The Effect of Tin Mining on Soil Damage in Pedindang Sub-Watershed, Central Bangka Regency

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Abstract. The practice of tin mining, especially in the Pedindang Sub-Watershed, Central Bangka Regency, Bangka Belitung Province was not carried out carefully and protectively because it produced soil damage or land degradation. The purpose of this study was to examine soil properties, particularly soil physical properties, and soil damage in the Pedindang Sub-Watershed with various land uses, namely tin mining, forests, dryland agriculture and thicket shrubs-bushes, on various slope classes. The properties of the soil studied were the content of organic matter, sand, silt, clay; bulk density; porosity, and soil permeability. Compared to other land use (forest, dryland agriculture and shrubs) in the Pedindang Sub-Watershed area, tin mining land use show the worst soil properties. Soils in tin mining land use were degraded, has very low organic matter content; the lowest clay content; the highest soil density as indicated by high bulk density and low soil porosity; and the highest sand content so that it can be understood if it has the highest and very fast soil permeability.

Keyword: land degradation, land use changes, soil damage, sub-watershed, tin mining

1. Introduction

As one of the biggest tin producer in the world, Bangka Belitung Island produced approximately 1,006,000 ton of tin in 2013 or more than one third of global tin supply. Tin mining is the most significant economic-driver in the Province of Bangka-Belitung, taking place inland and offshore, including protected forest and marine ecosystem. Activities of many tin mining neglect good mining practices, safety and land reclamation [1] in [2]. They do not pay attention to aspects of environmental sustainability. Tin mining activities lead to increase land and soil degradation and declining land and soil quality is increasingly widespread, so it continues to increase the area of critical land. Loss of topsoil, the low ability to hold and supply water for plants and very poor nutrients will inhibit of plant growth then provide and low productivity [3].

The same tin mining practices in Pedindang Sub-Watersheds, Bangka Regency, Bangka-Belitung Province, Indonesia. The land conversion of forest due to tin mining in the Pedindang Sub-Watershed is quite significant. Based on the Land Use Map of the Pedindang Sub-Watershed, the tin mining area reaches 10.2% Pedindang Sub-Watershed area. Non-environmentally friendly tin mining practices resulted in soil degradation and water pollution. The clearing of forests for tin mining areas certainly reduces the area of land cover by vegetation and shows an indication of increased soil bulk density and

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soil compaction, decreased soil infiltration capacity, increased soil erosion, increased sedimentation and turbidity of rivers and waters systems. These symptoms ultimately indicate a decline in the quality of the Pedindang Sub-Watershed and the surrounding area.

Based on Government Regulation Number 37 in 2012 concerning Management of Watersheds, state that: Watershed is a single unit of the river and its tributaries which has function to store, store and drain rainfall water to the lake or to the sea naturally, which the land boundary is the topographic separator, and the sea boundary to the water area which is still affected by land activities. Watershed is an ecosystem that interacts between the biogeophysical environments with living things on it and makes the system bound together dynamically, where the components are mutually symbiotic and bound in the preparation of the watershed system. Watershed consists of three parts, upstream, middle and downstream and all three interact and influence [4]. The watershed consists of various main constituent elements, land natural resources, vegetation, forests, and water which act as natural physical objects or targets as human beings who play a role and act as actors in the utilization of natural resources [5].

Soil is a natural body that comes from weathering and destruction of rocks and organic materials that are affected by climate, topography, organisms, and time. These factors are known as soil forming factors which carry out processes to produce soil as a result of natural formation [6]. For aspects of the variety of soil types, there is not much variation in soil types found in the area of Bangka Island. From the main material of granite, sandstone and clay skis will form Ultisol soil, diabes will form Latosol soil (Inceptisol/Oxisol), in the valley area will be formed alluvial soil (Entisol) and along the coast Regosol (Entisol/Inceptisol) soil will be found. Common soil sequences are Litosol, Ultisol, Podsol (Spodosol), Glei Humus (Histic Tropaquent) and Alluvial [7]. Physical properties of the soil such as texture, soil bulk density, total porosity, and soil permeability will greatly control the capacity of the soil to pass water into the soil, hold and drain water in the soil [8].

