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Impact of bauxite mine to natural forest biomass and soil properties in Kas Island, Riau Island Province in Indonesia

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ABSTRACT

In this investigation, the impact of bauxite mine to natural forest biomass and soil properties in Kas Island, Riau Island Province in Indonesia was investigated. On the island of Kas, bauxite mining permits have been issued. Mining activities will cause the destruction of natural forests as a source of wood, loss of flora and fauna, water regulator and medicines, besides it will also cause damage to land and the environment. Reclamation activities undertaken aimed at improving the vegetation structure and soil characteristics that undergo changes due to mine. The research method used is the analysis of vegetation and soil sampling is done by purposive sampling. Laboratory test data from physical and chemical properties of the soil, were analyzed by descriptive and statistical tests. Bauxite mining activities have caused the loss of biomass of natural forests by 168.8 tons / ha. Revegetation activities on bauxite mining sites should be restored through planting trees of *Pulcherrimum sp*, *Laplacea subintegerrima*, *Calophyllum soulatri*, *Thesposia populnea*, *Diosphyros sp*, *Schima wallichii* and *Hopea mangarawan*. Bauxite mining activities cause changes in soil properties, namely a significant increase in bulk density of 0.55 (76.39%) and a significant decrease in porosity of 22.39 (30.21%), drainage pore of 6.57 (52.77%), water available at 6.41 (36.59 %), permeability is 19.59 (82.69%), C-organic is 12.20 (93.99%), N is 0.47 (85.45%), and P is 29.88 (85.91%). Therefore, bauxite mine activity leads to significant changes in physical properties and soil chemistry properties for bulk density parameters, porosity, drainage pores, available water, and permeability, C-organic, nitrogen (N) and phosphorus (P) of the soil.

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INTRODUCTION

Kas island was bauxite issued mine permit area of 93 ha. On the island there is a tropical rainforest (Wasis and Fathia, 2011; Wasis, 2012; Wasis and Andika, 2017). Excessive exploitation of natural resources and no attention to environmental aspects will impact on natural damage and land quality degradation. One of the activities of exploitation of natural resources that impact on the degradation of land quality is the mining activities of mining materials, one of which is sand mining. This mining is very commonly done by companies and local communities traditionally. Recovery and prevention of environmental damage caused by mining shall be taken into account. One that can be done is post-mining land revegetation and utilization of mining waste. To undertake land reclamation activities, information on changes in vegetation structure and changes in soil characteristics due to mining activities (Bappenas, 2003; Soerianegara and Indrawan, 2005; Wasis, 2012).

Mining activities have potential to provide income for large regions and countries. However, mining activities also have a negative impact on the environment if production activities and waste produced are not treated properly (Setiawan and Qiptiyah, 2014, Siregar *et al.*, 2018). The negative impacts of mine production activities include the deterioration of soil and environmental conditions and quality, loss of flora and fauna, source of diseases, loss of soil solum, changes in soil morphology, damage to physical, chemical and biological properties of soil, soil erosion, landslides, surface runoff, the emergence of toxic compounds and water pollution (Wasis and Noviani, 2010; Abdullah *et al.*, 2010; Wasis and Fathia, 2011; Wasis and Andika, 2017). Bauxite mining activities on Kas Island are thought to cause forest biomass loss and changes in soil properties that have a major negative impact to small island capabilities. Mining activities on the small island will have a greater negative impact than mines on the big island. These activities will cause damage to other ecosystems such as natural forest, mangrove forests, seagrass and coral reefs (Wasis and Noviani, 2010; Soerianegara and Indrawan, 2005; Wasis and Fathia, 2011; Wasis and Andika, 2017). The purpose of this research is to analyze the impact of bauxite mine on natural forest biomass and soil properties in in Kas Island, Karimun District, Riau Island Province of Indonesia.

