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Vegetation stands structure and aboveground biomass after the shifting cultivation practices of Karo People in Leuser Ecosystem, North Sumatra

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ABSTRACT

Aththorick TA, Setiadi D, Purwanto Y, Guhardja E. 2012. Vegetation stands structure and aboveground biomass after the shifting cultivation practices of Karo People in Leuser Ecosystem, North Sumatra. Biodiversitas 13: 92-97. Vegetation stands structure and aboveground biomass after the shifting cultivation practices of Karo People in Leuser Ecosystem, North Sumatra. Shifting cultivation has been practiced by Karo People in Leuser Ecosystem for a very long time and caused a mosaic of patches that shift over time between traditional agriculture and secondary forest. The objectives of this study were to investigate the recovery of vegetation stands structure and aboveground biomass in four age classes of secondary forest, i.e. 5-years old, 10-years old, 20-years old, 30-years old and primary forest as a control. In total, 496 subplots were surveyed. Saplings contributed 62.82% of basal area in 5-years forest and still important in 10 and 20-years forest, but density decreased in 30-years and primer forest whereas tree stands dominated in 30-years and primary forest and shared basal area of 96.36% and 97.03%, respectively. Aboveground biomass of trees achieved its highest values in primary forest, i.e. 659.22 t/ha and contributed to total aboveground biomass of 99.38%.

Key words: Leuser ecosystem, traditional agriculture, secondary forest

INTRODUCTION

Agricultural encroachment by shifting cultivation occupies a central position in the debate on tropical deforestation. Shifting cultivators are often seen as the primary agents of deforestation in developing countries; estimates of their share range as high as 45% (UNEP 1992) to 60% (Myers 1992). Shifting cultivation could be considered as an early stage in the evolution of agricultural systems. The system is based on cutting and burning the vegetation in the dry season, and planting crops in the wet season. The field eventually grows into secondary forest, before the cycle is repeated. The length of this fallow period varies considerably 5-20 years is common (FAO 1974). Fallow duration and cultivation periodicity may be influenced by multiple factors, including ecological factors such as precipitation, soil conditions and topography, as well as socio-economic factors (Mertz 2002). Abandoned fields are distributed worldwide and therefore allow comparison of secondary succession from various geographical regions (Osboronova et al. 1990). A number of studies on these old-field successions have been conducted in many countries (Osboronova et al. 1990; Wilson and Tilman 1991; Lee, 2002).

Secondary forests, which comprise a large area of tropical forests (ITTO, 2002), are forests in the process of recovery following natural or anthropogenic disturbance, such as agriculture, logging, or ranching (Brown and Lugo 1990; Chazdon 2003). Secondary forests can serve as carbon sinks (Fearnside and Guimaraes 1996), as well as enhance regional biodiversity, environmental services, and forest-based economies (Brown and Lugo 1990; Finegan 1996; FAO 2005). Forests at different stages of succession differ in total biomass, net primary production, and species composition, which affects their relative contribution to regional and global carbon cycles (Fearnside and Guimaraes 1996). As the population depending on shifting cultivation increases, the system increasingly fails to satisfy the requirements for higher production per unit area. This may result in shorter fallow and longer cropping periods, initiating an accelerating and self-reinforcing process of land degradation (FAO 1974). Studies of succession after cessation of shifting cultivation in tropical region have also indicated that the diversity of woody species gradually increases with time since abandonment of fallow (Lawrence 2004; Lebrija-Trejos et al. 2008).

Tropical secondary forests play an essential role in the global carbon cycle and in determining a country's carbon storage for the REDD (reducing emissions from deforestation and degradation in developing countries) scheme (Gibbs et al. 2007) due to the degradation of large areas of tropical rain forest (Brown and Lugo 1990; Wright 2005). Accurate estimation of biomass changes in secondary forests after degradation contributes to calculating forest carbon storage in the region, because uncertainties in the rate of biomass accumulation in secondary forests create critical data gaps limiting our understanding of the role of tropical forests as sources and sinks of atmospheric carbon (Kauffman et al. 2009). In Southeast Asia, tropical secondary forests constituted 63% of the total forest cover in 2005 (Kettle 2010). However, knowledge of biomass changes after forest degradation in Southeast Asia is still limited compared with that of the neotropical region, particularly for belowground components (Brown and Lugo 1990). Quantifying the initial few decades of biomass changes in secondary forests after degradation will decrease these uncertainties since biomass accumulation during the initial stage is usually very large and shows complex changes (Brown and Lugo 1990). For example, many tropical secondary forests show rapid rates of aboveground production during the initial stage of succession (Ewel 1971; Ewel et al. 1983; Uhl and Jordan 1984; Lugo 1992; Jepsen 2006; Kendawang et al. 2007).

