Project

Mapping and Analyzing Tropical Cyclone-Induced Damages through Landsat Satellite Imagery: Case Study of Cyclone Amphan in Bangladesh

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Abstract

Tropical cyclones are extreme natural catastrophes and are anticipated to intensify strength and recurrence under upcoming climate change consequences in our coastal regions through Bangladesh. This study has tested and developed methods for evaluating considerable damages affected in 2020 by cyclone Amphan in Satkhira district (3817.29 km2) in Bangladesh from 30m spatial-resolution satellite imageries. Iso-cluster unsupervised classification procedures are applied to prepare maps in pre- and post-cyclone Landsat 8 imagery. A difference between the pre- and post-cyclone image classification and NDVI analysis give us evidence about the significant landscape changes at the Cyclone Amphan impact on the study area. The total accuracies for pre- and post-cyclone images classification were 70% and 68% respectively. The outcomes indicate that 35.09% of the study region was remarkably influenced by cyclone Amphan. Statistical analysis indicates that water bodies have dramatically increased 17.65% in different land cover areas due to the strong water surge. On the contrary, the classified image showed that the vegetation and agricultural land decreased 4.13% and 10.82%. Thus, land covers have inundated due to heavy flash during the cyclone. Barren land also decreased 1.80%, and low land areas were also flooded 0.36% due to heavy water flashes. NDVI analysis indicated no destruction of any vegetation species, but vegetation damage is considerable. The developed method may be imposed in future to measure the impacts produced by cyclones in Bangladesh and to make policies for the commitments of cyclone disaster controlling and management.

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1. Introduction

Tropical cyclones are significant natural disasters that affect coastal regions worldwide. This project assesses the damage caused by Cyclone Amphan in Satkhira, Bangladesh, using remote sensing techniques. Leveraging Landsat-8 imagery, we applied unsupervised classification and NDVI analysis to evaluate land-use changes and vegetation damage. Tropical cyclones are among the most destructive natural disasters, severely affecting coastal regions. In the context of climate change, the frequency and intensity of these storms are expected to increase, posing a significant risk to countries like Bangladesh. Cyclone Amphan, a Category 5 storm, struck the southwestern region of Bangladesh in 2020, causing immense damage to land, infrastructure, and livelihoods. The ability to accurately assess such damage is crucial for disaster management and future risk mitigation strategies.

The geographic position of Bangladesh and the funnel-shaped Bay of Bengal intensify devastating tropical cyclones (Salman, 2022; Das, 1972). Tropical cyclones predominantly affect the lives and properties in low-lying coastal areas. Cyclone-induced storm surges in this area typically initiate in the central and southern parts of the Bay of Bengal or in the Andaman Sea. Due to the shallow continental shelf, the surge amplifies significantly as it is headed for land and causes catastrophic floods along the coast (Murty et al., 1986). In the northern Bay of Bengal, a unique combination of high tides, a funneling coastal configuration, the low flat coastal terrain and a high population density have originated some of the highest mortality figures associated with storm surges (Flierl & Robinson, 1972). However, Bangladesh is one of the most vulnerable countries due to global climate change and sea-level rise. The country is likely to be affected by more powerful cyclonic events in the anticipatable future. The consequences of climate change lead to an increase in the cyclone-prone area and put many people at risk.

2. Literature Review

The increasing frequency and severity of tropical cyclones, attributed to climate change, necessitate innovative and efficient methodologies for assessing their impacts. Satellite remote sensing has emerged as a cost-effective and scalable solution for evaluating post-disaster damage across large geographic areas. This literature review highlights the key studies and methodologies that inform the proposed project on Cyclone Amphan's impact assessment in Satkhira District, Bangladesh.

The utility of satellite imagery in disaster management has been extensively documented. Salman et al. (2021) underscored the importance of using high-resolution satellite data to evaluate cyclone-induced damages in coastal areas. Their research demonstrated the effectiveness of remote sensing in capturing changes in land cover and supporting disaster response strategies.

Similarly, Gandhi et al. (2015) explored the use of the Normalized Difference Vegetation Index (NDVI) to assess vegetation health and changes due to disasters. NDVI, calculated using the difference between near-infrared (NIR) and red bands, has been a reliable indicator for monitoring vegetation damage and recovery. These findings are pivotal to the current project's focus on vegetation health post-Cyclone Amphan.

