0.5639 post- monsoon, reflecting inundation and seasonal vegetation loss. By 2021, values declined further due to urbanization and deforestation, with Cyclone Yash contributing to vegetation washout and sediment deposition along riverbanks. In 2025, NDVI increased slightly during monsoon (0.7211) as rainfall improved cultivation and vegetation regeneration. Nevertheless, the long- term trend indicated declining vegetation cover as urban areas expanded.

Urban Expansion (NDBI and Night Lights) -Built-up areas, measured through NDBI, showed consistent expansion over time. Values rose from 0.2595 (2018) to 0.3611 (2025). Urbanization was concentrated along rivers, roads, and low-lying areas, with the largest clusters observed in Paschim Medinipur town and Kharagpur. Post-monsoon seasons showed reduced settlement coverage due to demolishment from rainfall and flooding. Night Light maps confirmed the same trend, with luminosity values increasing steadily from 41.51 (2018) to 53.43 (2025), indicating expanding settlements and improved infrastructure. These findings highlighted the correlation between urbanization, vegetation loss, and environmental degradation. Land Surface Temperature (LST) -LST analysis demonstrated that temperature remained consistently higher in pre-monsoon than post-monsoon due to tropical and sub-humid climatic conditions. Temperatures increased from 49.39°C (2018) to 54.16°C (2021), primarily in built- up areas. Post-monsoon values were comparatively lower due to rainfall and cyclone-induced cooling, as observed in 2021. By 2025, LST slightly decreased to 47.48°C in pre-monsoon, associated with moderate vegetation growth. However, the overall trend confirmed urbanization as a driver of rising land temperatures.

Rainfall Patterns: Rainfall distribution maps revealed spatial and seasonal variability. In 2018, sparse rainfall was observed in pre-monsoon, while heavy rainfall affected the eastern and southern regions in post-monsoon. In 2021, rainfall increased drastically due to Cyclone Yash, causing floods, inundation, and vegetation loss. The highest precipitation recorded was 291.96 mm (June 2025), while the lowest was **0**.00 mm (pre-monsoon 2018). These patterns suggested increasing climatic unpredictability, with cyclones and low-pressure systems contributing to extreme rainfall events.

Water Availability (MNDWI and NDMI): MNDWI values confirmed higher water availability in post-monsoon seasons across years, reflecting rainfall-fed nourishment of rivers and tributaries. In 2021, the highest value (0.9275) corresponded with flooding caused by Cyclone Yash. However, in 2025, water levels declined, reflecting increasing variability in precipitation. NDMI analysis indicated higher vegetation moisture during pre-monsoon than post-monsoon, with maximum moisture recorded in 2025 (0.3611). Seasonal variation highlighted the influence of deciduous vegetation, which reduced moisture in winter.

Dry Bare Soil (DBSI): DBSI maps indicated increasing dry bare soil over time. In 2018, pre- monsoon values ranged between 0.02–0.50, which expanded to 0.01–0.66 by 2025. Heavy rainfall reduced bare soil post-monsoon, with moss and shrubs regenerating in water-recharged areas. However, pre-monsoon dryness was intensified by deforestation and settlement expansion. Urbanization, coupled with reduced vegetation, contributed significantly to increased bareness and soil degradation.

Overall Assumption: The findings confirmed that Paschim Medinipur district is undergoing severe environmental degradation under the influence of climate change and urbanization. Vegetation cover has declined, urban settlements have expanded, temperatures have risen, and rainfall patterns have become more unpredictable, with cyclonic activity intensifying waterlogging and flooding. Soil degradation, bare land expansion, and increased LST values demonstrated the cumulative effects of deforestation and settlement proliferation. Overall, the study emphasized that climate variability and human-induced urbanization are interconnected drivers of ecological imbalance in the district, highlighting the urgent need for sustainable land- use planning and mitigation strategies.

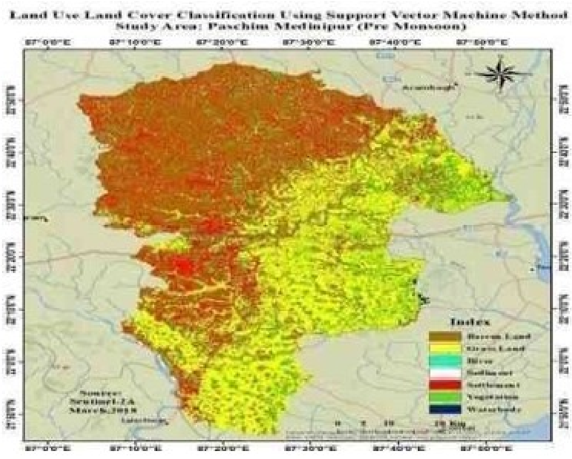


Figure. 3.a

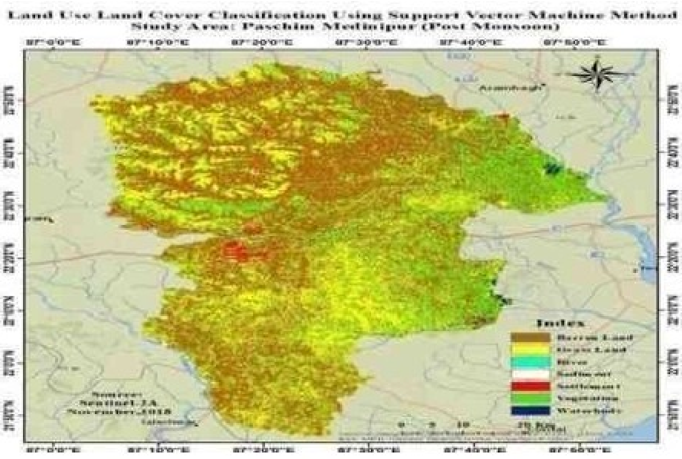


Figure. 3.b

Figure-3(a,b): The Land use and Land cover map (Fig:3.a, Fig:3.b) illustrate the changes of land area in Paschim Medinipur district

Figure. 3.a.1

Figure. 3.b.1

Figure-3(a.1.,b.1): Tabular Output : The Land use and Land cover map (Fig:3.a, Fig:3.b) illustrate the changes of land area in Paschim Medinipur district

Interpretation- The area is classified into seven LULC classes, showing seasonal variations with higher barren land and settlements in pre-monsoon (κ=69%), while post-monsoon shows increased vegetation and grassland with reduced settlements (κ=88%).

