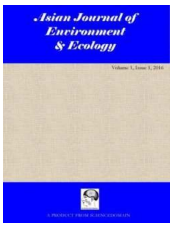

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Study on Soil Spread at Rehabilitation Area for Promotion of Plant Growth in Open Cut Coal Mine in Kalimantan Area in Indonesia

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Authors' contributions

This work was carried out in collaboration between both authors. Author AH designed the study, performed the laboratory and field research and wrote the protocol and wrote the first draft of the manuscript. Authors TS and HS managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Rehabilitation is one of the important and considerable topics for an environment protection in mine closure process. A lot of open cut mine keep the topsoil in the natural forest during soil stripping process to spread the topsoil to rehabilitation area for success of revegetation. However, there are some considerable points for handling with the topsoil in situ such as the soil properties and severe compaction by heavy equipment. Therefore, we carried out field researches and laboratory experiments to investigate the characteristics of soil spread in rehabilitation area in terms of plant growth: particle size distribution, Atterberg limits, soil bulk density, soil moisture contents, soil pH and soil EC, permeability, and soil hardness. As a result of the series of tests, different types of soil with natural soil were backfilled in the rehabilitation area due to mixing with overburden. This result suggest that revegetation process should be designed with consideration of soil conditions.

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Keywords: Topsoil; rehabilitation; medium for plant growth; open cut mine.

1. INTRODUCTION

Indonesia produces over 350 Mt of clean coal in 2012 and is the second largest coal exporter to Japan, accounting for 30 Mt/y. Almost all clean coal is produced from open cut mines in Indonesia. As the demand for coal not only in Indonesia but also in the rest of the world increased dramatically due to increasing energy supply in the world, the development of coal mining is advancing in order to meet the demand of coal [1]. However, a mining operation of open cut mines has some disadvantages in the surrounding environment such as disturbance of the tropical rainforest, the pollution of surface and/or ground water, subsidence and erosion. Under such situations, rehabilitation is one of the important and considerable approaches for sustainable development. Adequate rehabilitation program will improve these environmental conditions and recover the nature and ecosystem.

The large scale development of open cut mines in Indonesia causes destruction of tropical rainforest. Now, the government and local residents show deep interest in environmental protection. Accordingly, mining companies have to pay more attentions on the rehabilitation program after the open cut mining operation has finished. Furthermore, the basic purpose of rehabilitation is to establish a stable and self-sustaining land surface. Therefore, rehabilitation has to be considered from the perspectives of environmental protection and reconstruction. If rehabilitation is conducted adequately in post mine surface, it is possible to restore almost the original environment before development of open cut mining. In order to achieve such situation, the appropriate rehabilitation program has to be considered in the initial stage when the mine plan is designed [2].

2. TOPSOIL MANAGEMENT FOR REVEGETATION

Generally, post mine surface shows poor conditions as medium for plant growth and also some of overburden strata contain the toxic material for plant growth. Therefore, consideration of selective placement has to be made in order to avoid an adverse effect for vegetation and success for the revegetation process [3].

Good soil management is critical for land restoration. Most of topsoil contains much plant growth medium, soil organic matter and seed of native species and fewer adverse chemical impacts for plant growth (Table 1) [4]. Hence, a lot of open cut mine keep the topsoil impoverished and scattered in the natural forest during soil stripping process and spread the topsoil to rehabilitation area in order to form good

Table 1. Advantages and disadvantages of the use of stockpile topsoil in the rehabilitation

	Advantage		Disadvantage
1.	Reservoir of plant nutrients – reduced fertilizer requirements.	1.	Risk of weed infestation from seed of undesirable seed present in soil – can normally be managed by sowing at the correct time.
2.	Contains beneficial microorganisms which reduce fertilizer requirements by improving nutrient uptake (mycrorrhizae), supplying nitrogen (Rhizobium) or aiding nutrient cycling.	2.	Greater erosion hazard during high intensity storms on unprotected soil than spoil.
3.	Important source of seed of native species.	3.	Cost of stripping, stockpiling and respreading of soil can be high.
4.	Commonly a more favourable germination medium than spoil – promotes a rapid stabilizing cover.	4.	May increase area of disturbed land if borrow pits are needed to obtain sufficient material.
5.	Generally fewer adverse chemical characteristics than spoil (salinity, acidity etc.).		
6.	Less damaging to cultivating equipment than rock-containing spoil.		

