Environmental site engineering and integrated bio-cycles management for rehabilitation of degraded tin mining land in tropical ecosystem

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Abstract. Indonesia is known as the emerald of equator that has high values of natural resources although it also has a huge disaster risk. It is because Indonesia is located in the strategic areas, namely: (i) the equator, (ii) ring of fire, and (iii) earth plates of Eurasian, Pacific & Indo Australia. Mining activities of natural resources in tropical region exposes carbon and heavy metals and thus are the main cause of severe local, regional, and global environmental damage. The change of national economic development from extraction to empowerment of natural resource will facilitate shifting paradigm from red & green economic to blue economic concept that more smart, global, focus, and futuristic. Site engineering on critically degraded land through land preparation, soil amendment & biofertilizer could facilitate a better rehabilitation of mining land and have added value on environment, economy, sociocultural and health aspect. Synergism to genetic engineering using fast-growing species (indigenous and exotic) will improve success rate of land rehabilitation. An integrated bio-cycle management for managing land resources (i.e., soil, water, mineral, air, and microclimate) and biological resources (i.e., fauna, flora, and human) is an important strategy for sustainable productivity in protective tropical ecosystems.

1. Introduction
Indonesia has a natural gift in the form of abundant natural resource wealth inheritance for free [1]. However, it is also as the centre of heart-breaking disaster source. At least there are three strategic reasons namely: (i) geological structure, (ii) ring of fire, and (iii) equator line. The Geological structure in Indonesian area has bestowed a lot of energy and mineral mining in the form of: oil, gas, coal and mineral, gold, tin, bronze, etc., which means that we have abundant natural resource wealth
Inheritance. Indonesia is traversed by the world volcano path so that it has 127 active volcanoes that always remove new volcanic ash fertilizing the agricultural land.

Indonesia is located in the equator line so that it gets the optimal and abundant sunlight, rainfall, temperature, humidity along the years [1]. Indonesia wet tropical forest becomes the lungs of the world and has the greatest biodiversity in the world. The tropical land productivity of 750 grC/m²/year means tenfold compared to the Temperate region constrained by the season that is less favourable for the growth [1]. Nevertheless, the tropical economic value is still small, only half part compared to the Temperate region.

The Indonesian development still depends more on the exploitation solely on the abundant natural resource inheritance [1]. All is even not managed by itself; it asks the other parties to take them so that it only gets fee and tax. Due to the excessive exploitation, the abundant inheritance that should be enough for more than seven generations evidently has been drained in only one generation. Indonesia must be able to recognize its potential nature. We must improve our science and technology to process the abundant natural resource in accordance with the dignified and sustainable nature of universe.

The severe exploitation of tropical forest ecosystems, including open mining, has led to widespread degradation and damage [1,2]. The deforestation rate in Indonesia in the period of 1985-1997 is 22.46 million hectare or 1.87 million hectare/year [2]. However, in the range period of 1997-2000 the deforestation rate has increased significantly to be 2.84 million hectare/year [3], with the high rate of damage of the Indonesian forest in the period of 2000-2009 about 1.5 million hectare/year.

According to Forest Watch Indonesia [4], deforestation in Indonesia on mining concession in the period of 2009 – 2013 is 488,374 hectare or more or less 10% of the Indonesian deforestation. The tin mining also uses the open pit mining system so that it gives great contribution to the deforestation and land degradation in Indonesia. The main step of tin mining with open pit mining system includes: land surface opening from vegetation covering (land clearing), stripping the top soil (stripping), excavation, dam making, washing, and disposal of solid materials left over from tin washing (tailing) [5].

The characteristics of the post-tin mining land experience very heavy damage due to the dismantling of growing media on the land surface. The post-tin mining land has bad chemical, biological and physical properties [6]. The post-tin mining land is differentiated into three types namely: pit (former mining land in the form of a small lake with a depth reaching 40 m), overburden (clay deposits), and the overlay of tailings in the form of swamps or dry land [7].

The tree planting on degraded lands could restore the physical and biological effects of forest regeneration and initiation of the return of indigenous communities from the forest [8,9]. There are three main activities in carrying out the planting on the former tin mining land are: cover crop planting, major crop planting, and maintenance. The local and exotic pioneer species have a strategy of living of mutualism symbiosis and adapting to utilize the limited marginal land condition. The natural and organic soil amendment could repair the soil condition [1,10,11], by providing the nutrients for plants and improving the physical, chemical and biological properties of the soil itself.

