Estimation of aboveground carbon stock using the 8 operation land imagery in Lemo Nakai community forest, Indonesia

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Abstract. Estimation of aboveground carbon stock on stands vegetation, especially in community forests in Indonesia has become an urgent issue in the effort to calculate, monitor, manage, and evaluate carbon stocks. The study aims to test the accuracy of the estimated model of aboveground carbon stocks, to ascertain the total carbon stock, and to map the spatial distribution of carbon stocks on stands vegetation in Lemo Nakai community forest lying on 3°25'59,588" - 3 27'57,982" alt. and 102°19'25,108" - 102°22'23,416" long., covering 1,053. 53 ha. The study was conducted from February to June 2022 at Baturaja Village, North Bengkulu District. Forest structure grouped classified into three classes; dense, medium and sparse stand using stratified sampling plots systematically spread out at the forest studied forest area. Above-ground biomass and carbon stock of the forest stand were estimated using allometric models. Spatial data collected from Landsat 8 OLI (operational land imager) were used to produce land-use maps of the Lemo Nakai community forest to estimate the total carbon stock, obtained from the United State Geological Survey (USGS, 2021). The result showed that the dense-, medium-, and sparse forest structure covered about 753,69 ha, 3232,41ha, and 32,49 ha, respectively. Above-ground biomass of the Lemo Nakai community forest was estimated at the dense-, medium-, and sparse structures were, respectively 389.74 tons ha^{-1}, 278.88 tons ha^{-1}, and 149.28 tons ha^{-1} with carbon stock at 179.40 tons ha^{-1}, 128.29 tons ha^{-1}, and 68.67 tons ha^{-1}, respectively. Furthermore, estimated CO2eq absorption at the dense-, medium-, and sparse forest structure, respectively 657.80 tons ha^{-1}, 470.58 tons ha^{-1}, and 26.98 tons ha^{-1}.

1 Introduction

The benefits of forests to human life are vital. Sequestering carbon dioxide from the atmosphere through photosynthesis and storing it in forest biomass is one of the benefits provided by forests [1]. Climates (i.e., temperature and humidity) that are ideal for many tree

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species to grow also support these circumstances. The majority of the carbon trapped and stored in forest biomass can aid in reducing the effects of climate change, specifically global warming [2].

Indonesia has had significant issues with deforestation [3]. At the national and regional levels, there is still a severe dearth of knowledge about the intricate processes that cause deforestation, including the functions of direct and indirect drivers of forest loss [4]. In addition, a large number of people who live in or close to these woods depend heavily on forest resources, and the destruction of forests and unsustainable logging pose a threat to their way of life. Their nearby forests should be used as much as possible for these communities as a national resource [5]. The communities living adjacent to the forests could reap the greatest benefits if forest management practices produced high-quality and sustainable forests. Therefore, it has been determined that community forest management is a beneficial strategy for reducing deforestation.

Community forests' fundamental function in reducing carbon emissions depends heavily on their productivity, and the buildup of forest biomass is a key factor in this process [6]. To calculate the community forests' carbon store and assess their strategic role in assisting climate change mitigation, the accurate quantification of biomass is required [7]. Due to tree harvesting, widespread destructive tactics can reduce forest regrowth [8].

To accomplish this, the development of an allometric equation and a biomass expansion factor may prove to be useful tools for facilitating the precise calculation of individual tree biomass in community forests. The allometric equation has been used in numerous studies to measure the biomass of individual trees in Indonesian forests. As a result, the goal of this study is to ascertain if the allometric equation can accurately measure the amount of tree biomass in Indonesian community forests.

This study seeks to determine the total carbon stock, to map the geographical distribution of carbon stocks on stands of vegetation in Lemo Nakai Community Forest, Bengkulu, and to assess the accuracy of the calculated model of aboveground carbon stocks.

2 Methods

The study area was situated in the Lemo Nakai community forests in Baturaja Village, North Bengkulu District, Bengkulu Province, Indonesia geographically lying on 3°25’59,588” - 3°27’57,982” alt. and 102°19’25,108” - 102°22’23,416” long., covering 1,053. 53 ha. The study was conducted from February to June, 2022. The study sites with the tropical forest density shown in Fig. 1 and the details of Landsat-8 classification method used for mapping the extent of the Lemo Nakai community forest is schematically presented in Fig. 2.

