Dynamics of basal area increment and carbon value of natural forest stands in response to the El Nino occurrence in East Kalimantan

F H Susanty1*, Abdurachman1 and D D N Cahyono2
1Dipterocarps Forest Ecosystem Research and Development Center, Jl. A.W. Syahranie No.68 Sempaja Selatan 75119, Samarinda, East Kalimantan - Indonesia
2Forest Tree Seed Technology Research and Development Institute, Jl. Pakuan Cieheluet PO BOX 105 Bogor 16001, West Java - Indonesia
*Corresponding author: fhsusanty@gmail.com

Abstract. Climate change will have an impact on ecosystems, both flora and fauna. Forest stands or vegetation will have different resilience. This is indicated by a varied growth response. This study aims to show the dynamics of vegetation increment and carbon value of natural forest stands in response to the occurrence of El Nino. The research was conducted on permanent sample plots of primary mixed Dipterocarps forest in Labanan, East Kalimantan, which was built as many as 12 plots (12 ha) which were monitored along for 30 years (measurement period 1990-2020). The approach to assessing the vegetation response is based on the parameters of the basal area increment level and the carbon value of stands which are divided into aboveground and total. The analysis of the dynamics of the response is arranged in terms of time, with the existence of long post-el Nino drought conditions that occurred in 1997/1998 and 2015 in East Kalimantan. Variations in growth dynamics will occur in species groups based on ecophysiology factors. Assessment of primary forest provides an overview of growth rates based on genetic characteristics of the vegetation composition. The existence of El Nino as a factor in this condition is possible to decrease the density and basal area increment of stand after fourth year. The El Nino effect will reduce the total carbon value of primary forest stands by around 7.7-20.3% from the initial reserve.

1. Introduction
El Nino events as one climate change conditions occur in 1997/1998 and 2015 resulted in long periods of drought globally. The study on Borneo indicated that had a strong impact on tropical forest tree dynamics [1]. Especially in East Kalimantan, this condition triggered large forest fires and many hotspots. The shifting in the microclimate will have an impact on the condition of the ecosystem including the flora and fauna in it. Changes in water availability, a source of food for animals to the growth of forest stands. Each forest stand with different vegetation characteristics will have a different response to these environmental changes. One of the stand responses for which the data is quantified is a different growth pattern. Stand growth will be optimal in stands that have enough growth space and sufficient nutrient needs. Long-term observations will be able to explain the changes that occur, including the conditions before and after the El Nino event.

In the report from the Regional Council for Climate Change (Dewan Daerah Perubahan Iklim/DDPI) of East Kalimantan in 2020, data from the Meteorology, Climatology and Geophysics Agency (BMKG)
for Balikpapan station stated that climate change had occurred in East Kalimantan. The temperature in this region has increased by 1 degree in the last 30 years, starting from 1990-2020 [2]. The pattern of the dry season and the rainy season has changed. If the temperature increases in the next few years, it is predicted that the dry season will be drier and the rainy season will get more abundant water. The trend of rainfall is also increasing which can cause flooding in several areas in East Kalimantan. Community around in this study area highly dependent on exploitation and management activities natural resources for survival. In this regard, changes in the temperature pattern seasonality and rainfall (precipitation) has the potential to lower their level of well-being and reduce socio-ecological resilience as well as capacity to cope and/or adapt to external (exogenous) changes [3].

The occurrence of fragmentation in forest vegetation will occur after climate change. This change will be indicated by a shift in the growth pattern of the stands. Long-term observations of forest stands make it possible to see the dynamics that occur in response to environmental changes [4-6], including climate change. This study aims to show the dynamics of growth by stand basal area increment and the value of carbon in lowland tropical rainforest stands in response to El Nino occurrence. Changes in the characteristics of forests due to climate change are important to determine the right actions in efforts to conserve forests. Thus, to restore the function of the forest ecosystem for the flora and fauna live well.

2. Methodology

2.1. Study site
The study was carried out on primary low land tropical rainforest in Labanan forest research station. It is located in Labanan Village, Berau Regency, East Kalimantan, between 117°10'22" - 117°15'35" East Longitude and 1°52'43" - 1°57'34" North Latitude geographically. This location included on the Forest Area with the Special Purpose (KHDTK) Labanan under the management by Dipterocarps Forest Ecosystem Research and Development Center.

2.2. Data collecting
The design of the research plot is 200 m x 200 m (4 ha) divided into 4 subplots with a size of 100 m x 100 m (1 ha). The research plots were primary forest condition consisting of 3 plots with a total area of research plots of 12 ha. Stand data collection is based on field inventory carried out by census for all tree species with dbh limit of 10 cm. Measurements include tree species number, circumference/diameter of the trunk at breast height and the condition of the individual trees. In this study, using stand measurement data for the years along 1990-2020. Stand observation is carried out every 2 years.

