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Planetscope Imagery Capabilities for Mapping Aboveground Carbon Stock Estimation of Mangroves in Part of Mandeh Area, Pesisir Selatan Regency, West Sumatera Province

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ABSTRAK

PlanetScope memiliki sensor multispektral yang dapat mengidentifikasi dan memetakan berbagai jenis tutupan lahan yang semuanya berperan penting dalam penyimpanan karbon. Tujuan dari penelitian ini adalah memetakan estimasi stok karbon mangrove secara spasial. Metode penelitian yang digunakan adalah pendekatan penginderaan jauh dengan menggunakan indeks vegetasi Difference Vegetation Index (DVI) dan analisis regresi antara nilai karbon lapangan dengan nilai indeks vegetasi untuk menghasilkan estimasi stok karbon di atas permukaan mangrove. Pada penelitian ini, spesies dominan yang ditemukan meliputi *Rhizophora apiculata* dan *Sonneratia alba* dengan rata-rata diameter pohon 10,84 cm untuk spesies *Sonneratia alba*, dan diameter pohon 38,82 cm untuk spesies *Rhizophora apiculata*. Total nilai biomassa di lokasi kajian sebanyak 147,752 ton/ha dengan nilai biomassa terendah 0,386 ton/ha pada spesies dominan *Sonneratia alba*, dan tertinggi sebanyak 25,943 ton/ha pada spesies dominan *Rhizophora apiculata*. Nilai total stok karbon lapangan sebanyak 69,443 ton/ha dengan nilai karbon terendah 0,182 ton/ha dan tertinggi 12,193 ton/ha dari hasil perhitungan menggunakan alometri berbasis spesies, sedangkan total nilai estimasi stok karbon dari citra sebesar 0,080 ton/ha. Penelitian ini menghasilkan eror sebesar 3,163 ton/ha yang berarti memiliki nilai akurasi yang baik. Tingkat akurasi yang lebih baik ditunjukkan dengan semakin rendahnya nilai yang diperoleh dari standar error estimasi.

Kata kunci: PlanetScope, Mangrove, Stok Karbon, Biomassa, Difference Vegetation Index (DVI)

ABSTRACT

PlanetScope has a multispectral sensor that can identify and map various land cover types, which play an important role in carbon stock. The purpose of this study was to map the estimated mangrove carbon stock spatially. The research method used was a remote sensing approach using the Difference Vegetation Index (DVI) vegetation index and regression analysis between field carbon values and vegetation index values to produce an estimate of the carbon stock above the mangrove surface. In this study, the dominant species found included Rizophora apiculata and Sonneratia alba with an average tree diameter of 10.84 cm for the *Sonneratia alba* species, and a tree diameter of 38.82 cm for the *Rhizophora apiculata* species. The total biomass value at the study location was 147,752 tons/ha with the lowest biomass value of 0.386 tons/ha in the dominant species Sonneratia alba, and the highest being 25.943 tons/ha in the dominant species *Rhizophora apiculata*. The total value of field carbon stock is 69.443 tons/ha with the lowest carbon value of 0.182 tons/ha and the highest of 12.193 tons/ha from the calculation results using species-based allometry. In comparison, the total estimated value of carbon stock from imagery is 0.080 tons/ha. This study produced an error of 3.163 tons/ha which means it has a good accuracy value. A better level of accuracy is indicated by the lower value obtained from the standard error estimate.

Keywords: PlanetScope, Mangroves, Carbon Stock, Biomass, Difference Vegetation Index (DVI)

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1. INTRODUCTION

Mangrove plants play an important role in carbon stock, making them one of the most effective ecosystems in mitigating climate change (Bindu et al., 2020; Trettin et al., 2021; Hidayah et al., 2022). This carbon stock process occurs both through the mangrove biomass itself, such as stems, leaves, and roots, and through the accumulation of organic matter in submerged soil. Mangroves have a fast growth rate and high adaptability to extreme coastal environments, such as high salinity and anaerobic conditions. Therefore, mangroves can absorb carbon dioxide (CO_2) from the atmosphere very efficiently, storing it in the form of biomass (Jennerjahn et al., 2017; Friess et al., 2020; Pricillia et al., 2021; Alongi, 2022).

