Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 28 (2015) 124 – 131

Procedia
Environmental Sciences

The 5th Sustainable Future for Human Security (SustaiN 2014)

The comparison of soil properties in heath forest and post-tin mined land: basic for ecosystem restoration

Dina Oktavia[a]*, Yadi Setiadi[b], Iwan Hilwan[c]

[a]*Postgraduate Student of Tropical Silviculture Bogor Agricultural University, Darmaga Bogor 16680, Indonesia*
[b]*Biotechnology Research Center Bogor Agricultural University, Darmaga Bogor 16680, Indonesia,*
[c]*Department of Silviculture Faculty of Forestry Bogor Agricultural University, Darmaga Bogor 16680, Indonesia*

Abstract

Heath forest is a restricted forest ecosystem in the world. In Indonesia, heath forest degradation caused by tin mining activity on Belitung Island emerges biodiversity lost and soil properties lost. In fact, they play important role as main aspect for rehabilitiation. This study aims to describe soil properties and vegetation in heath forest and two different ages of tin mined land. The result shows thatin 3 year tailing contains very high amount of sand, low organic matter, low CEC which effect to desertification that hindered plant to grow. Indeed, low organic matter affects low water absorbtion. Meanwhile, 130 year tailing results lower amount of sand than 3 year tailing. Adequate organic matter closes to organic matter in the forest and appropriate CEC. Soil development in tin tailing soil takes hundreds years to slightly improve naturally. Several soil amendments could be implemented to improve sandy soil, such by adding organic matterial, following with polymer fertilizer. Heath forest restorationby natural succession approach should select local species which well adapted as pioneer and apply seedbank from forest floor as seed source of native species.

*Keywords:*soil properties; heath forest; tin mining; restoration; natural succession

* Corresponding author. Tel.: +62-251-8626806; fax: +62-251-8626886.
*E-mail address:*oktaviadina@yahoo.com

doi:10.1016/j.proenv.2015.07.018

1. Introduction

Belitung Island produces the best tin deposit in the world[1]. It is one of World Tin's Belt islands[2]. Exploitation and producing process in tin mining activity gives negative impact to human health as well as environment, particularly radiation of radioactive substancee dan water pollution[3,4,5] shows units of land capability analysis of soil fertility in East Belitung. There are 218.101 hectares of land in poor condition (±87% of total district area).

Forest covers potential tin source in Belitung is called *kerangas* forest or heath forest. It is a fragile forest ecosystem derives from quartz parent material and standing on podzol soil, with poor nutrient and has low pH[6,7,8]. Degradation of heath forest has impacted to some environmental problems, particularly of soil. Heath forest might become the most endangered ecosystem in Sumatra. It should be restored as soon as possible.

Ecosystem restoration is as a key component in conservation programs and essential to the quest for the long-term sustainability of our life[9]. Soils are essential components of the environment and the basis of terrestrial ecosystems management[10]. Mined land is totally change the forest ecosystem then the rehabilitation is presented as an ideal case study for developing an ecosystem starting from point zero on "terra nova"[11]. We do not only have to recover the existence of ecosystem but also functions of its forest. The objectives of this study is to describe soil properties in heath forest and tin mined land, then recommend restoration techniques with natural succession approach.

2. Site Description and Method

2.1. Study Site

Research was conducted in East Belitung District, Belitung Island, Indonesia E 107º45' – 108º18' dan S 02º30' – 03º15' (Fig. 1). The average air temperature in East Belitung District is 25,8ºC-27,3ºC. East Belitung Distric has total area of 250.691 ha withvalley plateau topographyin larger, with elevation between 0-100 m above sea level. Rest of the area is mountains and hills. East Belitung land contains many minerals and tin ore mineral such as sand, quartz sand, granite, kaolin, clay and others. Soil type is podzols with soil texture particles dominated by clay (48,45%), coarse sand (27,43%) and remaining fine-textured (24,12%)[12].