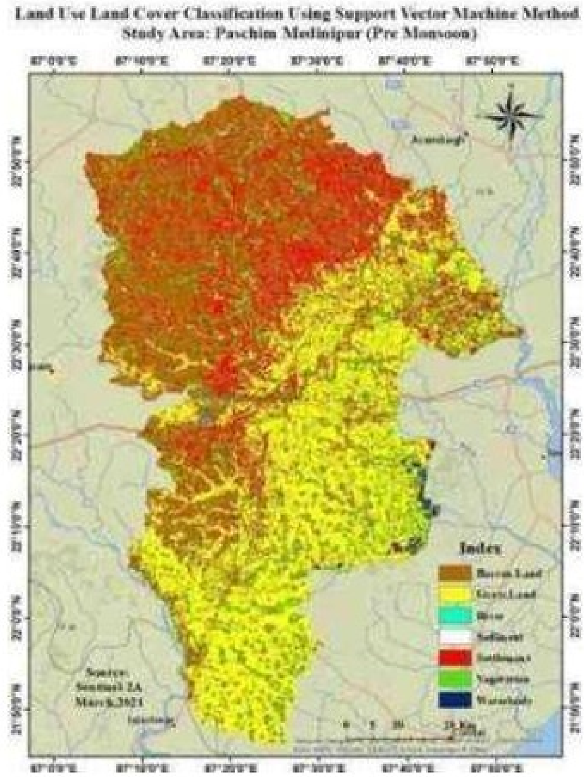


Figure 3.c

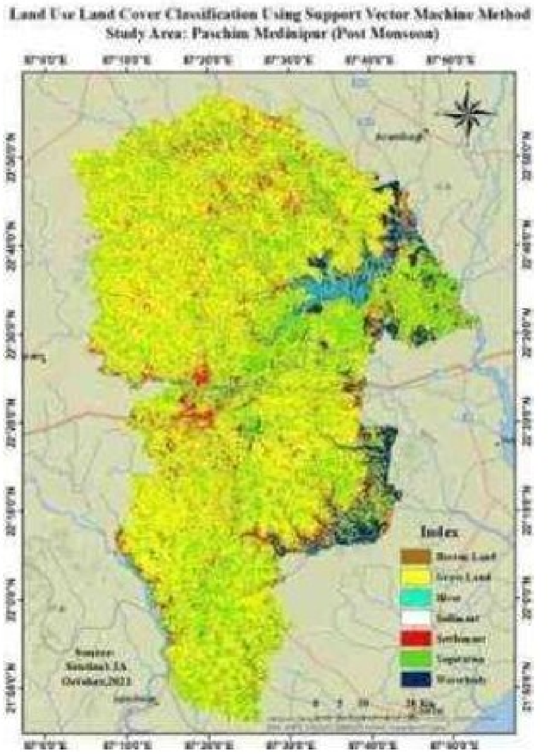


Figure 3.d

Figure-3(c,d). Showing the changes occurred in the pre monsoon and post monsoon season of 2021 respectively

Figure-3(c.1,d.1): Showing the changes occurred in the pre monsoon and post monsoon season of 2021 respectively in Tabular Form

Figure. 3.c.1

Figure. 3.d.1

OID	ClassValue	River	Waterbody	Grassland	Vegetation	Settlement	Barrenland	Sediment	Total	U_Accuracy	Kappa
0	River	56	0	4	0	0	8	1	69	0.811594	0
1	Waterbod	0	110	12	4	2	6	0	134	0.820896	0
2	Grass land	0	4	1314	44	8	39	0	1410	0.931915	0
3	Vegetatior	0	3	56	564	1	18	0	642	0.878505	0
4	Settlemen	0	0	13	4	197	10	0	224	0.879464	0
5	barren lan	0	0	1	0	0	9	0	10	0.9	0
6	Sediment	0	0	0	0	0	2	12	14	0.857143	0
7	Total	56	117	1400	616	208	92	13	2503	0	0
8	P_Accurac	1	0.940171	0.938571	0.915584	0.947115	0.097826	0.923077	0	0.903716	0
9	Kappa	0	0	0	0	0	0	0	0	0	0.842431

Interpretation- In 2021, pre-monsoon maps show higher settlements and vegetation with less barren land (κ=84%), while post-monsoon maps reflect increased waterbodies, vegetation, and grassland with reduced settlements due to cyclone Yash (κ=84%).

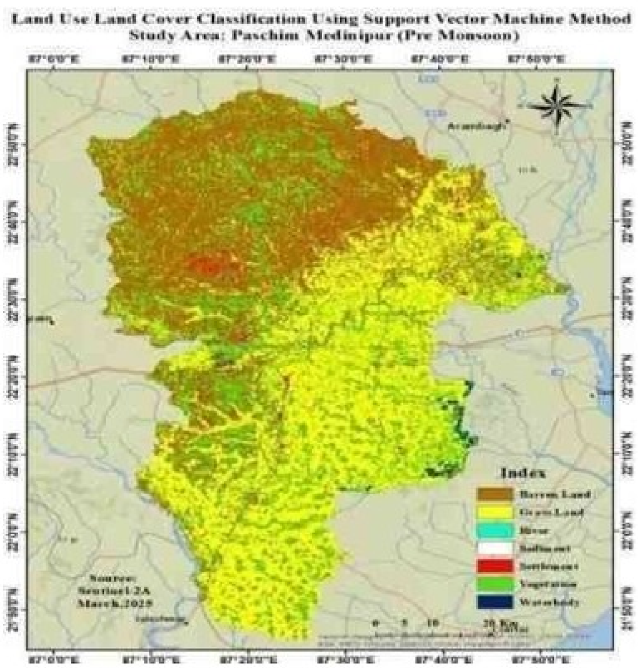


Figure 3.e

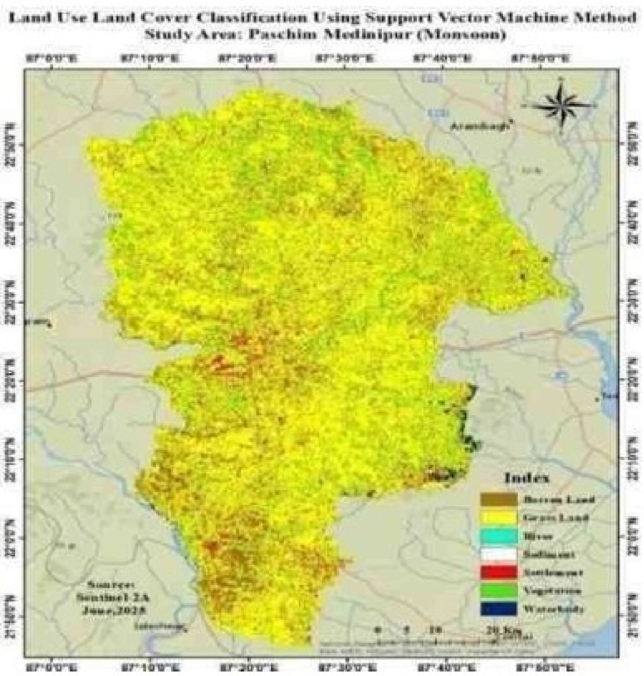


Figure 3.f

Figure (3.e,f): maps (Fig:3.e, Fig:3.f) illuminate on the Land use Land cover changes in the year 2025 during pre-monsoon and monsoon season.