The condition of mangroves in Indonesia is very diverse and reflects the richness of biodiversity and important ecological functions. As the largest archipelagic country in the world, Indonesia has one of the largest mangrove ecosystems, with around 3.48 million hectares of mangroves spread along the coastline from Sabang to Merauke. Indonesian mangroves consist of various types, including *Rhizophora, Avicennia, Bruguiera, and Sonneratia*, all of which play an important role in maintaining the balance of coastal ecosystems (Murdiyarso et al., 2015; Murdiyarso et al., 2023).

Mandeh is a coastal area that has a relatively intact mangrove ecosystem, with various types of mangrove plants growing abundantly along the coast. The existence of this mangrove forest functions as a buffer zone that protects land areas from the impacts of waves, erosion, and seawater intrusion, which is becoming increasingly important in the context of climate change.

Mapping mangrove carbon stocks using remote sensing methods is an innovative and effective approach to obtain information on the condition and extent of mangrove forests, as well as estimating the carbon stocks stored in them (Jin et al., 2017; Pham et al., 2021; Zhang et al., 2022). Overall, mapping mangrove carbon stocks using remote sensing methods not only provides accurate and comprehensive data but also improves our capacity to manage and conserve mangrove ecosystems. By utilizing this technology, we can better understand the important role of mangroves in carbon stock and climate change mitigation efforts, as well as support the sustainability of ecosystems that provide many benefits to the environment and society. The aim of the mangrove carbon stock mapping research is to obtain accurate data on carbon stocks in mangrove ecosystems to support climate change mitigation strategies and sustainable environmental management.

2. METHODS

The mangrove area in Mandeh is located in Pesisir Selatan Regency, West Sumatra Province, Indonesia. Mandeh is located on the west coast of Sumatra and is part of Mandeh Bay, which is surrounded by a cluster of small islands and beautiful bays. Its strategic geographical location makes this area have rich biodiversity, including a fertile mangrove ecosystem. Mandeh is located between coordinates 1°43′S and 100°37′E and has a varied topography, ranging from lowlands to hilly areas adjacent to the coast. The mangrove area in Mandeh stretches along the coastline, with characteristics of muddy and watery soil, ideal for the growth of various types of mangrove plants. Some types of mangroves that can be found in this area include *Rhizophora*, *Avicennia*, and *Bruguiera*, all of which play an important role in maintaining the balance of the coastal ecosystem.

This study uses remote sensing data, namely PlanetScope Imagery which has a spatial resolution of 3 meters. Planetscope imagery has available data that has been corrected up to the Top of Atmospheric Radiance so in this study there is no need to do image correction anymore. This imagery can capture better landscape details compared to other satellites with lower resolutions (Frazier et al., 2021; Planet Labs, 2024). In addition, PlanetScope is equipped with a multispectral sensor that can capture various wavelengths of light. This allows researchers to identify and map various types of land cover, such as forests, agricultural lands, and degraded areas, all of which play an important role in carbon stock (Munyati, 2022; Matiza et al., 2024; Neyns et al., 2024). In mapping the mangrove carbon stock estimate using the DVI (Difference Vegetation Index) vegetation index. Based on previous studies, the vegetation index can map carbon stock estimates with a good level of accuracy, so the vegetation index was chosen to analyze this study (Wicaksono et al., 2011; Zhu et al., 2020; Purnamasari et al., 2021).

Determination of samples in the field using the purposive sampling method. Purposive sampling is a sampling technique with certain considerations. This method was chosen because in determining the sample was chosen intentionally based on certain characteristics. In addition, this method was chosen so that fieldwork can be more efficient in terms of time, energy, cost, and accessibility. taking survey points based on vegetation density at the research location. At the location, observations were made, including measurements of the diameter at breast height (DBH) and the type of mangrove. The number of survey points is 20 points spread throughout the study location and divided into 2 parts, namely, 10 for the model and 10 for the accuracy test. Due to time constraints and the terrain being quite difficult, we were only able to take 20 survey points. This study uses a remote sensing method approach so that samples are needed to determine the accuracy value.