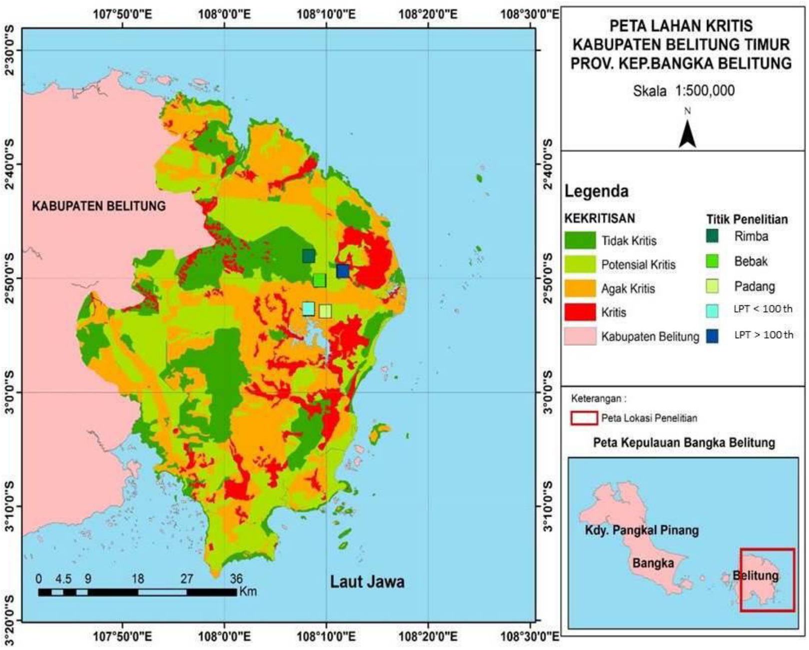

Fig. 1. East Belitung District

The study site is located at two places, old secondary heath forest (Rimba-RB) and ex-tin mine land with more than 100 years of mining activity.Total area is 13.000 m2. In post-tin mined land >100 years, there are two re-mining operation clusters that left about <10 years. However, several parts are being cleared away or left about >100 years to grow in order to become small forest. Therefore, this location devided into two clusters with sandy cluster (TL1) and forest cluster (TL2) see Fig. 2.

Fig. 2. (a) Heath forest; (b) post-tin mined land sandy cluster; (c) post-tin mined land vegetation cluster

2.2. Method

Composite soil samples were collected from 3 points in two depths (0-20 cm and 20-40 cm) by using auger.We analyzed soil parts, such as pH 1:1 (H_2O& KCl), C organic (Walkley&Black), Total N (Kjeldhal), P (Bray l), Ca (*N* NH4Oac pH 7.0), Mg (*N* NH4Oac pH 7.0), Cation Exchange Capacity (*N* NH4Oac pH 7.0), and soil texture in Soil Science Laboratory of Bogor Agricultural University.Vegetation were analyzedby using modification of square method[13]. Due to stunted tree on heath forest which restricts presence of big tree, each plot was made to 10 m x 10m with total of 20 plots in one site with distance between plot was 20 m.10mx 10m plot was for tree analysis, 5mx5m plot was for sapling analysis and 1m x 1m plot was for seedling and herbs analysis. Vegetation were analized for diversity index[14], richness index[14], Evennes index[14]and similarity index[15].

3. Results and Discussions

3.1. Soil Texture

Heath forest damages increase sand proportion in soil texture. Composition of sand in mineland is 70% – 98%. It is caused by open system tin mining which unveil topsoil (top soil) to alluvial tin deposits that appears as Cassiterite (SnO2). Tin oreis separated through washing process. The result of soil and clay with sandy texture separation then known asland of tin mining wastes (tin tailings soil)[16]. Fine materials and some minerals will lose through run off due to high porosity of coarse in soil.The high amount of sand (> 90%) in two layers in TL1 is a main problem in ecosystem resilience. Due to this condition, the soil is not able to hold and store water in large amount, thus it is very susceptible to be erosion, landslide and sedimentation. These conditions will also increase leaching of nutrients in the soil, affectingavailability of nutrients for plant growth. There is nearly novegetation covered in the surface. White sand also makestemperature on the land surface become high (35.5^0C – 40^0C) in dry season. Soil texture in layer 0-20 cm and 20-40 cm are sandy.