quality of medium for plant growth. Whenever topsoil is stockpiled, it can lose some of its qualities [5,6]. Therefore, topsoil should be used as soon as possible even if the soil has to be kept in a soil stockpile. However, during topsoil spread process, excess compaction by heavy equipment causes a reduction in root growth and inhibits plant growth due to decreasing permeability and hardening of the soil in the field. More careful consideration has to be taken in order to eliminate severe soil compaction in the rehabilitation area. For example, only low ground-pressure bulldozers are used for spreading topsoil, and the ripping equipment works after the soil-spreading step for cultivating and loosening the ground by structural breakdown. These works give benefit for preparation of the ground to promote plant growth due to improving water infiltration rate and relief of soil hardening [7,8].

3. SITE DESCRIPTION

Our study was conducted in one of the open cut coal mines in Indonesia and located in East Kalimantan near the equator. The mine site belongs to tropical rainforest climate and the average annual rainfall shows 2,000 - 4,000 mm/year and the average temperature vary from 26 to 32 . This mine is working rehabilitation program based on site and industry experience. It is difficult to establish vegetation associated with the disturbed land without the proper rehabilitation process for revegetation because post mine surface shows poor conditions as medium for plant growth. The proper management of topsoil can provide a suitable medium for plant growth without adverse effect.

In this mine, it is recommended that topsoil is stripped and placed immediately for rehabilitation. In some cases, it may be necessary to stockpile topsoil. Stockpiles should be used as soon as possible, therefore, topsoil should be stored no more than one year even if the soil has to be kept in soil stockpile. The topsoil is spread to rehabilitation area to a depth of one metre. In soil placement procedures, only low ground pressure bulldozers is used for spreading topsoil in order to minimize compaction by heavy equipment. The ripping equipment works after soil spreading step for cultivating and loosening the ground by structural breakdown. Fig. 1 shows the topsoil stripping and placement process in this mine.

4. METHODS

Topsoil spread to rehabilitation area has important role for establishing suitable medium for plant growth. In this study, the soil samples were collected for laboratory tests from natural forest and rehabilitation area and field researches were conducted in both areas (Fig. 2) in order to assess the ground conditions as medium for plant growth. The ground condition and soil properties in the rehabilitation area were also evaluated by comparison with that of natural forest.

4.1 Laboratory Test

The basic characteristics of the soil were investigated by the distribution of particle-size analysis and an Atterberg limits test, according to the ASTM D 422-63 and ASTM D 4318-00 standard. From these tests, the typical soil properties was estimated such as soil permeability and water retention capacity. Basically, water and fertilizer holding capacity reduces with increasing sand rate in the soil and permeability reduces with increasing clay content. After that, soil bulk density, soil moisture contents, soil pH and soil EC [9] were measured from the collected samples by soil augur with each 150 mm interval depth.