Figure (3.e.1,f.1): maps (Fig:3.e, Fig:3.f) illuminate on the Land use Land cover changes in the year 2025 during pre-monsoon and monsoon season in Tabular Form

OID	ClassValue	River	waterbody	Grassland	Vegetation	Settlement	Barren land	Sediment	Total	U_Accurac	Kappa
0	River	10	0	0	0	0	0	0	10	1	0
1	waterbody	0	185	4	35	1	5	0	230	0.804348	0
2	Grassland	0	0	870	3	0	6	0	879	0.989761	0
3	Vegetation	0	0	0	284	0	0	0	284	1	0
4	Settlement	1	0	23	65	372	36	0	497	0.748491	0
5	Barren land	0	1	61	46	13	372	0	493	0.754564	0
6	Sediment	1	0	29	0	1	32	48	111	0.432432	0
7	Total	12	186	987	433	387	451	48	2504	0	0
8	P_Accuracy	0.833333	0.994624	0.881459	0.655889	0.96124	0.824834	1	0	0.855032	0
9	Kappa	0	0	0	0	0	0	0	0	0	0.811286

Figure 3.e.1

Figure 3.f.1

Interpretation - Above maps (Figure:3. e, Figure:3. f) illuminate on the Land use Land cover changes in the year 2025 During pre-monsoon 2021, moderate rainfall led to increased vegetation and grassland though barren land was still visible (κ=81%), while in monsoon, rainfall reduced barren land, increased vegetation and grassland, and slightly declined settlements (κ=79%). Between 2018 and 2025, Paschim Medinipur experienced LULC degradation, with pre- monsoon area reducing from 1146.88 ha to 1105.49 ha in monsoon; built-up, agricultural, and industrial areas increased, while vegetation cover declined, as confirmed by accuracy assessment.

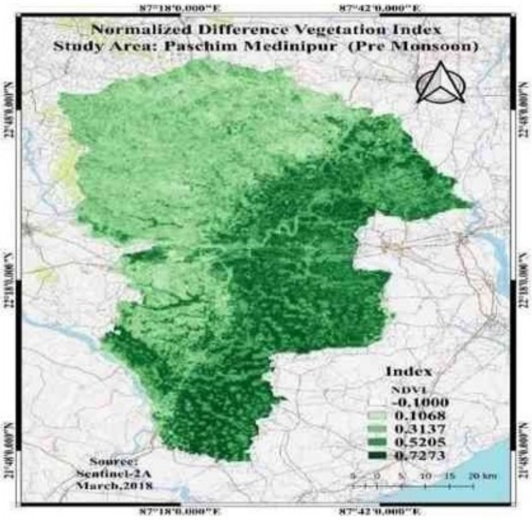


Figure 4.a

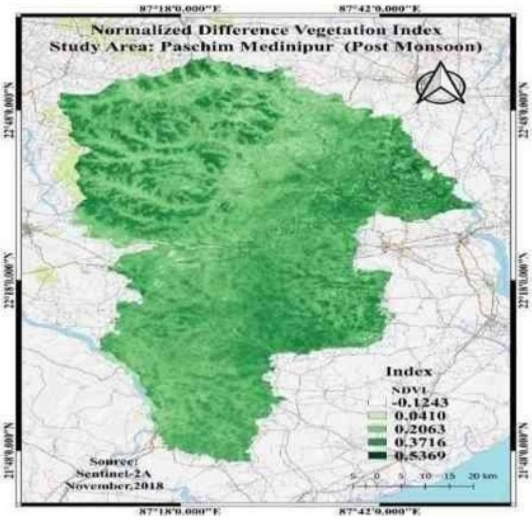


Figure 4.b

Figure (4.a,b): Depicts that the NDVI values decreases in the post monsoon than pre monsoon season.

Interpretation- The NDVI maps show higher greenness in the low-lying northeast and southeast during pre-monsoon 2018, shifting to the elevated northwest post-monsoon due to rainfall and inundation. NDVI values dropped from 0.7273 in pre-monsoon to 0.5639 in post-monsoon.

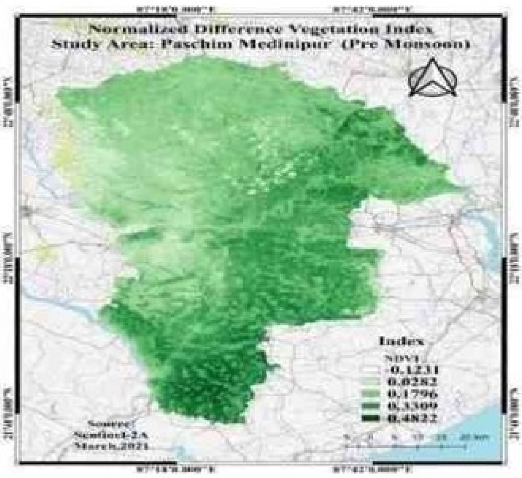


Figure 4.c

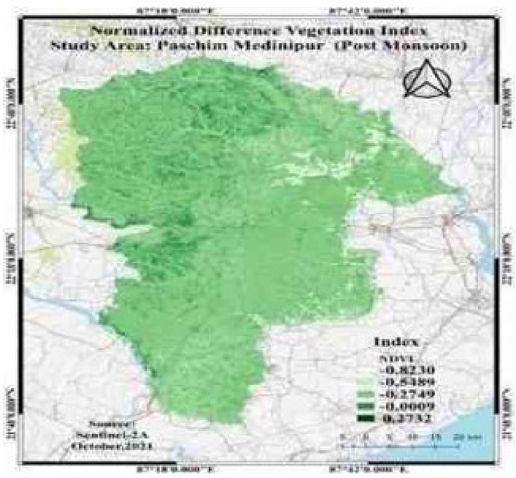


Figure 4.d

Figure (4.c,d). A Continuous decrease observed in both the NDVI maps of 2021.

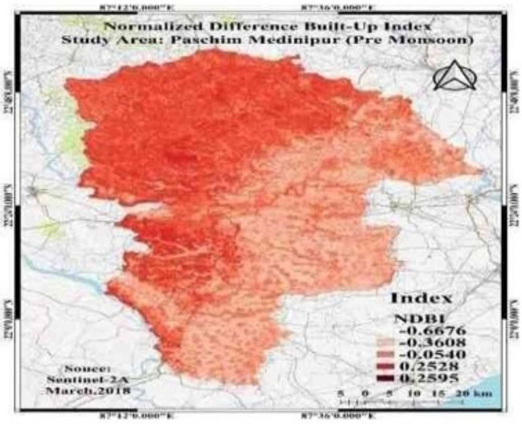
Interpretation- In 2021, NDVI values declined due to urbanization-driven deforestation and conversion to settlements and agriculture, as seen in LULC and NDBI maps. Post-monsoon values further dropped after cyclone Yash, with floods causing vegetation loss, settlement damage, and increased riverbank sedimentation.

Figure 4.e

Figure 4.f

Figure (4.e,f): Illustrates that the vegetation cover and the health of the vegetation increases in the monsoon season as compared to pre monsoon season

Interpretation- The NDVI maps reveal higher vegetation cover during monsoon due to the southwest monsoon, though post-monsoon values decline as vegetation gets washed out and is dominated by deciduous types. Overall, NDVI decreases from 0.7273 (2018) to 0.7211 (2025), mainly due to natural calamities, deforestation, and settlement expansion.



