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The Potential of Cultivating Fruit on Ex-Mined Soil in Indonesia

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Abstract
For centuries, forests have been food resources, particularly for local people. However, mining operations in forests result in a substantial reduction and even the loss of flora and fauna such as fruit plants. To restore the forest function as a food resource, fruit plants can be cultivated during mine reclamation. In terms of fruit production, fruit plants require macro and micro elements from the soil to achieve maximum yields and quality. Planting fruit plants in ex-mined areas proves to be challenging due to the poor soil condition such as low pH, inadequate organic matter and barrenness. This study, therefore, aims to review the potential of cultivating rambutan (*Nephelium lappaceum* L.) on ex-mined soil in comparison with the guideline on land suitability assessment provided by the Indonesian Ministry of Agriculture. The study also evaluates *N. lappaceum* production on Binungan Site, PT Berau Coal, East Kalimantan Province, Indonesia. The plantation of *N. lappaceum* requires 1.786 ha with 1,016 trees in three cultivars: Binjai, Rapiah and Garuda. The plantation of *N. lappaceum* was opened in 2005 and first harvested in 2010. The crop yield records in 2020 were over 1,345 kg. The soil analysis results show that Binungan Site had a very low value of pH (3.7-4.3); organic carbon of 0.31-1.34%; nitrogen total of 0.06-0.19%; cation exchange capacity (CEC) of 8.8-22.5 cmol/kg; P_2O_5 of 79-234 ppm; and K_2O of 80-219 ppm. Based on the guideline, this ex-mined soil is classified as "S2" which means the soil is quite adequate for plantation although with limiting factors. Despite lower soil quality in the ex-mined area, *N. lappaceum* can still grow and produce fruit. To improve the soil quality and fruit production, the intensification process, such as fertilization and proper cultivar plantation, has to be conducted. The evaluation reveals that the ex-mined area can be cultivated as a food and new economy source for the local community around the mining area.

Introduction
Forest has been a resource for life besides its protective and recreational function (Krott, 2005). Not only wood product, forest provides non-wood product (NFWP) from its biodiversity including the products from animals and plants besides timber such as fruits and mushroom which benefits for local livelihood. However, in some Asia-Pacific countries, expansion of mining increases and is threatened the biodiversity (Food and Agriculture Organization of the United Nations, 2010). Nevertheless, it is undeniable that mining product is also important as a Gross Domestic Product of a country such as Indonesia for tax and non-tax revenue (Handoko, 2019). In order to create a balance in the management of forest resource, mining has an obligation

to restore the functions of forest through mine reclamation. Groninger *et al*. (2017) explained that the mixed species, such as fruits and local species, are recommended to enrich the value of forest and life of plants especially when fast-growing die. In addition, cultivating fruit plants on ex-mined land is a food security improvement particularly for local people (Maftukhah *et al.*, 2019).

In terms of fruit resource re-establishment, fruit plants require macro and micro elements from the soil to achieve yields and quality (Natale *et al*., 2012). Planting fruit plants in ex-mined areas proves to be challenging due to the poor soil condition in physical and chemical properties (Sukarman & Gani, 2020). This study aims to review the potential of cultivating tropical fruit (rambutan (*Nephelium lappaceum* L.)) on ex-mined soil in comparison with the guideline on land suitability assessment provided by the Indonesian Ministry of Agriculture. The study also evaluates *N. lappaceum* production on Binungan Site, PT Berau Coal, East Kalimantan Province, Indonesia.

Material and Methods

Study Area

This study was conducted in PT Berau Coal, East Kalimantan Province, Indonesia which has 4 sites: Lati, Binungan, Sambarata and Gurimbang. PT Berau Coal applies open pit based on the formation and characteristics of coal seams. The company cultivates rambutan (*N. lappaceum*) on ex-mined land (Disposal P Block 5, Binungan Site) since 2005 of 1.786 ha with 1,016 trees in three cultivars: Binjai, Rapiah and Garuda. The first harvest was in 2010 and continues today.

Method

The study took the soil analysis in Binungan Site was taken in 2016 to test the suitability for N. *lappaceum* cultivation on other ex-mining land. The soil samples were taken in 6 locations with different ages of mine reclamation. The samples were taken from 2 depths: 0-30 cm; and 30-60 cm depth and tested for pH, organic carbon, cation exchange capacity (CEC), P_2O_5 and K_2O. The soil quality was analysed and classified based on the guideline on land evaluation for agricultural commodities (Ritung *et al*., 2011).

Results and Discussion

The study took some chemical properties to be tested such as pH, organic carbon, cation exchange capacity (CEC), P_2O_5 and K_2O. Soil yields showed very low soil acidity due to the pH value of 3.7-4.3 (Table 1). Natale *et al*. (2012) reported that pH was the key factor to be considered in cultivating fruits. In order to improve the soil acidity, the addition of lime, fertilizer and microbes were used to neutralize the acidity (Sopialena *et al*., 2017).

Table 1. Comparison between soil analyses and Land Evaluation for Agricultural Commodities Guidelines for N. *lappaceum* L. (Ministry of Agriculture, Indonesia, 2011).