Nature has a mechanism to recover itself. At TL 2, sand content decreases (71%), following to increase of clay content from < 5% in TL1 become 18%-20% in TL2. This condition supports several native plants to grow, particularly heath forest vegetations such as *Dillenia suffruticosa*, *Malaleuca leucadendron*, *Ploiarium alternifolium* and *Tristaniopsis obovata*. Soil texture in layer 0-20 cm is loamy sand and in layer 20-40 cm is clay loam sand. In terms of soil fertility, soil texture component is important in the presence of the clay fraction as well as absorbent mineral content and exchanging ions in the soil thus it can provide nutrients for plants[17]. Moreover, the longer the post-mining land is abandoned, the higher decrease of sand percentage and increase dust and clay percentage[18]. Soil texture in TL1 is close to 7 years old post- tin mined land in Bangka and tin mined land which still operating in Singkep[18,19].

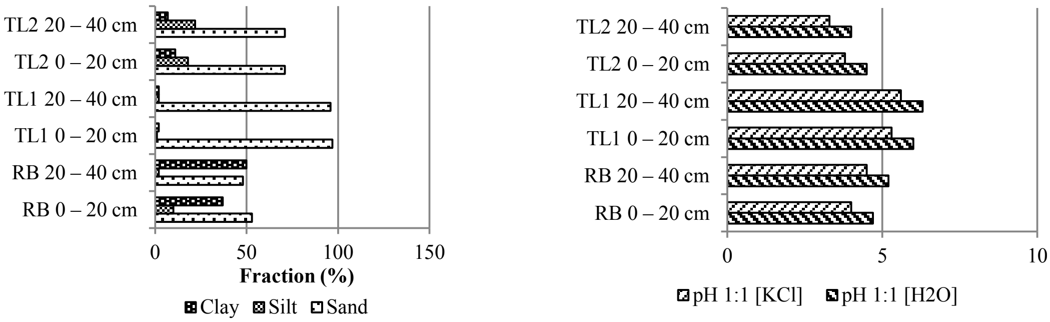

Fig 3. Soil texture and pH in each locations

The lowest pH was found in TL 2, due to there has been the addition of organic matter in soil and this condition favor micro organism activities to develop. It accelerated process of decomposition. Moderate precipitation in study site about 250 mm impacted to high potential of leaching in sandy texture. Nevertheless, although pH of forest and TL 2 is lower than TL 1, plant growth is supported by availability of nutrients and clay conditions contained in that location. Heath forest vegetation which well adapted at low pH such as several pitcher plants (*Nepenthes* spp.) were found in location. At other locations with no vegetation cover, soil conditions become thin and have poor organic materials thus there are plant nutrient scarcity. At low pH the H^+ ions are bound with many other anions other, thus it cannot support other cation exchange reactions. The addition of fertilizer will not be effective since it will be lost due to leaching[17].

3.2. Organic Matter

Generally, organic matter content in the RB is the highest than other, which is 1.11 to 2%. Organic matter decreases dramatically into 0.08% in TL 1 when mining occurred and increases 1.17% - 1.83% aftermore than 100 years succession. Natural succession process in post mining land shall not increase organic matter rapidly. Study in Bangka and Singkep states that organic matter content in several ages of post tin mineland of 0 years, 7 years,11 years, 13 years, 26 years, 38 years and more than 40 years is still less than 1%[18,19]. In TL2, succession process lasts more than 100 years and presence of forest vegetation supports availability of litter and microclimate conditions for decomposition of organic material (Fig. 3). Organic matter content is also determined by condition of soil texture, the more viscous the more organic matter contained.

