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Integrating Satellite Technology and Machine Learning for Accurate Mangrove Species Classification in Thailand

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Abstract:

Mangrove forests are vital ecosystems in Thailand, providing essential ecological services such as coastal protection, carbon sequestration, and biodiversity preservation. However, these ecosystems are threatened due to urbanization, industrialization, and tourism, particularly in Chonburi Province, where mangrove degradation has led to significant environmental challenges. Accurate species classification is fundamental to these forests' restoration and sustainable management. This study integrates high-resolution multispectral satellite imagery from Pleiades Neo with machine learning (ML) models, specifically Random Forest (RF) and Decision Tree (DT), to classify five mangrove species: *Rhizophora mucronata* (Rm), *Rhizophora apiculata* (Ra), *Avicennia marina* (Am), *Avicennia alba* (Aa), and miscellaneous species (Ms).

The research methodology involved the acquisition of six-band Pleiades Neo imagery, collecting field data, and applying ML algorithms. Advanced processing tools like ArcGIS Pro, ENVI, and Python libraries were employed to preprocess data and train the ML models. RF and DT were compared based on classification accuracy, precision, and recall, with RF demonstrating superior performance. The RF model achieved an overall accuracy of 85.23%, outperforming DT's 82.37%. These results underscore RF's robustness and precision in handling high-dimensional and heterogeneous datasets typical of mangrove ecosystems.

A detailed analysis of the classified mangrove areas revealed that RF provided more reliable results, especially for species such as *Avicennia alba* and miscellaneous species, where DT struggled. Table 1 below summarizes the species-wise classification accuracy of both models.

Mangrove species	Area (hectares)	
	DT	RF
Rm	114.16	109.64
Ra	8.65	7.21
Am	221.88	219.06
Aa	131.24	138.60
Ms	89.67	91.09
Total	565.60	565.60

Table 1. Area of five mangrove species, including Rm, Ra, Am, Aa, and Ms, as determined by the DT and RF models

Integrating ML with satellite imagery offers transformative ecological research and resource management potential. By providing accurate, scalable, and cost-effective methods for monitoring mangrove forests, the findings of this study can significantly contribute to the development of targeted conservation strategies. Furthermore, the successful application of RF highlights its suitability for ecological applications, particularly in diverse landscapes requiring precise species differentiation.

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