

Estimating Above-Ground Carbon Stock of Loa Haur Conservation Forest in East Kalimantan, Indonesia

Finalia Retno Vinanthi^{1*} Ali Suhardiman² Yohanes Budi Sulistioadi³

¹Education and Training Institute of Ministry of Environment and Forestry, P. Untung Suropati Street, Samarinda, East Kalimantan, Indonesia

²Lab. of Forest Inventory and Planning, Faculty of Forestry, University of Mulawarman, Samarinda, East Kalimantan, Indonesia

³Soil and Water Conservation Laboratory, Faculty of Forestry, University of Mulawarman, Samarinda, East Kalimantan, Indonesia

*Corresponding author. Email: finavinanthi@gmail.com

ABSTRACT

Conservation forest in Indonesia holds the primary function as biodiversity preservation and maintains forest ecosystem, and therefore plays a significant role in reducing emission from deforestation and forest degradation (REDD) in East Kalimantan. To understand the forest's role in holding emissions, information on current carbon standing stock is vital. This study aims to estimate above-ground carbon from East Kalimantan conservation forest, contributing up to 5.3% of the total forest area in this province. The study area is located at the Loa Haur education and training forest (Loa Haur forest) part of Bukit Soeharto Grand Forest Park. As many as 48 sample plots were established over 43.1 km² of Loa Haur forests cover three main land cover types, i.e., secondary forest, shrub, and bare land. Above-ground biomass from sample plots was calculated using Chave allometric equations, while land cover types were derived from high-resolution Sentinel-2 satellite imagery. Carbon was estimated simply by multiplying biomass with a conversion factor of 0.47. Land cover of the study area was carefully classified using visual interpretation and was validated using actual land cover from the ground (sample plots). Accuracy assessment on land cover classification using Kappa value exhibited excellent results (Kappa index =0.83). This study also showed that the above-ground carbon stock of secondary forest, shrub, and bare land is 111.30 Mg/ha, 10.84 Mg/ha, and 4.63 Mg/ha, respectively. This above-ground carbon stock may refer to the emission factor, which can be used as a basis for calculating East Kalimantan carbon emission for a specific period.

Keywords: Above ground carbon stock, conservation forest, Chave allometric equations, Sentinel-2 satellite imagery

1. INTRODUCTION

Loa Haur forest is currently part of Bukit Soeharto grand forest park located in the Loa Haur river between Samarinda and Balikpapan. This forest has been managed by Samarinda Education and Training Center for Environment and Forestry (Balai Diklat Lingkungan Hidup dan Kehutanan or BDLHK) – an affiliated institution to Ministry of Environment and Forestry - since 2002 [1]. Loa Haur forest and Bukit Soeharto grand forest are designated for conserving the lowland tropical forest ecosystem's biodiversity, which means these forests should be managed under strict conditions. Research and development and education are most likely suitable for this conservation forest and

ecotourism in certain areas. That conservation forest plays a significant role to sink carbon from the atmosphere as much as this forest grow. However, for more than 15 years, the carbon standing stock of Loa Haur forest has never been estimated.

The most extensive method to estimate carbon stock over a vast forest area is to use remote sensing imagery and ground measurement. Satellite imagery covers a broader area at a single acquisition period better than aerial photo or ground survey. The availability of satellite imagery brings carbon stock estimation study more efficient [2]. Sentinel-2 is a European multi-spectral satellite launched in 2015 and has a prime mission similar to SPOT and Landsat, earth observation.

It is designed to give a high revisit frequency of 5 days at the Equator. Each of the satellites carries an optical scanner called Multi-Spectral Instrument (MSI) that sampled 13 spectral bands. Four of the available spectral bands have 10 m of spatial resolution, another six bands are 20 m, and the last three bands are 60 m spatial resolution [3]. Four bands at 10 m spatial resolution represent three visible spectra and one near-infrared. These four bands are suitable for vegetation-related studies, including above-ground carbon stock estimation of a forest. This study aims to estimate Loa Haur forest's carbon stock by exploiting four of 10 m-bands of Sentinel-2, an ultimate earth observation satellite technology from the European Space Agency (ESA).