Conditions of soil fertility and plant growth influence each other in certain, particularly from availability of N in soil. However, N in form of the element cannot be absorbed by the plants. Plants need activities of microorganisms to decompose organic material and break it down into nitrite, nitrate or ammonium that can be absorbed by plants. The main source of N is derived from the atmosphere (78%) and only slightly off the ground in which from organic ingredients. Low organic matter content impacts to low availability of N in soil of all locations. Good ratio between organic matter content and nitrogen (C/N ratio) for plant to grow is under 10 [20]. In general, the C/N ratio in all locations is below 10. It indicates that organic matter has decomposed. Nonetheless, N in soil is low in all locations, which is below 0.2%. The process of decomposition of organic matter is strongly influenced by physical environmental conditions such as limited water and high temperatures during summer, particularly in the post-mined land reaching to 40ºC. Thus, these conditions are less favorable for microorganisms activity, especially bacteria that play a role in nitrification and amonification process.

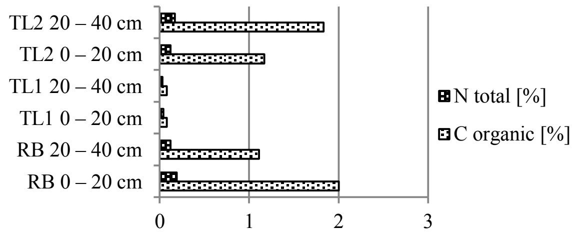

Fig 4. Persentage of C organic and N.

3.3. Phosphorus

The main role of phosphorus is in energy transfer process of plant cells chloroplasts. Moreover, it improves work efficiency. P-deficient plants will show symptoms such as stunted growth (stunted) and the leaves become purple or brown starting from the tip of the leaf[17]. In general, the total P content in each study site is in the category of deficiency ranges from 4.3 to 9.5 ppm[20], this indicates that the appearance of vegetation growing at the study site become skinny and stunted. It also becomes one of the characteristics heath forest ecosystems, where vegetation can survive under conditions of nutrient deficiency. In RB and TL2, P in the layer 0-20 cm and 20-40 cm respectively 7.8 ppm; 4.3 ppm and 5.7 ppm; 4.5 ppm. In Liebig's law (1840) of the minimum states that the growth of a plant depends on the amount of food provided for it in a minimum amount[21]. At low nutrient conditions, several plants might grow with the appearance of diverse morphology, several plants have thin rod-dwarf, small leaves-thick, wide-bit hairy, thick-a bit watery and others. This is a form of adaptation to the environmental conditions of each plant.

3.4. Ca, Mg, K, Na

Minerals analysis results availability of Ca, Mg, K and Na in low concentration between the 0.0 to 0.5 me/100 g. Due to soil washing process and the local host rock weathering process, soil mineral becomes low. High mineral content of quartz indicates low soil nutrient reserve, meanwhile soil parent material is acidic. Granodiorite host rock (igneous rock) in RB contains minerals quartz>70%, the weathering of rocks contains Na, Ca, Si and Al needed by plants in post-tin mined land 100 years with quartz sandstone as a host rock (sedimentary rock)[22]. Weathering of these rocks produces a high percentage of the mineral quartz, clay and slightly acidic soil.

3.5. Cation Exchange Capacity

Rated Cation Exchange Capacity (CEC) in each location is relatively very low, ranging from 0.6 to 6.84 me/100 g or below 16 me/100 g. This condition will create stagnant growth for plants[23]. Moreover, the value of CEC is influenced by several factors, including amount of clay, organic matter and pH. At locations, soil containing clay and organic matter will slightly lower the ability of colloids to be exchanging ions in the soil, thus it has low CEC value.

3.6. Vegetation

Vegetation analysis shows that there is no tree found in the TL due to re-operation of mining activity where several area are opened and cleared. However, several vegetations are found in TL, particularly on TL2 area where soil condition has adequate conditions for plant to grow. Number of species of herbs, seedling, sapling and tree which found in Rb are 8, 25, 42 and 24 respectively. Number of species of herbs, seedling, sapling and tree which found in TL are 14,18, 19 and 0 respectively. The similarity index between Rb and TL for herbs, seedling, sapling and tree are 9.09%, 32.56%, 28.57 and 0% respectively. Table 1 shows diversity index, richness index and Evennes index in both sites.

