Measuring Environmental and Socio-economic Impact of Deforestation at Kalimantan Island

Irmadi Nahib, Soma Trenggana, Turmudi, Jaka Suryanta, Sri Lestari Munajati and Rizka Windiastuti

Geospatial Information Agency
Jl Raya Jakarta Bogor KM 46 Cibinong, Jawa Barat, 16911, Indonesia

E-mail: irmnahib@gmail.com, irmadi.nahib@big.go.id

Abstract. Indonesia’s forests in the period of 2000-2009 has been deforested by about 15.158 million ha out of 103.309 million ha. Deforestation caused carbon emissions. One method for measuring emissions from deforestation and forest degradation is GeOSIRIS model. A modeled GeOSIRIS policy used a carbon payment system to incentivize emission reductions. Data used in this study were maps of forest cover in 2005 and 2010, map of deforestation 2005-2010, carbon and agricultural price and driver variables for deforestation such as slope, elevation, logarithmic distance to the nearest road or provincial capital, or the amount of area per pixel included in a national park, or a timber plantation. The result of this study showed rate of deforestation was 1.417 million ha/5 years (observed). The REDD policy could decrease deforestation in Kalimantan Island by 0.170 million ha (16.70%), with assumption that international carbon price of US$ 10/tCO$_2$. The change of emissions due to REDD was 22.29%, or reduced emissions by 245.03 million tCO$_2$/5 years. Finally, Gross National Revenue from carbon payments (NPV 5 years) was US$ 2,450.34 billion, where incentivize emission reductions to sub-national entities (NPV, 5 years) was US$ 2,150.07 million and net central government surplus from carbon payments was US$ 300.26 million (NPV, 5 years).

1. Introduction

Tropical forests and other vegetated landscapes like grasslands and wooded savannahs play a major role in the global carbon sequestration process and their conservation and protection offers immense potential for reducing greenhouse gas emissions and global warming [1]. Referring to Barlow, et al [2] that clearing of primary forests also results in the destruction of unique tropical forest habitats, thus causing the loss of biodiversity.

Among tropical countries Indonesia experiences the second highest rate of deforestation. Therefore, accurate and up-to-date forest data are required to fight deforestation and forest degradation to support initiatives of climate change mitigation and biodiversity conservation policy [3]. Meanwhile, Sumargo, et al [4] explained that the largest of deforestation in Indonesia, occurred in Kalimantan and Sumatra with a percentage of 36.32% and 24.49% respectively, followed by Sulawesi 11.00%, Java 9.12%, Maluku 8.30%, Bali-Nusa Tenggara 6.62%. Papua became the smallest area contributing to deforestation of 4.15%. It could be seen that deforestation in Indonesia until 2009 was concentrated in Kalimantan and Sumatra.

Out of the 15.79 Mha of forest cover loss for Indonesia, reported 38% (6.02 Mha) happened inside primary intact or damaged forests [5]. Meanwhile, Margono et al., (2014) said that over the study period annual primary forest cover loss increased with the highest total loss happened in 2012 (0.84Mha). The number was greater
than the reported forest loss of Brazil (0.46Mha; ref. 33), which was the historical leader in the tropical forest clearing. Referring to [6], Borneo Island in the period 2000-2011 has deforestation amounted to 3.040 million ha, namely deforestation in peat forests of 0.560 million (18.42%) and deforestation in mineral land (non-peatland) for 2,480 million (81.58%). Based on the period of time of deforestation, 48.5% of deforestation occurred in the period 2006-2011, i.e. deforestation on peat forests of 0.334 million ha (59.69%) and deforestation in mineral forests of 1.144 million (46.15%).

In Indonesia deforestation is usually linked with production of timber and expansion of settlement and agricultural area. When this existing trend continues without implementing any corrective measures, it is projected to result in a reduction of forest cover by 15% between 2015 and 2030, going from approximately 880,000 km² to 749,941 km². On average, 8,300 km² of forest would be cleared for timber extraction or land conversion every year between 2015 and 2030. When the forest cover declines, so does the amount of carbon stored. The cumulative emissions from 2015 to 2030 due to forest loss would reach 2.5 billion tCO₂, which, assuming an average carbon price of USD 5 to USD 10 per ton (based on international average market prices), would translate in a cumulative loss of about USD 10 billion to USD 25 billion between 2015 and 2030. [7]

REDD is not directed at stopping planned conversion of forests to other economic uses, nor at stopping the use of forests for timber. REDD signifies a way to value natural resource of carbon so that it can be considered along with other regular forest assets, when making decisions about land use and forest use [8].

