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Research Article

Land suitability evaluation of abandoned tin-mining areas for agricultural development in Bangka Island, Indonesia

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Abstract : Kepulauan Bangka Belitung, Indonesia is one of the tin mineral-producer in the world. Agricultural crops could be a wise option for the reclamation since abandoned tin-mining lands have a high potency to be used as agricultural lands. This study was aimed to evaluate of the land/soil characteristics of abandoned tin-mining areas and to establish land suitability of the land area for agriculture used to formulate appropriate land development measures and amelioration strategies forutilization of mined areas for crop production. The land evaluation was conducted by comparing the land characteristics in every type of abandoned tin-mining areas with its crop requirements. The current suitability showed that in general food crops, vegetable crops, fruit crops, and industrial crops were consider as not suitable (N). Spice and medicinal crops [pepper (*Piper nigrum* L.)] and citronella (*Andropogoh nardus* L. Rendle)] were consider as not suitable (N), while the Jatropha (*Jatropha curcas* L.) and Kemiri Sunan (*Aleurites moluccana* L. Willd) crops were considered as marginally suitable (S3) in abandoned tin-mining areas. The forest crops and forage crops were considered as marginally suitable (S3). The water availability, soil texture, and low soil fertility were considered as the limiting factors of all crops to get optimum production. For agricultural development, the soil physical and chemical properties of abandoned tin-mining land must be improved through integrated farming.

Keywords: *Indonesia, land suitability, mining areas, tin*

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Introduction

Kepulauan Bangka Belitung, Indonesia is one of the tin mineral-producers in the world (Weber, 2003) with production of 95,200 ton (USGS, 2015) since Kepulauan Bangka Belitung laid under *Southeast Asia Tin Belt* (Cobbing, 2005). This industry had huge impacts on economic and social life of the communities (Masialeti and Kinabo, 2005; Onwuka et al., 2013; Nurtjahja and Agustina, 2015). Besides, it had also impact on the environment (Adewole and Adesina, 2011; Reynolds and Reddy, 2012; Ndace and Danladi, 2012; Narendra and Pratiwi, 2016). One of the impacts of tin-mining activities is the change of landscape (Sheoran et al., 2010; Nurtjahja and Agustina, 2015). Lands abandoned after tin-mining activity are degraded lands with undulating landscape (Asmarhansyah, 2016a) and low soil fertility status (Inonu, 2011; Asmarhansyah, 2016b), and land productivity (Gao and Liu, 2010).Soil texture of tailings generated due to former-tin mining activities are dominated by sandy texture (Setiadi, 2002; Ashraf

et al., 2010; Ashraf et al., 2013; Nurcholish et al., 2013) and it caused soil properties ofthe tailings are very bad as a growth media. Tailings have a high portion of sand, low clay content, low soil pH, low organic matter content, low cation exchange capacity (CEC), low water-holding capacity, and very low essential macro elements (Nurtjahja et al., 2009; Budianta et al., 2013; Asmarhansyah, 2016a). As reported by previous researchers, it is said that former-tin mining lands have poor physical and chemical properties. Inonu (2011) and Asmarhansyah (2016b) stated that former-tin mining areas were dominated by sandy texture and low nutrient content. Mine reclamation programs commonly use only a single, exotic, fast-growing species, especially *Acacia mangium* and *Falcataria moluccana (*Kodir et al., 2017). However, agricultural crops could be a wise option for the reclamation of these areas since former-tin mining lands have a high potency to be used as agricultural lands. Studies into the application of various types of organic materials to ameliorate tin-tailings and trials on the suitability of various types of legumes have been carried out (Inonu, 2011). The environmental impact of the activities needs to be addressed with technologies which are economically viable and environmentally sound (Suhartini and Abubakar, 2017). It means that through the improvement the soil properties, the former-tin mining areas have a potency to be used as crop production areas. Land use of abandoned tin-mining areas for agriculture use must determine land characteristic/quality and climate, through land suitability evaluation. Ritung et al. (2007) stated that determination of post mining land use should be considering the physical land properties, topography properties, and climate. This study was aimed to evaluate of the land/soil characteristics of abandoned tin-mining areas and to establish land suitability of the land area for agriculture used to formulate appropriate land development measures and amelioration strategies forutilization of minedareasfor crop production.