2. METHODS

2.1. Study Area

This study's object is 43.1 km² of Loa Haur forest located at Kutai Kartanegara District, East Kalimantan Province, Indonesia. The forest area lies between 116007'00'' east and 00040'00'' south. Before establishment as a preservation area, Loa Haur forest was a former logging concession. Like other places in East Kalimantan, especially in the Mahakam basin, the long dry season due to El-Nino in 1982/1983 has burnt most of the area in this forest. The footprints of such catastrophe can be seen and reflected on the forest's current structure stands and covers. A shrub is easily found along with young to mid secondary forest.

2.2. Materials

Four Sentinel-2 imageries (level 1C) dated back to March 4th, 19th, 24th, and April 3rd, 2018, were selected based on the lowest cloud coverage over the study area. The imageries were freely downloaded from <https://scihub.copernicus.eu/> and then proceed with image analysis and processing using Quantum GIS and ArcGIS. All of the field data was collected in July 2018.

2.3. Satellite data procession

Satellite data processing encompasses image clipping, band stacking, cloud masking, and mosaicking. Images were clipped following the boundary of the study area to reduce processing time and storage. All four bands were stacked into a single geo-tiff file for further analysis. Cloud and shadow were masked to obtain free cloud cover images.

2.4. Land cover interpretation and classification

Post-processing Sentinel-2 images were digitized directly on a computer screen (visual interpretation)

using GIS software. Three forest and land cover classes were obtained from this process: secondary forest, shrub, and bare land. Land and forest cover types were named following 23 land cover classifications provided by the Ministry of Environment and Forestry (Peraturan Direktur Jenderal Planologi Kehutanan dan Tata Lingkungan No.P.1/VII-IPSDH/2015).

2.5. Sample Plots Design

Sample plots were established on the ground for forest inventory and validation of Sentinel-2 image interpretation. In sampling theory, the sample plot should represent the scale of variation of the targeted parameter, carbon stock. Therefore, some sample plots were needed to be carefully determined. A statistical method in the form of the spreadsheet file provided by Winrock International was used to calculate the number of sample plots for this study [4].

Input data to the Winrock spreadsheet file is an arithmetic mean and standard deviation of carbon/biomass stock from previous studies. Those input data were collected from Pusat Penelitian dan Pengembangan Sosial, Ekonomi, Kebijakan dan Perubahan Iklim (P3SEKPI) – a center on socio-economic, policy, and climate change studies under Forest Research and Development Agency, Ministry of Environment and Forestry, which has been established more than 100 sample plots across East Kalimantan in 2017. From this statistical procedure, 31 sample plots were needed to apprehend biomass/carbon stock variation in secondary forests. Meanwhile, shrub and bare land need 14 and 3 sample plots, respectively. Total sample plots were 48 and spatially distributed over the study area using GIS software (see Figure 2).

2.6. Field Data Collection

Nested sample plots were established on the ground, as seen in Figure 1. Sapling (a small tree with dbh 5.0-9.9 cm) was measured in a 5 × 5 m or 25 m² sub-plot. Poles (medium size tree with dbh 10.0 -19.9 cm) were measured in a 10 × 10 m sub-plot (100 m²), while medium to big trees with dbh above 20 cm were measured in a 20 × 20 m plot (400 m²).

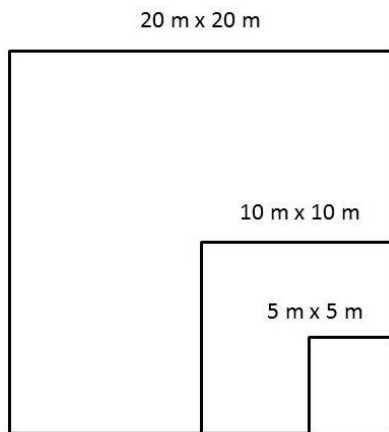


Figure 1 The layout of the sample plot established on the field

Independent variable data collected from sample plots were diameter at breast high (dbh), total tree height, tree species (botanical or local names), actual slope (%) of plot and sub-plot borderline, and existing land cover.

