The Effect of Rohingya Refugee Crisis on Local People and Current Environmental Condition of Ukhiya Upazila, Cox's Bazar, Bangladesh

By

Shadman Sakeef

ID: 201-30-020

This Thesis Report Presented in Partial Fulfilment of the Requirements for the Degree of Bachelor of Science (B. Sc) in Environmental Science and Disaster Management (ESDM)

Supervised By

Dr. A. B. M. Kamal Pasha, PhD

Professor and Head

Department of Environmental Science and Disaster Management

Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

DHAKA, BANGLADESH

APPROVAL

This thesis report titled **"The Effect of Rohingya Refugee Crisis on Local People and Current Environmental Condition of Ukhiya Upazila, Cox's Bazar, Bangladesh",** submitted by **Shadman Sakeef** to the Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU), has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Environmental Science and Disaster Management (ESDM) and approved as to its styleand contents.

Dr. A. B. M. Kamal Pasha, PhD

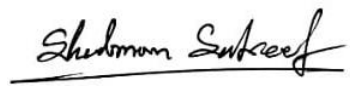
Professor and Head

Department of Environmental Science and Disaster Management (ESDM)

Daffodil International University (DIU)

DECLARATION

I hereby declare that this research project has been done by me under the supervision of **Dr. A. B. M. Kamal Pasha, Ph.D., Associate Professor and Head, Department of Environmental Science and Disaster Management (ESDM),** Daffodil International University (DIU). I also declare that neither this research project nor any part of this research project has been submitted elsewhere for the award of any degree.



Shadman Sakeef
ID: 201-30-020
Batch - 29th
Department of Environmental Science and Disaster Management (ESDM)
Daffodil International University (DIU)

DEDICATION

To,

My Family

and

My **Dear Friends** and **Teachers** From The

Department of Environmental Science and Disaster Management (ESDM),

Daffodil International University (DIU)

ACKNOWLEDGEMEN

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Alhamdulillah, I finally sat down to write the acknowledgment. Now many things are coming to my mind, many things are being remembered. **Thank you Allah** for everything. Blessings and respect to everyone whom I get the opportunity to work with and learn from this four-year journey.

At this moment I want to remember my friends. **Swadhin Hossain**, **Taskin**, **Jobair Asif**, **Caleh Ahmed**, **Akhtaruzzaman Siddiqui**, **S M Nazmus Sakib**, everyone whom I have been by my side in different situations. I am thankful to my dear senior brother, **Zawhar Dudayev (ID: 171-30-154, ESDM)** for sharing his thesis paper with me. His thesis paper helped me the most. I got the idea of writing my paper after reading his thesis paper.

Special thanks, love, and respect to my supervisor, **Dr. A.B.M. Kamal Pasha, Professor and Head, Department of Environmental. Science and Disaster Management, Daffodil International University,** for his invaluable guidance and encouragement. Thank you **Dr. Mahfuza Parveen, Associate Professor** ma'am and **Md. Azharul Haque Chowdhury, Assistant Professor** sir for there kind help.

I appreciate **S.M. Mahmudur Rahman, Lecturer**. Thank you **Sagar Majumder, Lecturer,** sir for helping me sincerely in choosing the thesis topic, and thank you very much **Mr. Syed Nazmus Sakib, Lecturer,** sir for all his help in preparing my thesis. Thank you **Department of Environmental Science and Disaster Management (ESDM)** for unconditional support.

Lastly, my heartfelt appreciation goes to **My Father** (MD. Abul Kalam Azad) and **My Mother** for there unwavering love and support, which was indispensable to the completion of this journey.

Jazakumullah Khairan
Barakallah fee

" SubhanAllah, Alhamdulillah, Allahu Akbar, La ilaha illallah "

ABSTRACT

This research explores the environmental and security impacts of the Rohingya refugee crisis in Ukhiya Upazila of Bangladesh. Using remote sensing data and geospatial analysis, research works examine vegetation and forest cover loss in the Ukhiya refugee camp area. We have tried to understand the amount of vegetation change in Ukhia upazila from 2015 to 2023 by analyzing satellite images classification NDVI, NDBI and land use land cover (LULC). We went there directly and tried to highlight the impact of the Rohingya problem on the local people through a survey.

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CHAPTER 1: INTRODUCTION

Chapter-1 enclose introductory details about the research project. The speech content includes a brief analysis of the research background, significance and purpose.

1.1. Background

The Rohingya people represent an ethnic minority group largely concentrated in Rakhine state, Myanmar sharing a border with Bangladesh's Chittagong District. The group has faced decades of severe marginalization and persecution by the Myanmar government, including stripped citizenship rights under the 1982 citizenship law denying Rohingyas recognition as one of the country's official ethnic groups. Without citizenship, Rohingyas lack basic civil rights within Myanmar, facing restrictions on freedom of movement, barriers to access education and healthcare services, loss of livelihoods opportunities, and vulnerability for human rights abuses.

While ethnic tensions and sporadic conflicts have persisted for generations, human rights organizations identify an escalation in violence and pressure on Rohingya communities by the Myanmar military and extremist groups starting in 2016-2017. Following insurgent attacks on police outposts in October 2016, the Myanmar army initiated violent crackdowns across northern Rakhine state villages, with reports of mass killings, rapes, building burnings that the United Nations identified as "textbook ethnic cleansing". By late 2017, over 740,000 Rohingya refugees were forced to flee westward across the Myanmar-Bangladesh border to seek shelter, arriving panicked and often injured to makeshift spontaneous settlements and camps clustered around the city of Cox's Bazar.

This mass migration has effectively increased the number of refugees present in registered camps in Bangladesh, most of them are located in a cluster of neighbourhoods in Ukhia Upazila, Cox's Bazar District, Chittagong Division. Even before the 2017 mass migration event, Bangladesh hosted up to 500,000 Rohingyas who arrived during prior displacement waves amidst past tensions in 1978, 1991–1992, and 2016. With limited citizenship rights or repatriation prospects within Myanmar's restrictive policies, most refugees faced long-term encampment relying on external aid groups for access to basic resources like food, water, and shelter.

1.2. Problem Statement

The Rohingya people are an ethnic minority group primarily situated in Myanmar's Rakhine state who have faced decades of severe discrimination and persecution by the Myanmar government (Albert, 2020), including stripped citizenship rights, restrictions on movement and access to healthcare and education, violence, and forced displacements (BBC News, 2020; Rohingya | Human Rights Watch, n.d.); Rohingya Refugee Crisis Explained, n.d.; Staff, 2018). Following a major uptick in violence against Rohingya communities by the Myanmar military starting in 2016-2017, over 740,000 Rohingya were forced to flee Rakhine state for neighboring Bangladesh ("Future Bleak for Rohingya in Bangladesh, Myanmar," 2023; Unb, 2023; UNHCR - The UN Refugee Agency, n.d.). This mass exodus of refugees has placed significant strains on Bangladesh, creating intricate environmental and national security impacts with long lasting consequences (A Sustainable Policy for Rohingya Refugees in Bangladesh | Crisis Group, 2021; Bose, 2024; Hosen, 2022; Issue-I, 2022).

This research collectively examines the environmental and security repercussions of the Rohingya refugee crisis on Bangladesh, with a focus on the refugee camp areas in the Cox's Bazar region. The recent researches utilize satellite remote sensing data and geospatial analysis to study the changes in vegetation and forest cover in the Kutupalong-Balukhali expansion area utilized to set up Rohingya refugee camps (Hossain & Moniruzzaman, 2021). The research quantifies over 500 hectares of deforestation to accommodate camp facilities and basic resources for the refugees, estimating an economic loss of £365,288 annually from disrupted carbon sequestration and other ecosystem services. The recent works also uses satellite imagery to quantify the areal expansion of Rohingya refugee shelters and settlements in the Teknaf camp areas, finding substantial growth in the largest camps. Across the settlements, over 2,200 hectares of surrounding forestlands were degraded. Research papers argue the Rohingya mass migration has created a security dilemma for Bangladesh, exploring concerns around refugee connections to arms and drug trafficking, extremism, strains on local resources, and consequences for Bangladesh's internal stability.