Fig. 1. Topsoil stripping and placement

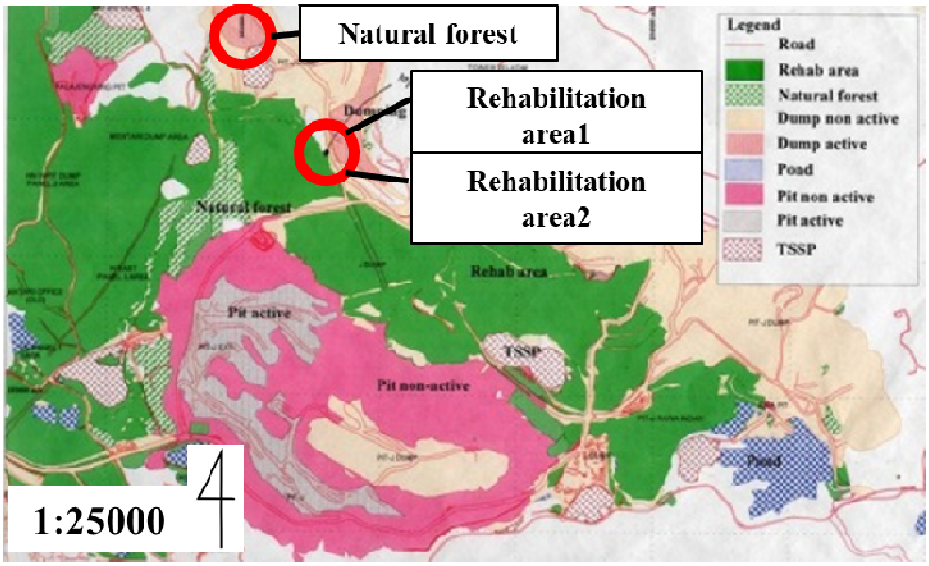
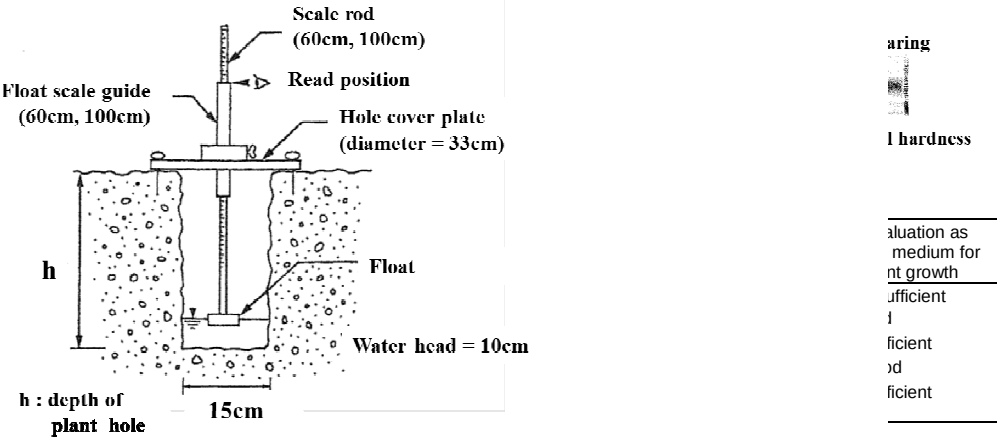


Fig. 2. Soil sampling area

4.2 Field Research

The compaction by heavy equipment is critical in the rehabilitation area. Soil compaction inhibits root growth of seedlings by increasing the bulk density and soil strength, and by decreasing porosity and water infiltration [10,11]. The important factor for plant root growth is permeability and soil hardness. Under low permeability, root rot appears in high rainfall by filling water into planting hole. This is the reason why the root cannot respire due to the lack of oxygen by preventing air infiltration into the ground in high water contents [12]. Also, there may be adverse effect from anaerobic microorganism in absence of oxygen. Soil hardness is strongly related to root extension. Decreased growth occurred in high soil hardness since the plants cannot expand their roots into the hard ground [13]. Therefore, it is important for good plant growth to investigate and evaluate these parameters as medium for plant growth in situ. In this research, the field permeability test, and soil hardness test in situ were implemented in each area (Fig. 3).



(a) Field permeability test **(b) Soil hardness test**

Fig. 3. Field research equipment

5. RESULTS AND DISCUSSION

First of all, the basic characteristics of soil were investigated. From the results in Table 2, the soil spread to rehabilitation area shows different composition despite backfilling the topsoil derived from similar natural forest. This is caused by mixing overburden as contamination during soil stripping and soil stockpiling process. Furthermore, the different soil component affects soil characteristics. Fig. 4 shows plasticity chart that is convenience for comparing a variety of soils. Rehabilitation area 2 has different soil characteristics compared with rehabilitation area 1 and natural forest because the position of plot is quite different with others in this chart [9]. In order to discuss the effect for plant growth by different soil composition, more detailed researches were carried out by collecting soil samples in each depth.

Fig. 5 shows the results of soil bulk density and moisture content. In rehabilitation area 2, soil bulk density is relatively high compared with other area. This can be considered due to the effect of compaction from the heavy equipment. Therefore, it can be thought that the different soil composition may affect to the degree of compaction. The soil moisture content shows low value in rehabilitation area 2 because of the characteristics of sandy soil. The water content in the ground is one of important factor for plant growth though water requirement is different and depends on the type of plants. From this point of view, it can also be said that soil management for spread in rehabilitation areas should be considered for good plant growth.