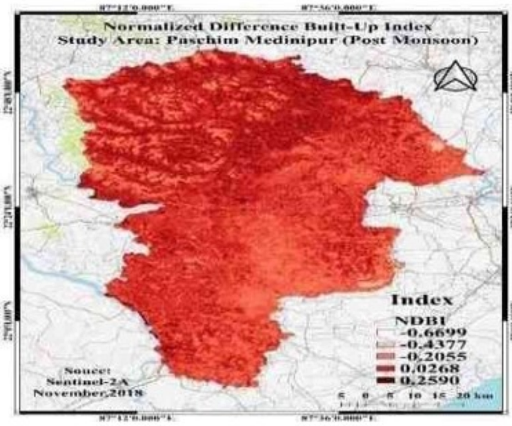
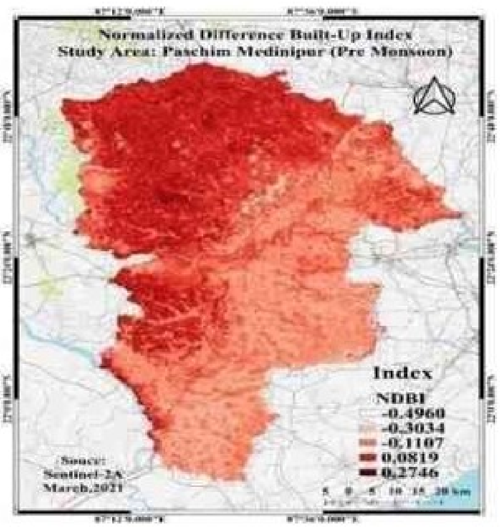


Figure 5.a Figure 5.b

Figure (5.a,b). The built-up areas of our study area during the pre-monsoon and post monsoon season of 2018.

Interpretation- The NDBI maps (Fig:5.a, Fig:5.b) depict built-up areas in 2018, showing higher values (0.2595) in pre-monsoon near rivers and roads due to rapid urbanization. Post- monsoon values (0.2590) are lower as heavy rainfall leads to settlement demolishment.



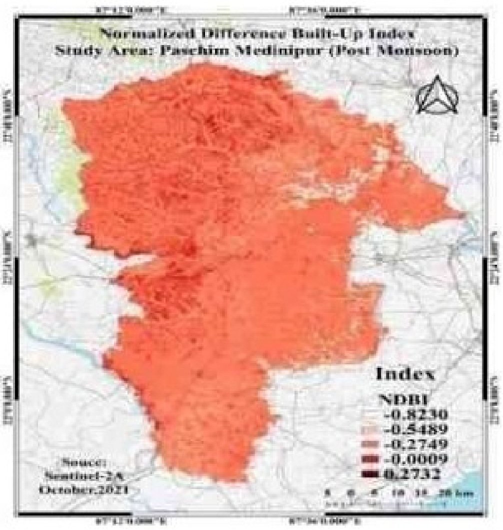
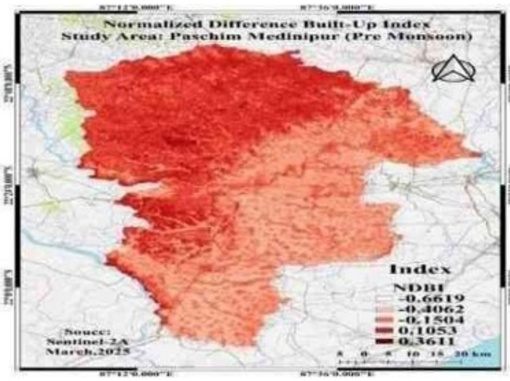


Figure 5.c Figure 5.d

Figure (5.c,d). Shows the changes in the built-up areas in pre monsoon and post monsoon season of 2021

The above maps (Fig:5.c,Fig:5.d) shows the changes in the built-up areas in pre monsoon and post monsoon season of 2021. In the pre monsoon season (Fig:5.c) the amount of built-up was high i.e., 0.2746. But in the post monsoon season (Fig:5.d) the amount decreases due to heavy rainfall occurrence. The amount of built-up was 0.2732 in this season.



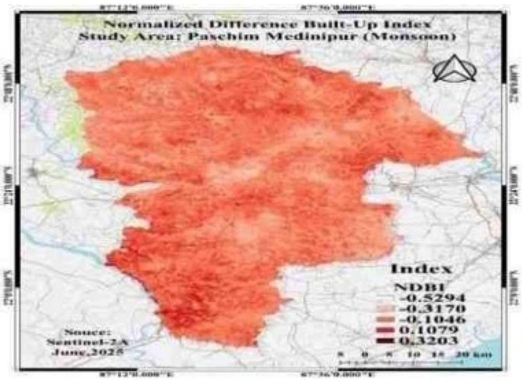


Figure 5.e Figure 5.f

Figure (5.e,f). The changes in built-up pattern in pre monsoon and monsoon season of 2025

Interpretation- The NDBI maps (Fig:5.e, Fig:5.f) show higher built-up areas in pre-monsoon (0.3611) than monsoon, with urban growth scattered along roads, rivers, and flat terrains, especially in eastern and northeastern parts. In 2021, NDBI dropped to 0.2732 due to cyclonic events that expanded water bodies (0.9275), causing settlement demolishment.

Figure 6.a

Figure 6.b

Figure (6.a,b). The conductress of the luminosity represents the presence of lights during the night time in the settlements and along the main high roads

Interpretation- The luminosity maps indicate increased night lights in settlements, highways, and urban centers like Kharagpur and Paschim Medinipur, reflecting ongoing urbanization. Post-monsoon values rise further due to clear skies, highlighting the region's development.

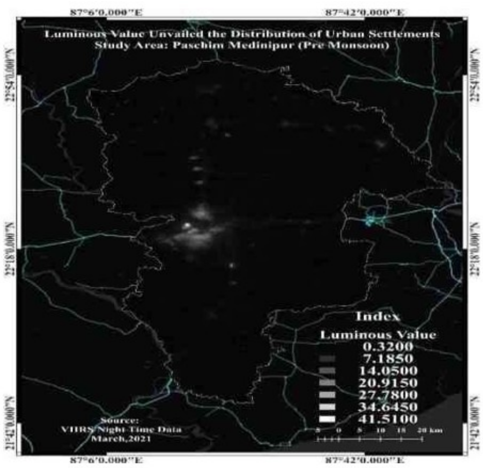


Figure 6.c

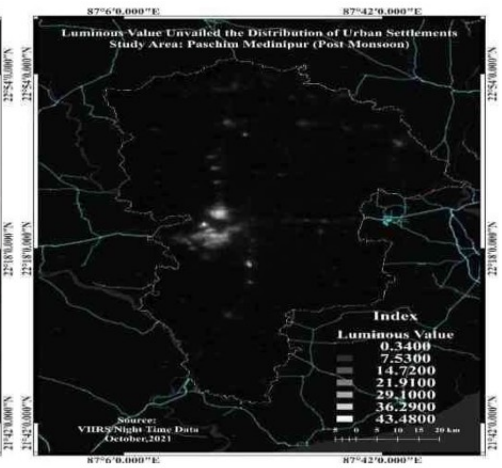


Figure 6.d

Figure- (6-c,d): The luminous maps unveiled that continuous urbanization is taking place from 2018 (Fig 6.a, Fig 6.b) to 2021 (Fig 6.c, Fig 6.d)

Interpretation - The luminous maps (Fig:6.a–6.d) reveal steady urbanization from 2018 to 2021, with values rising from 41.5100 to 43.4800, especially along roads in the post-monsoon season. Increased lights in rural areas reflect improved livelihood and expanding development.