Materials and Methods

Time and place of study

The research was conducted in abandoned-tin mining areas, where small-scale and large-scale mines were operating. Site visits and soil characterization were done in April-May 2015.

Assessment the land use of the study areas and their requirement and limitation

As observed in the field, the abandoned tin-mining areas have high potentials to be developed as agricultural areas. The requirements and limitations for growth of various crops were obtained from literatures such as Sys et al. (1993) and Indonesian Center for Agricultural Land Resources Research and Development (2011).

Determining types of abandoned tin-mining areas and land quality

Based on field observation, the types of abandoned tin-mining areas assessed were (1) Sand tailing, (2) Sand tailing with vegetation, (3) Mixture of sand tailing and overburden, (4) Mixture of sand tailing and overburden with vegetation, (5) Sand tailing from unconventional mining, and (6) Overburden from unconventional mining. The agricultural land was taken as comparison. Land characteristics developed were based on climatic, soil, and topographic data. Soil samples taken from the soil profiles were sent to Indonesian Soil Research Institute in Bogor, Indonesia for analyses.

Comparison of land use and land quality requirements

The land evaluation was conducted by comparing the land characteristics in every type of abandoned tin-mining areas with its crop requirements. The land suitability classifications were defined based on their most serious limiting factors which may consist of one or more factors depending on land characteristics.

Land suitability evaluation

Land suitability evaluation was conducted in order to interpret the combination of land suitability classes. The evaluation process will determine whether certain land types of abandoned tin-mining areas are recommended for food, vegetable, fruit, industrial, spice and medicinal, forestry, and forage crops.

Results and Discussion

Climate

The annual average rainfall in the study area was 2,406 mm. The mean annual temperature of the area is 26.97^{o} C, the lowest temperature is 26.21^{o} C, while the highest temperature is 27.65^{o} C. The area has a mean annual relative humidity of 81.23%, with lowest relative humidity of 75.34%, while the highest relative humidity is 85.75% (Meteorology Station of Pangkalpinang, 2015)

Abandoned tin-mining soils assessed

The abandoned tin-mining areas used in this study are shown in Table 1.

Table 1. Location of abandoned tin-mining soils of Bangka Island, Indonesia

Abandoned Tin-Mining Soils	Elevation (m, above sea level)	Coordinate Point		Location
		South	East	
Sand Tailing	11	02°24'24"	106°01'54"	Lampur, Central Bangka
Sand Tailing with vegetation	26	02°14'39"	106°08'54"	Cambai, Central Bangka
Mixture of Sand Tailing and overburden	12	01°39'70'	105°48'07"	Nyatoh, Bangka
Mixture of Sand Tailing and overburden with vegetation	10	01°59'41"	106°08'41''	Batu Ampar, Bangka
Sand Tailing from Unconventional Mining	11	02°16'48''	106°12'25''	Belilik, Central Bangka
Overburden from Unconventional Mining	11	02°16'48''	106°12'25''	Belilik, Central Bangka
Agricultural Land	25	02°14'59''	106°08'25''	Cambai, Central Bangka

Physical properties

Physical properties of abandoned tin-mining soils from Bangka Island, Indonesia, are shown in Table 2. As shown in Table 2, agricultural area has sandy clay loam textural class; mixture of sand tailing and overburden with vegetation has sandy loam textural class, and other abandoned tin-mining areas have loamy sand textural classes. Composition of tin tailings dominated by sand fraction has implications on other properties. Brady and Weil (1996) stated that the high percentage of sand particles implies a low specific surface area of the tailings, and thus a low aggregation and capacity for binding nutrients and retaining water.