2.7. Data Analysis

2.7.1. Kappa Test for Land Cover Classification

Kappa test is the statistical parameter used to quantify the accuracy of image interpretation and classification process. Kappa value ranges from 0 - 1 or 0 – 100%. A value closer to 1 or 100% indicates the accuracy is getting better. Kappa value was calculated using the following equation [5-8]:

$$\hat{K} = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r X_{i+} X_{+i}}{N^2 - \sum X_{i+} X_{+i}} \times 100\% \quad (1)$$

Where \hat{K} for Kappa value, N is the number of samples/observations, r is the sum of row or column on false matrix, X_{i+} is the sum of class in row i, X_{+i} is the number of class in column i, and X_{ii} is diagonal value.

2.7.2. Biomass and Field Carbon Calculation

Diameter at breast height (dbh) and tree height (h) was used to yield total above-ground biomass (TAGB) simply by substitute those two values in the allometry equation [9] as follows:

$$TAGB = 0.0509 \times \rho \times (dbh)^2 \times h \quad (2)$$

Where TAGB stands for total above-ground biomass (kg), ρ is wood density (kg/m³), dbh is the diameter at breast height (cm), and h stands for total tree height (m).

The Source of wood density value was taken from World Agroforestry Centre online database, which can be accessed via <http://db.worldagroforestry.org/wd>. Finally, the carbon of each tree in the sample plot was calculated by multiplying TAGB with a constant value of 0.47 [10]. Overall carbon stock of *Loa Haur* forest was estimated by interpolating arithmetic mean carbon from sample plots to each land cover class (Mg/ha). The data then be generated to assess biomass and carbon whole study area [11,12].

Table 1. Land cover classes of *Loa Haur* forest from Sentinel-2 image in *Loa Haur* forest

Land cover classes	Land cover acronym and code	Hectares	Percentage
Secondary forest	Hs/ 2002	1,764.18	40.93
Shrub	B/ 2007	2,465.41	57.20
Bare land	T/ 2014	42.92	1.00
Waterbody	A/ 5001	37.78	0.87
Total (Ha)		4,310.29	100.00

Table 2. Confusion matrix to compare actual land cover and land cover classification map

		Actual land cover			Total X_{i+}
		Secondary forest	Shrub	Bare land	
The land cover classification map	Secondary forest	12	2	0	14
	Shrub	2	29	0	31
	Bare land	0	0	3	3
Total X_{+i}		14	30	3	48