The purpose of this study is to comparing soil properties in tin mining area with forest, dry land farming, and shrub land uses and to examine the effects and consequences of practices of tin mining activities on soil damage or degradation in the Pedindang Sub-Watershed area. The guideline used to assess land damage or degradation is Government Regulation Number 150 in 2000.

2. Methods

2.1. Study Site
Research was conducted from December 2016 to October 2017. Field surveys and observations as well as sampling of soil and water were carried out in the Pedindang Sub-Watershed area, Bangka Regency, Bangka Belitung Province (see figure 1). Laboratory analysis was conducted at the Chemistry and Fertility Laboratory and the Soil and Water Conservation Laboratory, Department of Soil and Land Resources, Faculty of Agriculture, IPB University.

2.2. Materials and tools
Research tools needed is equipment for field observation and sampling for soil, water quality and sediment concentration (ring samplers, knife, hoe, thermometer, pH meter, bottles, plastic bags, cool boxes) and other supporting equipment especially GPS, laptops, and software Arc.Gis 10.1 version.
Figure 1. Location of research area, Sub-DAS Pedindang, Bangka District.

The materials used are thematic maps, non-spatial data, stationary, and documents (reports from previous researchs, statistical and other secondary data) and questionnaires, interview instruments to collect primary data and information related to changes in soil, water, vegetation, hydrology, socio-economic and cultural conditions.

2.3. Sampling of Soil Sampling
From overlaying the soil map, land use map, slope map and the Pedindang Sub-Watershed area boundary, it was finally obtained 20 Land Map Units (LMUs) as presented in figure 2. The location of field observation, soil sampling and ground check are done randomly at 19 LMUs (LMU 1 to LMU 19), 3 sites for each slope class in each land use with total of 40 sites (only 2 sites for class slope > 40% for each forest and dry land farming land uses). Sampling of soil was carried out on surface layers (0-10 cm) at each site for determination of soil permeability, soil porosity, soil bulk density, soil texture, and soil organic matter content in the laboratory.
Figure 2. Location map of soil sampling where 40 soil samples were taken randomly in the 19 LMUs (LMU 1 to LMU 19) that are devoted for tin mining, forest, dry land farming and shrub.

2.4. Methods
Some methods used to analyse the selected soil properties are shown in Table 1.

Table 1. Methods for analysing the selected soil properties.

| Soil Parameters                  | Analytical method                      |
|----------------------------------|----------------------------------------|
| Soil Texture                     | Laboratory (Pipette)                   |
| Soil Bulk Density                | Laboratory (Gravimetric-weighing)      |
| Soil Carbon Organic content      | Laboratory (Walkey and Black)          |
| Soil Total Porosity              | Laboratory (Gravimetric)               |
| Soil Permeability                | Laboratory (de Boodt-Constant Head)    |

2.5. Data analysis
Government Regulation Number 150 in 2000 is used as a guideline for analyzing primary and secondary data to determine the occurrence of soil damage in the Pedindang Sub-Watershed (see Table 2).

Table 2. Criteria to evaluate soil degradation based on Government Regulation Number 150 in 2000 [9].

| No | Parameter         | Unit  | Critical Threshold          |
|----|-------------------|-------|----------------------------|
| 1  | Sand Fraction     | %     | > 80 quartzitic sand        |
| 2  | Soil Total Porosity | % (v) | < 30 and > 70              |
| 3  | Soil Bulk Density | g/cm³ | > 1.4                      |
| 4  | Soil Water Content | % (v) |                           |
| 5  | Soil Permeability | cm/hr | < 0.7 and > 8.0            |
| 6  | C organic         | %     |                           |
3. Results and Discussions