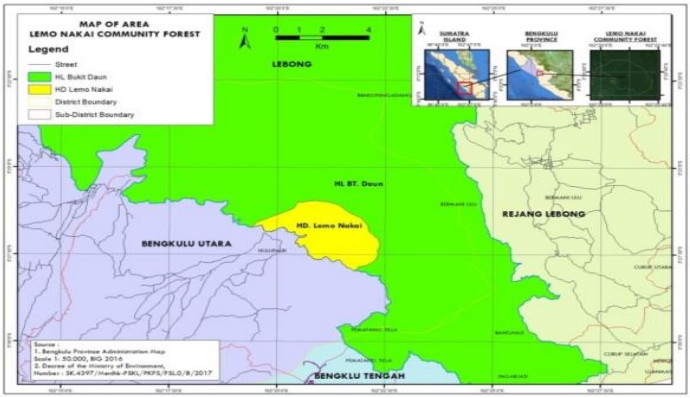

Fig. 1. Research location area.

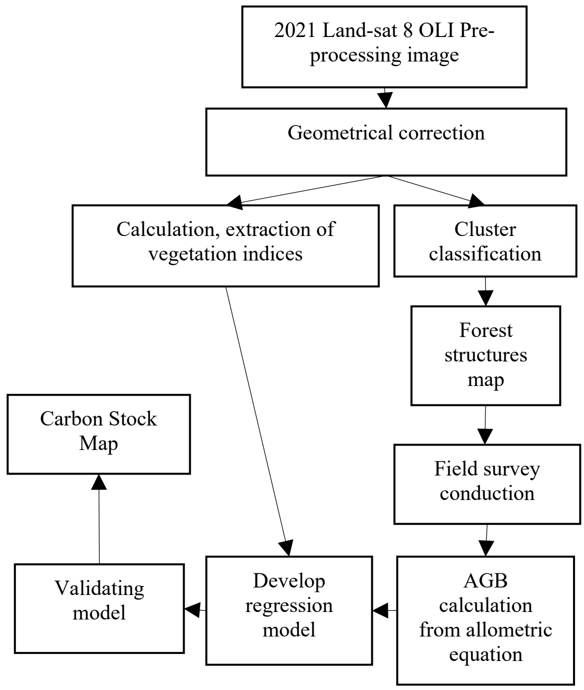

Fig. 2. The flowchart of research.

Forest stand measurement used stratified sampling plots (20 m x 50 m each) for "pohon", pole (10 m x 10 m) and stake (5 m x 5 m) [9]. These were set up to measure tree diameter at the breast height (DBH, 1.3m).

In this investigation, the Operational Land Imager (OLI) data from Landsat 8 was received from the United States Geological Survey (USGS) 2021. The Landsat imager was then geometrically corrected in ArcGIS 10.8 to reduce mistakes and increase accuracy. The Normal Difference Vegetation Index was used to extract the land cover in order to produce the appearance of stands of vegetation. The vegetation index algorithm can highlight elements in the image such vegetation density, chlorophyll concentration, number of canopies, etc. [10]. After that, the NDVI technique was used to create three classes defined by the forest's structural features. The outcome of the forest structures represented the vegetation class of stands that was used for additional analysis.

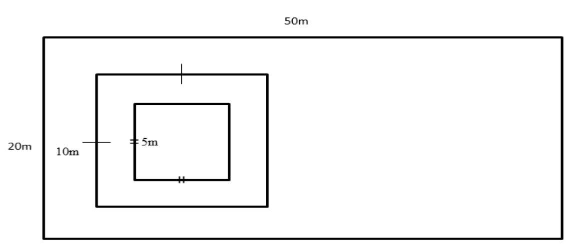

Fig. 3. Lay out of sampling plot and sub-plot based on stratified systematic sampling at the Lemo Nakai community forest.