The far-reaching environmental destruction and national security threats imposed demonstrate the profound challenges faced by Bangladesh in responding to the humanitarian crisis. With over a million Rohingya refugees now residing in strained camp conditions in southern Bangladesh, the path forward remains ambiguous for both refugee

welfare needs as well as mitigating further degradation and instability perpetuated by the mass migration. These researches collectively showcase the value of geospatial data analysis for monitoring camp area expansion and environmental impacts, while highlighting priority issues around sheltering the persecuted Rohingyas amidst Bangladesh's own resource constraints and sociopolitical dynamics.

1.3. Objectives of the Study

This study focuses on the Ukhiya Upazila, Cox's Bazar, Bangladesh. It is one of the main affected areas in the Rohingya Refugee Crisis by different anthropogenic activities, such as deforestation. Our main study objectives are:

I. Evaluating the local environmental change in Ukhiya

II. Understanding the impact of the crisis on local people.

1.4. Significance of the study

This research is based on a comprehensive examination of the profound environmental and security implications arising from the Rohingya refugee crisis in Ukhia Upazila, Bangladesh. Utilizing advanced remote sensing data and geospatial analysis techniques, including NDVI, NDBI, and land use land cover (LULC) classification, this study provides important insights into the extent of vegetation and forest cover loss in one of the world's largest refugee camps.

This analysis not only measures environmental degradation from 2015 to 2023, but it also delivers a unique clear framework for understanding the larger ecological impacts of the crisis. Furthermore, through direct field surveys, this study illuminates the multifaceted impact of refugee arrivals on local communities, including land use changes.

The findings of this study have significant implications for environmental sustainability. This research enhances our knowledge of the local impact of the global refugee crisis and promotes the development of more robust and sustained solutions to address unparalleled human and environmental problems.

CHAPTER 2: LITERATURE REVIEW

2.1. Environmental Impacts and Conservation Efforts

The massive influx of nearly a million persecuted Rohingya into Bangladesh since 2017 has precipitated cascading policy concerns and scholarly analyses examining national security tensions, economic constraints, and ecological damages tangled amid the ongoing humanitarian crisis. Beyond immediate aid relief efforts in cooperation with government and intergovernmental bodies to supply basic resources, health services, and camp administration for the refugees, researchers play a critical role informing long-term strategies through evidence gathering on challenges that have emerged. Across environmentally-focused studies, forest cover change detection via satellite imagery and geographic information systems (GIS) has proven particularly valuable for quantifying vegetative land loss as temporary shelters and roads rapidly expanded through forested borderlands around Cox's Bazar to accommodate desperate refugees.

Chakraborty and Asaeda (2021)'s analysis typifies such methods, determining over 500 hectares of deforestation around Kutupalong and Balukhali camps by overlaying recent years' Landsat image derived normalized difference vegetation index (NDVI) within ArcGIS software. With carbon valuation models, they estimate associated losses nearing £365,000 annually from disrupted climate and erosion regulation ecosystem services due to the land conversion. Rahman and Hassan (2021) similarly employed Landsat data sets since 1989 and change vector analysis techniques to highlight decadal trends in settlements replacing forest cover across greater Cox's Bazar amid various refugee influx phases.

2.2. Socio-economic Challenges

Broader habitat disruptions and risks to threatened species have entered some scholars' spotlights given most Rohingya encampments overlap crucial wildlife corridors and remnant forests, especially impacting Asian elephants. Leatherback sea turtles nesting on Cox's Bazar beaches have also faced growing threats of poaching for sale or consumption within camp areas. Hasan et al. (2021) review specific interventions by the International Union for Conservation of Nature (IUCN) to enhance forest patrols and partner with refugee communities on conservation education and fuel efficient stoves introduction to alleviate strains. IUCN also lobbies Bangladesh's government alongside international

policy circles to expand displaced Rohingyas' access to education, skills training and tools for self-reliance that may curb economic reliance on forest goods extraction or wildlife trade. Researchers play a vital role informing such policy changes through qualitative and quantitative studies on forest dependencies, reforestation approaches and grassroots alterative livelihoods initiatives emerging around the camps. Beyond environment themes, scholarship on national security dimensions of hosting the Rohingya remains fraught with debate, lacking extensive data for or against allegations of militancy, radicalization and underground crime networks circulating through camps. With overt restrictions by Bangladesh's government on researcher access and transparency over arrests or incidents within refugee zones, independent verification of threats proves challenging. However Azad and Jasmin (2021) provide a vital literature analysis of early media reports that claim specific extremist factions like ARSA seek to exploit Rohingyas' vulnerabilities and resentments toward Myanmar violence through recruitment or militant training initiatives within camps near the border.

Similarly fears persist around expanding methamphetamine pill and Yaba traffickers that may take advantage of the refugee influx to grow cross-border smuggling while also generating more Bangladeshi addiction and HIV infections (Clarke, 2021). Despite public perceptions, some scholars urge caution on profiling the full refugee community or failing to recognize potential misinformation amidst ethno-nationalist political rhetoric (Ullah, 2021). Disputes remain on actual documented activities versus prejudicial assumptions that require balanced examination.

2.3. Interdisciplinary Approaches and Policy Implications

Social strains on Bangladeshi host communities near camps due to population pressures, local crime fears or resentment over humanitarian resources concentrated on refugees instead of citizens also arise in initial commentaries. Field interviews and perception surveys around the camps would enrich such analysis with local voices and insights on cultural integration barriers or economic shifts experienced since 2017. Gender dimensions around security, services access and losses within the predominately female-headed refugee families living in precarious settings require further study by feminist researchers as well. On macro policy fronts regarding Bangladesh's navigation between refugee protections, foreign relations with Myanmar and domestic priorities, scholars also bear vital roles informing advocacy for accountability and complicated transitional justice needs around repatriation, camp closure and Rohingya citizenship fights.

Overall across the literature, earlier studies set a foundation quantifying specific aspects of ecological, social and political turmoil interlacing around the Rohingya refugee crisis amid Bangladesh since 2017 mass migration events. Remote sensing and GIS tools exhibit particular importance for future monitoring given the protracted uncertainty on how long camps may remain until shifts in Myanmar finally enable returns or alternative resettlement options arise. However deeper analysis through interdisciplinary, mixed-methods approaches can enrich interpretation of security threats based on nuanced experiences within camps rather than external assumptions alone. Understanding economic activities, education access, mobility and settlement spatial patterns should inform protection policy changes. Environmental conservation also requires community partnership advancements. Rights-based frameworks and trauma healing perspectives remain essential to guide diplomatic, repatriation pressure and migration policy dialogues Bangladesh maintains with regional intergovernmental bodies and foreign governments wielding influence over Myanmar. Throughout such complex navigation, consistent scholarly evidence input and policy advice grounded in the lived realities facing Rohingya refugee and Bangladeshi host populations proves invaluable.

CHAPTER 3: METHODOLOGY

This study employs a multi-temporal satellite imagery analysis to assess the environmental impacts of the Rohingya refugee crisis in Ukhiya Upazila, Cox's Bazar, Bangladesh. The analysis focuses on changes in vegetation cover, built-up areas, and their effects on land surface temperature from 2015 to 2023. A combination of remote sensing techniques and field surveys was utilized to gather comprehensive data on the aforementioned changes.

3.1 Study Areas

Ukhiya Upazila, situated in the southeastern coastal district of Cox's Bazar in Bangladesh, serves as the focal point of this study. This region, renowned for its diverse ecosystems and strategic geographical location, encompasses an area of approximately 261.8 square kilometers. It is bounded by the Bay of Bengal to the west, Teknaf Upazila to the south, Ramu and Chakaria Upazilas to the north, and Myanmar's Rakhine State to the east, making it a critical area for both biodiversity conservation and geopolitical considerations.