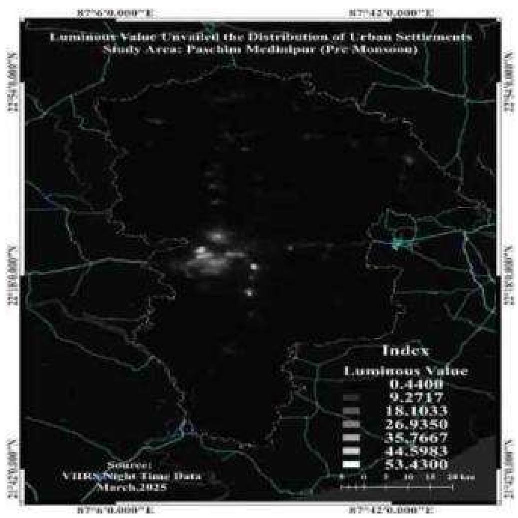


Figure 6.e: The value increases from 43.4800 (Fig 6.d) to 53.4300 (Fig 6.e) in just 4 years interval.

Interpretation- The luminous maps show a rise from 43.4800 (Fig:6.d) to 53.4300 (Fig:6.e) within four years, with scattered lights along roads and rivers, mainly in western and northeastern regions. Alongside rising NDBI values (0.2595–0.3611), this indicates continuous urbanization, with major clusters in Paschim Medinipur and Kharagpur.

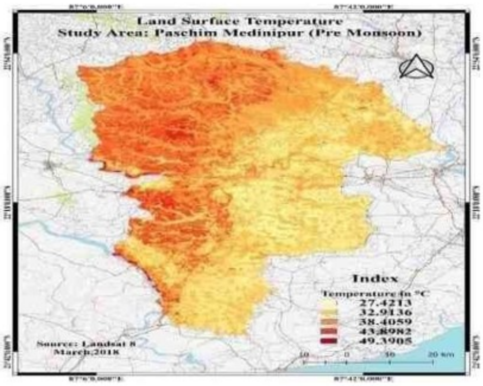


Figure7.a

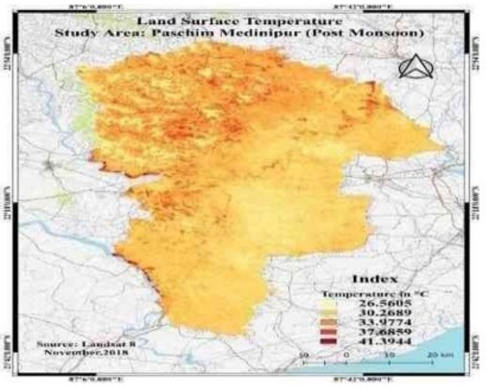


Figure 7.b

Figure- (7-a,b): The land surface temperature maps of pre monsoon season (Fig 7.a) and post monsoon season (Fig 7.b) delineates that temperature remains high in the pre monsoon season as compared to post monsoon season due to its climatic characteristics that is Topical and sub-Humid climate.

Interpretation- The LST maps (Fig:7.a, Fig:7.b) show higher temperatures in pre-monsoon (49.39°C) over barren and urban areas, while post-monsoon values drop to 41.39°C due to southwest monsoon and cooler winter conditions.

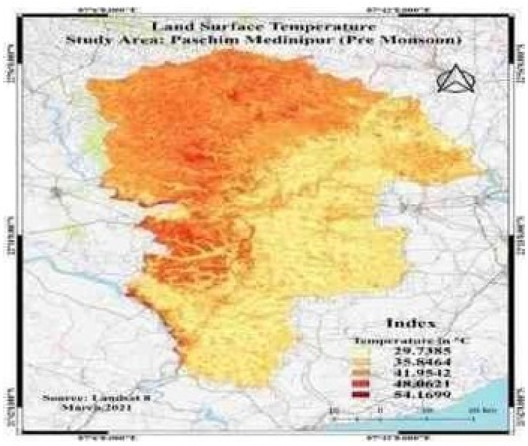


Figure 7.c

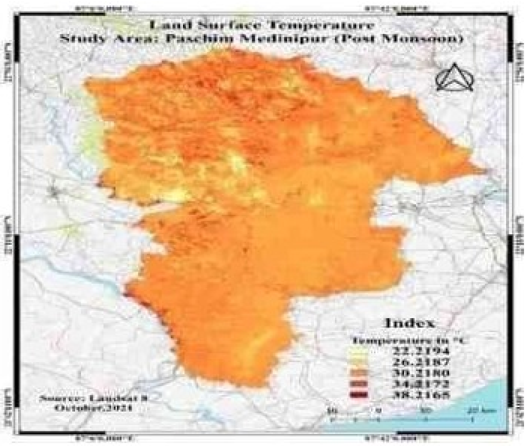


Figure 7.d

Figure- (7-c,d): Land surface temperature maps (Fig 7.c, Fig 7.d) that the temperature shows a continuous increasing trend in the pre monsoon season due to the adverse impact of climate change.

Interpretation- The LST maps (Fig:7.c, Fig:7.d) reveal a rise in pre-monsoon temperature from 49.39°C (2018) to 54.16°C (2021), especially in built-up western areas. Post-monsoon 2021 shows a sharp fall due to Cyclone Yash, causing inundation and waterlogging that lowered temperatures.

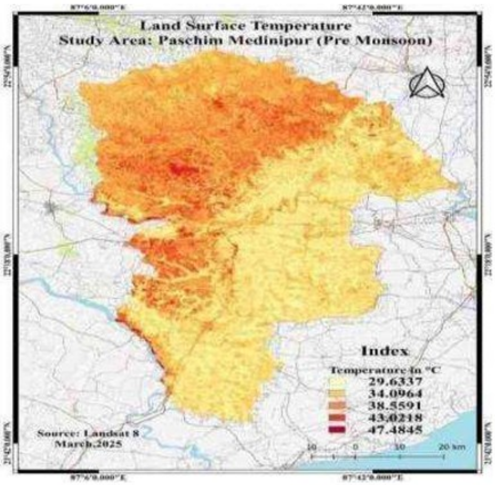


Figure 7.e. This land surface temperature map (Fig 7.e) of pre monsoon season of 2025 shows that the temperature is slightly decreasing than the year 2021 from 54.1699°C to 47.4845°C (Fig 7.d) as it is seen that the amount of vegetation is increasing (Fig 4.f)

Interpretation- The LST map (Fig:7.e) shows a slight temperature drop in 2025 (47.48°C) from 2021 (54.16°C) due to increased vegetation, though built-up areas remain hotter. Overall, LST rose from 49.39°C (2018) to 54.16°C (2021) with urbanization, before decreasing under low-pressure conditions in 2025.

