

Estimasi Biomassa Hutan Mangrove Kangean, Madura, Berbasis Integrasi Multi Model Alometrik

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INTISARI

Indonesia memiliki kawasan mangrove terluas di dunia, sehingga estimasi biomassa dan stok karbonnya penting bagi inventarisasi karbon nasional. Persamaan alometrik yang berbeda dapat menghasilkan estimasi biomassa yang sangat bervariasi untuk pohon yang sama, sementara pengembangan persamaan baru melalui destructive sampling mahal dan merusak ekosistem yang tertekan. Penelitian ini menyusun model alometrik biomassa berbasis DBH untuk mangrove Kangean, Madura, melalui integrasi data sekunder tanpa destructive sampling baru. Data individu direkonstruksi dari statistik ringkasan tujuh publikasi menggunakan simulasi Monte Carlo dengan penjenjangan mutu data (Grade A–D), digabungkan dengan data individu asli menjadi 400 titik data dari 11 sumber independen. Data dipooling melalui regresi berbobot (WLS), divalidasi dengan leave-one-study-out cross-validation (LOSO-CV), dibandingkan terhadap data destruktif acuan, dan diuji heterogenitas antarspesies dengan ANCOVA. Model akhir, $W = 0,1387 \cdot D^{2,4616}$ ($R^2 = 0,9214$; DBH 1,27–88 cm), mencapai cakupan prediction interval 95% sebesar 91,98% dan $r = 0,9119$ pada LOSO-CV, serta berselisih hanya 0,5% dari total biomassa data destruktif acuan; eksponennya berbeda kurang dari 0,1% dari model Komiyama. Pada 1.575 pohon inventarisasi Kangean (68% *Rhizophora apiculata*), model ini berkorelasi tinggi dengan model Komiyama ($r = 0,990$) namun berbeda rata-rata 441,95 kg/pohon; estimasi stok karbon antar-model berkisar 57,06–210,65 ton C/ha, dengan selisih maksimum 153,59 ton C/ha (setara 563,66 ton CO₂-eq/ha) pada kawasan seluas 14.706,38 ha. Hasil ini menunjukkan bahwa persamaan alometrik terpublikasi dapat diintegrasikan tanpa penebangan pohon baru, namun pemilihan persamaan tetap sangat memengaruhi estimasi mangrove tingkat kawasan.

Kata kunci: Biomassa Mangrove, Persamaan Alometrik, Rekonstruksi Data Sekunder, Simulasi Monte Carlo, Stok Karbon

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Mangrove Forest Biomass Estimation in Kangean, Madura, Based on Reconstruction and Integration of Multimodel Allometric Data

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ABSTRACT

Indonesia holds the world's largest mangrove area, making accurate biomass and carbon-stock estimation essential for national carbon inventories and climate policy. Different allometric equations can yield widely varying biomass estimates for the same trees, while building new equations through destructive sampling is costly and disturbs an already stressed ecosystem. This study developed a DBH-based biomass allometric model for Kangean mangroves, Madura, Indonesia, by integrating secondary data without new destructive sampling. Individual-tree data were reconstructed from summary statistics in seven publications using Monte Carlo simulation under a data-quality grading scheme (Grade A–D), then pooled with genuine individual-tree data into 400 data points from 11 independent sources. Data were pooled via weighted least squares regression, validated by leave-one-study-out cross-validation (LOSO-CV), benchmarked against an independent destructive-sampling dataset, and tested for interspecific heterogeneity using ANCOVA. The final model, $W = 0.1387 \cdot D^{2.4616}$ ($R^2 = 0.9214$; DBH 1.27–88 cm), achieved 91.98% prediction-interval coverage and $r = 0.9119$ in LOSO-CV, differing by only 0.5% from total destructive-reference biomass; its exponent differed by under 0.1% from Komiyama's model. Applied to 1,575 inventoried Kangean trees (68% *Rhizophora apiculata*), the model correlated strongly with Komiyama's model ($r = 0.990$) but diverged by a mean of 441.95 kg per tree; carbon-stock estimates across models ranged 57.06–210.65 Mg C/ha, a maximum difference of 153.59 Mg C/ha (about 563.66 Mg CO₂-eq/ha) across the 14,706.38-ha area. Results show published equations can be integrated into one model without further felling, while equation choice remains a major source of variation in landscape-scale blue-carbon estimates.

Keywords: Mangrove Biomass, Allometric Equations, Secondary Data Reconstruction, Monte Carlo Simulation, Carbon Stock

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