In the calculation and modeling for carbon emissions, there are several methods and approaches. One model is the GeOSIRIS model developed by Jonah Busch at Conservation International. The GeOSIRIS model was originally developed as OSIRIS as a transparent decision support tool for REDD+ policy makers [9].

The GeOSIRIS modeler is different from the REDD modeler found in Land Change Modeler (LCM). The REDD modeler in LCM predicts how carbon emissions and deforestation would change if a certain reference area were shielded from deforestation. Meanwhile, the GeOSIRIS modeler adopt an alternate strategy. A carbon payment system is used by a modelled GeOSIRIS policy to give incentives to emission reductions. The policy can be governed at various administrative levels, such as province or district. Rather than defending a specific section of land from deforestation, scope of work for GeOSIRIS projects would be on regional or national scale, by setting a certain price to every ton of carbon dioxide emitted ($/tCO₂e). The GeOSIRIS model assumes forest users encounter a trade-off between the carbon revenue obtained by protecting the forests and the agricultural revenue obtained from deforesting the land. Given some variables such as a proposed carbon price and maps of previous deforestation, the model predicts how carbon emissions, deforestation, and agricultural and carbon revenues would change if such policy were implemented [9].

The model designs balance incentives to lower usually high deforestation emissions with incentives to keep usually low deforestation emissions. Approximations of emission reductions under REDD depend significantly on the degree to which demand for tropical agriculture in the borderline generates leakage. This emphasizes the potential importance to REDD of balancing strategies to supply agricultural needs outside the forest borderline [10].

The purposes of this study were to measure deforestation and carbon emissions in period of 2005-2010 at Kalimantan Island and to know the incentive value to be paid by the government.

2. Material and Methods

2.1 Data used

This study used data from https://clarklabs.org/download/terrset-tutorial-data/, accessed on April 4, 2017, either: (a) forest cover maps in 2005 and 2010, deforestation map 2005-2010 (see Figure 1); (b) map of potential driver variables for deforestation, consisting of maps: slope, elevation, logarithmic distance to the nearest road, distance from the provincial capital, national park map, plantation area map (see Figure 2). These data are global data with spatial resolution of 3 km x 3 km. These data include global data that can be used for monitoring a large area (such as the whole Indonesia), due to the availability of sufficient data. However, for more specific planning, medium and detail scale data are needed to obtain more accurate results.

The disadvantage of these data is that the spatial resolution is too small (where one pixel represents an area of 900 ha). Therefore, areas with less than 900 ha (one pixel) will be combined into a more dominant class. The map actually covered the entire territory of Indonesia, but for this study it was cropped to cover only Kalimantan Island.
Figure 1. Forest area at Kalimantan Island.

a. Elevation (m dpl)  b. Slope (percent)  c. Logging (Ha per pixel)  d. Timber (ha per pixel)

e. National Park (ha per pixel)  f. Peat Swamp (0= Non Peat, 1= peat)  g. Protected areal (ha per pixel)  h. Emission factor (ton CO$_2$e per ha)

i. Tree Crops (ha per pixel)  j. Agricultural Revenue (USD per hectare)  k. logarithmic distance to the nearest road (km)  l. logarithmic distance to the nearest province capital
m. Above and Ground carbon (tons/hectare)  

n. Solil carbon (tons/hectare)

**Figure 2.** Potential driver variables for deforestation.

The GeOSIRIS model in REDD impact calculations is based on an enhanced OSIRIS model [9]. The flow chart of the GeOSIRIS modeling stage is presented in figure 3. In general, GeOSIRIS model has two main steps: (1) regression analysis, where the regression coefficient(s) and Effective Opportunity Cost image are calculated, and (2) calculations of proportional national change in agricultural price and output images, then the summary Excel spreadsheet is generated.