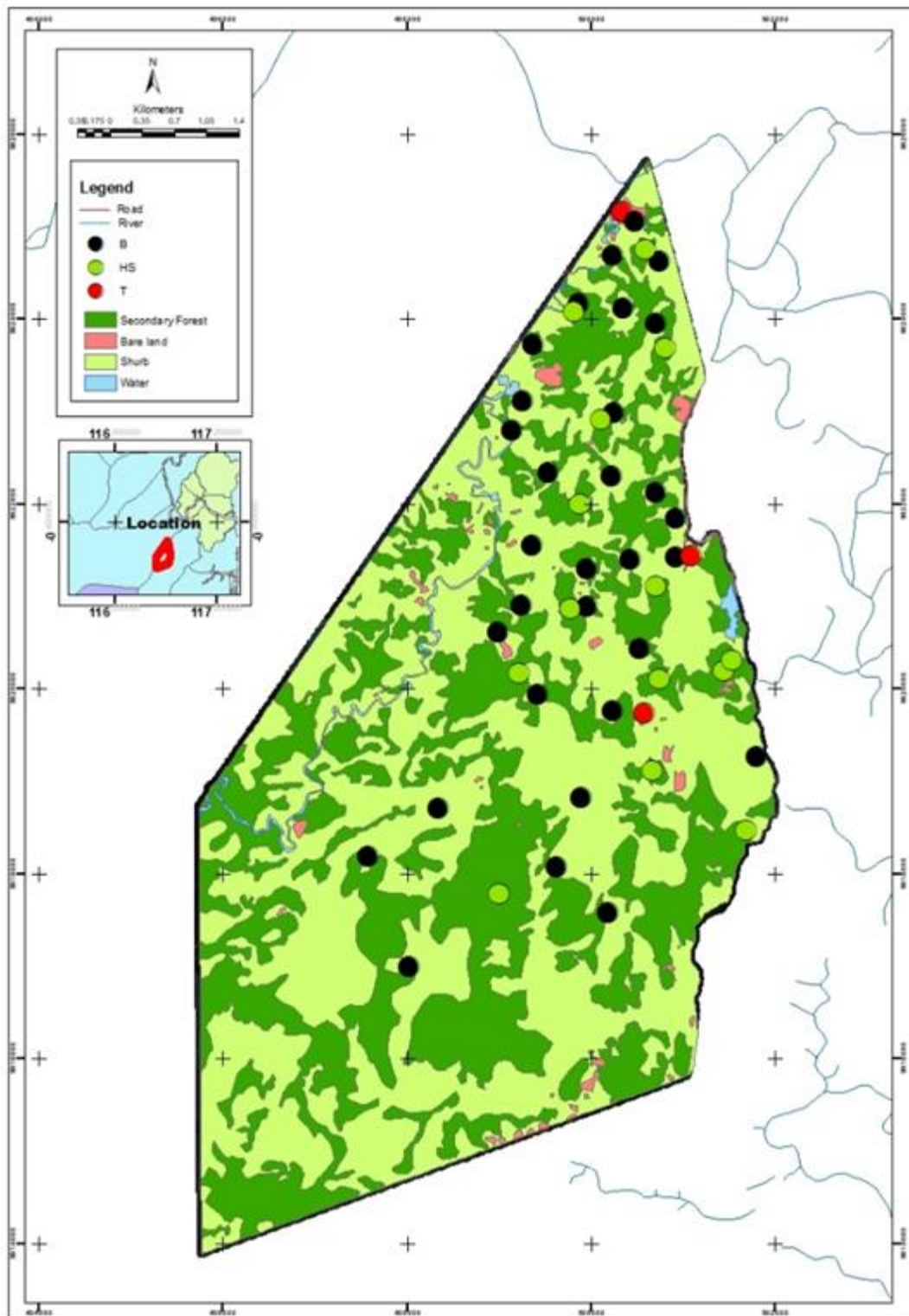


Figure 2 Land cover classification maps and sample plots distribution over Loa Haur forest

3. RESULTS AND DISCUSSION

Table 1 shows the composition of three land and forest cover of Loa Haur forest derived from Sentinel-2 imageries taken in 2018. The shrub is dominant in this forest, followed by secondary forest. Waterbody was also identified as Sentinel-2 captured flowing rivers and streams. Bare land is sparsely found in the study area,

which reflected logged over or former mixed plantation planted by people who have a land certificate from sub-district before it is decided to be a conservation area.

Comparison between actual land cover from sample plots and land cover classification map based on visual interpretation was shown in the confusion matrix (Table 2). Two secondary forest sample plots were

misinterpreted, which in fact, are shrub on the ground. Meanwhile, two sample plots that representing shrub based on Sentinel-2 image were, in fact, secondary forest. Bare land is a distinctive land cover and therefore easy to be classified.

The accuracy of land cover classification is essential to ensure carbon stock estimation is valid and less uncertain. The more accurate the category of land cover, the more precise the estimated carbon stock produced. Using the confusion matrix shown in Table 2, the Kappa value was yielded, and the result is quite promising. Kappa values score is 0.83 or 83% which can be concluded that visual interpretation of Sentinel-2 image over study area is perfect [13,14]. This result also indicates that the uncertainty is relatively small, so that above-ground carbon stock estimation would be less biased.