MATERIALS AND METHODS

Time and location and research materials

This study was conducted from June to December 2010. Data collection was conducted on natural forest and damaged land (former bauxite mine) in Kas Island, Karimun District, Riau Islands Province. The research material used by the land came from Kas Island, Karimun District, Riau Islands Province.

Preparation of forest observation plots

Measurements and observations of potential timber were conducted on 20 meters × 20 meters for trees (natural forest trees), and 10 meters × 10 meter plot for trees (mangrove forest trees). Limits for trees in natural forests if trees have stem diameters > 20 cm and mangrove forests if trees have stem diameters > 10 cm (Kusmana and Istomo, 1995, Soerianegara and Indrawan, 2005). The measurement results are recorded in tally sheets that have been distinguished in each plot size.

Soil sampling and analysis

Soil sampling is done by purposive sampling on mined land, and natural forest on Kas Island. The study was conducted on three plots on ex-mining land, natural forest, and mangrove forests of 20 m × 20 m (0.04 ha) each. Within the mine and natural forest plots, three subplots of 1m × 1m were placed randomly for ground sampling. Then the soil sample is composited. Soil sampling for the chemical properties and biological properties of soil is taken evenly on the soil surface of 0-20 cm deep. Soil taking is done by composite as much as 1 Kg. Soil sampling for soil physical properties was done at ground level of 0 - 20 cm depth. Intake of soil is done intactly by using ring sample diameter of 7 cm with the height of 5 cm. The soil taken from the field is then analyzed in the laboratory. Soil analysis for physical properties of soil density, porosity, drainage pore, available water and permeability. Chemical properties analyzed are soil pH, C-organic, nitrogen (N), phosphorus (P), calcium (Ca), magnesium(Mg), potassium (K) and sodium (Na). The location of sample skill in natural forest and post mining land area is located side by side, so the differences of soil type, topography, climate and others are relatively assumed the same.

Statistical analysis of data

Data of laboratory test of soil physical and chemical properties are analyzed by statistical test. Descriptive analysis is done by describing the average value of each variable on three replicates and categorized based on the criterion of the soil properties. Statistical analysis is conducted by using T Test at 95% confidence interval. This is to determine the impact on soil physical and chemical properties as a result of the forest encroachment. Software used in statistical analysis is SPSS 16.00 (Mattjik and Sumertajaya, 2013; Stell and Torries, 1991; Wibisono, 2009).

RESULTS AND DISCUSSION

General condition of Kas Island and forest biomass

The island of Kas in the natural forest has soil type of podsolic and litosol. Regosol soil found in coastal areas has generally been damaged. Alluvial soil types are commonly found in mangrove and swamp forests. In the hilly area is a very sensitive area of erosion. This area has curving slopes - rather steep (3 - 25%), so this area is prone to erosion and landslides. Kas Island has a soil solum with the depth of 20 - 70 cm, the main rocks about 3 - 4 m and layer of clay (kaolinite) on the bottom. The condition of Kas Island vegetation in hilly (foot to ridge) is natural forest, and few mixed rubber garden, while in coastal area is mangrove forest found. In natural forest, there are 7 (seven) tree species such as *Pulcherrimum sp*, *Laplacea subintegerrima*, *Calophyllum soulatri*, *Thesposia populnea*, *Diosphyros sp*, *Schima wallichii* and *Hopea mangarawan* with biomass potential of 168.7 ton / ha. In the mangrove forest found 1 (one) type of tree that is *Rhizophora mucronata* with biomass potential of 36.4 tons / ha. While in the natural forest of ex-bauxite mine land is not found natural forest vegetation again because it has been felled and the soil solum has also been lost due to peeling the soil. At open sites, there are *Imperata cylindrica*, *Pandanus tectorius*, *Melastoma malabathricum*, *Ischemum aristritum*, and *Matteuccia struthiopteris* (Table 1). Types of vegetation that can be used as a source of medicines are *Rhizophora mucronata*, *Imperata cylindrica*, *Pandanus tectorius*, *Ischemum aristritum*, and *Matteuccia struthiopteris*. The loss of natural forest vegetation on Kas Island as a result of bauxite mine causes loss of environmental function, loss of flora and fauna and loss of timber, food sources and medicines (Abdullah *et al.*, 2010; Takoy *et al.*, 2013; Setiawan and Qiptiyah, 2014). The benefits and functions of natural forest ecosystems are water regulator, carbon sequestration, wildlife habitats, erosion and flood defenses, protecting shallow water ecosystems such as coral reefs and seagrass beds and so forth (Lee, 1990; Asdak, 1995; Tan, 1995; Wasis, 2012). Revegetation activities on bauxite mining sites should be restored through planting trees of *Pulcherrimum sp*, *Laplacea subintegerrima*, *Calophyllum soulatri*, *Thesposia populnea*, *Diosphyros sp*, *Schima wallichii* and *Hopea mangarawan*. As for the closure of ex-bauxite mine land can be used endemic plants such as *Pandanus tectorius*, *Melastoma malabathricum*, *Ischemum aristritum*, and *Matteuccia struthiopteris*.