Table 1. Diversity index (H'), richness index (R) and Evennes index (E) in RB and TL

Index	Location	Herbs	Seedling	Sapling	Tree
H'	Rb	1.81	2	2.85	2.64
	TL	2.07	2.03	2.06	0
R	Rb	1.7	3.77	5.98	5.06
	TL	2.16	3.13	3.31	0
E	RB	0.88	0.62	0.76	0.83
	TL	0.77	0.7	0.7	0

The similarity index of seedling between RB and TL shows the highest of all. The same seedling species are *Callophyllum lanigerum*, *Syzygium incarnatum*, *Syzygium euneura*, *Adinandra sarosanthera*, *Tristaniopsis obovata*, *Syzygium lepidocarpa* and *Syzygium rostratum*. For sapling, there are *Calophyllum lanigerum*, *Syzygium incarnatum*, *Syzygium euneura, Adinandra sarosanthera*, *Tristaniopsis obovata*, *Syzygium lepidocarpa*, *Syzygium rostratum* and *Schima wallichii*. For herbs, there is merely*Syzygium buxifolium* and no species of tree which is found in TL. The most dominant family is Myrtaceae, several are pioneer species,which has good adjustment in lack condition. Beside that, we also found several vegetations in TL having potential to be catalyitic plant, such as *Dillenia suffruticosa*, *Rhodomyrtus tomentosa*, *Melastoma malabathricum* and *Baeckea frutescens*. The last vegetation one of characteristic plants in white sandy soils[24].Although there are various dissimilar plants, soil condition supports these plants to grow naturally and gradually by providing adequate nutrients. These plants are potential to be seedling for restoration heath forest.

3.7. Ecosystem Restoration

Bradshaw distinguishes the definition of restoration, rehabilitation and reclamation where restoration involves returning the damaged ecosystem to its original state, rehabilitation only a partial return and reclamation implies ending up in some new state where either structure or function is different from the original[25]. The purpose of restoration does not merely to recover soil or vegetation but also recover previous ecosystem function. Several considerations to restore damaged ecosystem are selection of native species, planting stock production, site preparation, soil amendment, planting technique, maintenance, monitoring and evaluation[23]. Rehabilitating post-tin mined land into heath forest is not so economically promising than other lowland forest. Restoring heath forest ecosystem needs strong commitment and good understanding of ecosystem function. There is anomaly in soil condition, where commonly the expectation after restoration is the neutral pH and ideal soil texture. Beside that, planting big trees and high biomass also become the expectation.

Soil condition in TL 2 is similar to Rb, although it takes long time to recover naturally. Due to soil development in podzols can take several thousands of years to reach its mature state[25], several restoration techniques with natural process approach should be implemented to accelerate soil development in post tin mined land. Planting can facilitate forest succession, particularly by applying the catalytic plant to stimulate other vegetations and good soil condition[26]. Some key points to select plant for restoration are relatively fast growing, light demanding and low nutrient demanding, perform function as a catalytic, easy to propagate, low cost for planting and maintenance, easy to manage and appropriate to land used[23]. The presence of vegetation as initial establishment may require the addition of fine, however it could used locally available material[25]. With the planting trees, the fine material can be placed in small pockets into which the trees are planted.When it already sucession naturally it improve self sustaining in the long term as an ecological engineering[25].