Table 2. Textural class of abandoned tin-mining soils of Bangka Island, Indonesia

Abandoned Tin-Mining Soils	Particle Size (USDA)			Texture
	%Sand	%Silt	%Clay	
Sand Tailing	81	11	8	loamy sand(LS)
Sand Tailing with Vegetation	81	18	1	loamy sand (LS)
Mixture of Sand Tailing and Overburden	80	18	2	loamy sand (LS)
Mixture of Sand Tailing and Overburden with vegetation	77	12	11	sandy loam (SL)
Sand Tailing from Unconventional Mining	85	7	8	loamy sand (LS)
Overburden from Unconventional Mining	80	18	2	loamy sand (LS)
Agricultural Land	69	4	27	sandy clay loam (SCL)

Chemical properties

Chemical properties of abandoned tin-mining areas are shown in Table 3. It can be seen from Table 3 that the pH of abandoned tin-mining soils are very strong acid according to the classification of soil reactions. The organic matter and nitrogen of agricultural soil is higher compared to sand tailing and overburden, or its mixture. It could be understood since the physical characteristics, especially soil texture, will affect their chemical characteristics. Sand tailings are highly porous and have a very low organic (Ang, 2002; Asmarhansyah, 2016a). The content of P_2O_5, K_2O, and exchangeable bases of sand tailing and overburden are classified as very low to low.

Table 3.Chemical characteristics of abandoned tin-mining soils of Bangka Island, Indonesia

Abandoned Tin-Mining Soils	**pH**		**Organic Matter**			**HCl25%**		**Exchangeable Cations (NH_4-Acetate 1 N, pH 7)**						**BS**	**KCl1 N**	
	H_2O	**KCl**	**Org. C**	**N**	**C/N**	**P_2O_5**	**K_2O**	Ca	Mg	**K**	**Na**	**Tot**	**CEC**	**%**	**Al^{3+}**	**H^+**
			%			**mg/100 g**				**$cmol_c$ /kg**					**$cmol_c$ /kg**	
Sand Tailing	4.7	4.3	0.13	0.01	13	4	1	0.11	0.04	0.01	0.03	0.19	1.22	15.57	0.00	0.08
Sand Tailing with Vegetation	4.8	4.4	0.19	0.02	10	5	2	0.14	0.05	0.01	0.04	0.24	1.49	16.10	0.00	0.16
Mixture of Sand Tailing and Overburden	4.6	4.3	0.10	0.01	10	5	1	0.31	0.04	0.01	0.03	0.39	1.69	23.07	0.06	0.16
Mixture of Sand Tailing and Overburden with Vegetation	5.1	4.6	0.16	0.02	8	4	2	0.38	0.05	0.03	0.03	0.49	4.27	11.47	0.03	0.12
Sand Tailing from Unconventional Mining	5.0	4.7	0.11	0.01	11	4	1	0.15	0.03	0.01	0.03	0.22	1.18	18.64	0.06	0.15
Overburden from Unconventional Mining	5.1	4.6	0.24	0.04	11	5	3	0.18	0.06	0.01	0.04	0.29	3.24	8.95	0.05	0.14
Agricultural Land	5.2	4.7	1.94	0.19	10	19	3	0.23	0.11	0.04	0.05	0.43	6.66	6.45	1.19	0.25

Current suitability of different abandoned tin-mining soils

Current suitability is the suitability of the soils to crop grown based on their climate, physical and chemical qualities, while potential suitability is obtained when the limitations posed by the current suitability rating are corrected depending on the level of input(s). The classes for the limitation and suitability of different abandoned tin-mining soils to various crops were determined based on temperature (tc), water availability (wa), rooting media (rc), nutrient retention (nr), nutrient availability (na), toxicity (xc), erosion hazard (eh), and land preparation (lp). The suitability classes are helpful indices to indicate and determine the limitations and constrains to crop production. The suitability classes of the lands denote the qualitative analysis of the soil's potential to the crops commonly grown in the area. It implies what type of crop would give the highest benefit in terms of productivity and profitability from a given soil indicated by S1 as the most suitable, S2 as moderately suitable, and S3 as marginally suitable. The symbol N implies that the crop is not suitable. The land quality/characteristics of abandoned tin-mining areas in Bangka Island, Indonesia are shown in Table 4.