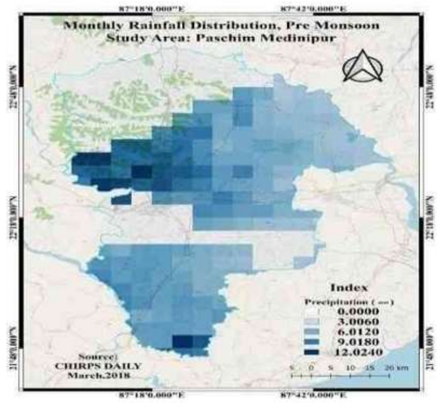


Figure 8.a

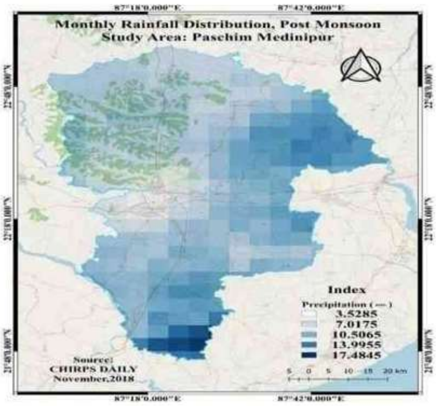


Figure 8.b

Figure-(8 a, b): This map depicts the monthly average rainfall of pre monsoon and post monsoon season of 2018 (Figure 8.a, Figure 8.b).

Interpretation- The rainfall maps (Fig:8.a, Fig:8.b) show sparse pre-monsoon rainfall in most areas except the south, central, and west, while post-monsoon brings heavy rain to the east and south with values ranging from 0.0000 mm to 12.0240 mm.

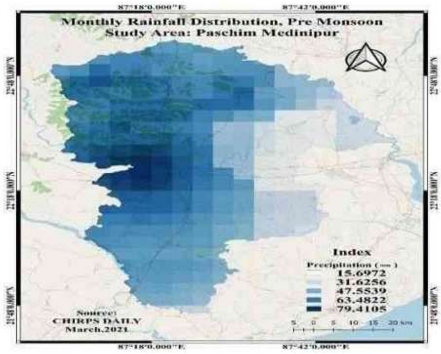


Figure 8.c

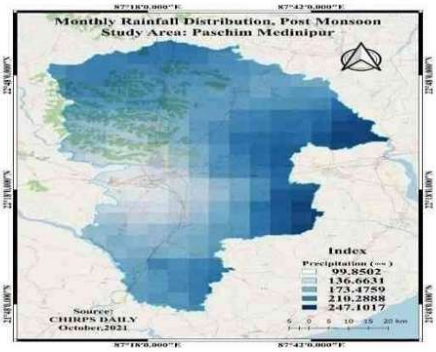


Figure 8.d

Figure-(8 c, d): The distribution of rainfall is shown in the Fig no 8.c and 8.b for both pre and post monsoon period. At the time of pre monsoon, the northern, northwestern, western and the central part of the district receives high rainfall, which is situated in high elevated terrains.

Interpretation- The rainfall maps (Fig:8.c, Fig:8.b) show high pre-monsoon rainfall in elevated northern and western areas, with runoff accumulating eastward (Fig:9.c). Post- monsoon 2021 saw heavy rainfall from Cyclone Yash (99.85–247.10 mm), causing floods, reduced bare soil, and increased vegetation (Fig:4.d, Fig:11.d, Fig:9.d).

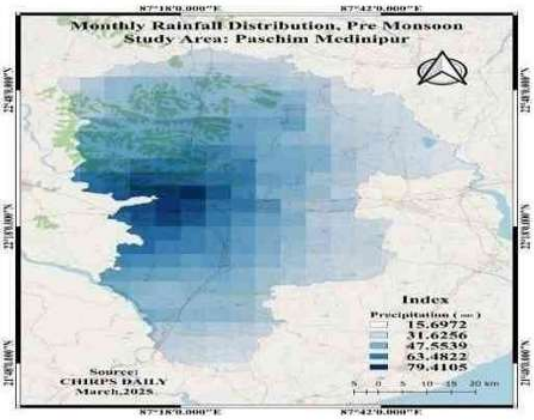


Figure 8.e

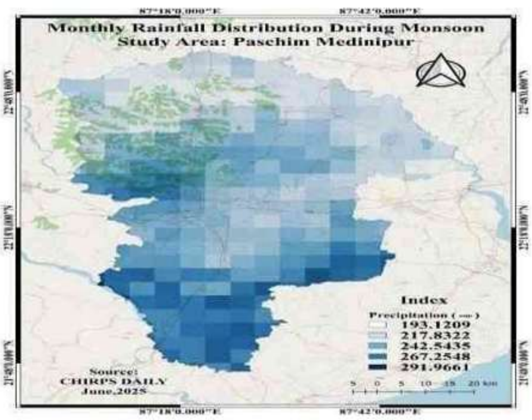


Figure 8.f

Figure-(8 e, f): Precipitation map of 2025 during the pre and the post monsoon season is showed in the Figure 8.e and 8.f

Interpretation- The precipitation maps (Fig:8.e, Fig:8.f) show heavy pre-monsoon rainfall in central and western areas, with uneven June distribution peaking at 291.97 mm. Overall, rainfall has increased over the years due to frequent low-pressure and cyclonic events, with the lowest in pre-monsoon 2018 (0.00 mm).

Figure 9.a

Figure 9.b

Figure-(9-a,b): The MNDWI maps (Fig: 9.a and Fig: 9.b) depicts that the values of MNDWI has increased during the post-monsoon season, as compared to the pre monsoon.

Interpretation- The MNDWI maps (Fig:9.a, Fig:9.b) show higher post-monsoon values (0.7081) compared to pre-monsoon (0.6833), with water presence shifting from the east to both eastern and northeastern parts. This variation is due to runoff from elevated northwestern terrain flowing toward low-lying eastern regions.

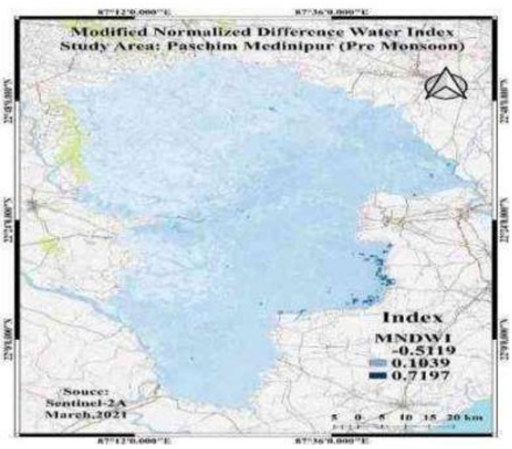


Figure 9.c

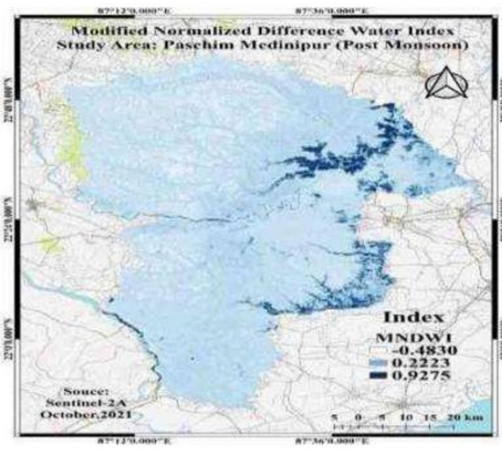


Figure 9.d

Figure-(9-c,d). The MNDWI maps of Figure 9.c and Figure 9.d illustrates that the values of MNDWI have increased for both pre monsoon and post monsoon as compared to the MNDWI map of 2018 (Figure 9.a and Figure 9.b).