In Bangka Island, revegetation was conducted by using legume cover crop technique with *Calopogonium mucunoides* and planting native vegetation such as *Hibiscus tiliaceus*, *Calophyllum inophyllum*, *Syzygium grande* and *Ficus superba*. The combination of higher planting density and legumes and the combination of higher planting density, legumes and top soil increased the organic matter, and improve the microclimate by covering the bare ground faster[18]. Although small amount of organic matter, it can exert a profound effect on soil physical dan chemical properties[27]. Native species should be given preferences over exotic, in part to help minimize the risk in ecosystem[26]. Thus, silvicultural treatment to accelerate restoration could be conducted. On the other hand, experiment in the glasshouse by using mycorrhiza innoculation and planting tree species (*Accacia auriculiformis*, *Paraserianthes falcataria*, *Leucana leucocephala* and *Gliricidia maculata*) resulted that planting *Leucana leucocephala* in combination mycorrhiza and manure fertilizer application is recommended to implement in post tin mining land[19]. However, in many region, *Leucana leucocephala* has potential to invade in some areas [26].

The main problems in post- tin mined land are sandy texture, low CEC and low organic matter. Soil augmentation may be applied such as adding organic fertilizer and liming. Organics include chicken dung, peat, sewage sludge, skim latex, rice husks, sawdust and palm oil mill can be used as organic fertilizer[28]. For liming, the consideration to reach quick effect to the soil is size of lime. The smaller lime (fine) will be react quicker than the big or coarse lime[29]. After soil amendment, natural regeneration could be stimulated by spread off the seed bank from forest floor into restoration area. As most native species in the soil seed banks were dispersed by birds, management startegies should be carried out for enrichment planting with native secies in the early stage of succession [30] to support ecosystem restoration.

Natural succession improve self sustaining in the long term as an ecological engineering[25]. On the other hand, ecological engineering is the design of sustainable system, consistent with ecological principles, which integrate human society with its natural environment for the benefit of both[31]. Some fuctions of heath forest such as water and soil nutrient storage, water purifying, health and food security must be reversed. Rehabilition is already done, however several environmental problemsare still occurred. Natural succession approach is needed in rehabilitation, as a restoration of heath forest ecosystem.

4. Conclusion

Restoration post-tin mined land into heath forest ecosystem should consider several aspects of soil properties such as soil texture, soil organic matter content and CEC. Soil problems exist in post tin mined land such as sandy, lack of organic matter and very low CEC. Change of soil condition in TL1 to soil condition in TL2 has developed soil properties and supported plant growth. The important aspect is soil amendment conducted by adding organic matter, applying polymer fertilizer to keep the fertilizer in the soil and selecting local species which well adapted as pioneer. Seedbank from forest floor, also potential to be seeds source of native species. Several rehabilitation techniques might be implemented to restore heath forest ecosystemsuch as *Legume Cover Crops*, *Seeds Soil Augmentation*.

References

1. Hess FL, Hess E. *Bibliography of The Geology and Mineralogy of Tin*. Washington: The Smithsonian Institution; 1912
2. Van Bemmelen. RW. The Geology of Indonesia Vol IA. Netherlands: The Government Printing Office, The Hague; 1970
3. Wahyudi B. Studi tentang Radioaktivitas Lingkungan dan Epidemiologi Lingkungan pada Area Pertambangan Timah Pulau Bangka Provinsi Kepulauan Bangka Belitung. Jakarta: Prosiding Seminar Aspek kesehatan Radiasi dan Lingkungan pada Industri Non-Nuklir; 2003
4. Henny C. Kolong bekas tambang timah di Pulau Bangka: permaslahan kualitas air dan alternatif solusi untuk pemanfaatan. Oseanologi dan Limnologi di Indonesia 2011;37(1):119-138
5. Pratiwi SD. Analisis kesesuaian geologi dalam rangka rehabilitasi lahan pasca penambangan studi kasus Belitung Timur [skripsi]. Jakarta: Program Studi Teknik Geologi Fakultas Teknologi Kebumian dan Energi Universitas Trisakti; 2010.
6. Brunig EF. *Ecological Studies in The Kerangas Forests of Sarawak and Brunei*. Malaysia: Borneo Literature Bureau; 1974
7. Whitmore TC. *TropicalRainforestoftheFarEast*. 2nd Ed. Oxford:Clarendon Press; 1984.
8. Whitten AJ, Anwar J, Damanik SJ, Hisyam N. *Ekologi Ekosistem Sumatera*. Yogyakarta: UGM Press;1984.
9. Aronson J, Alexander S. Ecosystem restoration is now a global priority: time to roll up our sleeves. *J Restoration Ecology* 2013;21:293-296.
10. Bech J, Abreu MM, Albanese A. Reclamation of mining sites soils. *Journal of Geochemical Exploration* 2012;113: 1-2
11. Huttl RF, Weber E. Forest ecosystem development in post-mining landscapes: a case study of the Lusatian lignite district. *J Naturwissenschaften* 2001;88:322-329.
12. BAPPEDA Belitung Timur. *Belitung Timur dalam Angka 2011*. Kabupaten Belitung Timur: BAPPEDA; 2011
13. Soeranegara I, Indrawan A. *Ekologi Hutan Indonesia*. Bogor: Bogor Agricultural University; 2008
14. Ludwig JA, Reynolds JF. *Statistical Ecology*: A Primer on Methods on Computing. New York: John Willey and Sons; 1988