Table 4. Land quality/characteristics of abandoned tin-mining areas in Bangka Island, Indonesia

Land Quality/ Characteristics	**Sand Tailing**	**Sand Tailing with Vegetation**	**Mixed Sand Tailing and Overburden**	**Mixed Sand Tailing and Overburden with vegetation**	**Sand Tailing from UM**	**Over burden from UM**
Temperature (tc)						
– Mean Annual Temperature (^oC)	26.97	26.97	26.97	26.97	26.97	26.97
Water Availability (wa)						
– Rainfall/Year (mm)	2,406	2,406	2,406	2,406	2,406	2,406
– Relative Humidity (%)	81.23	81.23	81.23	81.23	81.23	81.23
– Long of Dry Month (month)	1	1	1	1	1	1
Rooting Media (rc)						
– Drainage	G, M	G, M	G, M	G, M	G, M	G, M
– Texture	LS	LS	LS	SL	LS	LS
– Coarse Material (%)	<15	<15	<15	<15	<15	<15
– Effective Depth (cm)	>100	>100	>100	>100	>100	>100
– Peat: -Ripeness -Depth (cm)	-	-	-	-	-	-
Nutrient Retention (nr)						
– CEC ($cmol_c/kg$)	1.22	1.49	1.69	4.27	1.18	3.24
– BS (%)	15.57	16.10	23.07	11.47	18.64	8.95
– pH	4.7	4.8	4.6	5.1	5.0	5.1
– Organic-C (%)	0.13	0.19	0.10	0.16	0.11	0.24
Nutrient Availability (na)						
– Total-N (%)	0.01	0.02	0.01	0.02	0.01	0.04
– P_2O_5 (mg/100g) HCl25%	4.00	5.00	5.00	4.00	4.00	5.00
– K_2O (mg/100g) HCl25%	1.00	2.00	1.00	2.00	1.00	3.00
Erosion Hazard (eh)						
– Slope (%)	<3	<3	<3	<3	<3	< 3
– Erosion Hazard Level	-	-	-	-	-	-
– Flood Hazard (fh)						
– High (cm)	-	-	-	-	-	-
– Duration (day)	-	-	-	-	-	-
Land Preparation						
– Soil surface stoniness (%)	<5	<5	<5	<5	<5	<5
– Surface outcrops (%)	<5	<5	<5	<5	<5	<5

Remark: UM: Unconventional Mining; SCL: Sandy Clay Loam; LS: Loamy Sand; SL: Sandy Loam;G: Good; M: Moderate

Based on the rating for limitations and suitability of abandoned tin-mining areas (Table 5, 6, 7, and 8), in general food crops, vegetable crops, fruit crops, and industrial crops were consider as not suitable (N), except the mixture of sand tailing and overburden with vegetation was considered as marginally suitable (S3). The water availability, soil texture and low soil fertility were considered as the limiting factors of all crops to get optimum production.

Table 5. Rating for limitations and suitability of abandoned tin-mining land for food crop

	Abandoned Tin-Mining Land	**FoodCrop**				
		Corn (*Zea mays* L.)	**Cassava** (*Manihot esculenta* Crantz)	**Sweet Potato** (*Ipomea batatas* Poir)	**Taro** (*Colocasia esculenta* L. Schott)	**Peanut** (*Arachis hypogea*L.)
1	Sand Tailing	Ntwrn	Nwrn	Ntwrn	Nrn	Nwrn
2	Sand Tailing with Vegetation	Ntwrn	Nwrn	Ntwrn	Nrn	Nwrn
3	Mixture of Sand Tailing and Overburden	Ntwrn	Nwrn	Ntwrn	Nrn	Nwrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3twrn	S3wrn	S3twrn	S3rn	S3wrn
5	Sand Tailing from Unconventional Mining	Ntwrn	Nwrn	Ntwrn	Nrn	Nwrn
6	Overburden from Unconventional Mining	Ntwrn	Nwrn	Ntwrn	Nrn	Nwrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Table 6. Rating for limitations and suitability of abandoned tin-mining land for vegetable crop