The application of natural and organic soil amendment to improve the environment site on post-tin mining land in revegetation activities is very important. Thus it is expected to be able to increase the success of post-mining land rehabilitation in the tropical regions and to be able to support the creation of the more dignified and sustainable environment and life. This article is a summary of preliminary data of the research series on environmental site engineering in post-mining tin land rehabilitation. Articles from each research items will be separately published.

2. Materials and methods

Several research series on the use of natural and organic soil amendment for the environmental site engineering on the post-tin mining land in Bangka Island, Indonesia is carried out with in situ and ex situ. The primary and secondary observation data are carried out to formulate the potential improvement of degraded land quality due to tin mining, so it will support the plant revegetation growth in the post-tin mining land rehabilitation in Bangka Island. The in situ research series are
carried out in the post-tin mining land in Bangka Island, while the ex situ research is carried out in the Laboratory of Intensive Silviculture, Faculty of Forestry, UGM Yogyakarta Indonesia. The soil and tissues analysis is carried out in some Laboratories in UGM Yogyakarta Indonesia. The items of research series on environmental site engineering on post-tin mining land in Bangka Island, Indonesia with natural and organic soil amendment are as follows:

- Sugarcane Filter Mud Fertilizer in revegetation of Cemara laut Seedling (Casuarina equisetifolia)
- Vermi-compost Fertilizer in revegetation of Agarwood Plant (Gyrinops versteegii)
- Organic Material for revegetation of Kemiri Sunan (Reutealis trisperma)
- Biogas Waste and Vulcanic Ash for revegetation of Kemiri Sunan (Reutealis trisperma)
- Organic Pot and Legume Cover Crop for revegetation of Kemiri Sunan (Reutealis trisperma)
- Super Humus for revegetation of Nyamplung (Calophyllum inophyllum L.)
- Organic Soil Amendment for revegetation of Casuarina equisetifolia
- Biofertilizer for revegetation of Agarwood (Aquilaria malaccensis)
- Mycorrhizae and Phosphate Solvent Bacteria for revegetation of Trembesi (Samanea saman)
- Organic Growing Media and Mycorrhizae for revegetation of Cemara laut (Casuarina equisetifolia)
- Biofertilizer and Organic Pot for revegetation of Ketapang (Terminalia catappa)
- Biofertilizer for revegetation of Pelawan (Tristaniopsis merguensis)
- Solid and Bulk Compost for revegetation of Samanea saman (Jacq.) Merr.

Soil analysis including soil texture, pH-H₂O, electrolyte conductivity (EC) and redox potential (Eh) is measured by the electrometric method, av-N is observed using the Devarda’s alloy method, av-P is observed using the Bray II method, av-K is observed using the ammonium acetate method, and Cation Exchange Capacity (CEC) with the ammonium acetate method; total nutrition and other elements are observed using SEM (Scanning Electron Microscopic) + EDX method. The height and diameter of the plants are observed once in two weeks, while the plant harvest is carried out to measure the biomass dry weight and network analysis. The data is analysed using SPSS 16.

3. Results and discussions

3.1. Degraded post-tin mining land

The physical and chemical properties of the soil whether from the landfill forms, dredge former basin and waste sand of processing tin ore are almost as bad. The contents of sand fraction in all the soil reach 76.6%- 92.7%, while the cation exchange capacity value is 2–4.01 (me/100g), the electrical conductivity is 0.33–0.64 (dS/m), the available P is 1.2–2.18 (ppm) and the available K is 0.02–0.03 (me/100g), in which all have very low status (Table 1). The value of pH of the landfill tends to acid (5.79), the dredge former basin tends to neutral (6.52), and the waste sand of processing tin ore tends to base (7.79). The application of vermicompost fertilizer is able to improve the soil quality by increasing the CEC value to be 4.02–7.64 (me/100g), EC to be 0.78–1.6 (dS/m), the available P element to be 48.56–78.08 (ppm), the available K to be 0.23–0.96 (me/100g) and by changing the pH value around 7.5 on each post-mining land.

