学 位 論 文 内 容 の 要 旨/Dissertation Abstract

博士（環境科学）　　氏 名/Applicant　NABILA Irtifa Alam

学 位 論 文 題 名/Title of Dissertation

Assessing human impacts on coastal ecosystems: a spatiotemporal analysis of land use, mangrove forest degradation and land surface temperature
(沿岸生態系に対する人為干渉の評価：土地利用、マングローブ林劣化、地表面温度の時空間分析)

This study addressed the rapid degradation of coastal ecosystems, particularly mangrove forests, caused by human activities, and aimed to quantitatively assess the spatial extent of ecosystem deterioration and the mechanisms of restoration to recover lost ecosystem services. Focusing on southern Bangladesh, where mangrove plantations have been maintained since 1966 for coastal protection, this research investigated the impacts of a Special Economic Zone (SEZ) started in 2016. In particular, this study examined whether the SEZ development has caused disturbances not only in adjacent forest areas but also in distant mangrove areas. This research set out to address three primary objectives: (1) to detect land use and land cover (LULC) changes in mangrove forests and surrounding areas (Chapter 1), (2) to evaluate the ecological impacts of SEZ development using the normalized difference vegetation index (NDVI) and a before-after-control-impact (BACI) design (Chapter 2), and (3) to analyze the effects of LULC changes on land surface temperature (LST) (Chapter 3). To achieve these goals, a multifaceted approach combining remote sensing (RS) techniques and field surveys was employed.

In Chapter 1, supervised classification using a random forest (RF) algorithm was conducted in Google Earth Engine to map vegetation across the study area (192 km^2), based on Landsat and Sentinel satellite imagery. The landscape was categorized into nine LULC classes with high classification accuracy ($\kappa > 0.71$). Built-up land was absent until 2014 but expanded rapidly to 13 km^2 by 2021. Forest cover increased to 43 km^2 in 2014 but declined to 36 km^2 by 2021. Transition matrix analysis revealed that forest loss was primarily due to conversion into built-up land, mudflats, bare land, and artificial water bodies, with notable

transitions also occurring in grassland areas. These findings clarified the spatial drivers of reduced mangrove resilience under increasing anthropogenic pressure.

In Chapter 2, high-resolution satellite imagery from IKONOS and TripleSat was utilized to evaluate changes in the NDVI before (2011) and after (2021) SEZ development, employing a BACI design. Vegetation surveys were conducted in 18 forest plots, where disturbance intensity was ranked based on severity and scale of ecosystem damage. NDVI declined across 17% of the study area, with pronounced reductions near roads and construction zones. All impact plots showed post-construction NDVI reduction more than control plots, with inland areas faring better than intermediate and seaside. The intensity of the disturbance was significantly correlated negatively with NDVI changes. The ecological impact extended up to approximately 20 km from the SEZ, a spatial scale rarely reported in previous studies. These results demonstrated the effectiveness of the BACI approach in RS, a context where it is rarely applied.

In Chapter 3, long-term dynamics of LST were analyzed at ten-year intervals using Landsat data from 1996 to 2025. LST, being associated with vegetation moisture and land cover differences, is increasingly applied in ecosystem assessment and environmental monitoring. NDVI, an indicator closely related to LST, showed an upward trend until 2014 but declined by 2025 due to mangrove loss driven by urban expansion. That year, the northern region recorded peak LST values exceeding 32.5°C. All LULC types showed an increase in LST. However, land recently converted from vegetated surfaces, such as forests, to built-up areas showed the highest LSTs. Analysis of 350 randomly sampled locations revealed a negative correlation between NDVI and LST, and a positive correlation between the normalized difference built-up index (NDBI) and LST. These results indicate that the combined influence of vegetation loss and built-up expansion primarily contributed to the rising LST in coastal ecosystems.

Taken together, the findings demonstrate that SEZ development has exerted substantial ecological impact on mangrove ecosystems both locally and across broader spatial scales. The conversion of mangrove forests to built-up land and associated shifts in land use have led to measurable degradation of vegetation and elevated land surface temperatures. By integrating LULC classification, BACI-based NDVI analysis and long-term LST monitoring, this study provides a comprehensive spatial assessment of ecosystem deterioration and resilience. The application of BACI designs to RS data proved effective in capturing the extent and severity of ecological disruption, offering a robust scientific foundation for future coastal ecosystem conservation and restoration efforts.