	Abandoned Tin-Mining Land	**Vegetable**				
		Red Chili (*Capsicum annuum*L.)	**Mustard** (*Brassica chinensis* L.)	**Longbean** (*Vigna sinensis*L.)	**Cucumber** (*Cucumis sativus* L.)	**Eggplant** (*Solanum melongena*L.)
1	Sand Tailing	Nwrn	Ntwrn	Ntwrn	Nwrn	Ntwrn
2	Sand Tailing with Vegetation	Nwrn	Ntwrn	Ntwrn	Nwrn	Ntwrn
3	Mixture of Sand Tailing and Overburden	Nwrn	Ntwrn	Ntwrn	Nwrn	Ntwrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3wrn	S3twrn	S3twrn	S3wrn	S3twrn
5	Sand Tailing from Unconventional Mining	Nwrn	Ntwrn	Ntwrn	Nwrn	Ntwrn
6	Overburden from Unconventional Mining	Nwrn	Ntwrn	Ntwrn	Nwrn	Ntwrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Table 7. Rating for limitations and suitability of abandoned tin-mining land for fruit crop

	Abandoned Tin-Mining Land	**Fruit**							
		Papaya (*Carica papaya* L.)	**Banana** (*Musa acuminate Colla*)	**Citrus** (*Citrus aurantium* L.)	**Mango** (*Mangifera indica* L.)	**Rambutan** (*Nephelium lappaceun* L.)	**Watermelon** (*Citrullus lanatus*(Thunb.) Matsum	**Melon** (*Cucumisme lo*var. reticulatus)	**Pineapple** (*Ananas comosus* Merr)
1	Sand Tailing	Nwrn	Nrn	Nrn	Nwrn	Nrn	Nwrn	Nwrn	Ntwrn
2	Sand Tailing with Vegetation	Nwrn	Nrn	Nrn	Nwrn	Nrn	Nwrn	Nwrn	Ntwrn
3	Mixture of Sand Tailing and Overburden	Nwrn	Nrn	Nrn	Nwrn	Nrn	Nwrn	Nwrn	Ntwrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3wrn	S3rn	S2rn	S3wrn	S3rn	S3wrn	S3wrn	S3twrn
5	Sand Tailing from Unconventional Mining	Nwrn	Nrn	Nrn	Nwrn	Nrn	Nwrn	Nwrn	Ntwrn
6	Overburden from Unconventional Mining	Nwrn	Nrn	Nrn	Nwrn	Nrn	Nwrn	Nwrn	Ntwrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Table 8. Rating for limitations and suitability of abandoned tin-mining land for industrial crop

	Abandoned Tin-Mining Land	**Industrial**			
		Rubber (*Havea brassiliensis* Muell. Arg)	**Coconut** (*Cocos nicifera*L.)	**Palm Oil** (*Elaeis guineensis*Jacq.)	**Cacao** (*Theobroma cacao* L.)
1	Sand Tailing	Nwrn	Nrn	Nrn	Nwrn
2	Sand Tailing with Vegetation	Nwrn	Nrn	Nrn	Nwrn
3	Mixture of Sand Tailing and Overburden	Nwrn	Nrn	Nrn	Nwrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3wrn	S3rn	S3rn	S3wrn
5	Sand Tailing from Unconventional Mining	Nwrn	Nrn	Nrn	Nwrn
6	Overburden from Unconventional Mining	Nwrn	Nrn	Nrn	Nwrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

In general, spice and medicinal crops [pepper (*Piper nigrum* L.) and citronella (*Andropogoh nardus* L. Rendle)] were consider as not suitable (N), except the mixture of sand tailing and overburden with vegetation was considered as marginally suitable (S3), while the Jatropha (*Jatropha curcas* L.) and Kemiri Sunan (*Aleurites moluccana* L. Willd) crops were considered as marginally suitable (S3) in abandoned tin-mining areas (Table 9). The forest crops and forage crops were considered as marginally suitable (S3) in abandoned tin-mining areas (Tables 10 and 11).