Dewan and Yamaguchi (2009) provided insights into urban land-use changes following natural disasters, emphasizing post-classification comparison techniques. These methods facilitate the detection of specific changes in urban and non-urban regions, aligning with the current project’s aim to categorize land-use changes in Satkhira.

3. Methodology

3.1 Study Area

The study focused on Satkhira District, Bangladesh, bordered by the Bay of Bengal. The geographic coordinates range between 21°36'N–22°54'N latitude and 88°54'E–89°20'E longitude.

3.2 Data Collection

- Pre-cyclone image: May 8, 2020.
- Post-cyclone image: June 9, 2020.
- Tools: ArcGIS for preprocessing (geometric/radiometric corrections).

3.3 Analysis Techniques

- **Unsupervised Classification**: Iso-cluster methods segmented the region into categories such as vegetation, water bodies, and urban areas.
- **NDVI Analysis**: Quantified vegetation health using the formula: NDVI=NIR – Red/ NIR + Red

3.4 Accuracy Assessment

Accuracy assessment is prime important for pre- and post-classified images. Likewise, the Kappa coefficient values between 0.61-0.80 represent the substantial agreement (Landis & Koch, 1977). In this study, user, producer and overall as well as Kappa coefficient, are calculated through the following equations:

Overall Accuracy (OA):

$$OA = \frac{N_D}{N} \times 100$$

Where, ND is the total number of correctly classified pixels (diagonal) and N is Total Number of Reference Pixels.

User Accuracy (UA):

$$UA = \frac{N_C}{R_N} \times 100$$

Where, NC equivalences to number of correctly classified pixels in each category and on the other side, R_N is the total number of classified pixels in that category (The Row Total).

Producer Accuracy (PA):

$$PA = \frac{N_C}{C_N} \times 100$$

Where, NC equivalences to number of correctly classified pixels in each category and on the other side, CN is the total number of classified pixels in that category (The column Total). Kappa Coefficient (T):

$$T = \frac{(TS \times TCS) - \Sigma\ (Column\ Total\ \times\ Row\ Total)}{TS2 -\ \Sigma\ (Column\ Total\ \times\ Row\ Total)} \times 100$$

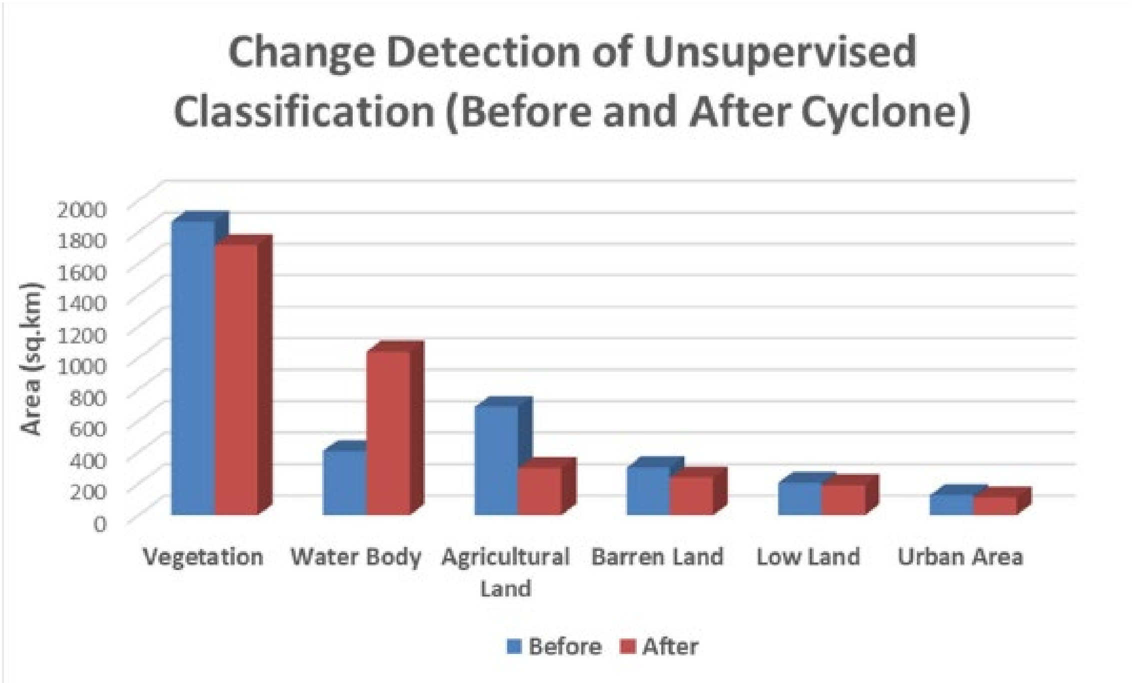
3.5 Change Detection

The changes in the land cover between pre- and post-cyclone Amphan are determined with the post-classification comparison change detection algorithm. Dewan and Yamaguchi (2009) use a post-classification algorithm for tropical cyclone impact assessment. The analysis procedure was performed by following the underlying flowchart.