![Flowchart of GeOSIRIS model](image)

**Figure 3.** Flowchart stage research activities.

2.2. **Regression Analysis**
Stage of activity in this research refers to Eastman [9]. The regression step of the GeOSIRIS modeler calculates the correlation between deforestation and some individual variables (14 variables), including agricultural revenue. There are several options to classify this regression, where GeOSIRIS will run a separate regression for several different classes. These classes can be based on the amount of preexisting forest cover. This study is based on geographic regions, such as provinces (5 provinces) or districts (55 districts).
The regression model used in this study is Poisson regression, in which the deforestation is counted by assuming that each pixel is composed of smaller subsections which may be individually deforested [9]. The Poisson regression uses the following formula:

\[ E(Y / X) = e^{\sum_{i=0}^{N} B_i X_i} \]  

(1)

where:

\( Y | X \) = the expected count of deforestation (Y) given certain input conditions (X)

\( X_i \) = independent variable \((X_0=1 \text{ for the constant term})\)

\( B_i \) = variable coefficients (or parameters)

The model parameters consist of external variables (economic variables) and parameters that affect the price of agricultural products. Net Present Value formula:

\[ NPV = \sum_{t=1}^{T} (B_t - C_t)(1 - i)^{-t} \]  

(2)

where:

\( R_t \) = total revenue generated in year \( t \),

\( C_t \) = total costs in year \( t \),

\( i \) = interest rate

\( T \) = expected lifetime (5 years)

The model parameters are economic and those affecting the price of agriculture products. The price elasticity is a measure on how sensitive the agriculture production price is to the change in deforestation. The external factors causing the increase in agricultural price (exogenous change) is a part of the final change in agricultural price as shown in figure 4.

![Figure 4. The exogenous increasing in agricultural price.](image)

The GeOSIRIS model can be applied at different administrative levels, such as the district or provincial level. Image files are inputted in the administrative levels table of the input image files panel. The emission factor map is used to calculate the amount of CO₂ (in tons) that will be emitted per hectare of deforestation. There are three components for the emission factor in the GeOSIRIS model: soil carbon, above and below-ground carbon, and peat. The calculations of the emission factor for each pixel are:

\[ E_{\text{soil}} = (AB + SC \times f_s) \times 3.67 \text{ where peat } P=0 \]  

(3)

\[ E = AB \times 3.67 + fp \text{ where peat } P>0 \]  

(4)
where:

\[ E = \text{emission factor (tCO}_2\text{e/ha)} \]

\[ AB = \text{above and ground carbon} \]

\[ SC = \text{soil carbon} \]

\[ fs = \text{soil carbon factor} \]

\[ fp = \text{emission factor for peat soil} \]

The final proportional change in the price of agricultural product is calculated in the output parameters panel. An iterative loop and two input parameters, which are model precision and maximum number of iterations, are used in this calculation. The price change is then calculated as the sum of endogenous change and exogenous change.

\[
\text{Change in Agricultural Price} = \text{endogenous change (independent)} + \text{exogenous changes} \tag{5}
\]

\[
\text{endogenous Change} = \left( \frac{\text{Deforestation without REDD}}{\text{Deforestation with REDD}} \right)^e \tag{6}
\]

where:

the exponent \( e \) = price elasticity

### 2.3 Calculating the Proportional Change in Agricultural Price

The GeOSIRIS model compares two consecutive values of changes in agricultural product price to see whether the value is appropriate. The model will keep on going until either the precision model or the maximum number of iterations are exceeded. The last iteration value obtained will be used for final calculation. Analysis of changes in agricultural prices, where proportional changes in agricultural prices are calculated, the image as a result of the analysis, and summary of the calculation results (in Excel worksheet) are then generated.

### 3. Results and discussion

#### 3.1 Deforestation

The total forest area at Kalimantan Island in 2005 was 29.321 million ha or about 56.33% of the whole Kalimantan Island. It consists of 4.032 million ha (13.75 %) peatland forest and of 25.259 million ha (86.25 %) non-peatland forest or mineral forest. Based on forest type, it consists of primary forest and secondary forest. In the period of 2005-2010 deforestation at Kalimantan Island was 1.417 million ha (4.83%), comprising 0.350 million ha (26.48%) of peatland forests and 1.066 million ha (75.26%) of mineral forests. The rate of deforestation at peatland forest was 8.69% and at non-peatland forest was 4.21%, as presented in Table 1 and Figure 5.

Deforestation that occured at mineral forests was higher than at peatland forests because people prefer to utilize forests in mineral land first, where accessibility is easier and the existence of forests is also wider. Reduced forests in mineral land would then trigger people to take advantage of peatland forests.