Table 9. Rating for limitations and suitability of abandoned tin-mining land for spice and medicinal crop

	Abandoned Tin-Mining Land	**Spice And Medicinal Crop**			
		Pepper (*Piper nigrum* L.)	**Citronella** (*Andropogoh nardus* L. Rendle)	**Jatropha** (*Jatropha curcas* L.)	**Kemiri Sunan** (*Aleuritesmoluccana*L. Willd)
1	Sand Tailing	Nrn	Ntwrn	S3wrn	S3wrn
2	Sand Tailing with Vegetation	Nrn	Ntwrn	S3wrn	S3wrn
3	Mixture of Sand Tailing and Overburden	Nrn	Ntwrn	S3wrn	S3wrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3rn	S3twrn	S3wrn	S3wrn
5	Sand Tailing from Unconventional Mining	Nrn	Ntwrn	S3wrn	S3wrn
6	Overburden from Unconventional Mining	Nrn	Ntwrn	S3wrn	S3wrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Table 10. Rating for limitations and suitability of abandoned tin-mining land for forest crop

	Abandoned Tin-Mining Land	**Forest Crop**			
		Sengon (*Albizia falcataria* L.)	**Acacia** (*Acacia mangium* Willd)	**Magahony** (*Swietenia mahagoni*L. Jacq.)	**Pinus** (*Pinus merkusii*Jungh.)
1	Sand Tailing	S3wrn	S3rn	S3rn	Ntwrn
2	Sand Tailing with Vegetation	S3wrn	S3rn	S3rn	Ntwrn
3	Mixture of Sand Tailing and Overburden	S3wrn	S3rn	S3rn	Ntwrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3wrn	S3n	S3rn	Ntwn
5	Sand Tailing from Unconventional Mining	S3wrn	S3rn	S3rn	Ntwrn
6	Overburden from Unconventional Mining	S3wrn	S3rn	S3rn	Ntwrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Table 11. Rating for limitations and suitability of abandoned tin-mining land for forage crop

	Abandoned Tin-Mining Land	**Forage**		
		Elephant Grass (*Pennisetum purpureum*Schum.)	**Setaria Grass** (*Setaria spachelata* Schum.)	**Leguminose** (*Leguminose sp*)
1	Sand Tailing	S3wrn	S3wrn	S3wrn
2	Sand Tailing with Vegetation	S3wrn	S3wrn	S3wrn
3	Mixture of Sand Tailing and Overburden	S3wrn	S3wrn	S3wrn
4	Mixture of Sand Tailing and Overburden with Vegetation	S3wrn	S3wrn	S3wrn
5	Sand Tailing from Unconventional Mining	S3wrn	S3wrn	S3wrn
6	Overburden from Unconventional Mining	S3wrn	S3wrn	S3wrn

Suitability Ratings: S1= Highly suitable, S2 = Moderately suitable, S3= Marginally suitable, N = Not suitable. Limitations: tc = temperature, wa = water availability (precipitation, RH), rc = rooting media (texture), nr = nutrient retention (CEC, BS, pH, Organic C), na = nutrient availability (N, P, K)

Potential suitability of different abandoned tin-mining soils

Based on the current limitations and suitability ratings of the abandoned tin-mining areas grown to food, vegetable, fruit, industrial, spice and medicinal, forest, and forage crops, these abandoned tin-mining areas were individually reassessed with the assumption that soil management technologies and practices being offered for each of the abandoned tin-mining areas were implemented. Table 12 summarizes the potential suitability of abandoned tin-mining areas for food, vegetable, fruit, industrial, spice and medicinal, forest, and forage crop. Table 12 shows that sand tailing, sand tailing with vegetation, and mixture of sand tailing and overburden are marginally suitable (S3) for spice and medicinal crops forestry trees, and forage crops. Mixture of sand tailing and overburden with vegetation is highly suitable (S1) for acacia; moderately suitable (S2) for citrus, spice and medicinal crops [pepper (*Piper nigrum* L.) and kemiri sunan (*Aleurites moluccana* L. Willd)], forest trees [sengon (*Albizia falcataria* L.) and mahogany (*Swietenia mahagoni* L. Jacq.)]; and

marginally suitable (S3) for food crops, vegetable crops, fruit crops, industrial crop, spice and medicinal crops and forage crops. Sand tailing from unconventional mining and Overburden from unconventional mining are moderately suitable (S2) for Sengon and Acacia, and marginally suitable (S3) for spice and medicinal crops forestry trees, and forage crops

Table 12. Potential suitability of abandoned tin-mining soils for food, vegetable, fruit, industrial, spice and medicinal, forest, and forage crops