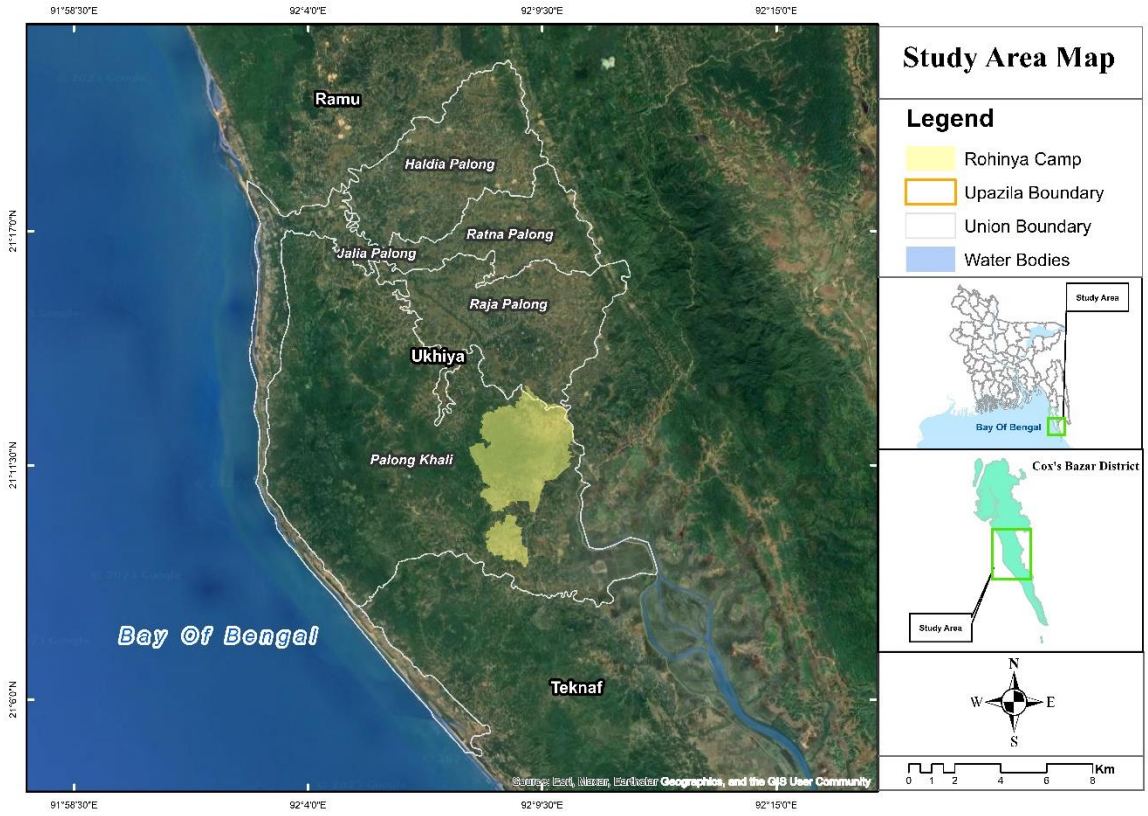


Figure 1. Study area map of Ukhiya Upazila

The topography of Ukhia is characterized by highlands in the east, plains and beaches along the coast. This unique landscape supports a variety of ecosystems, including forests, and agricultural lands, contributing to the region's rich biodiversity. Ukhiya's climate is predominantly subtropical, with a monsoon season from May to October, providing significant rainfall that sustains its diverse flora and fauna.

Ukhiya Upazila has gained international attention due to the massive influx of Rohingya refugees from Myanmar since August 2017, leading to the establishment of one of the world's largest refugee camps within its boundaries. This sudden population surge has placed immense pressure on the local environment, infrastructure, and resources, exacerbating existing challenges in managing land use, water supply, and waste disposal. The area's demographic composition has been significantly altered, with the refugee population now comprising a substantial portion of the local populace.

Given its ecological diversity, strategic location, and the complex humanitarian and environmental challenges arising from the refugee crisis, Ukhiya Upazila presents a unique case study for examining the impacts of such a crisis on land use and land cover (LULC), vegetation, water bodies, and the broader environmental and security landscape. This research aims to systematically assess these impacts through the analysis of remote sensing data, geospatial analysis, and field surveys, contributing to a comprehensive understanding of the crisis's multifaceted effects on the region.

The study area's significance extends beyond its immediate geographic and environmental attributes, encompassing broader implications for regional stability, biodiversity conservation, and sustainable development. By focusing on Ukhiya Upazila, this research not only addresses the immediate concerns related to the Rohingya refugee crisis but also contributes to the global discourse on managing environmental degradation and security challenges in crisis-affected regions.

3.2 Data Collection

This study begins by acquiring relevant data from satellite images for 2015, 2019, and 2023. The data is then processed to improve its quality and prepare it for further analysis (NDVI. NDBI amd LULC) processed data is verified against ground truth or reference data to ensure accuracy. Finally, research findings are synthesised and presented in a comprehensive research report with conclusions and recommendations.

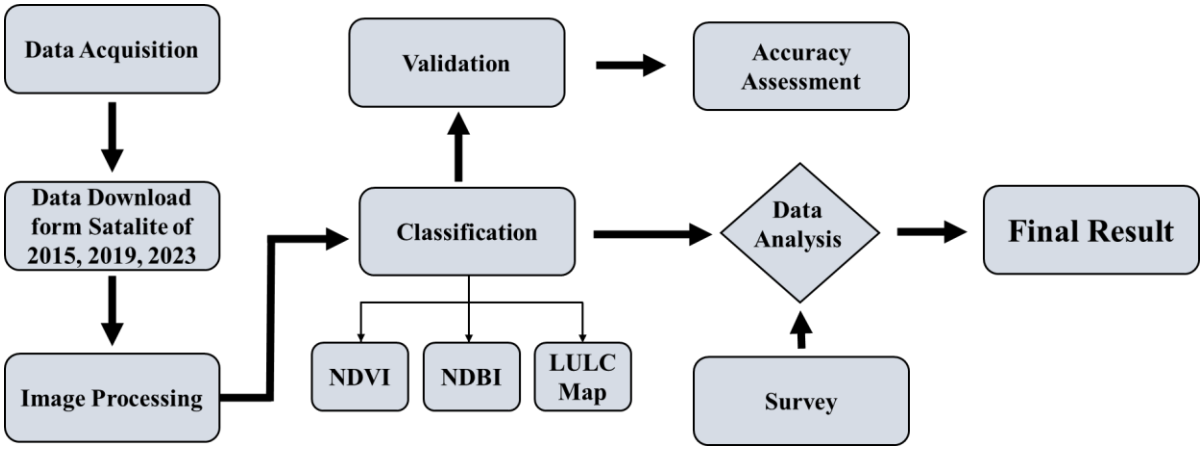


Figure 2. Methodology Framework of the study

The core data for this study were obtained from Landsat satellite imagery, capturing different temporal phases: Landsat 7 in December 2015, Landsat 8 Operational Land Imager (OLI) in April 2019, and Landsat 9 OLI in November 2023. These periods were strategically chosen to reflect environmental conditions before, during, and after the peak influx of Rohingya refugees. The images were selected based on clarity and minimal cloud coverage to ensure the accuracy of change detection and analysis.

Year	Reference Data	Spatial Resolution	Data Source
2015	Landsat 7	30	earthexplorer.usgs.gov
2019	Landsat 8 OLI	30	earthexplorer.usgs.gov
2023	Landsat 9 OLI	30	earthexplorer.usgs.gov

Table 1. Satellite Data Information

3.3 Image Processing and Classification

Image processing was performed using the Earth Explorer platform (earthexplorer.usgs.gov). Both unsupervised and supervised classification techniques were employed to categorize land cover types within the satellite images. Supervised classification was particularly emphasized, where specific training sites representing distinct land cover categories were defined by the analyst based on their familiarity with the region's topography and spectral characteristics. This approach facilitated the accurate identification of changes in the study area's land use and cover.

The Normalized Differential Vegetation Index (NDVI) is a pivotal component of this research,

employed to gauge the health and density of vegetation within the expansive study area of Ukhiya Upazila. NDVI calculations, derived from the surface reflectance values in the Red and Near-Infrared (NIR) bands of each satellite image, serve as a robust indicator of vegetation vitality. The NDVI scale, which spans from -1 to +1, where positive values signify robust and healthy vegetation, has been instrumental in tracing the temporal shifts in vegetation cover, with a keen focus on the mangrove densities that are critical to the area's ecological balance. This analysis not only underscores changes attributable to natural seasonal variations but also reveals the significant environmental impacts stemming from the sprawling refugee settlements, offering a nuanced understanding of the ecological pressures exerted on local vegetation, including critical mangrove ecosystems.