Interpretation - The MNDWI maps (Fig:9.c, Fig:9.d) show higher values than 2018, with pre- monsoon water accumulating in flat terrains due to rainfall and runoff from northern slopes. Post-monsoon values peak at 0.9275, exceeding pre-monsoon's 0.7197, as non-perennial rivers overflow and inundate nearby banks.

Figure 9.e

Figure 9.f

Figure-(9-e,f): The MNDWI map of Fig: 9.e and Fig: 9.f delineates that the values of MNDWI decreased as compared to the MNDWI map of 2018 (Fig:9. a and 9.b) and 2021 (9. c and 9. d).

Interpretation- The MNDWI maps (Fig:9.e, Fig:9.f) show lower values in 2025 compared to 2018 and 2021, with unusually high pre-monsoon water that declines by June due to low pressure. Seasonal maps reveal post-monsoon water rise from southwest monsoon and cyclones, with the highest value (0.9275) in 2021, while higher MNDWI corresponds to lower NDVI from vegetation submergence.

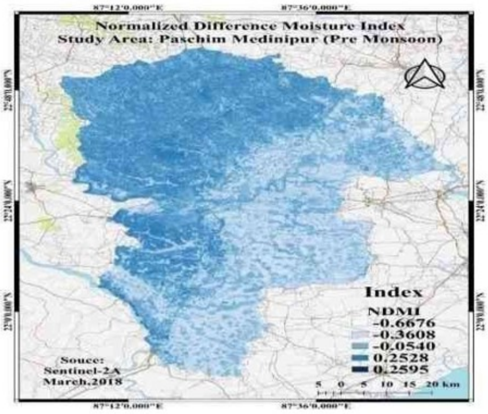


Figure 10.a

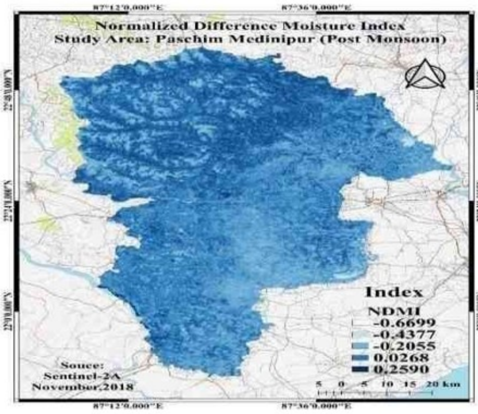


Figure 10.b

Figure-(10-a,b): Shows the Normalized Difference Moisture Index of Paschim Medinipur district.

Interpretation- The maps (Fig:10.a, Fig:10.b) shows the Normalized Difference Moisture Index of Paschim Medinipur district. The moisture is high in the north-western part of this district in the pre monsoon season (10.a). and the value is 0.2595. In the post monsoon season (Fig:10.b) the southern part of this district contains more moisture than the pre monsoon season where the highest value is 0.2590.

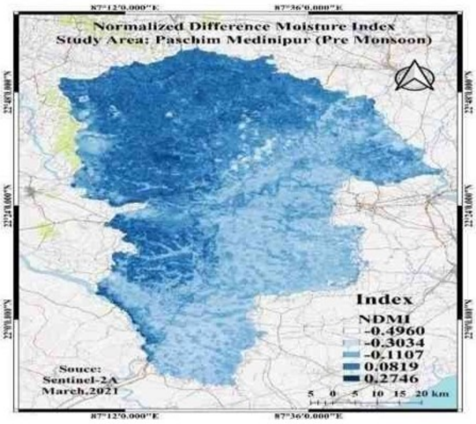


Figure 10.c

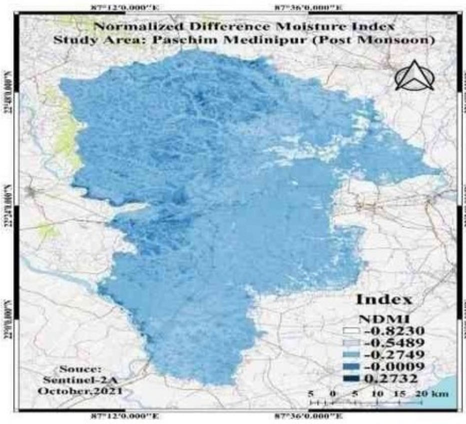


Figure 10.d

Figure-(10-c,d). Illustrates the changes in Moisture contains in the pre-monsoon and post monsoon season of 2021.

Interpretation- The above map (Fig:10.c,Fig:10.d) illustrates the changes in Moisture contains in the pre-monsoon and post monsoon season of 2021. As there was a low-pressure situation in the pre monsoon season of 2021, the moisture content is high in the north-western part and in the south western part of this district (Fig:10.c). The northern part and the western part of this district evidently contains more moisture in the post monsoon season (Fig:10. d).

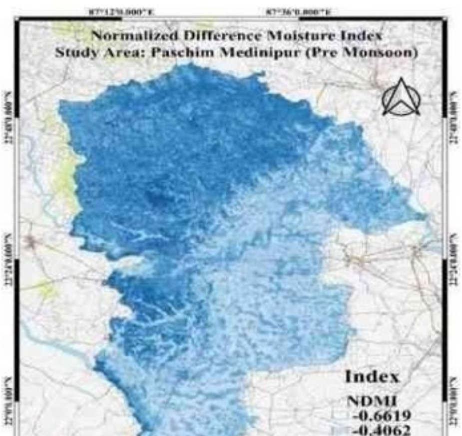


Figure 10.e

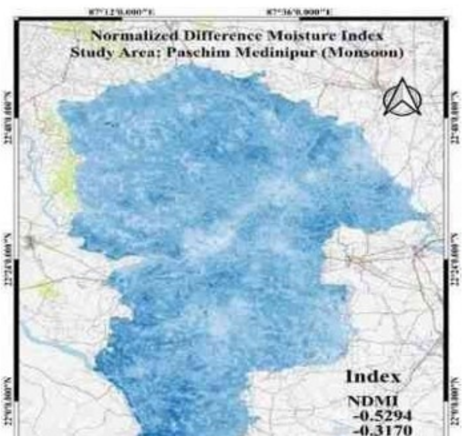


Figure 10.f

Figure-(10-e,f): Depicts the moisture contents of 2025 in pre monsoon and monsoon season accordingly

Interpretation- The NDMI maps (Fig:10. e, Fig:10. f) show higher moisture (0.3611) in the north-western and western parts during pre-monsoon 2025, while monsoon values are lower. Vegetation moisture is seasonally variable, with deciduous cover causing reduced moisture in winter.