4. Results and Analysis

1. **Land Cover Changes**:
   - **Water Bodies**: Increased by 17.55% due to storm surges.
   - **Vegetation**: Decreased by 4.13%, primarily affecting the Sundarbans mangrove forest.
   - **Agricultural Land**: Declined by 10.82%, severely impacting livelihoods.
   - **Barren Land**: Reduced by 1.80%.

- **Low-Lying Areas and Urban Areas**: Showed minor decreases.



2. **NDVI Analysis**:
   - NDVI values decreased significantly post-cyclone, indicating substantial vegetation damage, though no species destruction was observed.

5. Python Code Implementation

Below is a Python code snippet for NDVI computation and land cover change detection using Google Earth Engine (GEE):

```python
import ee

# Initialize the Earth Engine API
ee.Initialize()

# Define study area
study_area = ee.Geometry.Rectangle([88.9, 21.6, 89.2, 22.5])

# Load Landsat-8 imagery
landsat_collection = ee.ImageCollection("LANDSAT/LC08/C01/T1_SR").filterBounds(study_area)

# Select pre- and post-cyclone images
pre_cyclone = landsat_collection.filterDate('2020-05-01', '2020-05-10').median()
post_cyclone = landsat_collection.filterDate('2020-06-01', '2020-06-10').median()

# Calculate NDVI for pre- and post-cyclone
def calculate_ndvi(image):
    ndvi = image.normalizedDifference(['B5', 'B4']).rename('NDVI')  # NIR and Red bands
    return ndvi

ndvi_pre = calculate_ndvi(pre_cyclone)
ndvi_post = calculate_ndvi(post_cyclone)

# Detect NDVI changes
ndvi_change = ndvi_post.subtract(ndvi_pre).rename('NDVI_Change')

# Visualize results
ndvi_change_map = ndvi_change.clip(study_area).visualize(min=-1, max=1, palette=['blue', 'white', 'green'])

# Export results
export_task = ee.batch.Export.image.toDrive(
    image=ndvi_change,
    description='NDVI_Change',
    region=study_area.getInfo(),
    scale=30
```

6. Conclusion

This study highlights the devastating impact of Cyclone Amphan on Satkhira District. Remote sensing techniques provided accurate and scalable methods for assessing damages, emphasizing the importance of integrating technology into disaster management. Future research should explore high-resolution imagery and socio-economic data to enhance damage assessments.

The study makes an attempt to assess the potential damage and loss of the Bangladesh's top rated devastating region, Satkhira district, to a harshly cyclone Amphan, which was desolatedthe region on 20 May, 2020. There is a research gap between damage and loses assessment of the studied regions to extraordinary events like cyclone in the literature, which analysis longing to complete. Such studies may assume an intense work in forming the improvements of the regions for the

Government and NGOs authorities. The study verified the potentiality of a technological approach of remote sensing for evaluating manifold damages caused by the cyclone Amphan utilizing an object based unsupervised technique from Landsat-8 imageries.

In precise, 30 m spatial resolution Landsat-8 imageries were fit for representing pre- and postcyclone land-use/land cover in the studied region with a high level of accuracy and specified the practicality of an object based tactic in this study. A contrast between the pre and post cyclone image classification gives us evidence about the cyclone impact on the study area. Statistical analysis indicates that most of the area is highly or partially damaged by analyzing the results due to the vulnerability of cyclone Amphan. Inundated water body flooded or storm water in the study area has increased from 11.34% to 28.89%. In contrast to the water body, the vegetation decreased from 51.92% to 47.79% of the classified image. The impact of the cyclone dramatically affected agricultural land, reducing their area from 19.11% to 8.29% of the entire study region. Similar to farming land, the barren land decreased from 8.43% to 6.63% after the cyclone. Low land areas were also flooded due to heavy flashes of water, and it changed from 5.67% to 5.31%. Changes in urban areas were also quantified from 3.53% to 3.10% by the classified images.

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Dataset and Code

GitHub Link: https://github.com/satil025