Allometric models were used to determine the forest stand's above-ground biomass and carbon stock. An adequate allometric equation must be used to convert tree diameter into precise biomass estimations [11]. Created allometric regression equations to calculate the above-ground biomass (AGB) of individual trees in tropical forests as a function of breast

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height and height overall [12]. The AGB model employed in this investigation was as follows [13]:

$$(AGB)_{est} = \pi * exp\,(-1{,}449) + 2{,}148\ ln\,(D) + 0{,}207\ ln\,(D^2) - 0{,}0281\,(ln(D))^3) \quad (1)$$

Where AGB refers to aboveground biomass (kg) and D is the diameter at the breast height (cm).

To convert the AGB of the Lemo Nakai community forest into aboveground carbon (AGC) stock, a conversion ratio of 0.46 was applied as AGC = AGB*0.46. To propose for C sink, this study calculated the total CO_2 absorbed by the Lemo Nakai community forests using the formula:

$$CO_2 = carbon\ stocks\ (ton\ ha^{-1})\ x\ 44/12 \quad (2)$$

Vegetation indices (VIs) representing the amount of vegetation present [14]. In this study, the transformed VIs used following [15] are Normalized Difference Vegetation Index (NDVI) and Transformed Vegetation Index (TVI).

$$NDVI = \frac{\rho NIR - \rho red}{\rho NIR + \rho red} \quad (3)$$

$$TVI = sqrt\ \frac{\rho NIR - \rho red}{\rho NIR + \rho red} + 0{,}5 \quad (4)$$

Based on the value of another variable, regression analysis is used to forecast or estimate the value of the dependent variable (independent). The variance caused by independent factors that only have an impact on the dependent variable is then explained by adjusted R. The adjusted R should be at least 0.8 for a successful relationship. The AGB (dependent variable) of the research area was predicted using a regression equation (model) in this study based on the independent variable, VIs (NDVI and TVI). The correlation between VIs and AGB was calculated to demonstrate the relationship between the two variables and to validate the created AGB model. The correlation coefficient illustrates the strength of the association (r).

3 Result and discussion

Forest canopy density is divided into three categories, namely no forest, medium and dense forest. The NDVI value is used as a quantitative parameter to determine the forest canopy densities. The width area from each forest canopy densities at the Lemo Nakai community forest was illustrated in Table 1.

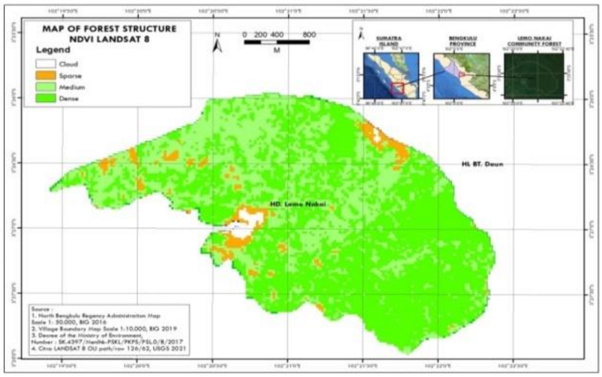

Fig. 4. Lemo Nakai Community Forest structures.

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Table 1. The width area for each forest structures at Lemo Nakai community forest.

Forest canopy density	NDVI value	Pixel number	Are (Ha)
Cloud	0.23 – 0.55	219	34,4
Sparse	0.56 – 0.70	108	32,5
Medium	0.71 – 0.85	3108	232,4
Dense	0.86 – 1	8268	753,7

The dense forests occupy a large area of around 70.67 % in the community forest systems and the rest are medium density, 26,56 % of the area and sparse density, 0,92% of the whole area.

The number of trees in each plot is different, as well as at each forest density. The numbers of trees at Lemo Nakai community forest were illustrated in Table 2.

Table 2. The numbers of trees at Lemo Nakai community forest.

Forest canopy density	Numbers of trees ha^{-1}			Total
	Tree	Pole	Stake	
Sparse	100	1.700	1.067	2.867
Medium	390	600	1.467	2.457
Dense	437	500	1.867	2.803

The forest investigated in the Lemo Nakai community forest was characterized by a high abundance of relatively small trees (diameter with the percentage of 76.04 % of all individuals sampled ranging between 2-30 cm). Furthermore, there are two key causes that are not exclusive of one another for the comparatively low frequency of towering trees with dbh values below 40 cm. First off, only a small number of species may be able to reach these heights or diameters naturally, thus in order for their seedlings to outcompete other (especially fast-growing) species, they must find the ideal conditions or locations for growth. Second, selective logging for local usage, particularly traditional home construction, may have already reduced the numbers of several large tree species (i.e., members of the family Dipterocarpaceae).

