

Landscape Function of Post Tin-Mining Land After Reclamation in Bangka, Indonesia

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Abstract. Tin mining has a negative impact on the environment of Bangka, Indonesia. Efforts have been conducted to reclaim post tin-mining lands. However, the ecological function of the land has not been evaluated. The objective of this research was to assess the landscape function of post tin mining lands in Bangka. This research was conducted at three locations that represented the tin mining conditions in Bangka. The landscape function analysis (LFA) was performed in each location for three types of land (A: unreclaimed tin-mining, B: reclaimed tin-mining, C: natural forest, as reference site). The results of LFA showed similar patterns for stability index among locations. The highest stability index (> 60%) occurred at land C. On the other hand, the post tin mining area, land A and land B have low stability index (less than 38%). The infiltration index, high (>59%) in land C, low (33-36%) in land A and B. The nutrient cycling index also showed a value comparable to the stability index of land and infiltration index. It could be concluded that the post tin-mining land has a critical landscape function. However, by planting trees for reclaiming the area gradually improved the function of the post tin mining landscape.

Keywords: landscape function, post tin-mining land, Bangka.

1. Introduction

Tin mining in Bangka Belitung Province has lasted a long time. It started in 1711 at Bangka and started in 1852 at Belitung [1]. Over a period of more than 200 years these activities have a negative impact on environmental devastation, forests and farmlands were destroyed and turned into barren and cratered landscapes. The Forestry Service of Bangka Belitung Province reported that in 2009 the barren landscape covers 112,838,86 hectares or 6.93% of the land area of Bangka Belitung Province, shifting 99,146,97 ha of the forests in this province [2]. The impact of tin mining, more specifically, is degraded lands; the physical and chemical properties of soil reduced, the topography changed, the natural vegetation and wildlife habitat disappeared. The tin mined land is a marginal land since water holding capacity of the soils are low; consequently, the evaporation rate is high, the soil hardens and cracks, the organic material and nutrient is poor [3].

Efforts at the reclamation of tin mined lands by replanting the lands with various species of trees, such as acacia, pelawan, and sengon have been made by the government of Bangka Belitung Province and tin mining companies. Reclamation on 2,000 ha and 1,600 ha of tin mined lands in this province have been conducted respectively in 2007 and 2008 [2]. PT Timah, the largest tin mining company, has reclaimed its mined lands, covering 1379.55 ha at Bangka and 241.6 ha at Belitung in 2010 [4].



The efforts at thereclamation by replanting the tin mined lands often fail as even the toughest trees, such as acacia, may struggle to grow on the poor soils left after mining. However, replanting the mined land with *Acasiamangium* which has lasting for six years by PT Timah is considered successful [5]. It indicates that this species is able to adapt with the acidic poor soils that characterized the mined lands. It is also a challenge for us to seek other species of plants that could survive well on the mined land. Hence, the diversity of plants on the mined land will be upgraded, the litters will multiply, the decomposed litters will improve nutrient cycle and physical properties of the soil. Reclamation success can be claimed based on analysis of the landscape function that reflects the quality of soil in three main indicators: land stability, water infiltration, and nutrient cycle. This study aimed to analyze the landscape function of reclaimed tin mining land, and to compare it with that of the non-reclaimed tin mining land and the natural land that is not mined.

2. Methods

This study was conducted at three sites in Central Bangka District, namely Air Pelempang, Air Jangkang, and Air Kabel. Three different land are, A) mined land that has not been reclaimed, B) mined land that has been reclaimed, and C) natural land that is considered representative of conditions prior to mining activities, were observed in each study site. Observations on general conditions, such as canopy density, presence or absence of understory plants, and litter conditions, were conducted in each landscape type. In addition, observation on the soil characteristicssuch as temperature, horizon, pH, moisture, porosity, organic and inorganic materials, and bulk density,were also performed. The microclimates data gathered in each landscape type was light intensity, temperature, and humidity.