Physical properties of the soil

Soil physical properties variable observed and measured in this research were bulk density, porosity, drainage pore, water availability and permeability. Here are the results of laboratory analysis of soil physical properties that have been done as presented in Table 2. Mining activities have caused damage to soil physical properties, namely a significant increase in bulk density of 0.55 (76.39%), a significant reduction in porosity of 22.39 (30.21%), drainage pore of 6.57 (52.77%), water available at 6.41 (36.59%) and permeability of 19.59 (82.69%). Damage to the physical properties of the soil is caused by the loss of soil solum, damage to soil structure, decrease in clay fraction and decrease in soil organic matter.

The higher the value of bulk density indicates the denser the land. Mining processes that use heavy equipment or other mechanical tools impacted the formation of plow sole plates that cause the compaction process on the soil. According to Hardjowigeno (2007), the denser a soil or the higher the bulk, density it will cause the inhibition of plant growth. Land with high bulk density will certainly have a low total pore space. The soil compaction process will cause the soil pore to become small. Porosity is the proportion of total pore space (empty space) contained in units of ground volume that can be occupied by water and air. According to the data presented in Table 2, of forest soil that has lower bulk density than the land on mining land. Soil without vegetation cover will cause rainfall that drops directly on the soil surface that affects internal erosion (clay pore blockage by clay and dust) due to lack of pore maturity (Hanafiah, 2005; Wasis, 2012). Lands that have macro pores will tend to be very fast in continuing the movement of air and water. Soils with coarse or sandy textures such as eroded soils and minerals have a low porosity because they have more macro pores making it harder to hold water (Soepardi, 1983; Hardjowigeno, 2007). Pore drainage shows the maturation of the soil in a well-aerated land. If aeration pores are above 10% of the volume, the plants will have sufficient aeration, except on shallow surface soils (Hardjowigeno, 2007; Wasis, 2012). Soft textured soil granulation facilitates aeration, not because of the increased amount of pore space but because the macro pore space to micro pore space increases. Soils that have high porosity will have high water availability as well. Soil treatment actually decreases the pore space. The mining process also causes the high particles of sandy soil due to the excavation process to the subsoil part which is generally sandy clay (Hardjowigeno, 2007; Soepardi, 1983).

