

**ESTIMASI STOK KARBON ATAS PERMUKAAN MANGROVE
MENGUNAKAN CITRA SENTINEL-2A DI *CLUNGUP MANGROVE
CONSERVATION (CMC)*, KABUPATEN MALANG, JAWA TIMUR**

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ABSTRAK

Pemanasan global akibat peningkatan karbon dioksida (CO_2) mendorong perlunya pemantauan stok karbon, termasuk ekosistem mangrove yang berperan sebagai penyerap dan penyimpan karbon. Pemanfaatan citra Sentinel-2A melalui transformasi indeks vegetasi dapat digunakan untuk mengestimasi stok karbon atas permukaan mangrove secara lebih efisien. Penelitian ini bertujuan untuk (1) menentukan indeks vegetasi yang paling akurat dalam mengestimasi stok karbon atas permukaan (*Above-Ground Carbon/AGC*) mangrove di Clungup Mangrove Conservation (CMC), (2) memetakan distribusi spasial AGC menggunakan model univariat dan multivariat berdasarkan nilai R^2 , RMSE, MAE, dan plot *goodness of fit* 1:1, serta (3) membandingkan performa model univariat dan multivariat dalam mengestimasi AGC mangrove. Model AGC dibangun menggunakan data pengukuran lapangan dan lima indeks vegetasi citra Sentinel-2A, yaitu *Normalized Difference Vegetation Index* (NDVI), *Enhanced Vegetation Index* (EVI), *Simple Ratio* (SR), *Difference Vegetation Index* (DVI), dan *Green Normalized Difference Vegetation Index* (GNDVI) dengan metode regresi *random forest*. EVI merupakan indeks vegetasi paling akurat dengan nilai R^2 model sebesar 0,729, RMSE validasi sebesar 0,226 ton C/piksel, dan MAE sebesar 0,183 ton C/piksel. Meskipun model multivariat menghasilkan nilai R^2 validasi lebih tinggi (0,711) serta RMSE dan MAE lebih rendah (0,183 dan 0,160 ton C/piksel), model tersebut memiliki gap R^2 negatif sebesar -0,206 sehingga kurang stabil. Model univariat EVI menghasilkan distribusi spasial AGC yang paling sesuai dengan kondisi lapangan dengan total estimasi AGC mangrove di CMC sebesar 3.140,80 ton C.

Kata Kunci: Mangrove, Stok Karbon Atas Permukaan, Indeks Vegetasi, *Random Forest*, Sentinel-2A, *Clungup Mangrove Conservation*

ESTIMATION OF MANGROVE ABOVE-GROUND CARBON STOCK USING SENTINEL-2A IMAGERY IN CLUNGUP MANGROVE CONSERVATION (CMC), MALANG REGENCY, EAST JAVA

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ABSTRACT

Global warming driven by rising carbon dioxide (CO₂) levels highlights the need for carbon stock monitoring, including in mangrove ecosystems that function as carbon sinks and reservoirs. The use of Sentinel-2A imagery through vegetation index transformation offers a more efficient means of estimating mangrove Above-Ground Carbon. This study aims to (1) determine the most accurate vegetation index for estimating mangrove Above-Ground Carbon (AGC) at Clungup Mangrove Conservation (CMC), (2) map the spatial distribution of AGC using univariate and multivariate models based on R², RMSE, MAE, and 1:1 goodness-of-fit plots, and (3) compare the performance of univariate and multivariate models in estimating mangrove AGC. The AGC models were built using field measurement data and five Sentinel-2A vegetation indices, namely the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Simple Ratio (SR), Difference Vegetation Index (DVI), and Green Normalized Difference Vegetation Index (GNDVI), with the random forest regression method. EVI was the most accurate vegetation index, with a model R² of 0.729, a validation RMSE of 0.226 ton C/pixel, and an MAE of 0.183 ton C/pixel. Although the multivariate model achieved a higher validation R² (0.711) and lower RMSE and MAE (0.183 and 0.160 ton C/pixel), it had a negative R² gap of -0.206, indicating lower stability. The univariate EVI model produced the spatial distribution of AGC that best matched field conditions, with a total estimated mangrove AGC at CMC of 3,140.80 ton C.

Keywords: Mangrove, Above-Ground Carbon Stock, Vegetation Index, Random Forest, Sentinel-2A, Clungup Mangrove Conservation