Landscape Function Analysis (LFA) for each landscape type was performed by a method developed by Tongway and Hindley with modifications [6]. Data were collected by three line transects in each type of landscape. The line transect was laid out according to topography and its length was adapted to land conditions. Organizational landscapes characterization and soil surface assessment (SSA) was carried out along the line transects. The characterization of organizational landscape aimed to check the existence of patches and inter patch. The SSA was performed by observing and measuring the SSA's criteria, that is areas covered by pioneer vegetation (herbs, shrubs, trees) and litters, degree of decomposition, violence (severity) and type of erosion, material deposited, surface roughness and resistanceagainst tampering, land stability when moist, and soil texture [7]. The data gathered from the SSA are inserted into the worksheets of LFA and combined in different combinations to reflect three major soil habitat quality indices: stability or resistance to erosion, infiltration/runoff and nutrient cycling. The data are presented in a 0 to 100 scale.

3. Results

3.1 Microclimate And General Condition in The Landscape Studied

The conditions of diffrent types of land in the three study sites (Air Palempang, Air Jangkang, and Air Kabel) showed generally similar pattern. Land A (non reclimed mined land) has inclined flat and cratered topography, does not have a canopy cover, and there are only a few species of herb and creeping perennial plants at the ground. Land B (reclaimed mined land) has similar topography to the previous landscape, but it has a relatively opened canopy cover of the planted plant, litters were found under the plants. It also has relatively more numerous ground plants than land A. Land C (natural non-mined land) has a canopy cover more tightly than land B, the canopy derived from native plants of the landscape, understory plants (herbs and shrubs) were abundance, otherwise a lot of litterswerefound at the ground (table 1).

Different microclimates were found in the three types of landscape observed. Light intensity and air temperature in the land A and B is higher than these in the land C. It is followed by a lower humidity than land C (table 2).

Table 1. The description of general condition at the three different lands, in the three study sites in Bangka.

Study sites	Type of Land	Description of general condition
Air Pelempang	A : non reclaimed tin mining land	no canopy cover, bare soil substrates (sandy and partly pebbly bare soil), the ground is covered by a few perennial creeping herbs, there is a bit of litter on the soil surface, the topography is slightly rough
	B: reclaimed tin mining land	there is canopy cover of the ± 2 m high of plants grown for reclamation, the litter and the ground plants is a bit more than the landscape A, the topography is similar to that in landscape A
	C : naturally vegetated land	The canopy is closed, the soil is covered by litters, there is a lot of trees species and understory plants (herbs, shrubs, small trees) that is spread and grow naturally, the topography is flat
Air Jangkang	A : non reclaimed tin mining land	no canopy cover, bare soil substrates (sandy and partly pebbly bare soil), the ground is covered by a few grasses and perennial creeping herbs, there is a bit of litter on the soil surface, the topography is flat and slightly slopping
	B: reclaimed tin mining land	there is canopy cover of the ± 2 m high of plants grown for reclamation, the litter and the ground plants occur under the planted plants and is a bit more than the landscape A, the topography is flat and slightly sloppy similar to that in landscape A
	C : naturally vegetated land	The canopy is closed, there is a lot of trees species and understory plants (herbs, shrubs, small trees) that is spread and grow naturally, the soil is covered by litters, the substrate is sandy clay, the topography is flat
Air Kabel	A : non reclaimed tin mining land	no canopy cover, bare soil substrates (sandy and crusted bare soil), the ground is dominated the tussock of grasses, a small area of grass that is thicker or longer than the grass growing around it, the topography is slightly rough and pitted with several large pools of stagnant water called "kolong"
	B: reclaimed tin mining land	there is canopy cover of the <i>Acasiamangium</i> planted for reclamation, a lot of litter and the ground plants occur under the planted plants, the topography is flat
	C : naturally vegetated land	The vegetation has closed canopy with the trees has larger diameter, the soil is covered by litters, the topography is flat

Table 2. The microclimates at the three different lands, in the three study sites in Bangka.