In comparison, the results of similar studies are presented here. Using moderate spatial resolution satellite imageries, the Kappa value varies from 84.2% [5] to 99.5% [15]. The Kappa values tend to get lower when a high spatial resolution of satellite image was used. The Kappa test was applied to assess land use classification accuracy using WorldView-2 and gained the value of only 60% [7]. A similar result [8] was obtained a Kappa value of 78.51% by using Quickbird.

Table 3 below showed the interpolation results of above-ground carbon based on established sample plots. From 31 sample plots, the secondary forest has average above-ground biomass of approximately 236.82 Mg/ha. This amount of biomass equals 111.30 Mg/ha of carbon. Above-ground biomass was estimated as much as 23.06 Mg/ha or equal to 10.84 Mg/ha of carbon in the shrub. Meanwhile, bare land showed less above-ground biomass and carbon, 9.85 Mg/ha and 4.63 Mg/ha, respectively. Total above-ground biomass for the entire Loa Haur forest is 475,071.22 Mg or equal to 223,283.48 Mg of carbon.

From the above result, the estimation of the above-ground carbon stock of secondary forest in Loa Haur is slightly higher than the national reference level, which is 103.59 Mg/ha. This national reference value was collected from various sources, including research reports, theses, dissertations, journal/scientific publications, and project reports. The secondary forests' national reference level ranges from 34.99 Mg/ha to 216 Mg/ha. East Kalimantan carbon stock for the secondary forest is 178 Mg/ha [16]. Carbon stock in Berau, East Kalimantan for the secondary lower montane rainforest, secondary upper montane rainforest, shrubs, bare area, and water land cover are 134.17 Mg/ha, 95.96 Mg/ha, 23.72 Mg/ha, 0 Mg/ha, and 0 t/ha, respectively [17]. The above-ground carbon stock in Samarinda, East Kalimantan for the secondary forest, shrub, and bushes are 69.93 Mg/ha, 31.14 Mg/ha 19.32 Mg/ha,

respectively [18]. The carbon stock in Amandit sub-subwatershed in South Kalimantan for the secondary forest, shrub, bare land, and water are 76.40 Mg/ha, 4.35 Mg/ha, 0 Mg/ha, dan 0 Mg/ha, respectively [11].

Based on those previous studies, it can be said that carbon stock in Loa Haur forest is a typical tropical forest of Kalimantan. Therefore it does not significantly different from place to place. The difference in the result of Loa Haur carbon stock and Amandit sub-subwatershed is made possible due to differences in the area's land-use dynamics. Loa Haur is a conservation forest where there is no human intervention on a large scale. Meanwhile, in the Amandit sub-sub watershed, there are many forms of land use around the forest, such as plantations, mixed plantations, settlements, rice fields, and moors that can affect the forest.

4. CONCLUSION

Loa Haur forest's above-ground carbon stock of secondary forest, shrub, and bare land is 111.30 Mg/ha, 10.84 Mg/ha, and 4.63 Mg/ha. The total carbon of the Loa Haur forest is 223,283.48 Mg.

ACKNOWLEDGMENTS

Authors thank Mr. Edi Kurniadi as Head of Education and Training Institute of Environment and Forestry in Samarinda for his support of this research, Fadil, Reski, Hasan, and Ari for their help in field data collected, Mr. Sugiarto for his shared knowledge, Mr. Trisnaputra for his comments, ISTFES, and other parties that cannot be mentioned one by one.

REFERENCES

- [1] Anonim, Laporan Pelaksanaan Kegiatan Survei Potensi di KHDTK Hutan Diklat Loa Haur, Balai Diklat Kehutanan, Samarinda, 2015.
- [2] R.H. Purwanto, I. Sukamdi, A. Wuryanto, Estimasi Biomassa Tegakan Jati (*Tectona grandis*) Melalui Analisis Data Digital Landat 7 ETM+ di BKPH Pasar Sore KPH Cepu, Perum Perhutani Unit I Jawa Tengah, Jurnal Manajemen Hutan, 1(2), 2009, p. 1.
- [3] Suhet, Sentinel-2: User Hand Book, European Space Agency, French, 2015, p. 9–54.
- [4] S.M. Walker, T. Pearson, S. Brown, Calculation of The Number of Sample Plots For Measurement Within A/R CDM Project Activities (CDM Executive Board UNFCCC/CCNUCC), 2007, pp. 2–4
- [5] M. Alkaf, K. Munibah, O. Rusdiana, Model Spasial Perubahan Penggunaan Lahan di Taman Nasional