The deforestation was relatively similar to the results of [4, 6]. Refer to Sumargo [4] explained that deforestation at Kalimantan Island in the period 2000-2009 amounted to 3.040 million ha, namely deforestation at peat forests of 0.560 million (18.42%) and deforestation at mineral land (non-peatland) of 2.480 million (81.58%). Meanwhile, motivated by [6] deforestation at Kalimantan Island in the period 2006-2011 amounted to 1.479 million ha (5.04%), namely deforestation at peat forests of 0.334 million ha (22.60%) and deforestation at mineral land (non-peatland) of 1.144 million ha (77.40%).
Table 1: Results of Deforestation Estimation Year 2005-2010 in Kalimantan Island.

| No | Kalimantan Island | All land | Peatland | Non-peatland |
|----|-------------------|----------|----------|--------------|
| 1  | Land area (ha)    | 52,049,200 | 8,175,614 | 43,873,588   |
| 2  | Starting forest area (ha) | 29,321,650 | 4,032,375 | 25,289,276   |
| 3  | Deforestation without REDD (observed; ha/5 years) | 1,417,493 | 350,562 | 1,066,931 |
| 4  | Deforestation rate without REDD (observed; %/years) | 0.986% | 0.905% | 0.430% |
| 5  | Deforestation without REDD (modeled; ha/5 years) | 1,020,521 | 299,114 | 721,406 |
| 6  | Deforestation rate without REDD (modeled; %/years) | 0.706% | 0.768% | 0.289% |
| 7  | Deforestation with REDD (modeled; ha/5 years) | 850,074 | 213,817 | 636,257 |
| 8  | Deforestation rate with REDD (modeled; %/years) | 0.587% | 0.543% | 0.254% |
| 9  | Reduction in deforestation (ha/5 years) | 170,447 | 85,298 | 85,149 |
| 10 | Change in deforestation due to REDD (percent) | -16.70% | -28.52% | -11.80% |

Figure 5. Map of deforestation at Kalimantan Islands.

The rate of deforestation in Kalimantan Island was lower than both deforestation occurred in Sumatera Island and average deforestation in Indonesia over the same period. Deforestation in Sumatera Island was 1.622 million ha (8.77%), comprising of deforestation at peat forest 0.824 million (50.50%) and deforestation at mineral soils 0.808 million ha (49.50%). While average deforestation in Indonesia was 4.647 million ha (5.00%), comprising of deforestation at peat forests 1.696 million ha (13.01%) and deforestation at mineral soils 2.950 million ha (3.69%). Based on type of forest, the rate of deforestation at peat forest in Kalimantan Islands (8.69%) was lower than in Sumatera Island (13.01%) and in average of Indonesia (26.49%). Furthermore, Margono [11] declared deforestation of primary forest at Kalimantan in 2000-2012 amounted to 2.377 million ha, comprising of deforestation at wetland forest 0.897 million ha and at dryland forest 1.390 million ha. The rate of deforestation of total primary forest was 7.92%, at wetland forest was 5.25%, and at dryland forest was 5.77%. The rate of deforestation at Kalimantan Islands varied depending on the level of spatial resolution of data sources used. Margono’s research used Landsat Image data, therefore he got larger amount of deforestation. This was because spatial resolution of the image was 30 m, more meticulous than the global data used in this study with spatial resolution of 3 km.

The deforestation in 2005-2010 happened as a result of government policy in the development of agricultural areas, the development of oil palm plantations and industrial plantations. This is in line with the
findings of study of expansion of agricultural policy, timber extraction and infrastructure expansion [12]. The main reasons of forest cover deficit in Kalimantan were related to the expansion of worldwide markets for pulp, wood and palm oil [13,14]. While Margono [15] asserted that in the period of 2000-2010 the cause of deforestation was the expansion of agricultural areas, especially palm oil plantations, expansion of pulp and paper plantation industrial areas and industrial forest clearance.

3.2 Carbon Emissions The impact of REDD
Implementation of REDD policies, which have an impact on reducing forest degradation, also directly impact on reductions of carbon emissions. Based on the variables affecting deforestation, carbon emissions and peat swamp factors have a strong effect to deforestation as shown in figure 6.

