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Estimating Forest Aboveground Biomass Density Using Remote Sensing and Machine Learning: A RSME Approach

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ABSTRACT

An accurate estimation of aboveground biomass (AGB) density is essential for effective forest management, carbon stock monitoring, and informed land management decisions. This study employs remote sensing datasets and collaborative efforts with ArcGIS to model AGB density across the Terengganu region. Integrated with the random forest algorithm in the Google Earth Engine for AGB density modeling at a spatial resolution of 1 km, the methodology incorporates GEDI Level 4, Sentinel-1 radar, Sentinel-2 optical imagery, and elevation/slope maps. The validation results indicated a root mean square error (RMSE) of 51.35 t per hectare and an average training error of 31.82 t per hectare, demonstrating the model's accuracy and reliability. The model's strong predictive performance ($R^2 = 0.77$) implies that the independent variables accounted for 77% of the variability in the AGB. With a standard deviation of 64.52 t per hectare, the average AGB in the Terengganu area was 90.94 t per hectare, with AGB values ranging widely from 16.89 to 206.99 t per hectare across the region. These findings highlight the potential of integrating multiple remote sensing data sources for comprehensive AGB density mapping, thereby enhancing the monitoring of forest carbon stocks and fostering informed management approaches. This study underscores the importance of open-access data and cloud-based technologies, thereby supporting the availability of tools to implement comparable projects. This research illustrates the significance of combining different datasets and machine learning techniques for the remote assessment of forest biomass, thereby facilitating the improved modeling of ecosystem characteristics and sustainability initiatives. By emphasizing the need for advanced technologies and collaborative strategies, this study enhances forest biomass assessments and supports informed environmental management practices.

1 | Introduction

Aboveground biomass (AGB) refers to the amount of vegetation in a forest, including trees, shrubs, and plants. The land cover, forest cover, and capacity of distribution of trees show how healthy the forest is and how much carbon it stores (Ni-Meister et al. 2010). Mapping forest AGB density (AGBD) is crucial for several important purposes. Accurate estimates allow the assessment of carbon sequestration and the role of forests in climate change mitigation (Hu et al. 2016). This information aids in mitigation strategies and policies aimed at reducing greenhouse gas emissions. Biomass models also guide sustainable forest management and planning by making decisions regarding harvesting, regeneration, and conservation. They help optimize resource use and identify areas for reforestation or protection to ensure long-term ecosystem sustainability. Additionally, biomass estimates support biodiversity conservation by recognizing regions vital for species. Understanding the