Next, as the chemical characteristics of soil are investigated, the soil pH and EC is measured in each depth (Fig. 6). First of all, soil pH shows acidity around pH = 4.0. This situation means the effect for the vegetation has more impact from ion toxicity or deficiencies to the plant by releasing or holding certain ions under acidity. The soil EC values show different tendency in each area; the soil EC in natural forest and rehabilitation area 2 is stable in any depth though the value is quite different, rehabilitation area 1 has considerable variation and shows relatively high value compared with that of natural forest in some depths. Considering mixing overburden as contamination in rehabilitation area, it can be considered from these results that the chemical adverse effect from the toxic materials for vegetation is easy to occur in clayey soil compared with sandy soil. On the other hand, in sandy soil, the lack of nutrients for plant growth can be estimated due to low soil EC value. Therefore, proper management of plants in each type of soil or the control of soil characteristics spreading to rehabilitation area has to be discussed for success of the revegetation.

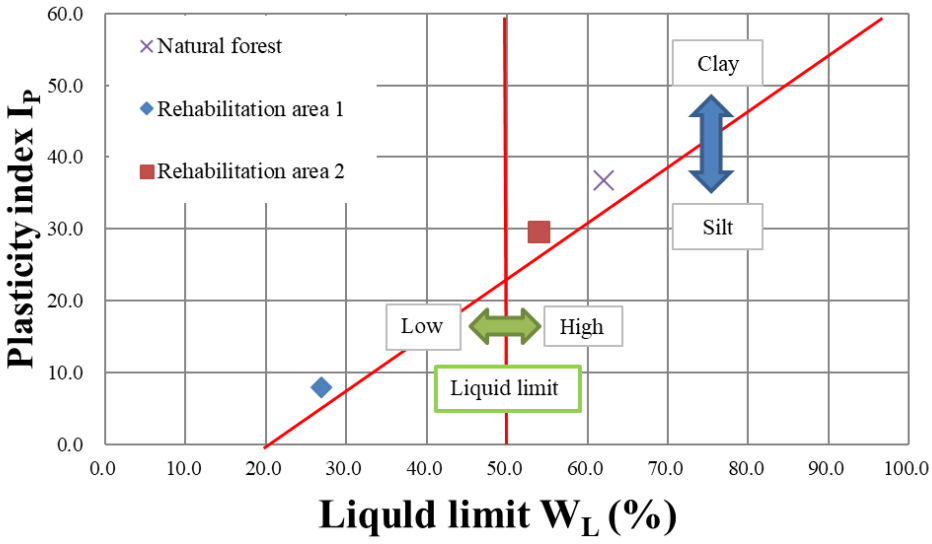


Fig. 4. Plasticity chart

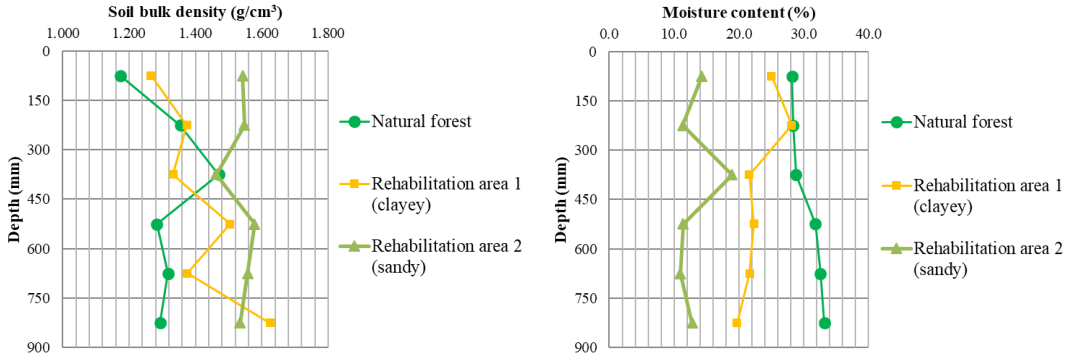


Fig. 5. Results of soil bulk density and moisture content

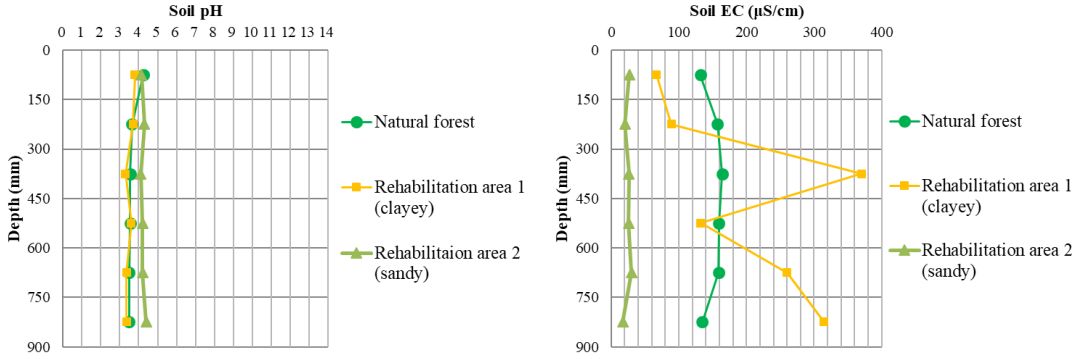


Fig. 6. Results of soil pH and EC

Table 2. Distribution of particle size

Soil sample	Sand (%)	Silt (%)	Clay (%)	Liquid limit W_L %	Plastic limit W_P %	Plasticity index I_P
Natural forest	10	30	60	62.0	25.3	36.7
Rehabilitation area 1	22	30	48	53.9	24.3	29.6
Rehabilitation area 2	75	8	17	26.9	19.1	7.9

Fig. 7 shows the results of field permeability and soil hardness in each depth from the surface. Field permeability shows the degree of water infiltration rate of the ground and is the related factor for available water and air for planting roots, and soil hardness shows the resistance force from the soil and can estimate the difficulty level of roots extension. From the results, it can be understood that both parameter of the soil backfilled in the rehabilitation area is similar or more easy and beneficial compared to the natural forest. Therefore, from this point of view, the ground condition in