Land that has high bulk density value will have a lower permeability value. This is evident in this study in which forest lands with low bulk density have higher permeability. Permeability refers to the speed of water in the soil mass medium. In the former land of bauxite mine, the permeability value has decreased compared to the forest land. This is caused by the internal erosion where the pore is blocked by dust and clay and damaged soil structure. The difficulty of water penetrating the underground layer is due to the high value of bulk density (Hardjowigeno, 2007; Wasis, 2012). Forests are most effective in preventing soil damage and erosion because the leaves are tight. For erosion prevention, at least 70% of soil should be covered with vegetation (Lee, 1990; Hardjowigeno, 2007). Closure of tropical rain forests is most effective in preventing erosion compared to other land uses because the ability of soil to reduce rain drops through layered canopy stratification, litter piles on the forest floor, high organic matter content, good soil structure and low soil density becomes the reasons for forest cover have the best water protection function (Richards, 1957; Lutz and Chandler, 1965; Lee, 1990; Ashdick, 1995; Tan, 1995; Wasis, 2012). The loss of natural forest vegetation, soil compaction and the destruction of this soil structure that causes soil erosion and contamination of seawater on Island Kas. The destruction of natural forests on Kas Island will damage the environment, destroy wildlife habitat and loss of vegetation and genetic sources. Tropical rainforests are the ecosystems also have the highest biodiversity on earth so that food sources and medicines are all available in the ecosystem. Widespread destruction of tropical rainforests will undoubtedly endanger civilization on earth (Richards, 1957, Abdullah *et al.*, 2010; Takoy *et al.*, 2013; Setiawan and Qiptiyah, 2014).

Chemistry properties of the soil

The soil chemistry properties measured and the lab tests were pH, C-organic, N Total, Bray P, Ca, Mg, K and Na. The following is the result of laboratory analysis which has been done as presented in Table 3.

Bauxite mining activities have caused damage to soil chemical properties, namely a significant reduction in organic C by 12.20 (93.99%), N by 0.47 (85.45%) and P by 29.88 (85.91%). Damage to the soil's chemical properties is caused by the loss of the top soil layer (A horizon) and loss of vegetation cover. The variables of pH, Ca, Mg and K show higher values on bauxite mine land than those in natural forest. While the variables of C-organic, N total, bray P and Na analysis results show the land in natural forest has a higher value than the other. In the variable of pH of the soil, Difference between the two sites is 0.07 which does not statistically show the real difference. This is caused by the loss of vegetation cover on ex-mining soil, causing dry soil and dissolved metals and minerals due to mining activities. In very dry areas (arid), soil pH is occasionally very high (pH greater than 9.0) because it contains many metals such as Ca, Mg, K and Na (Richards, 1957; Lutz and Chandler, 1965; Tan, 1995; Hardjowigeno, 2007; Fathia, 2011; Wasis and Andika, 2017). In natural forest ecosystem, nutrients such as N, Ca, Mg and K and others that decompose from soil organic matter will be reabsorbed by forest roots, resulting in nutrient conservation due to the occurrence of closed nutrient cycle. In Kas Island's mine land indicates that pH, Ca, Mg and K increase are attributable to the breakdown of primary rock minerals. Mined soil will cause disruption of nutrient balance.Therefore, organic matter and nutrients will be lost due to erosion that will be carried through the flow of the surface to the river and sea.

The growing vegetation is a major supplier of soil organic matter. The primary source of soil organic matter comes from the organic tissues of plants in the form of fruits, leaves, twigs, stems / branches, and roots, while the secondary source is an organic tissue fauna that includes the dirt and microflora. The high value of C-organic in natural forest land is supplied by the amount of vegetation and fauna present in the forest (Richards, 1957; Lutz and Chandler, 1965; Wasis, 2012). The logging process causes half of the soil organic matter to move. The loss of vegetation growth on the soil and the activity of soil microorganisms is the main cause of this. C-organic soil is the main constituent of soil organic matter that is very influential on soil fertility. Organic matter is the main source of N in the soil. Nitrogen in the soil comes from soil organic matter, binding by microorganisms and N in the air, fertilizer and rainwater. In addition, the process of direct infiltration of rainwater to the soil causes erosion and effluent streams that affect the loss of nitrate ion (NO^{3-}) due to leaching (Lutz and Chandler, 1965; Foth, 1994; Hardjowigeno, 2007; Wasis, 2006 and Wasis, 2012).