Shifting cultivation has been practiced by Karo People in Leuser Ecosystem for a very long time and caused a mosaic of patches that shift over time between traditional agriculture and secondary forest. As such, many forests in the Leuser Ecosystem are secondary forests at various stages of succession following crop cultivation. However, little attention has been given to long term forest recovery after abandonment of shifting cultivation so little is known regarding how abandoned fallow fields have changed over time. The objectives of this study were to investigated the recovery of vegetation stands structure and aboveground biomass in four age classes of secondary forest, i.e. 5-years old, 10-years old, 20-years old, 30-years old and primary forest as a control.

MATERIALS AND METHODS

Study area

Our study was carried out in secondary forests abandoned after traditional shifting cultivation by the Karo People at Telaga village in Leuser Ecosystem of North Sumatra (Figure 1). Vegetation in the study area is generally of the submontane forest type (800-1400 m asl) as proposed by Laumonier (1997). The area has a moist tropical climate. The average annual rainfall is 2777 mm, ranging from 2044 to 4022 mm over a 10-year period (measured from 2000 to 2009). The last cultivated crop and stand age of each site were recorded based on information from elderly villagers who were born in the village. Information on stand age, however, was credible until for 20-years old, whereas 30-years old villagers did not remember the exact year when they had opened up the field.

