Development of Modelling Approach to Estimate Mangrove Carbon Stock in Southern Thailand

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Abstract: The mangrove ecosystem is one of the most effective carbon sinks in the world. However, estimating mangrove carbon stock is challenging due to limited accessibility, workforce requirements, and time constraints. Additionally, linear models derived from remote sensing data often show low correlation with mangrove aboveground biomass (AGB) and carbon stock. Thailand is a country in Southeast Asia rich in mangrove ecosystems; however, few studies have developed methods with remote sensing to overcome these challenges. Banlaem mangrove forest is the study area for this study, located in Tha Sala district, Nakhon Si Thammarat, southern Thailand. Unmanned Aerial Vehicle (UAV) imagery was selected for the development of estimating the aboveground carbon stock at the study site. Machine learning was applied to generate linear and non-linear models between UAV-derived variables and ground-truth AGB. The models were validated using the coefficient of determination (R^2) and root mean square error (*RMSE*). This study aims to develop an accurate model for AGB in the Banlaem mangrove forest, located in Southern Thailand.

Key Words: *aboveground biomass, carbon stock, machine learning, mangrove*

I. Introduction

Despite the growing interest in carbon assessment, especially in mangrove ecosystems, Thailand still has limited studies using remote sensing to overcome fieldwork difficulty. A few previous studies have used remote sensing to estimate mangrove carbon stock (Jachowski et al., 2013), while most still rely on traditional field-based methods (Macintosh & Ashton, 2023; Sribut et al., 2020; Srimoh & Markphan, 2024). This study introduces a modelling approach for estimating mangrove carbon stock using UAV technology and machine learning. The results are expected to support accurate carbon stock assessments and contribute to the Thailand Voluntary Emission Reduction Program.

炭素評価への関心が高まっている中、特にマングローブ生態系においては、タイでは現地調査の困難さを克服する手段としてリモートセンシングを用いた研究は依然として限られています。過去のいくつかの研究では、リモートセンシングを用いてマングローブの炭素蓄積量を推定しています（Jachowski et al., 2013）が、多くは従来の現地調査に依存しています（Macintosh & Ashton, 2023；Sribut et al., 2020；Srimoh & Markphan, 2024）。本研究では、UAV技術と機械学習を活用したマングローブ炭素蓄積量の推定モデルを提案します。この結果は、炭素蓄積量の正確な評価を支援し、タイの自主的排出削減プログラムへの貢献が期待されます。