- Gunung Merbabu dan Daerah Penyangganya, *Globe*, 16(1), 2014, p. 46.
- [6] M. Khosyi'ah, M. Arozaq, H. Noor, V. Andarista, A.D. Rahmawati, R.K. Putra, Interpretasi Citra Quickbird untuk Identifikasi Penggunaan Lahan di Desa Karangtengah Kecamatan Sragen Kabupaten Sragen, *Geotik*, 2017, p. 260.
- [7] I.P. Putra, Pemetaan Bentik Habitat dan Tutupan Lahan Pulau Tunda Menggunakan Citra Satelit Worldview-2, Institut Pertanian Bogor, Bogor, 2016, p. 11.
- [8] I. Yanuarsyah, S.A. Hujimartsu, Analisis Perubahan Penggunaan Lahan Pertanian Presisi dengan Metode OBIA (Studi Kasus di Kecamatan Dramaga, Kabupaten Bogor), *Krea-TIF*, 3(1), 2015, p. 33.
- [9] J. Chave, C. Andalo, S. Brown, M.A. Cairns, J.Q. Chambers, D. Eamus, H. Fölster, F. Fromard, N. Higuchi, T. Kira, J.P. Lescure, B.W. Nelson, H. Ogawa, H. Puig, B. Riéra, T. Yamakura, Tree Allometry and Improved Estimation of Carbon Stock and Balance in Tropical Forest, *Oecologia*, 145, 2005, p. 92.
- [10] Chairul, E. Muchtar, T.M. Mansyurdin, G. Indra, Struktur Kerapatan Vegetasi dan Estimasi Kandungan Karbon Pada Beberapa Kondisi Hutan di Pulau Siberut Sumatera Barat, *Metamorfosa III*, (1), 2016, p. 17.
- [11] A. Fithria, Syam'aini, Estimasi Cadangan Karbon dan Emisi Karbon di Sub-Sub DAS Amandit, *Hutan Tropis*, 1(3), 2013, p. 221.
- [12] R.F. Noor'an, I.N.S. Jaya, N. Puspaningsih, Pendugaan Perubahan Stok Karbon di Taman Nasional Bromo Tengger Semeru, *Media Konservasi*, 20(2), 2015, p. 177.
- [13] J. Landis, G. Koch, The Measurement of Observer Agreement for Categorical Data, *Biometrics*, 33, 1977, pp. 159–174.
- [14] D. Altman, *Practical Statistics for Medical Research*, Chapman and Hall, (London, 1991, pp. 404–406.
- [15] R.M. Sampurno, A. Thoriq, Klasifikasi Tutupan Lahan Menggunakan Citra Landsat 8 Operational Land Imager (OLI) di Kabupaten Sumedang, *Teknotan*, 1(2), 2016, p. 68.
- [16] Y. Rochmayanto, A. Wibowo, M. Lugina, T. Butarbutar, R.M. Mulyadin, D. Wicaksono, Cadangan Karbon pada Berbagai Tipe Hutan dan Jenis Tanaman di Indonesia, *Kanisius*, Yogyakarta, 2014, pp. 9-11.
- [17] P. Navratil, K. Peterson, F. Siegert, Survey on The Land Cover Situation and Land Use Change in The District Berau, Indonesia. *Remote Sensing Solutions*, GmbH, Hamburg, 2012, p. 20-21.
- [18] Z. Ahzam, Estimasi Cadangan Karbon pada Tutupan Lahan Hutan Sekunder, Semak dan Belukat di Kota Samarinda, *Agrifor* 16(2), 2015, p. 335.