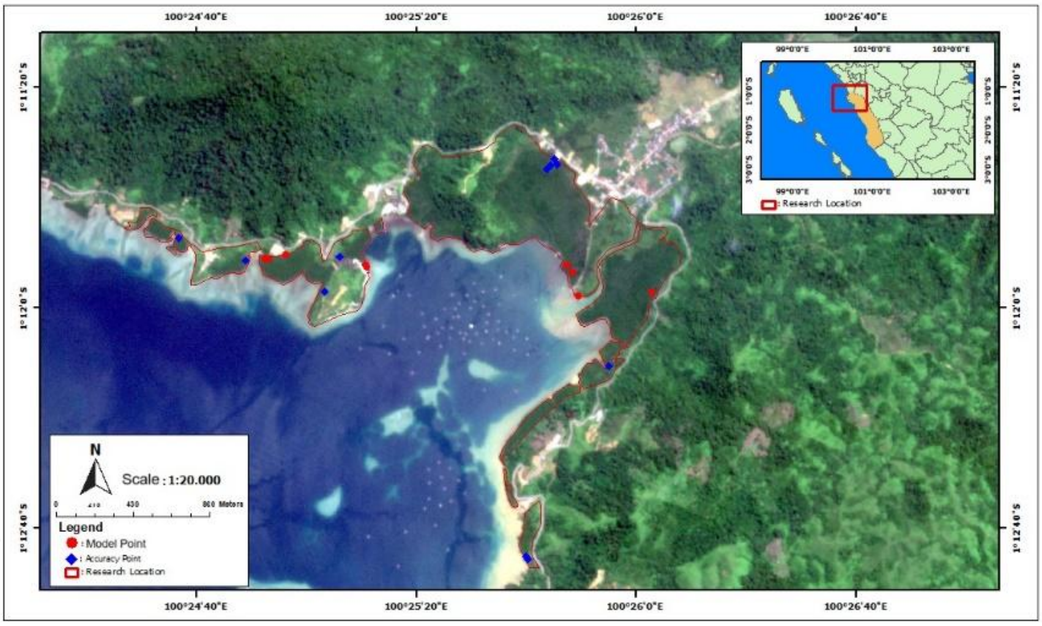

Figure 1. Field Survey Point Map

The carbon stock calculated in this study is the above ground carbon stock. The calculation of mangrove biomass was carried out using the allometric method based on the mangrove species in the Mandeh Mangrove Area, can be seen in Table 1. The value of carbon stock above the surface was obtained from the biomass value approach based on the rules of SNI 7724:2011 that 47% of biomass is carbon.

The regression analysis process begins with the collection of remote sensing data, usually obtained from satellites or drones, which can provide spectral information about mangrove vegetation. Next, carbon stock data measured in the field or through other calculation models are used as dependent variables. In regression analysis, the relationship and influence between the independent variable (remote sensing imagery) and the dependent variable (carbon stock) is calculated to find a model that can predict carbon stock in a wider area based on remote sensing data. Despite the widely used measures for assessing predictive models for numerical data, Alexander et al. (2015) and Li (2017) suggested that R^2 is not an appropriate measure to evaluate modeling results' accuracy. R^2 is only valid for developing models from training datasets and not suitable for model accuracy tests using validation sample datasets.

Accuracy test using the Standard Error of Estimate (SE) method which in its formula uses the carbon value calculated in the field with the carbon value from the regression equation. Standard Error of Estimate (SEE) is a statistical measure used to assess how a linear regression model can predict the actual values based on the data. In the context of regression, the model estimates the value of the dependent variable (Y) based on the independent variables (X). Although the model can provide predictions, not all predictions will be correct. SEE measures the degree of this prediction error, or how much deviation there is between the value predicted by the model and the actual value. The better level of accuracy is indicated by the lower value obtained from the standard error estimate.

3. RESULT AND DISCUSSION

This research activity was conducted in part of the Mandeh Area, Pesisir Selatan Regency, with as many as 20 sample points with a division of 10 points for carbon stock modeling and 10 sample points for accuracy testing. The measurement results are based on a field survey by taking diameter measurements on mangrove trees using a 5x5 meter plot. Based on the identification and measurement of tree diameters in the field, there are two dominant species in the study location, namely the *Rhizophora apiculata* and *Sonneratia Alba* species with an average tree diameter of 10.84 cm for the Sonneratia alba species, and a tree diameter of 38.82 cm for the *Rhizophora apiculata* species. *Rhizophora apiculata* and Sonneratia alba are two species of mangrove plants commonly found in tropical coastal ecosystems, especially in Southeast Asia and the coast of Indonesia. Older *Rhizophora apiculata* trees can have trunk diameters reaching 30 cm to 40 cm or larger. In certain areas, such as along the coast of Indonesia, very old *Rhizophora apiculata* trees can have trunk diameters of more than 50 cm (Duke, 2006; Nursinar et al., 2023). The diameter of *Sonneratia alba* trees is usually smaller, with younger trees having a trunk diameter of around 10 cm to 20 cm (Sarno et al., 2017). In older and larger trees, the trunk diameter can reach 30 cm to 40 cm. Some older *Sonneratia alba* trees in mangrove areas can have larger trunk diameters, although generally not as large as *Rhizophora apiculata*.