The availability of vegetation as the main source of organic matter is the major factor in the high content of phosphorus in natural forest land on the island of Kas. Element P in the soil derives from organic matter and minerals in the soil (apatite). Besides, the absence of land cover to the ex-mining land resulted in high levels of internal erosion and high surface flow, triggering in the process of washing of nutrients. The origin of calcium in soils is from primary minerals, carbonates, simple salts, and calcium phosphate. Calcium is secondary essential mineral elements similar to magnesium and sulfur. Calcium is taken from plants in the form of Ca^{2+}. The low amount of calcium in natural forests is caused by the uptake of vegetation and retrieval by microorganisms. (Hardjowigeno, 2007; Wasis *et al*., 2012; Wasis *et al*., 2018).

Table 1. Biomass in natural forest, mangrove forest and post mining land.

Cover land	Type of vegetation	Biomass (ton/ha)
Natural forest	*Pulcherrimum sp, Laplacea subintegerrima, Calophyllum soulatri, Thesposia populnea, Diosphyros sp, Schima wallichii, Hopea mangarawan*	168.7
Mangrove forest	*Rhizophora mucronata*	36.4
Post mining land	-	0

Table 2. Impact of bauxite mining on soil physical properties.

Phisical properties	Natural forest	Post mining land	Change
Bulk density (g cm^{-3})	0.72± 0.13*	1.27± 0.03	+0.55 (76.39 %)
Porosity (%)	74.11±3.81*	51.72±1.12	- 22.39 (30.21 %)
Drainage pore (%)	12.45±3.32*	5.88±0.64	-6.57 (52.77%)
Available water (%)	17.52±1.95*	11.11± 0.50	-6.41(36.59%)
Permeability (cm $hour^{-1}$)	23.69±3.47*	4.10±1.67	-19.59(82.69%)

*Significant at 95 % confidence interval.

Table 3. Impact of bauxite mining on soil chemical properties.

Chemical properties	Natural forest	Post mining land	Change
pH	5.23± 0.77 ^{tn}	5.30±1.10	+0.07 (1.34 %)
Organic C (%)	12.98± 0.78*	0.78 ± 0.13	-12.20 (93.99 %)
Nitrogen (N) (%)	0.55± 0.01*	0.08± 0.01	-0.47 (85.45%)
Phosphorus (P) (ppm)	34.78±5.52*	4.90± 0.50	-29.88 (85.91 %)
Calcium (Ca) (me 100 g^{-1})	5.93±1.67^{tn}	6.56±1.57	+0.63 (10.62 %)
Magnesium (Mg) (me 100 g^{-1})	1.94± 0.85^{tn}	2.40±1.22	+0.46 (23.71%)
Pottasium (K) (me 100 g^{-1})	0.57± 0.13^{tn}	0.58± 0.16	+0.01(1.75 %)
Sodium (Na) (me 100 g^{-1})	0.26± 0.02^{tn}	0.24± 0.03^{tn}	-0.02(7.69 %)

*Significant at 95 % confidence interval.

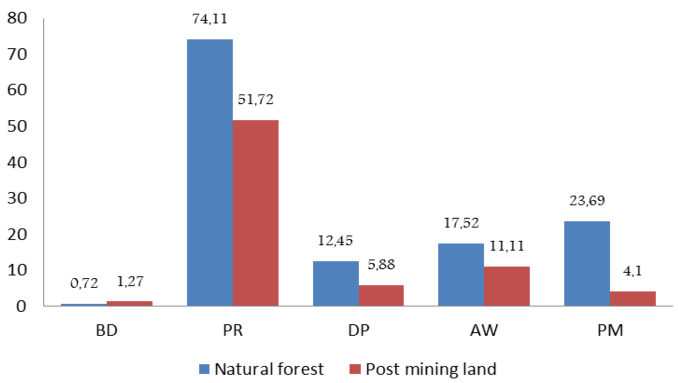

Figure 1. *The change of soil physical propertieson natural forest and post mining land. Description : BD (Bulk density : gram/cm^3), PR (Porosiys : %), DP (Drainage pore : %), AT (Available water: %) PM (Permeability : cm/hour).*