No	Sample location	Year of mine reclamation	Soil depth (cm)	pH		C-organic (%)	N-total (%)	CEC (cmol /kg)	P_2O_5 HCl 25% (ppm)	K_2O HCl 25% (ppm)
				H_2O	KCl					
1	IPD E	2015	0-30	4.1	3.7	0.63	0.07	15.2	134	11
			30-60	4.1	3.7	0.31	0.07	18	122	108
2	OPD E	2013	0-30	4.4	3.9	0.78	0.09	13.7	94	83
			30-60	4.3	4.2	0.55	0.09	22.5	79	80
3	IPD C6	2012	0-30	4.1	3.9	2.29	0.13	17.3	224	214
			30-60	4	3.7	1.34	0.1	12	139	183
4	OPD 4K	2010	0-30	4.4	3.9	1.1	0.09	10.4	234	219
			30-60	4.2	3.8	0.31	0.06	12.4	217	207

5	IPD D2 Ex	2008	0-30	3.9	3.7	3.52	0.19	15.4	146	140
			30-60	3.8	3.6	1.56	0.1	16.9	108	108
6	Disp G5	2006	0-30	4.2	3.9	1.24	0.12	9.2	234	142
			30-60	4.3	4	0.78	0.07	8.8	214	160
Land Evaluation for Agricultural Commodities Guidelines (for N. *lappaceum* L.)										
Classifiation : S2				4.5-5.0		0.8-1.2	low	5-16	low	low

Note: Based on soil fertility assessment by Eviati and Sulaeman (2009), the range of:
- N-total for low = 0.1-0.2%
- P_2O_5 for low = 15-20 mg/100 g = 150-200 ppm
- K_2O for low = 10-20 mg/100 g = 100-200 ppm

The range of tested chemical properties results were: organic carbon of 0.31-1.34%; nitrogen total of 0.06-0.19%; cation exchange capacity (CEC) of 8.8-22.5 cmol/kg; P_2O_5 of 79-234 ppm; and K_2O of 80-219 ppm. The mean of organic carbon in the upper layer showed "medium" (organic carbon = 1.59%) while in the lower layer showed "low" (0.81%). Otherwise, the classification of total nitrogen and P_2O_5 was "low" in in the upper layer (total nitrogen = 0.12%; P_2O_5 = 177 ppm) and "very low" in the lower layer (total nitrogen = 0.08%; P_2O_5 = 147 ppm). In general, the mean of CEC and K_2O both in the upper and lower layer were classified as "low" (CEC in the upper layer = 13.53 cmol/kg; CEC in lower layer = 15.10 cmol/kg; K_2O in the upper layer = 152 ppm; K_2O in the upper layer = 141 ppm).

Soil on ex-mined site was mixed due to clearing and excavation before exploiting the coal and change the physical, chemical and biological properties. The other tested chemical parameters generally showed sufficient value as classified in "S2". The "S2" means the soil was quite adequate for plantation although with limiting factors but needs farmer's action. To improve the soil quality and fruit production, the intensification process, such as fertilization and proper cultivar plantation, are required. The use of top soil, compost, manure and microbial were implemented to improve the soil quality (Sopialena *et al*., 2017; Sukarman and Gani, 2020). Groninger *et al*. (2017) also stated that the distance of reclamation area with natural forest was a key point. The birds may spread the seeds from the unmined forest to mine reclamation area. Another action was referred to control the erosion to avoid soil nitrogen and nutrient losses through drainage system and cover crop (Sheoran *et al*., 2010).

Other research from Ramadhana *et al*. (2019) on ex-coal mining in East Kalimantan Province showed similar result in mean of pH, organic carbon and total nitrogen but had lower phosphor. Fertilizer was also recommended to increase phosphor that has a role to form root. In line with root growth, clay content influenced its pattern. Yunanto (2018) studied the soil properties in the same province of some reclamation ages and found that the clay content remained higher (above 38%) in under 10-year-reclamation areas than nearest natural forest (26.18%).

Planning a mine reclamation required a comprehensive from the feasibility study, for example to prepare the soil management from land clearing to mine reclamation. Besides the quality, soil balance was organized to avoid the lack. For some purposes such as cultivation particular species, more data collection was prepared to arrange the soil treatment and quality improvement (Buta *et al*., 2019).

Despite of the first harvest was in 2010, the crop was unrecorded to collect the trend data. In February 2020, the crop yield was recorded of 1,345 kg (not calculated for all yields). Local community has participated to harvest the N. *lappaceum* together with the coal company and

service companies. Furthermore, the record has to be managed to determine the productivity and plans other possibility of cultivation.

Conclusions and Outlook

Forest rehabilitation on ex-mine reclamation site had lower soil quality but improved due to proper reclamation maintenance to be productive land for local community. Despite its extreme pH (<4.5), other tested chemical properties showed sufficient value as classified in "S2" means the soil was quite adequate for plantation. All tested locations were suitable for N. *lappaceum* cultivation with limiting factors. From the study, the ex-mined area can be cultivated as a food and new economy source for the local community around the mining area.

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