Field carbon stock is generated from mangrove tree biomass calculated based on the use of allometry of each species. The total biomass calculation at the study location was 147,752 tons/ha with the lowest biomass value of 0.386 tons/ha in the dominant species Sonneratia alba, and the highest was 25,943 tons/ha in the dominant species Rhizophora apiculata. The total carbon stock value was 69,443 tons/ha with the lowest carbon value of 0.182 tons/ha and the highest 12,193 tons/ha. The large difference in biomass and carbon is also due to the size of the tree diameter (DBH), carbon reserves with a diameter above 30cm have a good impact because trees with this diameter size make a significant contribution to carbon reserves.

This study used the Difference Vegetation Index (DVI) vegetation index, this vegetation index uses infrared and red wavelengths. High vegetation index values allow for the presence of high vegetation or vegetation density. The range of vegetation index values in this study is between -0.196 - 0.032. The use of this vegetation index is an initial step in calculating carbon stock estimates from imagery. Based on Figure 1, it can be seen that the spatial distribution of the DVI vegetation index map is predominantly red. The red area indicates that the area has a low vegetation index value. This is possible because visually the image of mangrove plants or trees has a smooth texture compared to other forest tree vegetation so the vegetation index algorithm reads the image as having a low canopy density. In addition, considering the condition of the mangrove plants in the study location, the tree diameter is not too large.

Regression analysis was conducted to find the relationship between field carbon and vegetation index. With this method, we can build a predictive model that allows carbon stock estimation in a wider area without the need for direct measurements at each location. The model generated from this regression can be implemented to map the spatial distribution of mangrove carbon, which is very important for ecosystem management planning and climate change policies. The regression results between field carbon and vegetation index in this study were $R^2 = 0.445$. A regression value that is not too high indicates a variation of different species or density of the mangrove canopy. The R^2 value shows the variation in data that has a value ranging from 0 to 1, the greater the R^2 value, the better the model (Atsilah and Aditya, 2024).

This study produces an estimate of carbon stock in the image used from the results of correlation or regression with a total carbon stock estimate of 0.080 tons/ha. The estimation results with carbon in the field are very different. This is because in modeling carbon stock estimates using a remote sensing approach, image data is only able to record the canopy of mangrove leaves. Remote sensing images are not able to record up to the tree trunk, so only the leaves are recorded from above, that's why this study maps the carbon stock estimate above the mangrove surface. However, the use of a remote sensing approach, especially Planetscope imagery, can map mangrove carbon stocks with quite good results.

Table 1. Allometric Equations

Spesies	Formula	References
Rizophora apicula	$B = 0,043*DBH^{2,63}$	Amira, S (2008)
Sonneratia alba	$B = 0.0825*DBH^{0.89}$	Kauffman and Donato (2012)