Overburden is formed from the stacking of the top layer of dredged former soil in the post-tin mining area. The post-mining land is reddish, which is caused by Fe in oxidation form (Fe³⁺), because had a good drainage [11]. Pit is a the soil dredged former basin that dominated by the dark grey lower mineral, because basically is always in flooded condition with Fe in reduction form (Fe²⁺) [11]. The sand tailing overlay is the waste from the processing tin ore buried that have the highest degradation rate. The natural and organic soil amendment must be given due to the presence of low organic material and nutrients and the worst micro climates [11]. The soil structure in this post-mining area is a single grain, the moist consistency is loose to very loose with coarse materials of 20 to 30%.
Table 1. The chemical properties of various post-tin mining land in Bangka Island

| Observed properties | Sand tailing | Overburden | Pit |
|---------------------|-------------|------------|-----|
|                     | Value | Status | Value | Status | Value | Status |
| pH                  | 7.79  | Base   | 5.78  | Acid  | 6.52  | Neutral |
| CEC (me/100g)       | 3.6   | very low | 4.01  | very low | 2 | very low |
| EC (ds/m)           | 0.49  | very low | 0.33  | very low | 0.64  | very low |
| Eh (mV)             | -77   | medium reduction | 21 | medium reduction | -3 | medium reduction |
| NH₄⁺ (ppm)          | 34.13 | Medium | 33.93 | medium | 31.46 | medium |
| NO₃⁻ (ppm)          | 51.93 | Medium | 64.63 | medium | 137.27 | very high |
| Available-P (ppm)   | 2.23  | very low | 1.2 | very low | 2.18  | very low |
| Available-K (me/100g) | 0.03 | very low | 0.02 | very low | 0.02 | very low |

3.2. Organic amendment

To increase the quality and health of the post-mining land, the early step carried out is the increase in content of the soil organic amendment [1,10,11]. Organic material could act as the soil conditioner, improve soil chemical, physical and biological properties.

3.2.1. Super humus

Through the concept of New Road of Synthetic Humification, SROP (slow release organic paramagnetic, patent number P00201401530) is developed by combining the terra preta soil concept and Hayes humus to get the stable humus [12]. The Biochar material that is rich in carbon element and stable is combined with the hydro-char containing a high biomolecule and stable so that it produces synthetic humus with abundant carbon and high stability against the chemical and biological degradation in its application to agricultural soil [12]. Synthetic humus is designed as natural humus, with ability as the electron transfer controller, water content controller, the breeding grounds for soil organisms and the soil organic content binding, the slow release agents of macronutrients and micronutrients in the presence of hydrogen bind, Van der Waals interactions, and interactions among other molecules occurring in the soil. The nature of synthetic as the electron transfer controller is due to the supramagnetic particle, which is a nanoparticle sized iron paramagnetic particle in synthetic humus [12].

3.2.2. Biogas waste

The application of biogas waste ameliorant material in each dose is able to improve the physical and chemical properties of tin tailing soil such as pH, EC, Eh, CEC, available-N, P, K, Ca, and Mg. The treatment of biogas waste application of 5% pH changes to 6.4 approaching neutral, while the biogas waste application of 10% pH also approaches neutral of 6.6. The application of biogas waste is significantly able to increase the pH from acid soil pH control. Biogas waste could increase the sustainable and environmentally friendly agricultural production due to the nutrient content, enzymes and growth hormones contained in it. Biogas waste is rich in nutrients such as nitrogen, phosphorus and other valuable organic materials, that are important for plants and needed in large quantities. The application of biogas waste ameliorant material on tin tailing soil could each increase the average growth of height, diameter, dry weight, top-root ratio of Kemiri sunan (Reutealis trisperma) compared with no application at all. The best growth in terms of height, diameter and total amount of dry weight is by 10% of biogas waste application.

3.2.3. Vermicompost
Vermicompost organic fertilizer contains small particles of organic materials after passing through the digestive process by *Eisenia fetida* or *Lumbricus rubellus* worms. Besides, N content is available more than the ordinary compost, because in the fresh vermicompost fertilizer N is already in the form of ammonium [13], with C/N ratio is less than 20. The vermicompost fertilizer will more quickly supply the nutrients needed by the soil than the ordinary compost fertilizer [13].