Study sites	Type of Land	Parameters of microclimate		
		Light intensity (lux)	Air temperature (°F)	Air humidity (%)
Air	A : non reclaimed tin mining land	$45,97 \times 10^3$	$85,3 \pm 1,0$	$89,3 \pm 0,6$
Pelempang	B: reclaimed tin mining land	$67,17 \times 10^3$	$87,8 \pm 2,1$	$79,0 \pm 0,5$
	C : naturally vegetated land	$1,87 \times 10^3$	$84,8 \pm 0,3$	$89,3 \pm 0,3$
Air Jangkang	A : non reclaimed tin mining land	$128,5 \times 10^3$	$89,5 \pm 0,5$	$80,2 \pm 1,8$
	B: reclaimed tin mining land	$117,7 \times 10^3$	$89,8 \pm 0,8$	$81,7 \pm 1,2$
	C : naturally vegetated land	$6,86 \times 10^3$	$84,2 \pm 1,8$	$85,0 \pm 3,7$
Air Kabel	A : non reclaimed tin mining land	118×10^3	$89,5 \pm 1,3$	$79,7 \pm 4,2$
	B: reclaimed tin mining land	$130,6 \times 10^3$	$91 \pm 3,5$	$77,0 \pm 0,5$
	C : naturally vegetated land	$8,22 \times 10^3$	$83,7 \pm 0,6$	$95,7 \pm 2,1$

3.2 Soil Characteristics of the Study Sites

There are differences on physical characteristics and chemical conditions of the soil in three different type of land in the study sites of Air Pelempang, Air Jangkang, and Air Kabel. The characteristics of soil in those study sites generally showed similar trends. Soil fertility in the land C is much better than that of the land A and B. In addition, the soil texture in the land A and B have over 90% of sand fractions, whereas the land C was dominated by clay fraction. This condition of land A and B was caused by tin mining activities that left expanse of tailings over 90% of sand [8]. Soil washing process on tin mining activities cause loss of nutrients in the soil; the level of C organic compounds in land A and B is lower (< 1%) than that in the land C (2-4%). The soil in the three study sites is commonly acidic ($\text{pH} \leq 5.5$), however the value of cation exchange capacity (CEC) in the land C (4:25 to 11:29 cmol / Kg) is higher than that in the land A and B (0.20-0.99 cmol / Kg).

3.3 Landscape Function Analysis for Monitoring and Assessing the Reclaimed Tin Mined Lands

The result of landscape function analysis is demonstrated by the value of land stability index, the water infiltration index and nutrient cycling index. The value of land stability index is obtained from the indicators of the SSA, such as the level of crust destruction, surface resistance, slake test, the type and severity of erosion, deposition materials, cryptogams cover, ground cover from the rain, and litters cover. The lowest land stability index (respectively 37.2%, 37.7%, 35.3%) was found in the land A at the three study sites (Pelempang Water, Air Jangkang, Air Kabel). Land B, reclaimed tin mined land, have a stability index slightly higher than land A. These conditions are found in the three study sites, Pelempang Water, Air Jangkang, Air Kabel; stability index values respectively 39.6%, 37.7%, 46.1% (table 3). Land C, natural land that is not mined, has the highest stability index among the other landscapes. Stability index value of 61.7%, 75.3%, and 82% was obtained respectively in the study sites Air Pelempang, Air Jangkang, and Air Kabel.

Table 3. The indices of landscape functions analysis at three different lands, in the three study sites in Bangka.

Study sites	Type of Land	The indices of landscape function analysis		
		stability	infiltration	nutrient cycling
Air Pelempang	A : non reclaimed tin mining land	37.2±0.78	33.6±0,35	10.3±0,33
	B : reclaimed tin mining land	39.6±1.19	33.2±1.50	11.4±1,43
	C : naturally vegetated land	61.7±0	62.3±0	54.4±0
Air Jangkang	A : non reclaimed tin mining land	37.7±2.01	33.4±1.34	8.6±0.55
	B : reclaimed tin mining land	37.7±1.21	31.4±3.15	8.8±0.91
	C : naturally vegetated land	75.3±5.48	59.3±2.74	54.9±0.49
Air Kabel	A : non reclaimed tin mining land	33.6±0,35	30.3±6.62	8.6±0.31
	B : reclaimed tin mining land	33.2±1.50	35.2±2.75	15.5±7.69
	C : naturally vegetated land	62.3±0	60.2±2.92	55.1±3.25

The infiltration/runoff index is defined as how the soil divides rainfall into soil-water (water available for plants to use), and runoff water which is lost from the local system, or may also transport materials (soil, nutrients and seed) away [6]. Index infiltration in the land A and B is less than 35 and categorized as low (table 3). On the other hands, high infiltration index is found at land C, natural non-mined land, in the three study sites. The value of index infiltration in AirPelempang, Air Jangkang, and Air Kabel, was respectively 62.3%, 59.3%, 60.2%.