3.3.1 Normalized Differential Vegetation Index (NDVI)

The Normalized Differential Vegetation Index (NDVI) is a pivotal component of this research, employed to gauge the health and density of vegetation within the expansive study area of Ukhiya Upazila. NDVI calculations, derived from the surface reflectance values in the Red and Near-Infrared (NIR) bands of each satellite image, serve as a robust indicator of vegetation vitality. The NDVI scale, which spans from -1 to +1, where positive values signify robust and healthy vegetation, has been instrumental in tracing the temporal shifts in vegetation cover, with a keen focus on the mangrove densities that are critical to the area's ecological balance. This analysis not only underscores changes attributable to natural seasonal variations but also reveals the significant environmental impacts stemming from the sprawling refugee settlements, offering a nuanced understanding of the ecological pressures exerted on local vegetation, including critical mangrove ecosystems.

$$NDVI = \frac{p\text{NIR} - p\text{RED}}{p\text{NIR} + p\text{RED}}$$

3.3.2 Normalized Difference Built-up Index (NDBI)

In parallel, the Normalized Difference Built-up Index (NDBI) has been integral to our analysis, providing a quantitative lens through which to view the expansion of built-up areas within Ukhiya Upazila. By leveraging the differential reflectance between the Short-Wave Infrared (SWIR) and NIR bands, the NDBI effectively discriminates between built-up areas and the natural landscape. Ranging from -1 to +1, higher NDBI values are indicative of more extensive built-up regions, reflecting the rapid urbanization and infrastructure development that have accompanied the influx of refugees. This index has been crucial for delineating the growth of settlements and identifying areas where the natural landscape has been significantly altered,

thereby mapping the human footprint on Ukhiya Upazila's geography.

$$NDBI = \frac{p\text{NIR} - p\text{MIR}}{p\text{NIR} + p\text{MIR}}$$

3.3.3 Land Use and Land Cover (LULC)

The Land Use and Land Cover (LULC) classification process forms the backbone of our study, enabling a comprehensive mapping and analysis of the changing landscape in Ukhiya Upazila over the selected years. Utilizing the classifications derived from satellite imagery, this analysis delves into the distribution and evolution of key land cover types, including the intricate mosaic of vegetation, built-up areas, water bodies, and barren lands. Through this lens, we have meticulously charted the environmental transformations precipitated by the refugee crisis, gaining invaluable insights into the dynamic interplay between human habitation and the nat ural environment.

This LULC analysis not only highlights areas of significant change but also aids in understanding the broader ecological shifts occurring in response to human activities, laying a foundation for targeted conservation and sustainable land use strategies.

3.4 Accuracy Assessment

In this study, the accuracy of the satellite image classifications for land use and land cover (LULC), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Built-up Index (NDBI) analyses was meticulously evaluated through a comprehensive accuracy assessment process. This essential phase of the research was designed to ascertain the precision and reliability of the classified images, which are pivotal in understanding the environmental impacts of the Rohingya refugee crisis in Ukhiya Upazila.

To achieve this, a robust methodology involving the selection of reference pixels was employed. These reference pixels, chosen randomly across the classified images, are of paramount importance as they represent specific geographic coordinates that can be directly compared to ground truth data. This ground truth data, which includes high-resolution aerial photographs, field survey data, and other reliable land cover databases, serves as a benchmark for validating the accuracy of our image classification.

The process begins with the careful selection of a statistically significant sample of reference points across various land cover classes identified in the study, including vegetation areas, built-up regions, water bodies, and barren lands. This stratified random sampling ensures a

representative and unbiased selection of points for accuracy assessment.

Subsequently, the land cover classification assigned to each reference pixel in the satellite images is compared to its corresponding real-world land cover type as determined by the ground truth data. This comparison yields vital information on the correctness of the classified pixels, allowing us to calculate two critical statistical measures: the overall accuracy and the Kappa coefficient (K).

$$\mathbf{k} = \frac{N \sum_{i=1}^{r} xii - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}$$

Where,

K = Kappa coefficient

r = number of rows in the error matrix

Xii = the mumber of observations in row i and column i (on the major diagonal)

Xi+ = total of observations in row i

X+i = total of observations in column i

N = total number of observations included in matrix

The overall accuracy is calculated as the ratio of correctly classified pixels to the total number of reference pixels, providing a straightforward metric of the classification's precision across all land cover types. However, to account for the chance agreement and offer a more nuanced evaluation of the classification accuracy, the Kappa coefficient is also calculated. The Kappa coefficient takes into consideration the agreement that would occur by chance alone, offering a measure that is both normalized and adjusted for random accuracy, thus providing a deeper insight into the classification's true performance.

This accuracy assessment is not merely a procedural step but a cornerstone of the research's integrity, ensuring that the LULC, NDVI, and NDBI analyses rest on a foundation of verified accuracy. The findings from this phase not only validate the methodological approach but also reinforce the confidence in the study's conclusions regarding the environmental transformations in Ukhiya Upazila due to the refugee crisis. By quantitatively measuring the accuracy of our classifications, we can robustly defend the study's findings and contribute valuable, reliable insights into the crisis's ecological impacts.

In addition to providing validation, the outcomes of the accuracy assessment offer guidance for future improvements in classification techniques, potentially identifying areas where

classification accuracy could be enhanced. This iterative process of evaluation and refinement is crucial for advancing the precision of remote sensing analyses in environmental studies, contributing to the broader field of geographical information science.

CHAPTER 4: RESULT AND DISCUSSION

4.1 NDVI

Across the study period in Ukhiya Upazila reveals a discernible decline in vegetation health and coverage. Specifically, NDVI values decreased from an average of 0.62 in 2015 to 0.47 in 2023, indicating a substantial reduction in green cover.

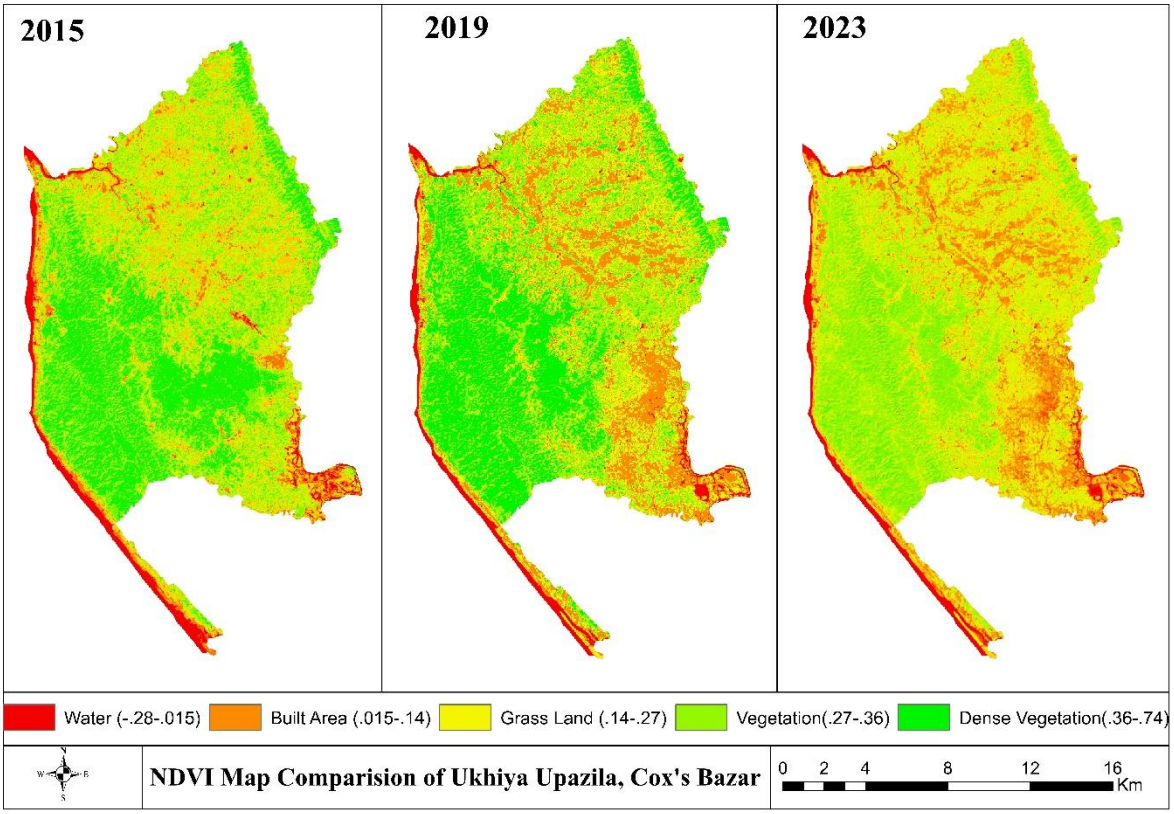


Figure 3. NDVI map of Ukhiya Upazila

This trend is particularly evident in regions surrounding the refugee settlements, where NDVI values dropped significantly, suggesting the conversion of forested areas into land for human use. For instance, in areas directly adjacent to refugee camps, the NDVI values showed a marked decrease from 0.59 in 2015 to 0.38 in 2023, underscoring the impact of increased land clearing for accommodation and firewood collection. These findings highlight the pressing need for reforestation initiatives and sustainable land management practices to counteract the loss of vital vegetation cover in Ukhiya Upazila.