15. Mueller-Dombois D, Ellenberg H. *Aims and Methods of Vegetation Ecology*. New York: John Wiley and Sons; 1974
16. Widhiyatna D, Pohan MP, Ahdiyat A. 2006. Inventarisasi potensi bahan galian pada wilayah PETI daerah Belitung, Provinsi Bangka Belitung. Proceeding Pemaparan Hasil-Hasil Kegiatan Lapangan dan Non Lapangan Tahun 2006, Pusat Sumber Daya Geologi.
17. Hakim N, Nyakpa Y, Lubis AM, Nugroo SG, Hong GB, Bailey HH. Dasar-Dasar Ilmu Tanah. Lampung: Universitas Lampung; 1986.
18. Nurtjahja E. 2008. Revegetation on tin-mined land using local tree species in Bangka Island [thesis]. Bogor: Bogor Agricultural University; 2008
19. Badri LN. Soil, vegetation and water gallery of mine characteristic of post mining: Tin land and land rehabilitation techniques for revegetation [thesis]. Bogor: Bogor Agricultural University; 2004
20. Landon JR. *Booker Tropical Soil Manual: a Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. London and New York. Longman; 1984,pp.450
21. Odum EP. *Dasar-Dasar Ekologi*. Traslated by Tjahjono Samingan from *Fundanmentals of Ecology*. Yogyakarta: Gajah Mada University Press; 1993
22. Herman M. Geology Map of Belitung Sheet Sumatera. Jakarta: Geological Research and Development Centre;1995
23. Setiadi Y. Lecture material: Restoration Ecology. Study Program of Forestry. Postgraduate Program Bogor Agricultural University; 2012
24. Mohr ECJ, Van Baren FA, Van Schuylenborgh J. *Tropical Soils A Comprehensive Study of Their Genesis*. Netherlands: Geuze Dordrecht; 1972
25. Bradshaw A. Restoration of mined lands-using natural processes. *JEcological Engineering* 1997;8:255-269
26. Parotta JA, Turnbbull JW, Jones N. Catalyzing native forest regeneration on degraded tropical lands. *J Forest Ecology and Management* 1997;1:1-7
27. Bohn Hl, McNeal BL, O'connor GA. *Soil Chemistry*. Canada: John Wiley&Sons; 1979
28. Lal R. Stewart BA. *Soil Restoration*. New York: Springer-Verlag; 1991
29. Sanchez PA. *Properties and Management of Soils in the Tropics*. Canada: John Wiley and Sons; 1976
30. Zhang H, Chu LM. Changes in soil seed bank composition during early succession of rehablitated quarries. *J Ecological Engineering* 2013;55:43-50
31. Bergen SD, Bolton SM, Fridley JL. Design principles for ecological engineering. *J Ecological Engineering* 2001;18:201-210