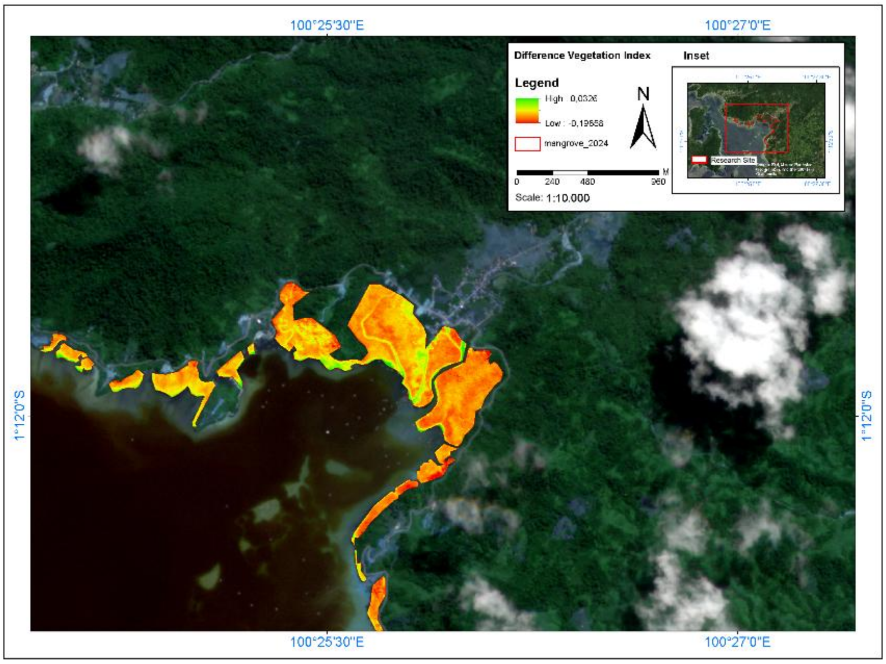

Figure 2. Difference Vegetation Index Map

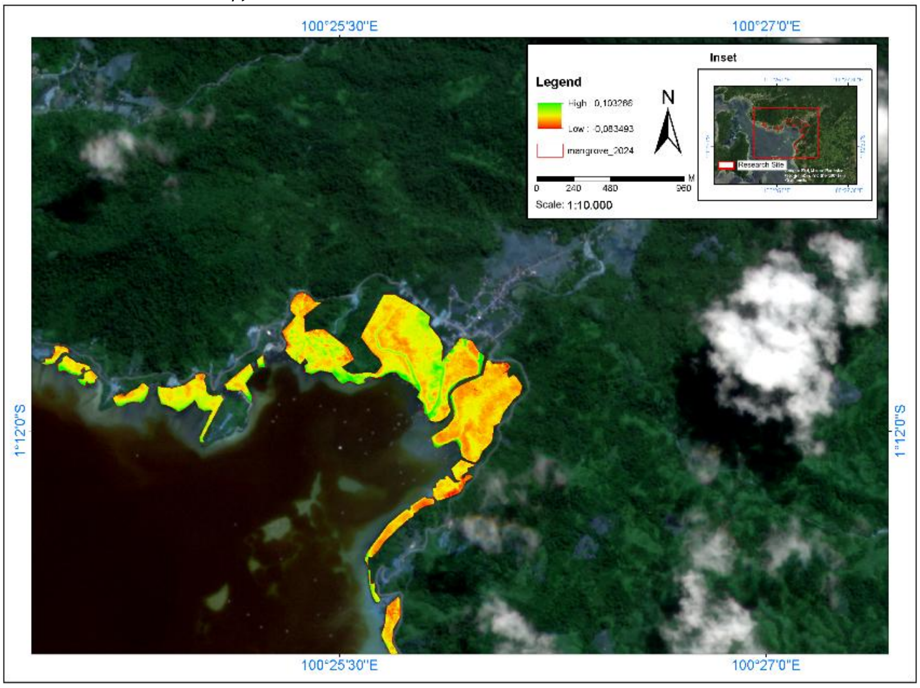

Figure 3. Carbon Stock Estimation Map

After obtaining the estimated carbon stock value, it is necessary to calculate the accuracy test of the estimation results. This study used 10 test points from a total of 20 sample points, the division of points was 10 test points and 10 model points. This study uses a remote sensing approach so that samples are needed for accuracy. Based on the calculation of the accuracy test using the Standard Error Estimate, this study produced an error of 3.163 tons/ha which means it has a good accuracy value. The better level of accuracy is indicated by the lower value obtained from the standard error estimate.

Based on the results of the accuracy test, it can be said that in its ability to provide images with high spatial resolution and fast retrieval frequency, PlanetScope imagery is a great tool for mapping mangrove carbon stocks. This not only allows carbon monitoring in large areas but also allows the identification of changes in carbon stocks over time, which is important for planning mangrove ecosystem management and measuring its contribution to climate change mitigation.

4. CONCLUSION

Based on the identification and measurement of tree diameter in the field, there are two dominant species in the study location, namely, *Rhizophora Apiculata* and *Sonneratia Alba* species with an average tree diameter of 10.84 cm for the *Sonneratia alba species*, and a tree diameter of 38.82 cm for the *Rizophora apiculata* species. This study estimates mangrove carbon stocks based on remote sensing imagery using the regression method, although this value is significantly different from field data because the imagery only records the canopy part of the plant. The accuracy results also show a good level of accuracy. The ability of remote sensing imagery to estimate carbon stock widely and periodically is very important for planning mangrove ecosystem management and climate change mitigation efforts.

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