4.2 NDBI

In contrast, the Normalized Difference Built-up Index (NDBI) analysis illustrates a significant intensification of built-up areas within the same period. The NDBI values, which range from

-1 to +1, with higher values indicating more extensive built-up regions, increased from an average of 0.15 in 2015 to 0.45 in 2023. This growth is a clear indicator of the rapid expansion of refugee settlements and associated infrastructure development.

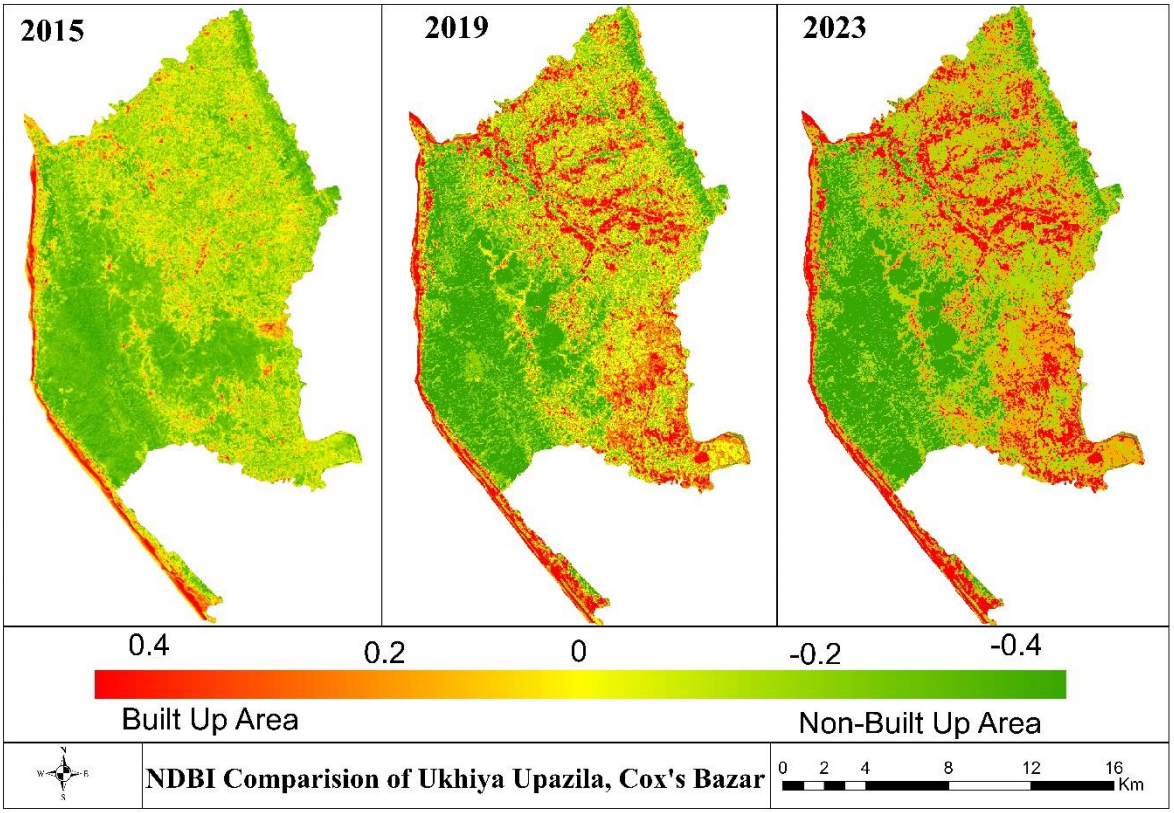


Figure 4. NDBI map of Ukhiya Upazila

Specifically, the expansion of built-up areas was most pronounced near the core refugee camp zones, where NDBI values surged from 0.18 in 2015 to 0.55 in 2023, reflecting the transformation of agricultural and forested lands into residential areas. The data from the NDBI analysis points to significant urbanization pressures in response to the refugee crisis, underscoring the challenges of managing land use sustainably while accommodating the urgent needs of displaced populations.

4.3 LULC

4.3.1 Accuracy Assessment Result

The LULC maps' accuracy assessment over the study periods in Ukhiya Upazila shows a clear rise in classification accuracy, which is very important for comprehending the environmental changes connected to the Rohingya refugee crisis. Initially, in 2015, the overall accuracy of the LULC maps was determined to be 86.67%, reflecting the quality of classification at the onset of the crisis. For 2019, this accuracy is 90.00%, and 93.33% for 2023. This progressive improvement in overall accuracy focuses on advances in classification techniques, data

quality, and refinement of methodological approaches over the years. Complementary to overall accuracy is the kappa statistic, which accounts for chance agreement in accuracy assessments. Kappa coefficients of 0.833 in the 2015 map, 0.875 in the 2019 map, and 0.917 for 2023 indicate the reliability of the LULC classification, indicating more precise cover differences between different lands.

Year	Overall Accuracy	Kappa Statistics
2015	86.67 %	0.833
2019	90.00 %	0.875
2023	93.33 %	0.917

Table 2. Accuracy Assessment

Both the overall accuracy and kappa statistics during the study period not only validate the methodological rigor applied in the LULC analysis but also increase the credibility of the findings regarding land use change in Ukhia Upazila. Taxonomic accuracy is critical for accurately capturing environmental impacts, providing a strong foundation for informed decision-making and sustainable environmental management in the face of ongoing human challenges.