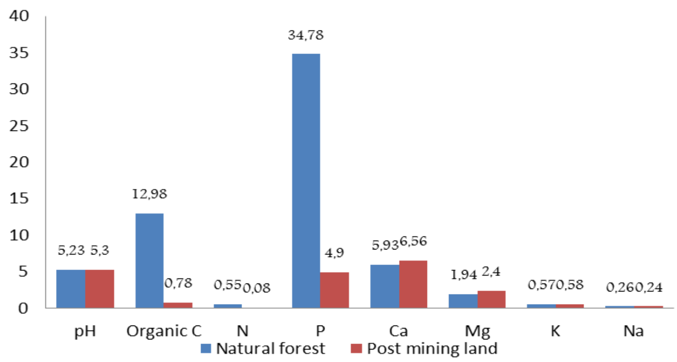

Figure 2. The change of soil chemistry properties on natural forest and post mining land; Description : pH (pH), organic C (%), N (Nitrogen : %), P (Phosphorus : ppm), Ca (calcium : me/100 g), Mg (magnesium : me/100 g), K (pottasium: me/100 g), Na (sodium : me/100g).

Conclusion

The present investigation concluded that the bauxite mining activities have caused the loss of biomass of natural forests by 168.8 tons / ha. Revegetation activities on bauxite mining sites should be restored through planting trees of *Pulcherrimum sp.*, *Laplacea subintegerrima*, *Calophyllum soulatri*, *Thesposia populnea*, *Diosphyros sp.*, *Schima wallichii* and *Hopea mangarawan*. Bauxite mining activities cause changes in soil properties, namely a significant increase in bulk density of 0.55 (76.39%) and a significant decrease in porosity of 22.39 (30.21%), drainage pore of 6.57 (52.77%), water available at 6.41 (36.59 %), permeability is 19.59 (82.69%), C-organic is 12.20 (93.99%), N is 0.47 (85.45%), and P is 29.88 (85.91%). Bauxite mining activities causes changes in soil chemical properties, such as an increase in the content of pH, Ca, Mg and K variables and a decrease in the content of C-organic, N total, bray, and Na. The result of statistical analysis using T test showed the significant differences on the C-organic, N total, and P Bray variables while the pH, Ca, Mg, K and Na variables does not show any significant differences. Therefore, the results of this study clearly indicated that bauxite mine activity leads to significant changes in physical properties and soil chemistry properties for bulk density parameters, porosity, drainage pores, available water, and permeability, C-organic, nitrogen (N) and phosphorus (P) of the soil.

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REFERENCES

Abdullah, M., Mustikaniangtyas, D. and Widiatningrum, T. (2010). Inventaritation of medicinal plant species at lowland rain forest of Nyamplung village of Karimunjawa Island. *Biosaintifika*, 2(2) : 75-81.

Asdak, C. (1995). Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gadjah Mada University Press.

Bappenas (2003). Indonesian biodiversity strategy and action plan dokumen regional. Badan Perencanaan Pembangunan Nasional (BAPPENAS) Republic of Indonesia, pp. 290.

Foth, H.D. (1994). Dasar-dasar Ilmu Tanah. PT Erlangga. Jakarta, Indonesia.

Hanafiah, K.A. (2005). *Dasar-dasar Ilmu Tanah*. PT Raja Grafindo Persada. Jakarta, Indonesia.

Hardjowigeno, S. (2007). Ilmu Tanah. Akademia Akapressindo. Jakarta, Indonesia.

Kusmana, C. and Istomo. (1995). Forest Ekology. Faculty of Forestry IPB, Bogor, pp. 190.

Lee, R. (1990). Hidrologi Hutan. Gadjah Mada University Press.

Lutz, H.J., and Chandler, R.F. (1965). Forest Soil. John Wiley & Sons, Inc. New York.