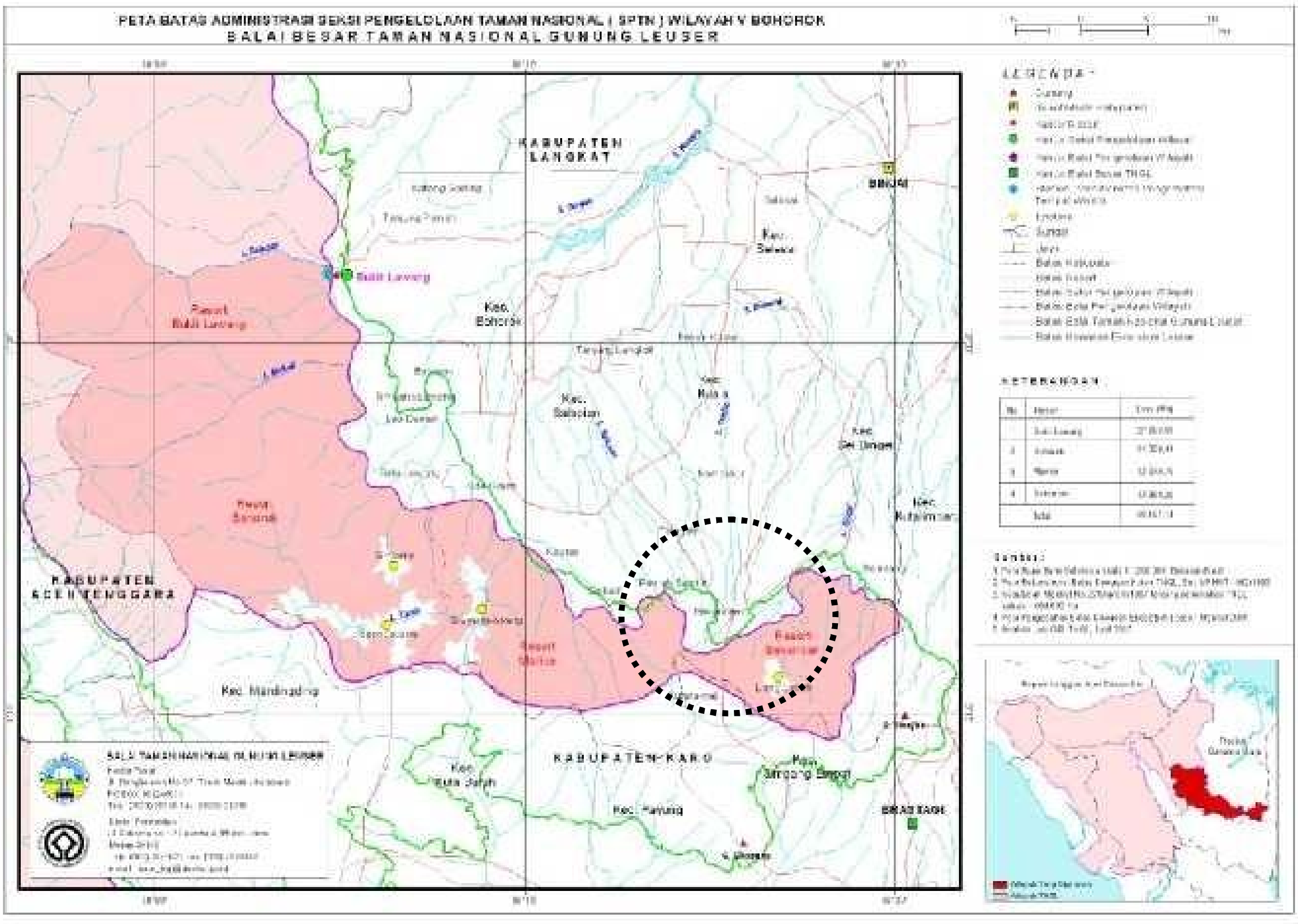

Figure 1. Study area at Telaga village in Leuser Ecosystem of North Sumatra. Dotted circle = study area

Data collection and analysis

In this study, we analyzed forest stands and above-ground biomass for sapling with diameters at breast height (DBH) 2-9.99 cm and tree with DBH ≥ 10 cm. Formulas and definitions were compiled from Mueller-Dombois and Ellenberg (1974), Greig-Smith (1983) and Schreuder et al. (1993). The number of subplot for each stage of secondary forest (5, 10, 20 and 30 years old) was 32 subplots for tree (10x10 m) and sapling (5x5 m) whereas primer forest was comprised 120 subplots for both stages. In total, 496 subplots were surveyed. Height, stem height, density, DBH, basal area and biomass for each stand age were measured with the purpose of characterizing forest stands in a quantitative basis. The analysis of aboveground biomass used two allometric equations. For trees, the equation given by Brown (1997) was used: $Y = \exp\{-2.134+2.530*\ln(D)\}$. For saplings, the equation given by Honzak et al. (1996) was used: $Y = \exp[-3.068 + 0.957 \ln (D2 * H)]$; where Y = biomass (t/ha), D = diameter and H = height. Finally, analysis of variance (ANOVA) was used as a statistical technique designed to determine whether or not a particular classification of the data is meaningful.

RESULTS AND DISCUSSION

Stands structure

Saplings

In 5 years secondary forest, species was dominated by pioneers such as light-demanding herbaceous plants, grasses, vines, seedlings, and saplings. These species have a short life cycle, high growth rate and high reproductive resource allocation (Gomez-Pompa and Vasquez-Yanes 1981). An important characteristic of this stage is the much higher density (1,425.00 individuals/ha) compared to the density of trees (64.06 individuals/ha). High sapling competition was expressed by its highest basal area compared to tree stands. Saplings contributed 62.82% of basal area in this stage indicated that saplings were very important at this stage of re-growth. In 10 and 20 years forest, saplings are still important for the stand as a whole (density of 2,175 and 2,725 individuals/ha, respectively) but density decreased in 30 years and primer forest (Table 1).

DBH of saplings in all classes age are constant relatively causing the classification of age stages is not meaningful ($p<0.41$). These indicated the closer values of DBH from 5 years forest to primer forest and mainly at the succession stages. For saplings, although total height did not increase distinctly, the difference between all variables for all classes is statistically significant ($p<0.00$).

Figure 2 illustrate the distribution of stand structure variables in density, DBH, basal area and total height of saplings in all classes. DBH in 5 and 10 years forest have many outliers indicating the variance of DBH in many individuals. This phenomenon was found too in total height especially in 10 years forest. These indicated the high competition in vertical and horizontal growth in saplings phase. Density and basal area have the similar trend of distribution, the values increase from 5 years up to 20 years forest and then decrease to primer forest. Ecologically, these trends are explained by the competition for light within the vegetation community. The growth of saplings was limited in 30 years and primer forest caused by covering canopy layers.