II. Methodology

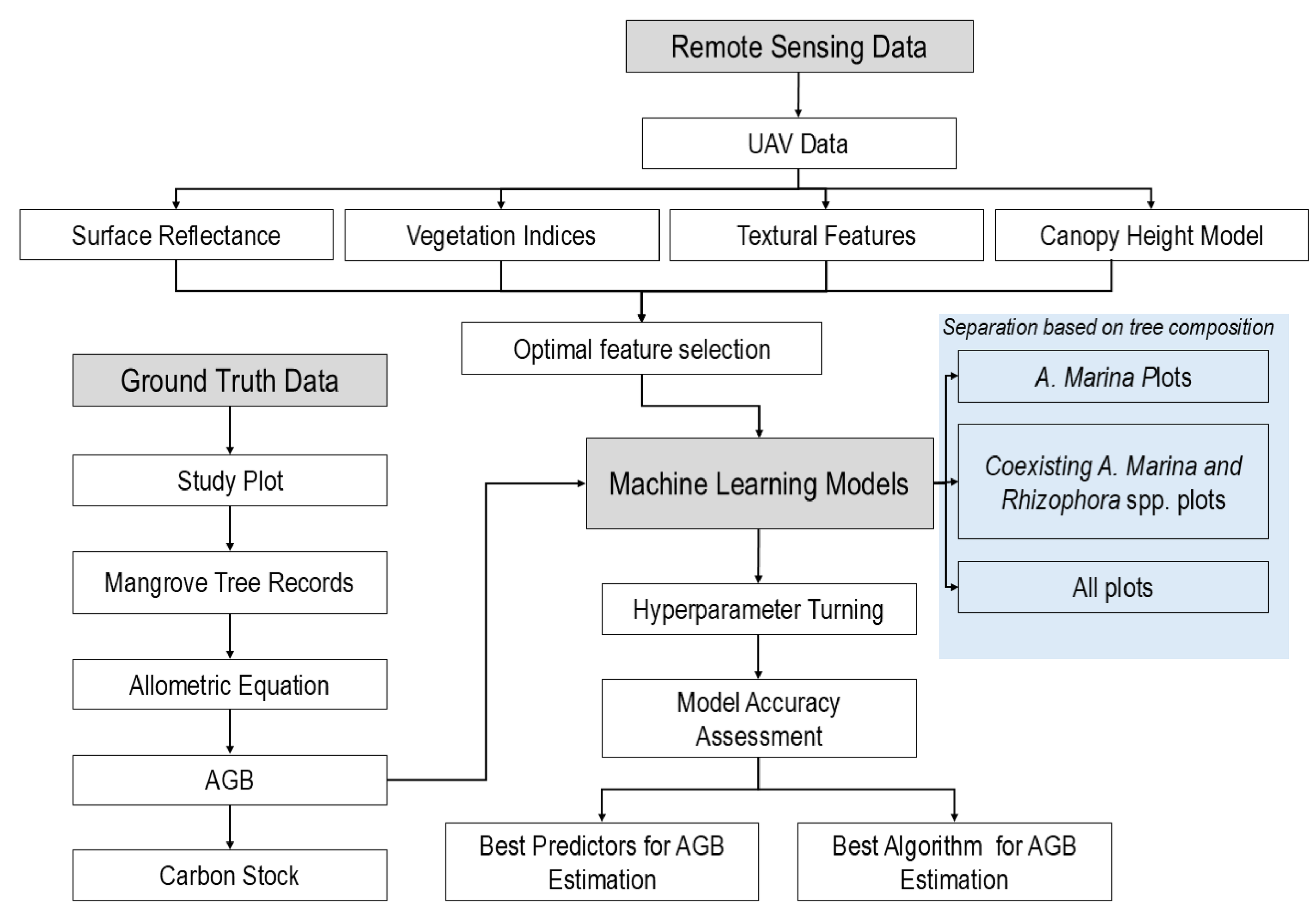

Fig1. Research framework.

Fig2. Study site.

III. Results and Discussion

Fig3. Mangrove species found at the study site: 1) *A. marina* (left) and 2) *Rhizophora* spp. (middle and right).

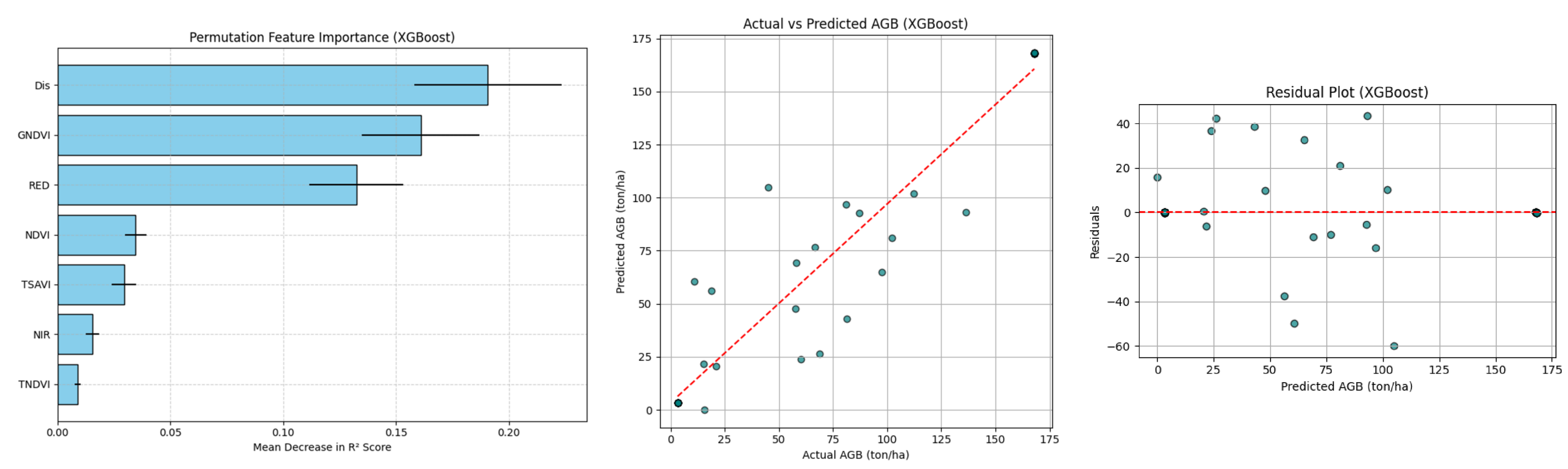

Fig4. All plots: feature importance, AGB estimation plot, and residual plots (from left to right).

Table1. Summary of AGB prediction models

Plot Type (Species Composition)	Best Model	R^2	*RMSE*
All plot (every composition)	XGBoost	0.90	20.81
A. Marina	SVR	0.92	11.55
Coexisting *A. Marina* and *Rhizophora* spp.	XGBoost	0.93	12.63

From testing 21 variables using a genetic algorithm (GA) for feature selection across four models—Multiple Linear Regression (MLR), Random Forest (RF), Support Vector Regression (SVR), and Extreme Gradient Boosting (XGBoost)—it was found that:

- Overall, based on cross-validation (CV), the analysis of models for each tree composition demonstrated high accuracy, as indicated by R^2 and *RMSE* (Table 1).
- Both XGBoost and SVR were among the most effective models.
- The optimal features varied across each tree composition (Fig 4-Fig 6).
- The AGB plots showed a good model fit, demonstrating the effectiveness of machine learning in estimating actual AGB (Fig 4-Fig 6).
- The residual plots were randomly scattered around zero, indicating that the models captured the relationship in the data without systematic bias (Fig 4-Fig 6).
- Future Work:
  1) Estimate AGB values using machine learning and compare them with actual AGB measurements.
  2) Study the mangrove blue carbon ecosystem services of this site.