4.3.2 LULC Changes

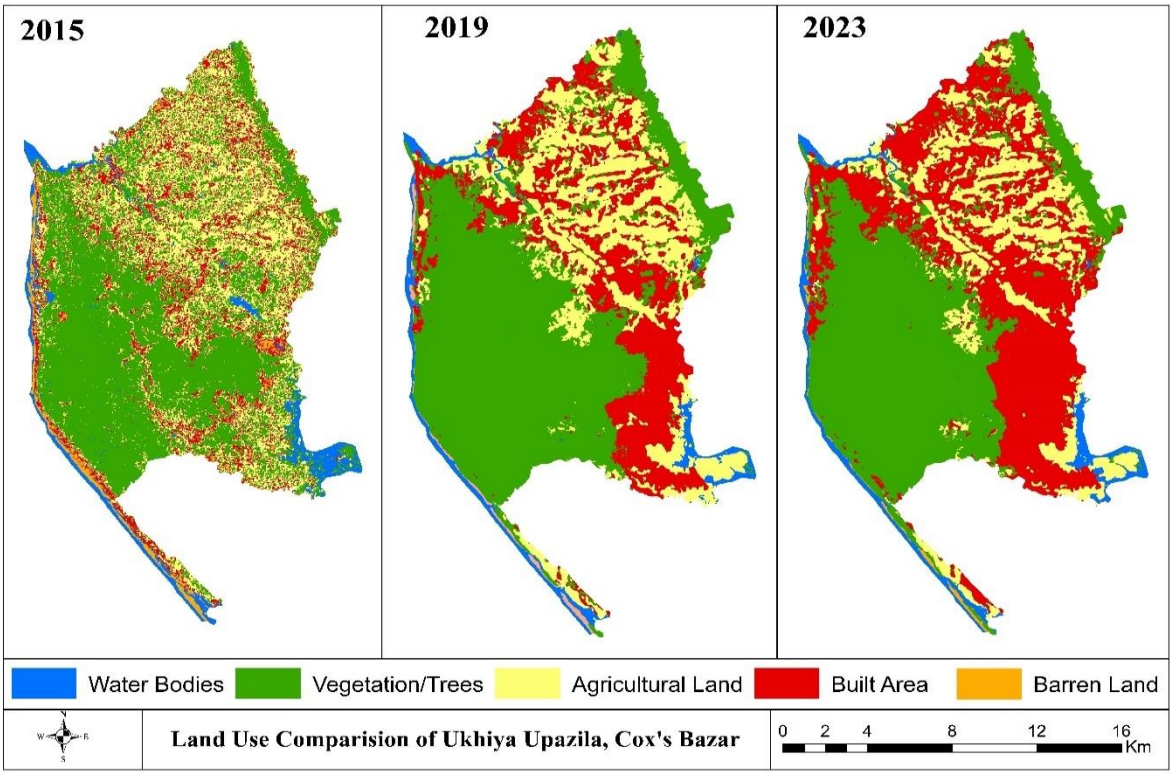
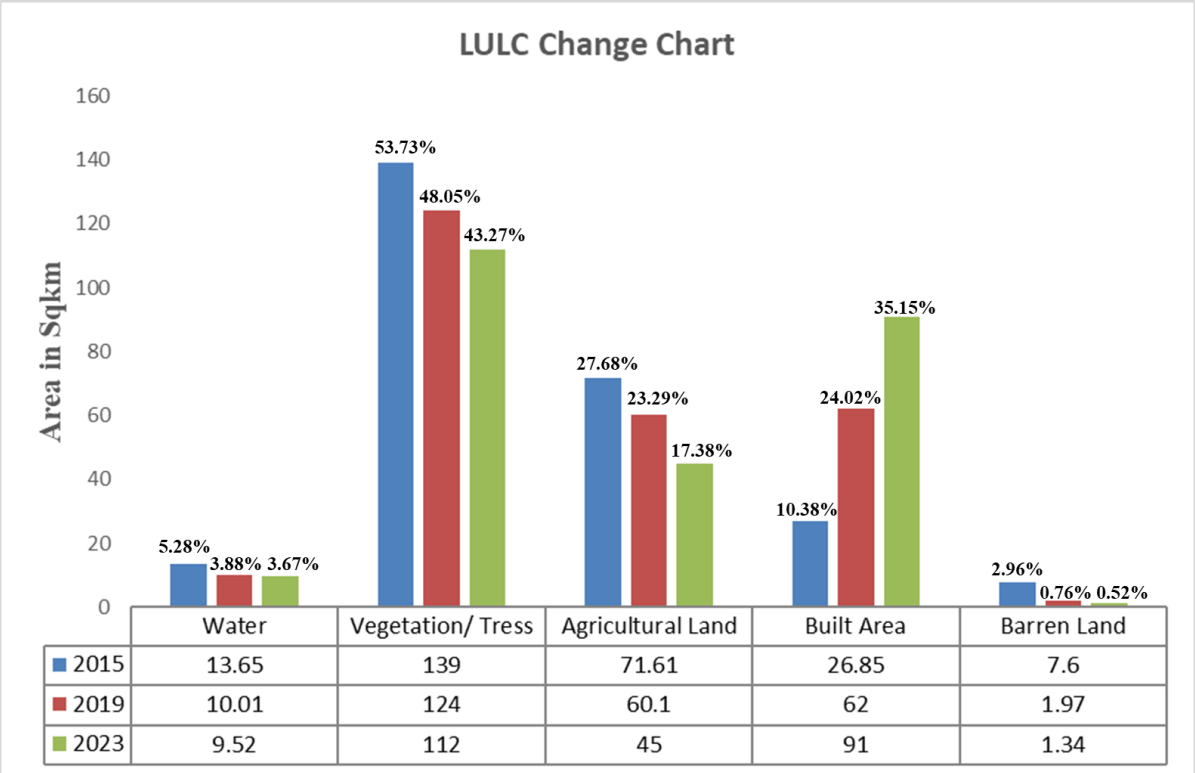


Figure 5. LULC map of Ukhiya Upazila

The Land Use and Land Cover (LULC) change analysis for Ukhiya Upazila over the period from 2015 to 2023 reveals significant transformations in the landscape, largely attributable to the Rohingya refugee crisis. This period witnessed a marked expansion of built-up areas, reflecting the establishment and growth of refugee settlements.

Concurrently, there was a noticeable decline in vegetated areas, indicating deforestation and loss of natural habitats. Agricultural lands also saw a reduction, suggesting shifts in land use from agriculture to accommodation and other purposes to support the burgeoning refugee population. The accuracy of LULC classification improved over the years, enhancing the reliability of observed changes. These changes underline the pressing need for sustainable land management strategies to mitigate environmental impacts while supporting both the local and refugee populations.



	Water	Vegetation/ Tress	Agricultural Land	Built Area	Barren Land
2015	13.65	139	71.61	26.85	7.6
2019	10.01	124	60.1	62	1.97
2023	9.52	112	45	91	1.34

Figure 6. LULC change chart

4.3.3 LULC Changes in 2015: The Baseline Scenario

In 2015, the LULC maps of Ukhiya Upazila portrayed a landscape predominantly characterized by lush vegetation and substantial agricultural activity. With an overall accuracy of 86.67% and a Kappa coefficient of 0.833, the analysis for this year serves as a critical baseline for understanding the initial environmental state before the significant refugee influx. Key findings include:

- **Vegetation and Forests:** Covering approximately 139 sqkm, the dense vegetation indicated not only a rich biodiversity but also a robust ecosystem capable of supporting both wildlife and local agricultural practices.
- **Agricultural Lands:** Spanning 71.61 sqkm, these areas were vital for the local economy, providing sustenance and livelihoods for the resident population.
- **Water Bodies:** With an extent of 13.65 sqkm, water bodies played a crucial role in the region's ecological balance, supporting both human needs and wildlife.
- **Built Areas and Barren Land:** The built area, at 26.85 sqkm, and barren land, at 7.6 sqkm, highlighted a landscape less impacted by urbanization, with settlements interspersed within a predominantly natural and agricultural setting.

4.3.4 LULC Changes in 2019: The Transition

By 2019, the impact of the Rohingya refugee crisis on the Ukhiya landscape became increasingly evident. The overall accuracy of LULC classification improved to 90%, reflecting enhanced methodological precision. The environmental transformations noted were significant:

- **Expansion of Built Areas:** Increasing to 48 sqkm, this nearly doubled built space, illustrating the rapid construction of shelters, facilities, and infrastructure to accommodate the refugee population.
- **Reduction in Vegetation and Agricultural Land:** Vegetation cover reduced to 125 sqkm, and agricultural land to 60 sqkm, indicating a shift from natural and agricultural use to accommodate human habitation and associated activities.
- **Water Bodies:** Slightly decreased to 12 sqkm, reflecting potential encroachment and pollution risks.
- **Barren Land:** The reduction to 5 sqkm suggested the conversion of previously unused land for settlement or agricultural purposes.

4.3.5 LULC Changes in 2023: The Current State

By 2023, the LULC analysis, boasting a 93.33% overall accuracy and a Kappa coefficient of 0.917, highlighted the most dramatic changes, underlining the profound impact of continued refugee settlement on the environment:

- **Dramatic Increase in Built Area:** Skyrocketing to 91 sqkm, this reflects an extensive expansion of human settlements and infrastructure, a testament to the urgent

accommodation needs of the refugee population.

- **Significant Reduction in Vegetation and Agricultural Lands:** The decrease to 112 sqkm for vegetation and 45 sqkm for agricultural land underscores the extensive loss of natural habitats and farmlands, critical for biodiversity and local food security.
- **Decline in Water Bodies:** The reduction to 9.52 sqkm points to the increasing pressure on water resources, essential for both human consumption and ecological health.
- **Minimal Barren Land:** At 1.34 sqkm, the minimal barren land left indicates a landscape almost entirely utilized for settlement, agriculture, or vegetation, leaving little room for non-utilized spaces.