Trees

Density of trees in 5 years forest is lower (64.06 individuals/ha) indicating the early vegetation has soon recovered. In general, the density of trees increased from 5 years up to primary forest, except in 20 years forest where its density (218.75 individuals/ha) is lower than in 10 years forest (279.69 individuals/ha). This phenomenon also was applied to basal area, where 10 years forest has 10.49 m2/ha, whereas 20 years forest has 9.34m2/ha. This result indicated the recovery process in 10 years forest more intensive compared to 20 years forest. Besides that, 20 years forest is close to village and forest was often disturbed by the people for harvesting the construction materials and fire woods. DBH increased significantly from 5 years up to primary forest indicating the success competition of horizontal growth.

Table 1. Stand structure variables for each age classes of forest in study area

Stand structure variables	Forest type 5 years	10 years	20 years	30 years	Primary forest	F.	Sig.
Density of saplings (individuals/ha)	1,425	2,175	2,725	687.50	850	19.37	0.00
Density of trees (individuals/ha)	64.06	279.69	218.75	329.69	544.17	68.94	0.00
DBH of saplings (cm)	4.28	4.15	4.00	3.97	4.29	0.99	0.41
DBH of trees (cm)	15.80	20.79	21.17	26.78	25.40	6.61	0.00
Basal area of saplings (m2/ha)	2.45	3.57	4.18	.96	1.45	14.32	0.00
Basal area of trees (m2/ha)	1.45	10.49	9.34	25.43	47.42	35.91	0.00
Total basal area (m2/ha)	3.9	14.06	13.52	26.39	48.87	-	-
Saplings contribution to basal area (%)	62.82	25.39	30.92	3.64	2.97	-	-
Trees contribution to basal area (%)	37.18	74.61	69.08	96.36	97.03	-	-
Total height of saplings (m)	4.25	4.03	4.65	4.58	5.10	13.22	0.00
Total height of trees (m)	7.57	14.66	14.19	18.52	22.30	65.70	0.00
Biomass of sapling (t/ha)	5.79	8.24	10.88	2.43	4.10	10.69	0.00
Biomass of trees (t/ha)	10.73	113.27	86.62	289.33	659.22	26.09	0.00
Total biomass	16.52	121.51	97.50	291.76	663.32	-	-
Sapling contribution to biomass (%)	35.05	6.78	11.16	0.0083	0.0062	-	-
Tree contribution to biomass (%)	64.95	93.22	88.84	99.17	99.38	-	-