Abandoned Tin-Mining Areas	**Highly Suitability S1**	**Moderate Suitability S2**	**Marginal Suitability S3**
Sand Tailing	-	-	1. Jatropha, Kemiri Sunan 2. Sengon, Acacia, Mahogany 3. Elephant Grass, Setaria Grass. Leguminose
Sand Tailing with Vegetation	-	-	1. Jatropha, Kemiri Sunan 2. Sengon, Acacia, Mahogany 3. Elephant Grass, Setaria Grass,Leguminose
Mixture of Sand Tailing and Overburden	-	-	1. Jatropha, Kemiri Sunan 2. Sengon, Acacia, Mahogany 3. Elephant Grass, Setaria Grass, Leguminose
Mixture of Sand Tailing and Overburden with Vegetation	Acacia	Citrus Pepper Kemiri Sunan Sengon Mahogany	1. Corn, Cassava, Sweet Potato, Taro, Peanut 2. Red Chili, Mustard, Longbean, Cucumber, Eggplant 3. Papaya, Banana, Mango, Rambutan, Watermelon, Melon, Pineapple 4. Rubber, Coconut, Palm Oil, Cacao 5. Citronella, Jatropha 6. Elephant Grass, Setaria Grass, Leguminose
Sand Tailing from Unconventional Mining	-	Sengon Acacia	1. Jatropha, Kemiri Sunan, 2. Mahogany 3. Elephant Grass, Setaria Grass, Leguminose
Overburden from Unconventional Mining	-	Sengon Acacia	1. Jatropha, Kemiri Sunan, 2. Mahogany 3. Elephant Grass, Setaria Grass, Leguminose

Integrated farming system in abandoned tin-mining areas

Based on land evaluation, most crops developed in abandoned tin-mining areas were categorized as marginally suitable (S3); some were moderately suitable (S2). This indicates that abandoned tin-mining areas are not an ideal growth medium because of poor soil physical and chemical properties. For agricultural development, the soil physical and chemical properties of abandoned tin mining must be improved through integrated farming system (IFS). IFS itself uses internal input that combines crop and livestock. In the IFS, the biomass produced can directly be used as materials for organic fertilizer and it can also be used as feed for ruminant. The manure from the ruminant can then be used as organic fertilizer materials. It means that the system can then improve the quality of abandoned tin-mining soils, reduce the use of chemical fertilizers (Gupta et al., 2012).

Based on potential suitability, IFS in abandoned tin-mining areas is divided into three types, namely: Type A, Type B, and Type C (Table 12).Type A is a group of (1) sand tailing, (2) sand tailing with vegetation, and (3) mixture of sand tailing and overburden. Type B is a mixture of sand tailing and overburden with vegetation. Type C is a group of (1) Sand tailing from unconventional mining and (2) Overburden from unconventional mining. The lands of Type A will be dominated by tree crops; Type B will be dominated by fruit crops, legume cover crops, and vegetable crops; and Type C will be dominated by both tree and fruit crops.

Conclusion

Abandoned tin-mining lands have low soil fertility status as indicated by domination of sand fraction and low soil pH, organic carbon, cation exchange capacity, and essential macro nutrients. Evaluation results showed that in general food crops, vegetable crops, fruit crops, and industrial crops were consider as not suitable (N). The water availability, soil texture and low soil fertility were considered as the limiting factors of all crops to get optimum production. In general, spice and medicinal crops [pepper (*Piper nigrum* L.) and citronella (*Andropogoh nardus* L. Rendle)] were consider as not suitable (N).The forest crops and forage crops were considered as marginally suitable (S3) in abandoned tin-mining areas.For agricultural development, the soil physical and chemical properties of abandoned tin-mining land must be improved through integrated farming system (IFS). Based on potential suitability, IFS in abandoned tin-mining areas are divided into three types. Type A is a group of (1) sand tailing, (2) sand tailing with vegetation, and (3) mixture of sand tailing and overburden. Type B is a mixture of sand tailing and overburden with vegetation. Type C is a group of (1) Sand tailing from unconventional mining and (2) Overburden from unconventional mining.

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