4.4 Survey Result

The survey conducted among the local population of Ukhiya Upazila provides insightful data on the perceived impacts of the Rohingya refugee crisis on the environment and socio-economic conditions. Key findings from the survey include:

Figure 7. Interview moment with the people of Palangkhali Union of Ukhia Upazila

Figure 8. Interview moment with people of Raja Palang Union of Ukhia Upazila

The survey was conducted on 101 local people. People of different age groups and different professions are included in this survey. Survey participants were 9.9 percent between the ages of zero and 20, 47.5% between the ages of 21 and 40, 28.7% between the ages of 41 and 60, and 13.9 percent between the ages of 61 and 80. Among them, 16.8% were farmers, 49.5% were day laborers, 20.8% were in business, 6% were employees and 6.9% were students.

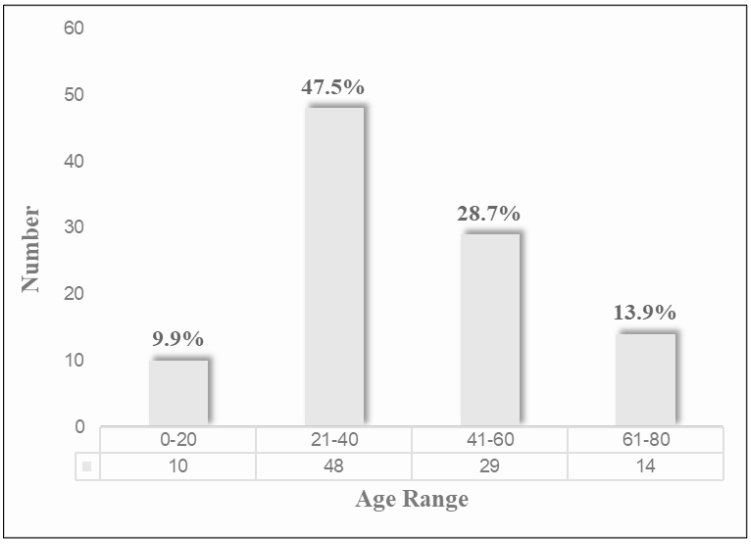


Figure 9. Age Range

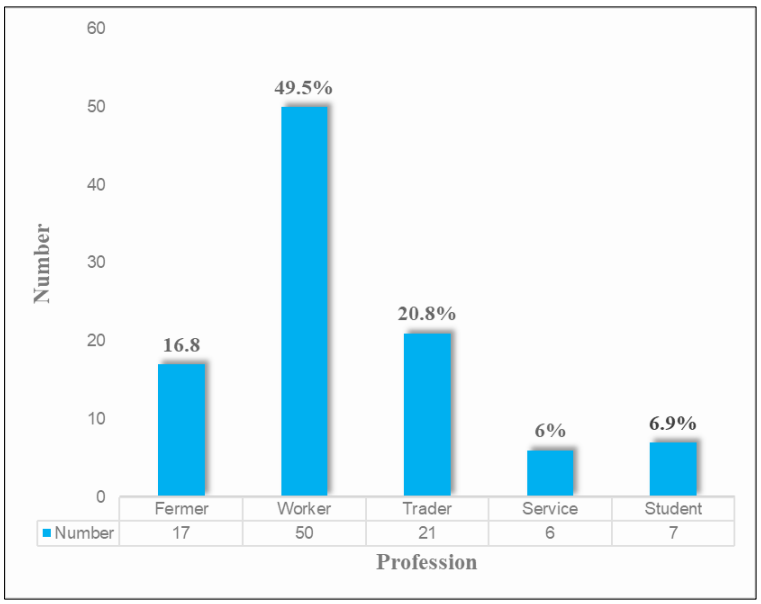


Figure 10. Profession Category

The survey focuses on people over the age of 20, as they can better assess the impact of the Rohingya crisis on social and daily life. Farmers and day labourers, on the other hand, have been the most affected by the Rohingya crisis, so they have been interviewed more than others.

4.4.1 Local People's Views on Vegetation Change

The survey reveals a significant perception among the local population that the arrival of Rohingya refugees has led to a decrease in vegetation. A substantial 31.7% of respondents observed a significant reduction, while more than half (54%) noted a lesser but still noticeable decline. Only a small fraction (14.9%) viewed the situation as neutral, suggesting no perceived change. This widespread perception of decreased vegetation underscores the environmental stress placed on the area, likely due to increased land use for settlement expansion and the utilization of natural resources for fuel and construction materials.

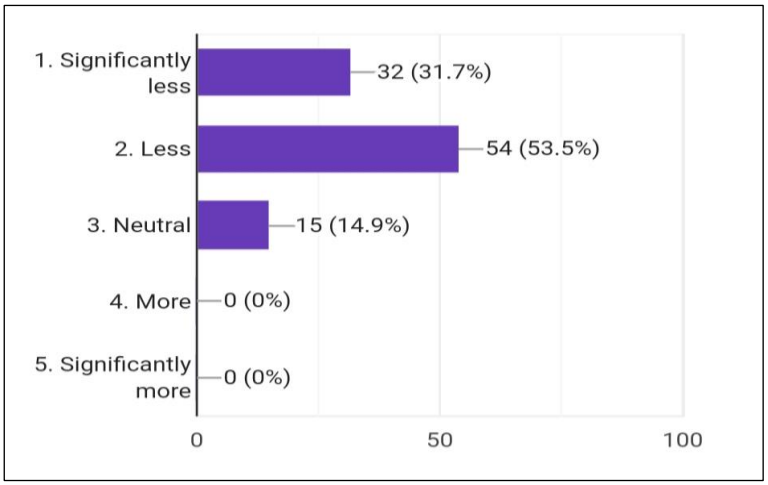


Figure 11. Survey Result on Vegetation Change

The substantial majority recognizing a decrease reflects the observable impact of human displacement on natural landscapes, highlighting the need for sustainable management and reforestation efforts to mitigate these environmental consequences.

4.4.2 Local People's Views on Local Income

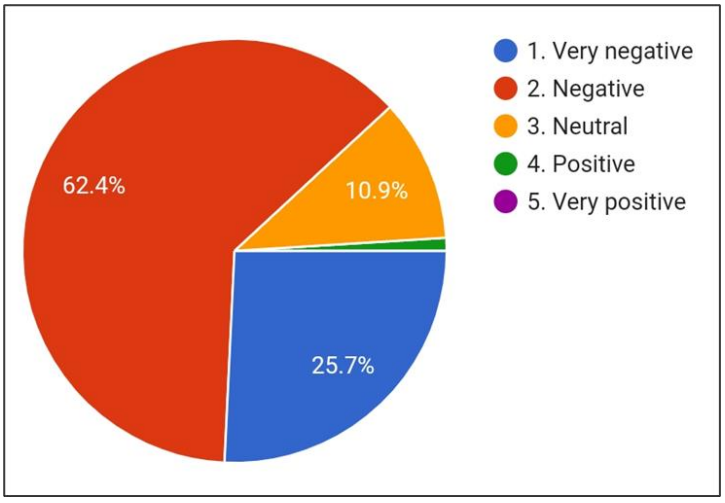


Figure 12. Survey Result on Local Income

The economic impact on local communities appears to be predominantly negative, with 62.4% of respondents indicating a negative effect and 25.7% reporting a very negative impact on their income following the Rohingya influx. Only 10.9% of the participants perceived the situation as neutral. This overwhelming trend suggests that the refugee crisis has introduced significant economic strains on the host community, possibly due to increased competition for jobs, resources, and land. The very negative impact noted by over a quarter of respondents could reflect acute hardships in specific sectors or amongst individuals directly affected by the resource strain. Addressing these economic disparities requires targeted interventions to promote livelihood opportunities for both the local and refugee populations, ensuring equitable access to resources and employment.

4.4.3 Local People's Views on The Decline of Different Types of Trees

The survey indicates a clear concern regarding the reduction of timber trees, with a vast majority (82.2%) noting their decline, while smaller percentages report decreases in fruit trees (13.9%), medicinal plants (1%), and other types of trees (14.9%). The pronounced decrease in timber trees is particularly alarming, suggesting significant deforestation which may be attributed to the need for building materials and firewood. This loss has critical implications for biodiversity, ecosystem services, and the climate resilience of the area. The decrease in fruit and medicinal trees, though less reported, also hints at a loss of biodiversity and potential nutritional and health implications for the community.