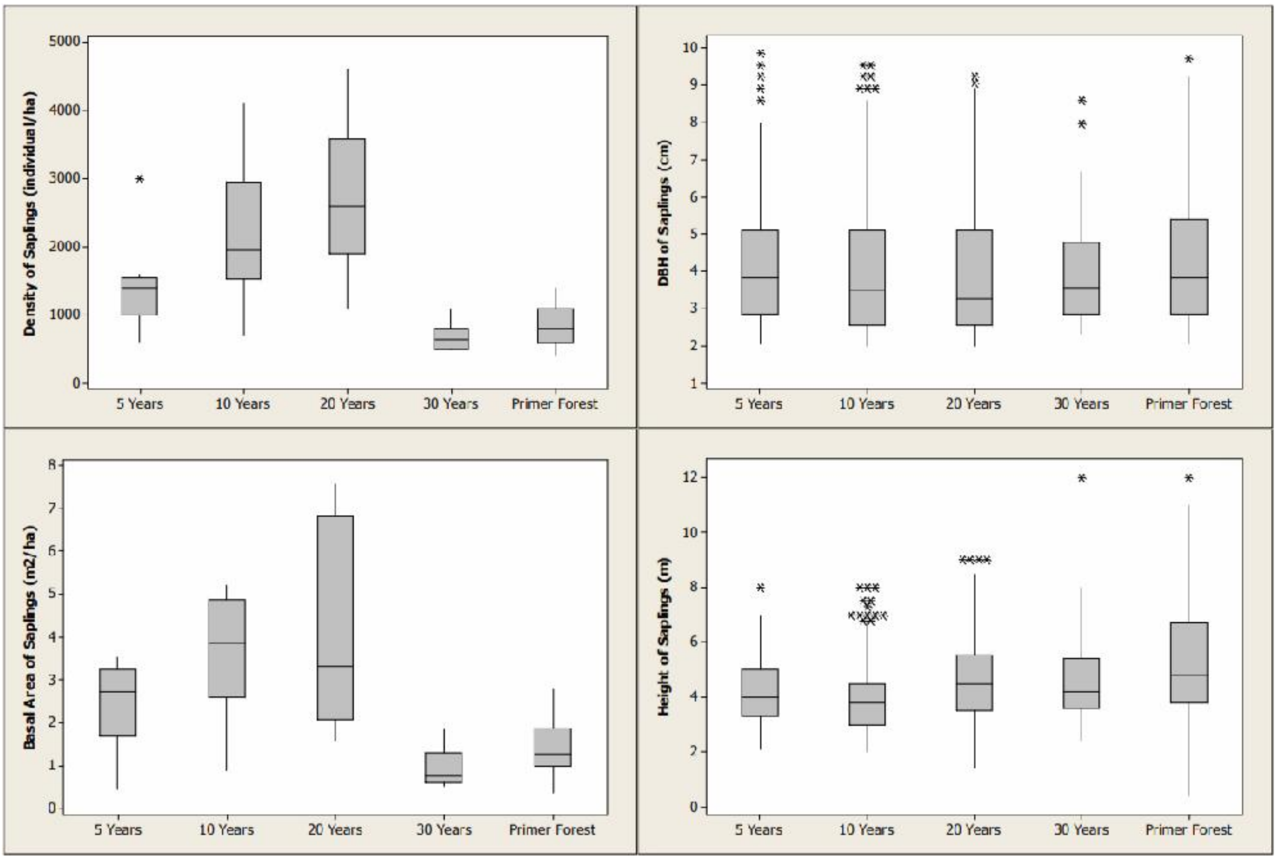

Figure 2. Distribution of density, DBH, basal area and total height of saplings in all classes.