The content in vermicompost fertilizer depends on the compost raw material and the type of cultivated worms. *Eisenia fetida* worms contain nutrients such as total N of 1.4-2.2%, total P of 0.6-0.7%, total K of 1.6-2.1%, total C/N of 12.5-19.2, total Ca of 1.3 -1.6%, total Mg of 0.4-0.95, pH of 6.5-6.8 with organic material 40.1 -48.7%. *Lumbricus rubellus* worms contain C of 20.20%, N of 1.58%, C/N ratio of 13, total-P of 70.30 mg/100g, total-K of 21.80 mg/100g, total-Ca of 34.99 mg/100g, total-Mg of 21.43 mg/100g, total-S of 153.70 mg/kg, total-Fe of 13.50 mg/kg, total-Mn of 661.50 mg/kg kg, total-Al of 5.00 mg/kg, total-Na of 15.40 mg/kg, total-Cu of 1.7 mg/kg, total-Zn of 33.55 mg/kg, total-Bo of 34.37 mg/kg and pH of 6.6-7.5 [14].

### 3.2.4. Blotong

One of the organic waste from the sugar factory is blotong, which is a sugar cane fiber mixed with impurities separated from the sap, in the form of dense moist, the temperature is high enough to form like soil. The composition of blotong consists of: carbon (8.215%), nitrogen (0.30%), C/N ratio (26.93), phosphorus (0.17%), potassium (0.034%), calcium (1.05%), magnesium (0.0024%), iron (0.312%), manganese (0.029%) [15].

Blotong may improve the soil physical fertility by increasing the capacity to hold the water, to reduce the rate of nutrient washing, and to improve the soil drainage. Another benefit of blotong is that it functions to neutralize the effects of Al that can be exchanged, which may cause the availability of P in the soil more available [16]. The pH value of blotong of 6.95 is included in the neutral pH category with a CEC value of 46.94 me/100g included in the very high criteria. The available N value is 80.35 ppm and the available P value is 636.75 ppm (very high). Besides being able to neutralize the effects of Al and Fe [16], the benefit of blotong in the soil is also being able to increase the availability of P in the soil.

The application of blotong to pre-mining soil media, post-mining, and post-mining reclamation could improve the soil properties including the increase in pH from acid to neutral; CEC value; electrolyte conductivity; redox potential value; the essential nutrient content of available-N, -P and -K. The blotong at a dose of 10% is more effective in improving the soil quality. The application of blotong fertilizer may significantly increase or improve the growth of height, diameter, and top-root ratio of *Casuarina equisetifolia* in pre-mining, post-mining, and post-mining reclamation media.

### 3.2.5. Volcanic ash

Volcanic ash is a falling volcanic material sprayed into the air when an eruption occurs and could fall at distances reaching hundreds or even thousands of kilometres from the crater due to the wind gust influence [17]. Volcanic materials that are the oxide compounds include Silica dioxide (SiO2) 54.56%, Aluminium Oxide (Al2O3) 18.37%, Ferric Oxide (Fe2O3) 18.59% and Calcium Oxide (CaO) 8.33% while the heavy metals are also in the form of Cadmium (Cd), Copper (Cu), Arsenic (Ar), Tin (Sn) and Plumbum (Pb) but in very low concentrations. The amount of volcanic ash is a potential natural resource that could be used as an addition to the soil mineral reserves, also could be used to enrich the nutrient content and to improve the physical properties of the soil [17]. Whereas, the Sinabung volcanic ash contains the nutrients, namely K2O 0.55%, P2O5-total 0.14%, MgO 2.45%, CaO 7.32%, S 0.18%, Fe 16.11 %, SiO2 59.92%, Zn 0.08%, MnO 0.17% and Cu 46.35 ppm.

The application of volcanic ash ameliorant material is not capable enough to improve physically but is able to support the increase in chemical fertility for both macro and micro elements and to reduce the toxic properties in the soil such as Cd. The application of 5% volcanic ash ameliorant material on tin...
tailing soil could increase the best average growth of height, diameter, dry weight, top-root ratio of Kemiri Sunan (Reutealis trisperma) compared to control.

3.2.6. Organic pot

On degraded and damaged land, which includes the former logging land, the former mining land (coal, tin, gold, copper, limestone, etc.), sandy land, rocky land, landfill, eroded land, landslides, former sand volcanic eruptions etc., the physical, chemical, mineral and biological properties are very bad. The environmental site engineering through the application of organic materials is carried out in order to optimally increase moisture regimes, temperature regimes, and nutrient regimes. This could be done by the application of organic material in the form of compost fertilizers, biological fertilizers, biofertilizer fertilizers, management of organic material cycles, pot systems, organic pots, organic media pots [1,18,19].