Figure 11.a

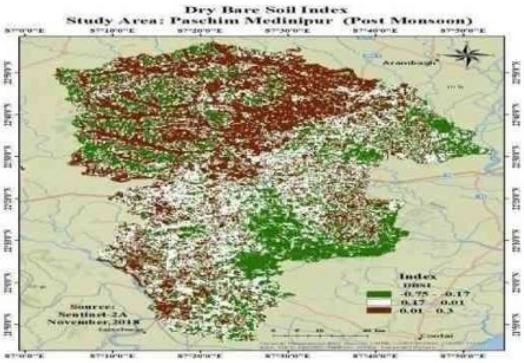


Figure 11.b

Figure-(11-a,b). The dry bare soil occurrence in pre monsoon and post monsoon season in 2018 of the Paschim Medinipur district.

Interpretation- The maps (Fig:11. a, Fig:11. b) show higher dry bare soil (0.02–0.5) in the western part during pre-monsoon due to low rainfall, while post-monsoon values drop to 0.01– 0.3 as vegetation regenerates after heavy rains.

Figure 11.c

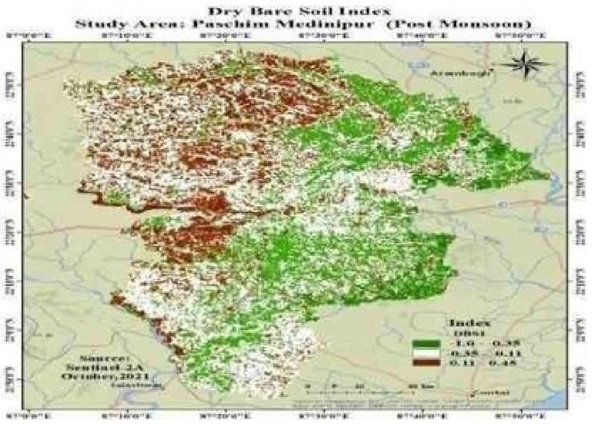


Figure 11.d

Figure-(11-c,d): Depicts the presence of dry bare soil in pre monsoon and post monsoon season of 2021

Interpretation- The Dry Bare Soil maps (Fig:11.c, Fig:11.d) depicts the presence of dry bare soil in pre monsoon and post monsoon season of 2021. The amount of dry bare soil was high in pre monsoon season as compared to post monsoon season. Due to the cyclonic condition, the amount of dry bare soil has decreased in the post monsoon season from 0.48 to 0.45 (Fig:11.d) and the amount of vegetation cover has also increased (Fig:4.d).

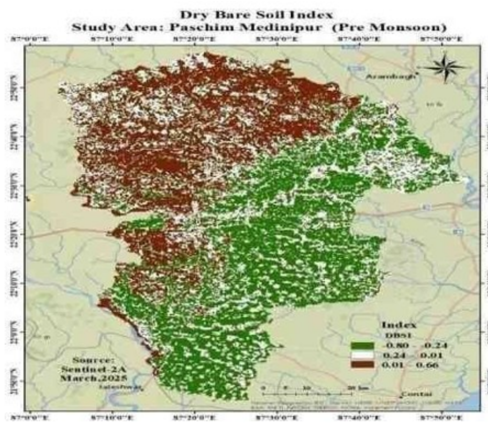


Figure 11.e

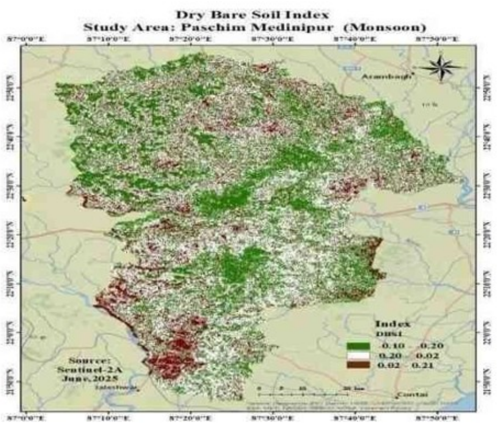


Figure 11.f

Figure(11.e, f): Shows the dry bare soil region over the district in pre monsoon and monsoon season of 2025.

Interpretation- DBSI maps show high dry bare soil in pre-monsoon 2025 (0.01–0.66), decreasing in monsoon due to rainfall, while overall bare soil has increased since 2018 because of urbanization and deforestation, with moss and small shrubs growing in wetter areas.

DATA VALIDATION

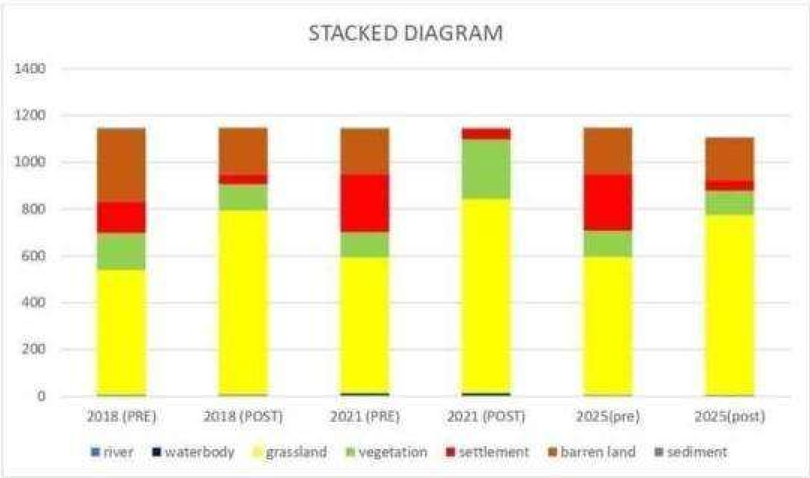


Figure.-12. Result and Discussion of the entire Analysis

Interpretation - The study, based on secondary data validated through statistical graphs and correlation, shows grassland expansion during post-monsoon and monsoon seasons, while pre-monsoon seasons (2018, 2021, 2025) face low vegetation and increased settlements. Rivers remain mostly invisible due to their non-perennial nature, with slight visibility in 2021 owing to high rainfall and cyclonic conditions.

Figure.-13: Result and Discussion of the entire Statistical Analysis using Statistical Tool

LULC classes for 2018, 2021, and 2025 were analyzed using Pearson correlation, showing all values as strongly significant ($P < 0.05$), with post-monsoon 2018 and monsoon 2025 perfectly correlated ($r = 1$, $P < 0.01$).

K-Fold Cross validation: 2018 and 2021 has been used as training dataset and 2025 has been used as testing dataset.

CONCLUSION

The study focused on assessing climate change and environmental degradation in Paschim Medinipur district, where significant shifts in temperature, precipitation, and land use were observed. Urbanization was found to drive deforestation and the conversion of forested land into agricultural and industrial areas, reducing vegetation cover while expanding settlements and farmland. LULC classification and spectral indices revealed rising land surface temperatures, declining NDVI values, and increasing luminous values between 2018 and 2025, confirming rapid urban growth. Proximity to the Bay of Bengal exposed the district to cyclones and altered rainfall patterns, with heavy post-monsoon precipitation leading to waterlogging and floods. Expanded dry bare soil further reflected ecological stress. Pearson correlation of secondary data indicated statistically significant relationships, reinforcing the conclusion that the district is experiencing severe environmental degradation under the influence of climate change.

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