![Figure 6. Carbon emission factor and peat-swamp.](image)

Carbon emission factors in West Kalimantan Province and Central Kalimantan have relatively higher value compared to other provinces. This is related to the presence of large peat forest located in this area, while peatland is the highest contributor to emissions. The forest emissions (emitable CO$_2$) at Kalimantan Island was 16.792 million tCO$_2$e, donation from peat forest 6.798 million tCO$_2$e (40.48%) and from mineral forest 9.994 million tCO$_2$e (59.52%). The amount of carbon emissions in Kalimantan Island was 27.163 million tCO$_2$e. Compared to Sumatra and average of Indonesia, carbon emissions at Kalimantan was lower (22.29%), followed by average carbon emissions that occur at whole Indonesia (24.75%) and Sumatra Island (46.83%). Both islands (Kalimantan and Sumatra) contributes carbon emissions as much as 69.14%. Meanwhile, according to Alliance (2008) stated that Indonesia had various emission levels from deforestation on each island. The highest emissions came from Sumatra, which were almost 56% of all emissions, and the second was Kalimantan with 28%, thus total for both islands was 84%. Therefore, it is important to focus on these two islands in implementing emission reduction strategies. The high emissions from Sumatra and Kalimantan were caused by the high deforestation rate on both islands, reaching 77% of Indonesia's total deforestation. Deforestation in Sumatra contributed the greatest importance of the existing focus on clearance of peat forest [16].

The REDD policy targeted carbon emissions of 1.099 million ha. Meanwhile, the gross emission reduction that could be obtained was 1.099 million tCO$_2$e, and emissions that could be absorbed by forests was 0.854 million tCO$_2$e. The REDD policy was capable of reducing carbon emissions at Kalimantan Island by 0.245 million tCO$_2$e (47.83%). Meanwhile, the reduction of carbon emission in peat forest area was 0.80 million tCO$_2$e (28.30%) and in mineral soil forest area was 0.64 million tCO$_2$e (14.02 %) as presented in Table 3 and Figure 7.
The decline in carbon emission levels at Kalimantan Island was lower than the reduced emission carbon that occurred at Sumatera Islands and also at Indonesia in the same period. The carbon emission reduction at Kalimantan Island was 245 million tCO$_2$e (22.29%), consisting of 180 million tCO2e (28.52%) at peatland forest and 64 million tCO2e (14.22%) at mineral soil. Meanwhile, the decline in carbon emissions in Indonesia was 1.091 million tCO2e (24.75%), comprising of 858 million (32.42%) at peatland forests and a decrease in mineral soil carbon emissions of 233 million tCO2e (13.22%).

Changes in carbon emissions were proportional to the rate of deforestation that occurred. The relatively smaller peatland forest area compared to the mineral forests caused the reductions deforestation rate (percentage of deforestation) in peatland forests to be greater than the rate of deforestation in mineral forests, with the same forest area.

Assuming that world carbon price was US $ 10 /tCO2e, impact of REDD Policy at Kalimantan Island was that the gross national revenue from carbon payments (NPV, 5 years) would be $ 2,450.34 million, with allocation for local government (provincial and district) as incentives (NPV, 5 years) was $ 2,150.07 million (87.56%). Net government surplus originating from carbon payments was US $ 300.28 million (NPV, 5 years).

Results of the study [17] that calculated carbon emissions in Bolivia, GeOSIRIS could also be used to evaluate how much reduction of deforestation could be achieved with the price of alternative carbon. With
international CO$_2$ price of $5/tCO$_2$, deforestation at the Kalimantan Island could be reduced by about 15% (assuming there was no transaction costs). With a price of $10 it could be reduced by about 30% and at $30 by around 57% (see Figure 8).

The increase in carbon prices will spur activities to protect the forests so that the forests will be better protected and deforestation will also occur. Conversely, if there is an increase in price of agricultural products, then the rate of deforestation will also increase, because more forest areas will be cultivated into agricultural areas.

![Relationship of carbon price with deforestation and carbon emission.](image)

Similarly, a success in reducing deforestation is linearly related to reduction of carbon emissions. The more forests that can be protected from logging, the more economically beneficial they will be. If the REDD policy scenario will be applied at the provincial or district level, then based on the trade-off between carbon revenues and agricultural income (minus fines for carbon payments), 4 provinces (80%) and 43 districts (78%) will be involved for the success of REDD programs in Kalimantan Island.