Mattjik, A.A. and Sumertajaya, I.M. (2013). Experimental Design with SAS Applications and Minitab. IPB Press. Bogor, Indonesia.

Richards, F. W. (1957). The Tropical Rain Forest an Ecological Study. Cambridge University Press. London, pp. 407.

Setiawan, H and Qiptiyah, M. (2014). Ethnobotany study of moranene ethnic community in Rawa Aopa Watumohai National Park. *Jurnal Penelitian Kehutanan Wallacea*, 3 (2): 107-117, http://www.jurnal.balithutmakassar.org/index.php/wallacea/article/view/38

Siregar, Y.F., B. Wasis, B. and Hilwan, I. (2018). Carbon stock potential of Narundong Forest KPH Region VI North Sumatera. *Indonesian Journal of Agricultural Science (JIPI)*, 23 (1): 67-73, http://jurnal.ipb.ac.id/index.php/JIPI/article/viewFile /21163/14444

Soerianegara, I. and Indrawan, A. (2005). Indonesian Forest Ecology. Department of Forest Management, Faculty of Forestry IPB, Bogor, Indonesia.

Soepardi, G. (1983). Sifat dan Ciri Tanah. Jurusan Ilmu Tanah Fakultas Pertanian IPB. Bogor.

Stell, R.G.D. and Torries, J.H. (1991). Statistical Principles and Procedures, A Biometric Approach. PT Gramedia Pustaka Utama Jakarta , pp. 149-167.

Tan, K.H. (1995). Enviromental Soil Science. Marcel Dekkker Inc. New York, pp. 255.

Takoy, D.H., Lindam, R. and Lovadi, I. (2013). Tumbuhan berkhasiat obat suku dayak Seberuang di Kawasan Hutan Desa Ensabang Kecamatan Sepauk Kabupaten Sintang. *Journal Protobiont*, 2(3) : 122-128, http://jurnal.untan.ac.id/index.php/jprb/article/ view/ 3878

Wasis, B., Setiadi, Y. and Purwanto, M.E. (2012). Comparation of soils chemical and biology characteristic caused land opennes of pine retorested forest in Pollung Sub-district of Humbang Hasudutan District North Sumatera. *Journal of tropical Silviculture Science and Technology*, 03(01): 33-36, http://jai.ipb.ac.id/index.php/jsilvik/article/view File/5393/3972

Wasis, B. (2006). Comporison of site quality between first rotation and second rotation *Acacia mangium* plantation forest (A Case study in Industrial plantation forest of PT Musi Hutan Persada, South Sumatra Province). Dissertation: Bogor Agricultural University (IPB). Bogor.

Wasis, B. and Fathia, N. (2011). Growth of gmelina seedlings with various doses of compost fertilizers on the media of former ground gold mine. *Journal of Tropical Forest Management*, 17 (1): 29-33, https://doi.org/10.7226/jmht.17.1.29-33

Wasis, B. (2012). Soil properties in natural forest destruction and conversion to agricultural land in Gunung Leuser National Park, North Sumatera Province. *Journal of Tropical Forest Management* (JMHT), 18(3): 206-212, http://doi.org/10.7226/jtfm.18.3. 206-212

Wasis, B. and Andika, A. (2017). Growth response of mahagony seedling (*Swietenia macrophylla* King.) to addition of coconut shell charcoal and compost on ex-sand mining site of West Java Province in Indonesia. *Archives of Agriculture and Enviromental Science*, 2(3): 238-243, https://www.aesacademy.org/journal/ volume2/issue3/ AAES-02-03-018.pdf

Wasis, B., Winata, B. and Andriani, R. (2018). Growth of Agathis dammara (Lamb. Rich.) seedling on gold tailing with addition of coconut shell charcoal and compost. *Archives of Agriculture and Enviromental Science*, 3(2):131-136, https:// doi.org/10.26832/24566632.2018.030205

Wibisono, Y. (2009). Metoda Statistik. Method. Gadjah Mada University Press. Yokyakarta, pp. 529-603.