学 位 論 文 審 査 の 要 旨

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Geospatial analysis of urbanization dynamics and ecosystem services for sustainable urban development in Dhaka city, Bangladesh
（バングラデシュのダッカ市における持続可能な都市開発のための都市化動態と生態系サービスの地理空間分析）

Urbanization represents a defining social transformation of the contemporary era, presenting numerous challenges, including flooding, air pollution, and the urban heat island effect, particularly in urban centers like Dhaka. Urbanization dynamics and ecosystem services (ES) assessments are important for fostering urban resilience and sustainable development. Dhaka's rapid urbanization has significantly impacted its natural capital, altered land use and land cover (LULC), and reduced ecosystem service values (ESV). This study utilized the Common International Classification of Ecosystem Services (CICES) framework to analyze ESV changes between 2000 and 2021 using multitemporal satellite imagery and spectral indices.

Five major LULC types were identified in the study area i.e. waterbodies, vegetation, built-up areas, agricultural land, and bare land. Built-up areas increased by 94%, while waterbodies decreased by 70%. Bare land initially increased until 2018, later transitioning to built-up areas. Agricultural land declined by 60%, with the rural-urban fringe area experiencing the highest conversion rate. Between 2000 and 2021, 16.80% of agricultural land, 21.64% of vegetation, and 12.63% of waterbodies were converted into built-up areas. Ecosystem services were categorized into provisioning, regulating, supporting, and cultural services. This study calculated ESV using regional correction factors and GIS zonal statistics. The highest ESV in 2000 was in the rural-urban fringe area (36.12%), while the lowest was in the new industrial (NI) area (11.29%). Over the study period, ESV decreased significantly, particularly in the rural-urban fringe (-87.95%) and urban zones. Waterbody conversions led to a $273 million ESV loss. All ES categories experienced losses with provisioning (-71.59%), regulating (-69.44%), and cultural services (-62.45%), respectively. Trade-offs between ES types revealed synergistic relationships, particularly between provisioning and regulating ES in agricultural areas ($R^2 = 0.97$).

To measure urbanization, the study analyzed technomass, a three-dimensional indicator of urban

material stocks, using vertical building height data. Dhaka's technomass increased significantly, particularly in the northwest and middle east regions. A Geographically Weighted Regression (GWR) model showed strong negative correlations between urbanization indicators (technomass, nighttime light data, and population density) and ESV. Technomass showed the highest negative correlation with ESV ($r > -0.96$). Urbanization caused an 87.55% decline in ESV, with a 243.11% increase in technomass.

Urban heat dynamics were examined using the Surface Urban Heat Island (SUHI) effect and the InVEST Urban Cooling Model. SUHI values were linked to LULC classes, with lower values in green, water-rich areas and higher values in built-up regions. From 2000 to 2018, SUHI values increased, particularly in built-up and bare land areas, but decreased in 2020 due to reduced commercial activities during the COVID-19 pandemic. The Heat Mitigation Index (HMI) dropped by 47.55% from 2000 to 2020, reflecting diminished urban heat mitigation capacity. Areas with higher HMI were typically rich in vegetation and hydrological features. Pearson's analysis revealed a strong negative correlation between Land Surface Temperature (LST) and HMI ($r = -0.77$).

This study emphasizes the importance of ecosystem services and urbanization management. The outcomes highlight that converting natural land to man-made utilization reduces ESV and heat mitigation capacities. Key recommendations include integrating regional parameters into ESV calculations, promoting ecological protection, and introducing payment for ecosystem services (PES) schemes. These strategies aim to prevent natural land conversion, encourage habitat restoration, and improve urban environmental quality. The study provides valuable insights for city planners and environmentalists in Dhaka and other cities by offering a framework applicable to ecosystem service management and sustainable urban planning.

The examination committee acknowledged that this thesis explores the differential impacts of vertical and horizontal city expansion on ecosystem services, providing valuable insights for regional urban ecosystem monitoring on a global scale. The study demonstrates the calculation of technomass using building height data. By applying regional parameters, it advances the development of Regional Ecosystem Service Value (ESV). The integration of frameworks like the CICES and tools such as the InVEST Urban Cooling Model and Geographically Weighted Regression (GWR) models highlight methodological rigor. The findings emphasize significant ecosystem service losses and urban heat impacts, offering actionable recommendations for sustainable urban management. In addition, Mr. Md. Alamgir Hossen Bhuiyan maintained a strong academic record throughout his Ph.D. studies and publications. Based on this evidence, the committee concluded that he is eligible for the degree of Doctor of Philosophy (Environmental Science).