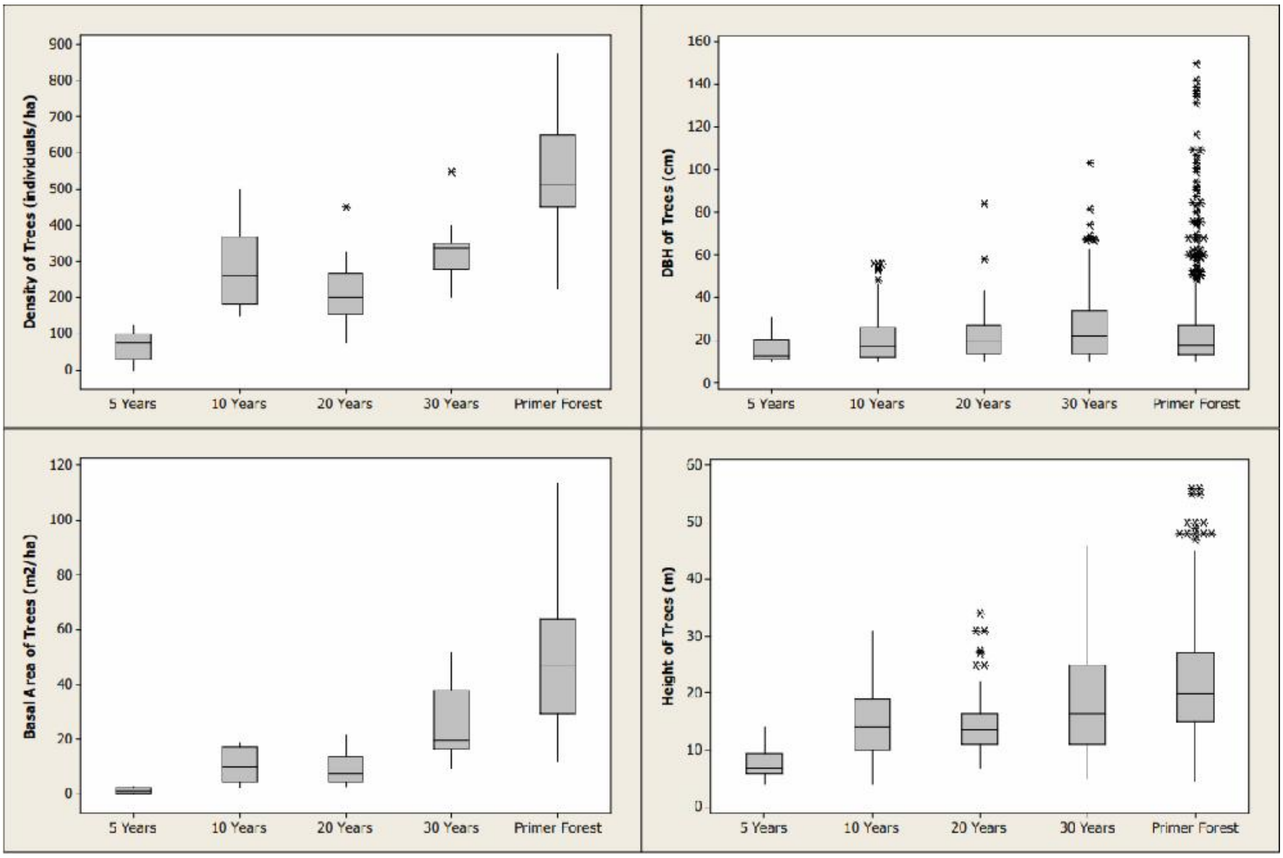

Figure 3. Distribution of density, DBH, basal area and total height of trees in all classes

Tree stands dominated in 30 years and primary forest and shared basal area of 96.36% and 97.03%, respectively but saplings still have a higher density (687.50 and 850 individuals/ha). A closer canopy alters the microclimate, improving conditions for shade-tolerant tree species and creating an unsuitable environment for pioneer species. This reality sets the path to a more advanced stage of vegetation re-growth.

Figure 3 illustrates the distribution of stand structure variables in density, DBH, basal area and total height of trees in all classes. The trend increased in all variables from 5 years forest up to primary forest, except 20 years forest. Same with saplings, DBH and total height of trees stage have many outliers indicating the big variance in many individuals, especially in primary forest. Total height of individuals is an important parameter indicating the stage of recovery. Height described the competition for light within the vegetation community.

Primary forest indicates the greatest range for all variables distinctly and has long whisker compared to the other classes age. This explains the recovery process of trees from 5 years forest to primary forest was a long way off. Saldarriaga et al. (1988) estimated that 190 years would be taken by a previously cultivated site to reach mature forest basal area and biomass values. Also, the number of tree species present after 40 years of succession is less than half the number in mature forests. In general terms, soil fertility and land-use history emerge as the critical factors influencing the rate of forest re-growth (Tucker et al. 1998). Uhl et al. (1982) found that the time of recovery depends on land use following removal. Slash-burn-agriculture-abandon cycles have increasing secondary succession duration. Large cleared patches, where seed sources are far away, may take hundreds of years to return to primary forest.

Aboveground biomass

Aboveground biomass of saplings increased from 5 years to 20 years forest, but decreased for 30 years and primary forest, due to the lower importance of saplings in closed tropical forest environments. As a function of DBH and height, the trends of aboveground biomass from 5 years to primary forest are affected by those variables. Aboveground biomass of trees achieved its highest values in primary forest, i.e. 659.22 t/ha and contributed to total aboveground biomass of 99.38% (Table 1). However, this result indicated that aboveground biomass of primary forest in this study was higher than in primary rain forests in Southeast Asia, which ranged from approximately 300 t/ha to 500 t/ha (Yamakura et al. 1986; Laumonier et al. 2010; Niiyama et al. 2010).

CONCLUSION

In the early stage of vegetation recovery, saplings have the important role expressed by the higher density and basal area compared to trees. In the next stage (in 30 years time), the growth of saplings was limited caused by covering canopy layers of trees. Trees taken over the role and forest developed to reach mature forest basal area and biomass values. Although vegetation recovery process was taking place in the study area, secondary forest need long time to develop to primary forest. The time of recovery depends on land use type, duration of cycles and large cleared patches.

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