2.3. Data analysis
The approach to assessing the dynamics of stand basal area increments and stand carbon values processed from Susanty [6][7], with the following formulas:

\[ rBa=\Sigma(\frac{1}{4} \pi d^2) \] (plot area) \[ rBD_i = \Sigma(bd_a - bd_i) \] (basal area increment)

whereas: \( Ba = \) basal area of stand (m\(^2\) ha\(^{-1}\)); \( d = \) diameter; \( \pi = \) constant (3.1415)

whereas: \( rBD_i = \) stand basal area increment (m\(^3\) ha\(^{-1}\) 2yr\(^{-1}\)); \( bd_o = \) stand basal area on the initial measuring (m\(^3\) ha\(^{-1}\)); \( bd_i = \) stand basal area of the next measurement/every period 2 year (m\(^3\) ha\(^{-1}\))

\[ \text{Log Vol} = - 3.6987519 + 2.3925507 \log (d) \] (volume of trees)

whereas: \( Vol = \) volume of trees (m\(^3\) ha\(^{-1}\)) [8]; \( d = \) diameter

\[ AGB = \text{Vol tegakan} \times \text{BCEF} \] (Stand Above Ground Biomass (ton ha\(^{-1}\)) [9]; Vol = stand volume (m\(^3\) ha\(^{-1}\)); BCEF =

\[ 2 \]
Biomass Conversion and Expansion Factor (based on IPCC 2006). This approach is used because it does not take the species density of each tree species in the stand into account.

\[
C_{AG} = AGB \times \% \text{C organic} \times (0.47)
\]

whereas: \(C_{AG}\) = Carbon on above ground (ton ha\(^{-1}\)) [10, 11]; \(AGB\) = Stand Above Ground Biomass (ton ha\(^{-1}\)).

\[
C_{Tot} = C_{AG} \times (1+RSR) \times (1.37)
\]

whereas: \(C_{Tot}\) = Total carbon [10, 11]; \(C_{AG}\) = Carbon on above ground (ton ha\(^{-1}\)); \(RSR\) = Root Shoot Ratio global for aboveground biomass estimation.

Assessment of the dynamic pattern of baseline area increments and the standing carbon value of natural forests during monitoring was carried out by means of regression analysis. The regression equations tested are linear, polynomial, exponential and logarithmic equations. The selection regression equation is carried out using a scatter technique diagram based on the highest correlation coefficient (r) and determination coefficient \((R^2)\).

3. Result and discussion

3.1. Stand basal area increment

Stand density conditions of lowland tropical rain forest ranged from 355-651 stems ha\(^{-1}\) at the beginning of the observation Figure 1. The dynamics of density values occur due to the presence of mortality and ingrowth which are included in tree measurements and observations. Throughout the 30 years of observation, it was stated that 2 El Nino events occurred in 1997-98 and 2015. The decrease in stand density response to drought occurred after 3-4 years after the El Niño year period (period 1 in 2002 and period 2 in 2018). On period 1, there was a decrease in stand density compared to the year before the drought due to this El Nino of 4.8% in 2002. On event period 2, the decrease of stand density of 1.2% on 2018. This indicates that the stand mortality rate in the drought that occurred in period 1997-2002 was higher compared the regeneration growth capabilities under observation. There was an increase in stand mortality after the El Nino drought [1].

In Figure 2 the pattern of increment value of primary forest stands during the observation year 1990-2020, there will be a similar pattern on El Nino 1 and 2 periods. The decrease in the ability of vegetation growth in the total stands was indicated by a decrease in the fourth year (period 1 in 2002 and period 2 in 2020). This condition indicates that the response of natural forest stands is not immediately visible after a drought occurs. Vegetation still has the ability to live optimally at 4 years after the drought. The decrease of basal area increments in period 1 cause el nino drought effect is lower \((r_{BA} = -0.78 \text{ m}^2 \text{ha}^{-1} \text{2yr}^{-1})\) than periode 2 \((r_{BA} = -4.13 \text{ m}^2 \text{ha}^{-1} \text{2yr}^{-1})\). In study on tropical rainforests [1], various tree dimensions and growth rates will provide various responses to environmental changes.
Figure 1. Dynamic of stand density (number of stem ha$^{-1}$) vegetation on primary forest along period 1990-2020 (Source: Primary data and using models were produces from [6]).

Figure 2. Dynamic of basal area increment of stand (m$^2$ ha$^{-1}$ 2yr$^{-1}$) vegetation on primary forest along period 1990-2020 (Source: Primary data).

3.2. Forest carbon value
The calculation of the estimated value of carbon stocks of stand refers to the formula that has been prepared in the Indonesian National Standard (SNI) Number 7724 of 2011. This provision explains about measurement and calculation of carbon stocks for estimating forest carbon stocks (ground based forest carbon accounting). For this study using standard specifies a field measurement method and the calculation of forest carbon stocks from five carbon pools at the level of detail (TIER) 3 in the context of monitoring forest carbon stocks. The equation for estimating carbon values using the specific on tropical rainforests in Kalimantan. For estimating root biomass content, it is too difficult to carry out measurements in the field. An alternative approach is to use the root to shoot ratio (RSR) method or the ratio of the ratio of root biomass (subsurface biomass) to aboveground biomass. The
Intergovernmental Panel on Climate Change (IPCC) in 2003 has also attached a global Root Shoot Ratio (RSR) table for estimating subsurface biomass of 0.37. This value is the same as the RSR value stated in SNI 7724 2011 for the calculation of total carbon (C total) in rainforests, especially in mixed Dipterocarp forest.