The highest score of index of nutrient cycling in the three study sites was found in the land C. This land has a score of the nutrient cycling of 54.4%, 54.9%, 55.1%; obtained in Air Pelempang, Air Jangkang, Air Kabel respectively (table 3).

4. Discussion

The low cover of vegetation on the land A and B causes high intensity of light irradiation. Conversely, the light irradiation intensity in the landscape C was low due to dense canopy cover of the natural vegetation. Vegetation plays an important role to control the thermal environment (air temperature, air humidity and air movement) through the evapotranspiration mechanism to accelerate the cooling on the leaf surfaces and eventually lowered the air temperature. Vegetation also provides a cooling effect of the air by means of shadowing (canopy effect) and reducing the sunlight that reaches the ground [9]. The opened area that covered only by a few ground plants and young trees on the landscape type A and B reduce the beneficial effects of such vegetation.

Tin post-mining land generally have lower pH values due to high concentrations of Al [10]. It is thought to be happen because of the high air temperatures and high rainfall intensity resulting soil weathering processes take place quickly. Basic cations such as Ca, Mg, K were leached from the soil profile, leaving a more stable material that is rich in Al and Fe [11]. The low content of the soil macronutrient and the high composition of the sand fraction in the land (A) and (B), which is a post-mining land of tin, shows the characteristics of critical land [12].

The low of stability index in land A indicates a low ability of tin mined lands that have not been reclaimed in terms with stand the soil erosion, and lack of ability to repair themselves after disruption [6]. Low stability occurred in land A was due to a lack of vegetation and the opened soil is more than 90%. Such conditions result in the least amount of litters on the ground and cover against rainfall on the soil is low. Land A, not reclaimed mined land, has a high potential to erode because it has a sandy soil that has cohesion among the particles that are not tight. The parameters contributed to the stability index in land B that is slightly higher than land A are the ground cover and cryptogam. The area covered by vegetation in land B is higher than land A. Cryptogamic plants, such as some species of mosses and ferns, were found in land B. However, the value of stability index in land B is still considered low and indicate a high potential for erosion. The existence of various species of trees that

are naturally dispersed in land C, contributes most to the stability. These tree species have the potential to reclaim land mined tin, it is due to the local plant are naturally adapted to the local climate better than the introduced plant [14].

The low infiltration index in land A and land B is evidenced by the low level of perennial vegetation cover and the soil surface roughness that could cause in low retention of groundwater and the loss of water wasted out the ground through runoff water. High infiltration index in land C indicates that runoff water in this land is low. The runoff water will decrease with the increase of vegetation [15]. Land C has a high perennial vegetation cover. This lush vegetation has plenty of underground roots that help the soil retaining water, increasing infiltration and reducing runoff water. In addition, the soil surface in the land C has high degree of roughness. It also supports the water retention in the process of infiltration. Sandy clay soil texture at this land also helps the process of infiltration, the soil has tight cohesion between the particles and high ability to retain water.

High nutrient cycling index in land C contributed by the lush perennial vegetation and a lot of decomposed litters. The lush vegetation supports the process of nutrient cycle by its contribution in providing a lot of litters. Decomposition of the litters eventually lead to the process of nutrient cycling. The decomposed litters released carbon into the atmosphere and nutrients into the soil, organic material of the litter are converted by microbes into inorganic compounds that are used by plants [15].

5. Conclusion

The results of landscape function analysis (LFA) showed that the reclamation on tin-mined lands have not been able to restore the natural function of the land, the biogeochemical processes in the tin-mined lands have not been going well. This can be affected to several factors, such as reclamation takes a long time to restore the function of the land. Additionally, the trees species planted can also determine the success of reclamation.

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