The use of organic pot media may function as a compact growth medium, being capable of storing the water, reducing the heat, reducing the evaporation, providing the nutrients through decomposition of organic pots slowly according to the plant needs, so that the moisture regimes, temperature regimes, nutrient regimes could be fulfilled as the requirements for living necessities of rehabilitation plants. With the improvement of soil fertility, the plant growth and the productivity of damaged land will increase drastically, thereby will increase the added value of economy, environment and life to be more dignified and sustainable.

3.2.7. Legume cover crop

The use of legume cover crop (LCC) is very important for biological soil amendment in the humid tropical region [1,19]. LCC increase soil fertility through high inorganic/available-N in the form of ammonium and nitrate [20,21]. LCC could sustainably increase the soil productivity in tropical short rotation forests by supplying nitrogen to the soil through aerial N$_2$ fixation by symbiotic mutualism with bacteria Rhizobium. LCC also supply of organic materials through decomposition of litterfall biomass. According to [22], LCC plants could provide input of organic material as much as 2-3 Mg/ha at the age of 3 months and 3-6 Mg/ha until the age of 6 months [23]. LCC could contribute biomass at 4-5 Mg/ha in a life span of 6 months [10]. This condition is very beneficial for staple crops that require the organic supply at the beginning of the growth period. LCC may contribute in controlling the plant weeds such as the grass (Imperata), preventing the erosion due to land cover produced and attracting the insects that are useful for the spread of LCC [12]. LCC may reduce about 27% to 95% of weed biomass [24], with Mucuna pruriens var. utilis if the main crops will be planted soon. If the LCC required is with specification to provide a longer land cover in longer period we can plant Centrosema or Pueraria [25].

3.3. Integrated organic cycle management

Integrated Bio-cycle Management (IBM) is an alternative system to manage tropical natural resources. We harmoniously combination of agricultural sectors (agriculture, horticulture, plantation, animal husbandry, fisheries, forestry) with non-agricultural sectors (settlements, agro-industry, tourism, industry) under landscape ecological management in one integrated areas [1,26]. The key characteristics of IBM are (i) an integration of agriculture and non-agriculture sector, (ii) value of environment, aesthetics and economics, (iii) rotation and diversity of plants, (iv) artificial and functional bio-technology, nanotechnology, pro-biotic, (v) management of closed organic cycle and integrated crop, nutrient, moisture management, (vi) integrated bio-protection and ecosystem health management, (vii) landscape ecological management, agro-politan concept, (viii) specific management of plant and (ix) holistic and integrated system [1,18]. The IBM has more advantage compare to the other various types of sustainable agricultural system such as: low input agricultural, integrated farming, organic farming, bio-dynamic, or agroforestry system [1].
IBM is an alternative solution for improving land productivity, program development and environmental conservation and rural development in an integrated management [26,27,28]. They will meet with the expected basic need at short-, medium- and long-term for food, clothing and shelter. IBM was expected to provide additional benefits for farmers with small, medium and big capital, through the recycling of organic waste into renewable resources to produce high-value production [1,18]. IBM can produce “golden of life”, such as: golden yellow (food, rice, corn), golden green (vegetables), golden brown (plantation wood), golden red (meat), golden white (milk, fish), golden black (organic fertilizer), golden transparent (water), golden gas (oxygen), golden blue (biogas, biomass energy, bio fuel), golden king (herbal medicine), golden prosperity (tourism), golden inner (mystic) [1,25]. IBM and education for sustainable development (ESD) could stimulate sustainable economic, environment and socio-cultural aspect for sustainable environment and life [29,30].

4. Conclusions
The physical and chemical properties of the post-tin mining land in the form of overburden, pit, and sand tailing, all of which are relatively bad. Environmental site engineering by providing the natural and organic soil amendment consisting of: super humus, bio-gas, blothong, vermicompost, volcanic ash, organic pots, legume cover crops in integrated organic cycle management could improve the quality of degraded land due to the tin mining process. The improvements in physical, chemical and biological properties of post-tin mining land have supported the growth of the most optimum revegetation plants. The concept and appropriate technology in rehabilitating the degraded tin land ecosystems have a high contribution to the environment and to the more dignified and sustainable life.

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