the rehabilitation area is good for plant growth. However, the field permeability in rehabilitation area 2 shows the uncomfortable value relative to rehabilitation area 1. Considering the results of Fig. 6, this is due to the compaction by heavy equipment. As this cause poor condition as medium for plant growth depends on the degree of compaction, more careful consideration and operation has to be carried out. By contrast, the soil hardness in rehabilitation area 2 is low more than that of rehabilitation area 1 due to low cohesive properties in sandy soil. Therefore, it is expected that plant can penetrate their roots into the soil under the low soil hardness such rehabilitation area 2 more easily.

In the rehabilitation area, there is dispersion of the soil composition due to mixing overburden during mining operation even though the topsoil comes from similar natural forest. Under such situations, it can be concluded that appropriate

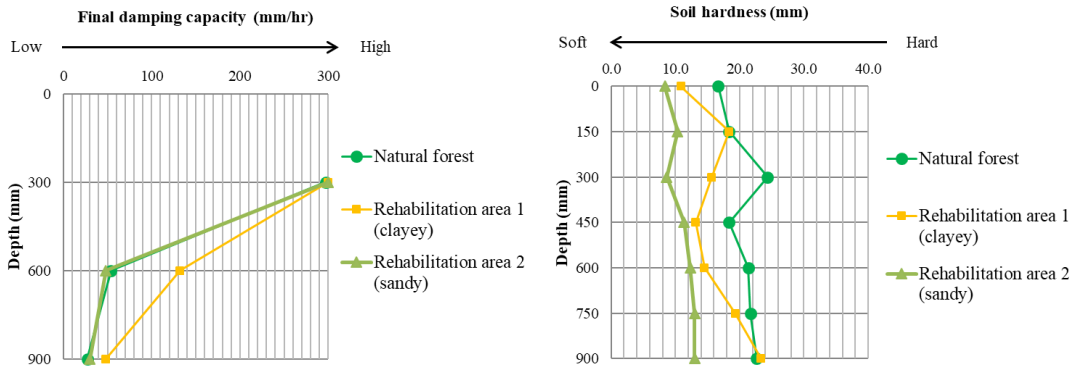


Fig. 7. Results of field research

soil management considering selection of species has to be undertaken in order to carry out revegetation efficiently.

6. CONCLUSION

Now, the development of coal mine in Indonesia becomes a beehive of activities to meet the demand of coal resources not only in the country but also all over the world. For increasing the coal production continually, the environmental aspects have to be considered toward sustainable development. Hence, adequate rehabilitation program has to be designed and conducted. In this study, the current topsoil management and the characteristics of soil spreading to rehabilitation area were investigated using laboratory and field tests. As the results of the series of tests, it was gathered that there are various soil conditions in the rehabilitation area due to mixing with overburden. The ground conditions as medium for plant growth are affected by the dispersion of soil composition in situ though topsoil from the natural forest is backfilled. In order to establish appropriate rehabilitation program, especially for revegetation process, the comprehensive study has to be conducted including the selection of plants for the rehabilitation area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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