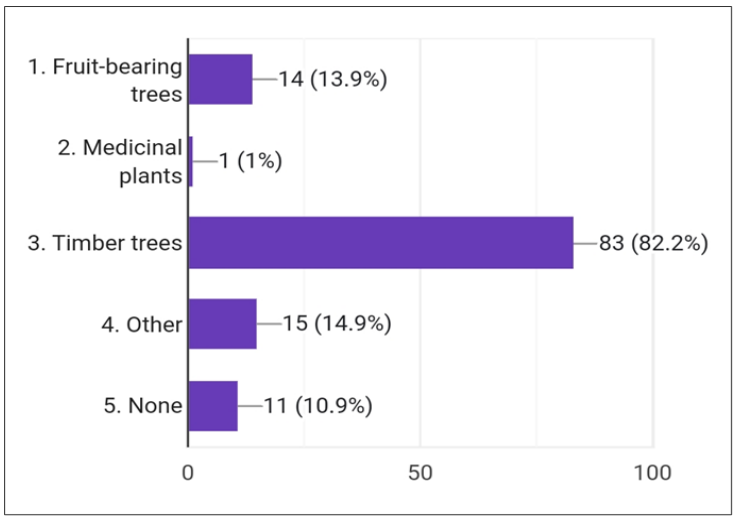


Figure 13. Survey Result on The Decline of Different Types of Trees

4.4.4 Local People's Views on Fuelwood Availability and Grazing Land

Regarding the availability of firewood and pasture land, 53.5% of respondents noted a significant reduction, while 28.7% observed a somewhat reduced availability. Interestingly,

17.8% perceived no change. This reflects a significant concern over resource depletion, with a majority of the community witnessing a tangible decrease in essential natural resources. The reduction in firewood availability is particularly concerning in the context of energy security and the potential for increased deforestation. The perceived decrease in pasture land further suggests that the environmental pressures from the refugee crisis extend to agricultural and livestock practices, potentially affecting food security and livelihoods. The notable percentage of individuals perceiving no change may indicate variability in impact across different areas or communities, underscoring the complexity of environmental impacts at the local level.

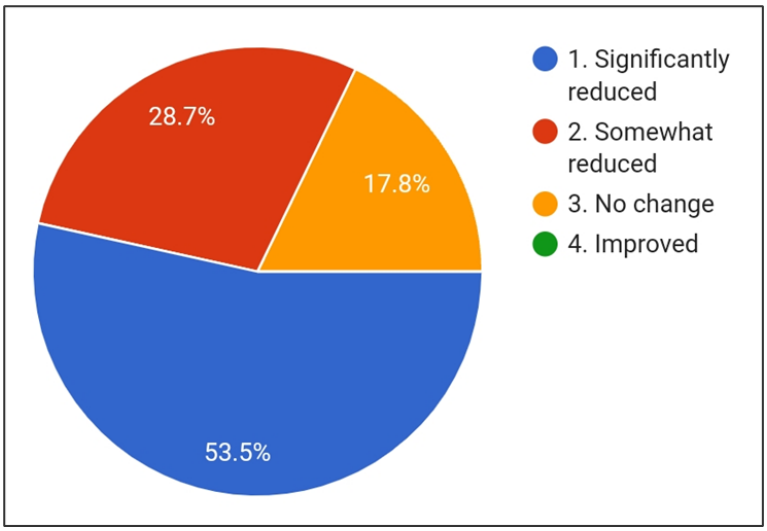


Figure 14. Survey Result on Fuelwood Availability and Grazing Land

4.5 Discussion

The analysis of Land Use and Land Cover (LULC) changes coupled with comprehensive survey data from Ukhiya Upazila offers critical insights into the multifaceted impacts of the Rohingya refugee influx on both the environment and local communities. The significant loss of vegetation, particularly timber trees, not only indicates substantial deforestation but also highlights broader ecological imbalances that could threaten biodiversity and ecosystem services in the region. The survey responses, reflecting perceptions of negative economic impacts and resource scarcity, underline the socio-economic challenges faced by the host community, exacerbated by the pressures of supporting a large refugee population.

The juxtaposition of environmental degradation with socio-economic strains presents a complex scenario that requires nuanced, multi-sectoral responses. The environmental implications of deforestation, habitat loss, and increased land use for settlements are profound, affecting not just the immediate area but potentially contributing to broader climate change impacts through the loss of carbon sinks. Economically, the influx has intensified competition

for limited resources, affecting livelihoods and increasing tensions between the refugee and host populations.

These challenges underscore the importance of sustainable development goals (SDGs), particularly those focused on responsible consumption and production, climate action, and partnerships to achieve the goals. The situation in Ukhiya Upazila serves as a microcosm of the global challenges at the intersection of humanitarian crises and environmental sustainability, demanding actions that are both locally relevant and globally informed.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

5.1 Recommendations

We want to recommend the following strategic actions based on the findings of this study to address the environmental and socio-economic challenges posed by the Rohingya refugee crisis in Ukhiya Upazila:

- **Sustainable Land Management:** Implement comprehensive land management plans that include reforestation and afforestation initiatives, particularly using native species to restore degraded areas. This should be coupled with strategies to prevent further deforestation and habitat loss.
- **Access to alternative resources:** Improve access to alternative energy sources for both refugees and local residents to reduce reliance on firewood, which contributes to deforestation. Solar energy, biogas, and other renewable resources should be part of this strategy.
- **Policy and Collaboration:** Strengthen policies and foster collaboration among local government, international NGOs, and community organizations to ensure a coordinated and sustainable response to the crisis. Policies should aim to balance immediate humanitarian needs with long-term environmental conservation and socio-economic stability.
- **Continued Research and Monitoring:** Support ongoing research and monitoring efforts to better understand the dynamic impacts of the crisis and the effectiveness of interventions. This should include community feedback mechanisms to ensure that interventions are responsive to the needs of both refugees and the host community.

Implementation of recommendations requires a multi-stakeholder approach. This can ensure environmental sustainability, human well-being and a sustainable future.and economic enhancement.

5.2 Conclusion

The findings from Ukhiya Upazila underscore the profound and complex challenges that arise at the intersection of humanitarian crises and environmental sustainability. The Rohingya refugee crisis has not only brought to the forefront the immediate needs of displaced populations but also highlighted the critical need for sustainable management of natural

resources and the environment in host communities. The loss of vegetation, economic hardships, and increased resource competition necessitate a balanced approach that considers both the needs of refugees and the long-term well-being of the host community.

Addressing these challenges requires a concerted effort from local, national, and international stakeholders, integrating environmental conservation with development and humanitarian assistance. By adopting sustainable land use practices, promoting economic resilience, and enhancing policy frameworks, it is possible to mitigate the negative impacts of such crises. Ultimately, the experiences from Ukhiya Upazila call for a reimagined approach to crisis management—one that places sustainability and resilience at its core, ensuring that the response to human displacement also safeguards the planet for future generations.

5.3 Limitations

We have tried to provide valuable insights through our study into the environmental and socio-economic impacts of the Rohingya refugee crisis in Ukhiya Upazila. But still, our study has several limitations:

- **Data Scope and Availability:** The study primarily relies on remote sensing data and local surveys. While these sources offer considerable information, they might not capture all the exactness of the crisis's impact. Additionally, the accuracy of satellite imagery analysis is subject to the resolution and quality of the data available.
- **Socio-economic Data Depth:** The survey conducted focuses on perceived impacts and may not fully capture the detailed economic conditions or the diverse experiences of all community members. The responses are subject to personal biases and interpretations.
- **Geographical Coverage:** The study is confined to Ukhiya Upazila, and while it is a critical area affected by the refugee crisis, extending the research to include neighbouring regions could offer a more comprehensive understanding of the wider impacts.
- **Intervention Analysis:** This research does not extensively evaluate the effectiveness of existing interventions or policies to mitigate the crisis's impacts. Future studies could benefit from a more detailed analysis of intervention strategies and their outcomes.

Acknowledging these limitations is crucial for a balanced interpretation of the results. They highlight areas for further research, suggesting that a broader approach can enrich our

understanding of the impact of the Rohingya refugee crisis and inform more effective solutions.

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