4. Conclusion

In the period 2005-2010, deforestation at Kalimantan Island was 1.417 million ha (4.83%). The simulation result, impact of REDD policy could reduce deforestation at Kalimantan Island by 0.170 million ha (16.70%) and also could reduce carbon emission by 245.03 million tCO$_2$e/5 years (22.29%), causing net government surplus originating from carbon payments by US $ 300.28 million (NPV, 5 years).

Acknowledgment

Thanks to the Head of Center for Research, Promotion and Cooperation, and Head of Research Division of Geospatial Information Agency of Indonesia (BIG) who have facilitated this research activity. Also, a huge thanks to TerrSett that provided data.

References

[1] Bununu Y A, Ludin A N M, and Hosni N 2016 Proc 10th SEATUC Symposium (Tokyo: Shibaura Institute of Technology)
[2] Barlow J, Gardner T A, Araujo I S, Ávila-Pires T C, Bonaldo A B, Costa J E, and Hoogmoed M S 2007 Proc of The National Academy of Sciences of the United States of America
[3] FAO 2010 Global Forest Resources Assessment 2010 Country Report Indonesia Forest Resource Assessment (FRA) 2010/095 (Rome: UNFAO).
[4] Sumargo W, Nanggara S G, Nainggolan FA, Apriani I 2011 Portrait of Indonesia's Forest 2000-2009 1st Edition (Jakarta: Forest Watch Indonesia)
[5] Hansen M C, Potapov P V, Moore R, Hancher M, Turubanova S, Tyukavina A, and Kommareddy A 2013 *High-resolution global maps of 21st-century forest cover change* (Science vol 34)

[6] MoEF 2016 *National Forest Reference Emission Level for Deforestation and Forest Degradation: In the Context of Decision 1/CP.16 para 70 UNFCCC* (Encourages developing country Parties to contribute to mitigation actions in the forest sector) (Jakarta: Directorate General of Climate Change. The Ministry of Environment and Forestry)

[7] Bassi A, Varma K, and Toppo W 2015 *Forest ecosystem valuation study: Indonesia. United Nations Office for REDD Coordination in Indonesia (UNORCID)*

[8] Ministry of Forestry of the Republic of Indonesia 2008. *Consolidation Report Reducing Emissions From Deforestation And Forest Degradation In Indonesia.*

[9] Eastman JR 2014 *Manual Terrset Manual (Chapter Eight : Geosiris).* Clark Labs, Clark University, Worcester, Massachusetts.

[10] Busch, J., Strassburg, B., Cattaneo, A., Lubowski, R., Bruner, A., Rice, R., ... & Boltz, F. 2009. Comparing climate and cost impacts of reference levels for reducing emissions from deforestation. *Environmental Research Letters*, 4(4), 044006

[11] Margono B A, Potapov P V, Turubanova S, Stolle F, and Hansen M C 2014 *Nature Climate Change* 4 730-735

[12] Fuller, D. O., Jessup, T. C., & Salim, A. 2004. Loss of forest cover in Kalimantan, Indonesia, since the 1997–1998 El Nino. *Conservation Biology*, 18(1), 249-254.

[13] Nawir A A, Murniati and Rumboko L 2007 *Forest Rehabilitation in Indonesia: Where to After More Than Three Decades?* (Bogor: CIFOR)

[14] Uryu Y, Mott C, Foad N, Yulianto K, Budiman, A, Setiabudi, F T, and Jaenicke J 2008 *Deforestation, forest degradation, biodiversity loss and CO2 emissions in Riau, Sumatra, Indonesia* (Jakarta: WWF Indonesia)

[15] Margono B A, Turubanova S, Zhuravleva I, Potapov P, Tyukavina A, Baccini A, and Hansen M C 2012 *Environmental Research Letters* 7 034010.

[16] Andersen L E, Busch J, Curran E, Ledezma J C, Mayorga J, and Bellier M 2012 *Environmental and socio-economic consequences of forest carbon payments in Bolivia: Results of the OSIRIS model* (Bolivia: Institute for Advanced Development Studies) p 35

[17] Alliance I F C 2008 *Reducing emissions from deforestation and forest degradation in Indonesia: IFCA consolidation report* (Jakarta: Forestry Research and Development Agency, Ministry of Forestry of Republic of Indonesia)