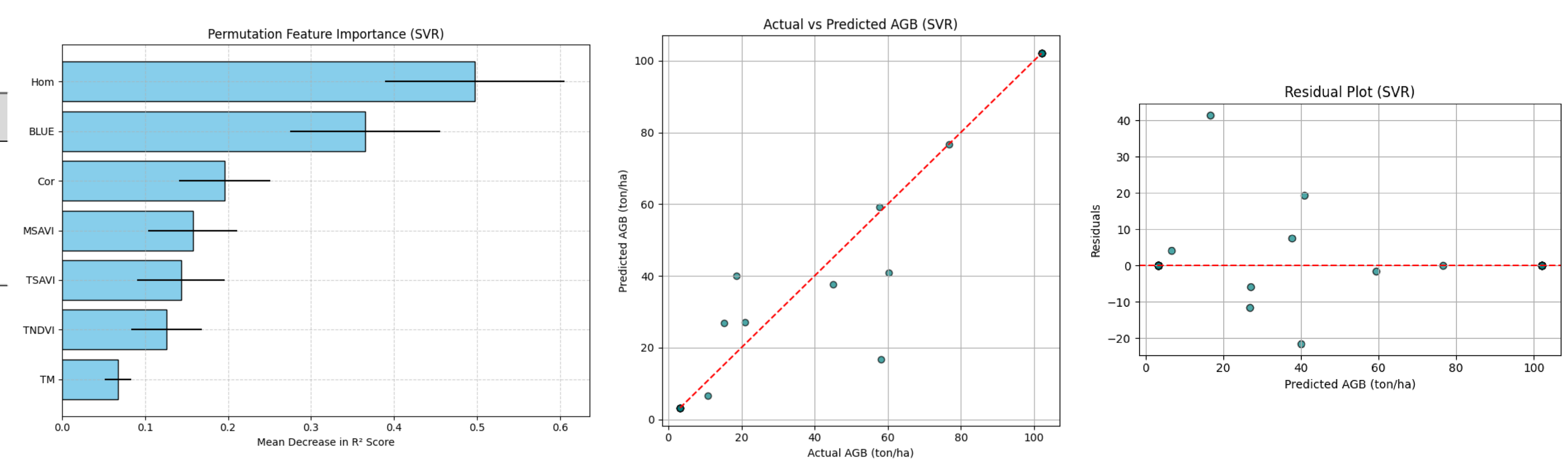

Fig5. *A. marina* plots: feature importance, AGB estimation plot, and residual plots (from left to right).

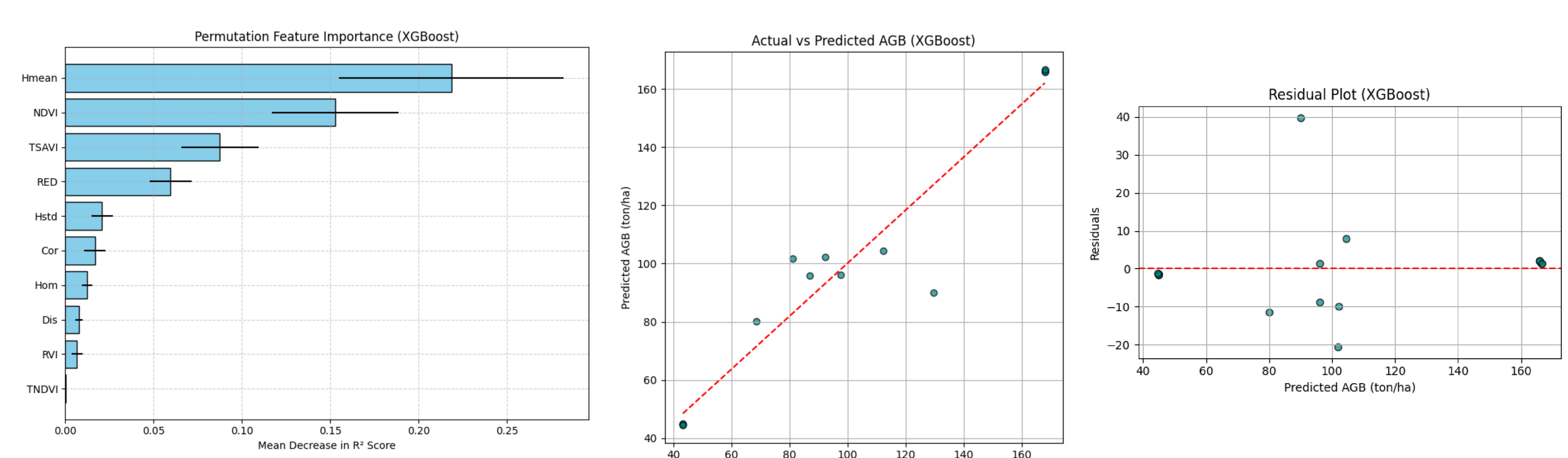

Fig6. Coexisting *A.marina and* Rhizophora *spp. plots*: feature importance, AGB estimation plot, and residual plots (from left to right).

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