The aboveground biomass and stand-level carbon stocks come next, suggesting a bigger overall carbon store in the community forest (Table 3). Fig. 5 illustrates the Lemo Nakai community forest's characteristic aboveground carbon sink.

Table 3. Aboveground biomass, C stock and CO2eq in the Lemo Nakai community forest.

Forest canopy density	Biomass tons ha-1	C-stock tons ha-1	CO2eq tons ha-1
Sparse	149.2	68.6	252.0
Medium	278.8	128.3	470.8
Dense	389.4	179.1	657.4

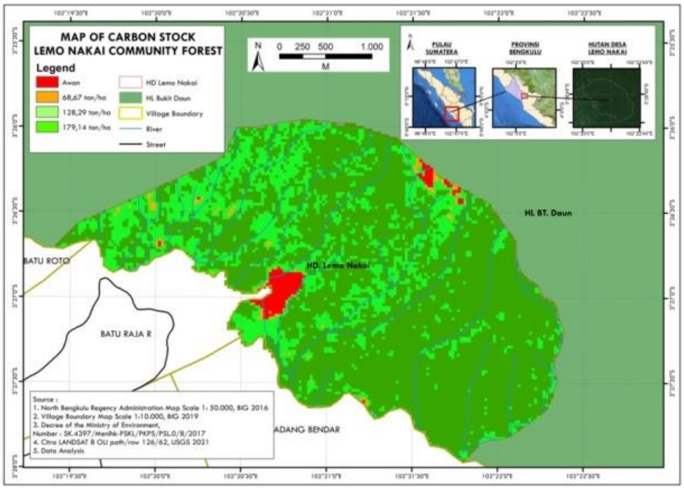

Fig. 5. Spatial distribution of above AGB.

There is a significant difference on stands biomass at each density cover that is sparse, medium and dense cover forest stands, 389.44 tons ha-1, 278.88 tons ha-1, and 149.28 tons ha-1, respectively. Total carbon stocks that found at the dense canopy cover class was 179,14 tons/ha, the medium canopy cover class stored 128,29 tons ha-1, and the lowest canopy cover class had 68.67 tons ha-1. Therefore, The Lemo Nakai community forest in North Bengkulu Regency saved as a whole of 1.053 ha saved 287,419.47 tons carbon

With 52.77 tons/ha, mixed community plantation forest in Toraja District [16], 72.38 tons ha-1, and urban community forest in Bandar Lampung with an average value of carbon storage of 54.59 tons ha-1, the AGC from this study was significantly greater than agroforestry methods [17]. The total aboveground C-stock in the sacred forest in Pasaman, West Sumatera, was 190.62 tons ha-1. The AGC stock in this study was a little bit closer to that amount [18].

The AGC stand stocks in the Lemo Nakai community forest were significantly closer to the conventionally managed community forest in Kanchanpur District, Nepal, with 183.72 tons ha-1 [19] and in the Sal (Shorea robusta) forest in Bagdaila Chisapani community forest of Dang district, Nepal, with a mean AGC 160.4 t ha-1 [20]. Learn from this study that the growth of forests can reduce regional and global atmospheric carbon emissions, and that community-based forest management has the potential to produce tree biomass. To combat global climate change, local participation in the sustainable management of community forests enhances sequestration.

4 Conclusion

The Lemo Nakai community forest, North Bengkulu District covered by the dense forest about 70.57 %, the medium density around 26.56 %, and only 0.92 % of the sparse forest The Lemo Nakai Community Forest managed by the Batu Raja Village Community has a role in mitigating climate change with a carbon stock 287,419.47 of ton and absorbing carbon of 484,780,8.39 ton in a forest of 1053 ha. Learn from the others, the Lemo Nakai community forest has the potential to produce tree biomass as well to reduce carbon emissions in the atmosphere. So, with this concern, the participation of the local people such as from the Baturaja village societies in sustainable management of the forests enhance the sequestration and meets strategy to mitigate the global climate change.

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