The review of changes in forest biomass restoration can be described based on the dynamics of the restoration of aboveground and total carbon values of natural forests. The results of this study used a BCEF value of 0.95 for all sampling plots, according to the IPCC guidelines (2006) [10] for volumes > 200 m³ ha⁻¹ in tropical natural forests. The calculation results for aboveground and total carbon value are presented in Figure 3-4, respectively.

In lowland tropical rain forests without disturbance (primary forest conditions) are shown in the first 2 monitoring periods. In this condition, primary forest stands have a total carbon value that ranges from 164 - 235 tons ha⁻¹. This value is close to the surface carbon value in primary forest in Nigeria of 210.93 tons ha⁻¹ [12], Vietnamese forests with light logging of 229 tons ha⁻¹ [13] and is higher than the average carbon value in the forests of Ghana, namely amounting to 173.0 tons ha⁻¹ [14]. Until 1998, both surface and total carbon value fluctuations would have relatively narrow movements. Fluctuations and decreases in the carbon value of forest stands occurred after the 1 El Nino period. A wider dynamic occurs after the second period of drought. The response of stands has become more varied after 2010. Based on the average total carbon value of standing stands, during the first period of drought there will be a total carbon decline of 20.3% after 4 years. Meanwhile, in period 2, the total standing carbon value will decrease by an average of 7.7% after 1 year of occurrence of drought. The decline in forest carbon value is generally due to forest degradation or logging. In a study in Vietnam [13], the surface carbon value for 10 cm diameter decreased by 48-52% if harvested with moderate to high intensity.

**Figure 3.** Dynamic of above ground carbon value of stand (ton ha⁻¹) vegetation on primary forest along period 1990-2020 (Source: Primary data and using models were produces from [7]).
Figure 4. Dynamic of total carbon value of stand (ton ha\(^{-1}\)) vegetation on primary forest along period 1990-2020 (Source : Primary data and using models were produces from [7]).

The dynamic pattern of forest stand parameters in the presence of 2 drought events throughout the 30 years of observation, was carried out using a regression approach with the results presented in Table 1. Based on the correlation and determination coefficient, a regression equation with a polynomial form was selected for the 4 parameters studied. The parameters of the density and increment of the basal area of the stand have a low correlation. It is possible that there are many other factors that influence the condition of mortality, ingrowth and growth rate. This was possible due to the diverse composition of species. Where each species or species group has a genetically different growth rate characteristic. Based on the selected regression equation, it shows that the time function has a correlation of more than 40% to the estimated above ground and total carbon stand values. Another study demonstrated that the allometric approach demonstrated the projection of stand carbon values based on structural parameters and stand physiognomy [15].

Table 1. The regression equation selected of stand growth dynamics parameters.

| Parameter                  | Equation regression                                      | r    | R\(^2\)   |
|----------------------------|---------------------------------------------------------|------|-----------|
| D (stems ha\(^{-1}\))     | \(y = 0.0174x^3 - 104.8x^2 + 209917x - 1E+08\) (polynomial) | 0.300| 0.0898    |
| rBA (m\(^2\)ha\(^{-1}\) 2yr\(^{-1}\)) | \(y = -0.0011x^3 + 6.7756x^2 - 13605x + 9E+06\) (polynomial) | 0.207| 0.0429    |
| C AG (ton ha\(^{-1}\))    | \(y = 0.0078x^3 - 46.62x^2 + 93390x - 6E+07\) (polynomial) | 0.637| 0.4053    |
| C Tot (ton ha\(^{-1}\))   | \(y = 0.0106x^3 - 63.87x^2 + 127944x - 9E+07\) (polynomial) | 0.637| 0.4053    |

Remarks: D = stand density; rBA = stand basal area increment; C AG = stand above ground carbon value; C Tot = Total carbon; r = correlation coefficient; R = determination coefficient (Source : Primary data).

Stand growth is the result of the interaction of the genetic characteristics of the species and the environmental conditions in which they live [5]. Mixed Dipterocarps forest having a difference of species composition in vegetation, by individual trees growth response will form the stand growth by totally. Stands with different species composition will have different stand productivity and growth pattern [16, 17]. The decline in forest carbon value as an indicator of forest productivity will be influenced by interventions on stands that cause degradation [13] and changes in habitat as forest ecosystems [11, 17]. In this study, climatic factors have not been described in more detail such as rainfall intensity and relative humidity yet. This becomes important in further research to review the dynamics
of change and its correlation to the dynamics of stand growth and even the condition of fauna and forest ecosystems.

4. Conclusions

Mixed Dipterocarps forest as a lowland tropical rainforest stands will naturally have resistance to the occurrence of El Nino drought. The impact of the long drought that occurs will be visible after 3-4 years on the total stand density and basal area increment as stand growth rate. This response will vary between natural forest stands, because it has a species composition with various characteristics that form a distinctive stand. The occurrence of El Nino drought will reduce the value of forest stand carbon of primary forest by around 7.7-20.3% from the initial reserve.

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