3.1. General Condition

3.1.1. Topography. The topographic conditions of the Pedindang Sub-Watershed vary, from flat, gentle to very steep. Distribution of land in Pedindang Sub-Watershed based on the slope can be seen in table 3.

| No | Slope (%) | Area (Ha) |
|----|-----------|-----------|
| 1  | 0 – 8     | 3,453.7   |
| 2  | 8 – 15    | 281.4     |
| 3  | 15 – 25   | 302.5     |
| 4  | 25 – 40   | 393.3     |
| 5  | > 40      | 190.9     |
|    | Total     | 4,621.8   |

3.1.2. Geology. Based on its geological formation, the Pedindang Sub-Watershed consists of four formations, namely: 1) Genting Tanjung Formation, 2) Complex Pemali Formation, 3) Granite Calabat Formation, and 4) Alluvium Formation. The Genting Tanjung Formation is composed of sandstone and clay formed from separation or decomposition by physical and chemical influences, which form the neritic precipitation of clay rocks with the insertion of sandstones and glauconite. The Pemali complex formation is composed of metamorphism rocks originating from sedimentary rocks which undergo metamorphosis composed of unstable minerals. The Klabat Granite Formation is composed of granite stones such as granite, granodorite and granite. While the Alluvium Formation is formed from the deposition of clastic or sedimentary rock formed from the Holocene period in the form of chalced, gravel, sand and mud chunks [10].

3.1.3. Soil. Soils in the Pedindang Sub-Watershed mainly consist of Hapludox and Dystrudepts. Hapludox is included in the Order of Oxisol which has an oxic horizon without clay accumulation and clay CECs less than 16 me/100 gr. Whereas, according to [11] classification, it is called the “Red Latosol”, spread widely on flat to wavy physiography and also commonly in old volcanic hills and tectonic hills. These soils developed from intermediate parent materials such as clay, tuft dacite and granite. The characteristics of these soils are deep (soil depth > 100 cm), good drainage, fine texture. Organic carbon content varies from low to very high, P content is very low to low, CEC varies, base saturation is low, and Aluminum saturation is very high [11].

Soils in the sub group Dystrudepts are included in the Inceptisol Order, with udix soil moisture. This land is often called “Brown Latosol”, because it has a base saturation of less than 60% in one or more horizons in a depth of 25-75 cm from the ground surface [11]. The soil that classified as Dystrudepts has the broadest spread, ranging from a sloping to wavy surface, having fine and acid parent material (clay stone) on flat terrain physiography. While in volcanic physiography the soil developed from andesite and basalt tuffs. According to [11], this soil has a deep soil depth (75-150 cm), with good drainage and generally has a somewhat fine soil texture, pH low to very low (4.5-5.6), organic carbon, CEC and the saturation of Aluminum varies greatly from low to very high.

Aside from Oxisol and Dystrudepts, another soil is formed from the alluvium material thought to be intergrades for Fluvents or Fluvaquents. In addition, there is soil which has a thin layer which has andic properties consisting of subgroups of soil types which are thought to be intergraded to Andisol.

3.1.4. Land Use. Forest encroachment, especially as a built area and tin mining will continuously reduce the area of conservation forest. At present the area of tin mining is 469.4 ha or 10.2% of the area of Pedindang Sub-Watershed (see table 4).
Table 4. Area of tin mining and distribution of other land use in Pedindang Sub-Watershed.

| No | Land Use       | Area  | %    |
|----|---------------|-------|------|
| 1  | Built Area    | 1,118.7 | 24.2 |
| 2  | Water body    | 11.6  | 0.3  |
| 3  | Golf Course   | 2.5   | 0.1  |
| 4  | Tin Mining    | 469.4 | 10.2 |
| 5  | Dry land farming | 1,243.4 | 26.9 |
| 6  | Shurb         | 61.7  | 1.3  |
| 7  | Forest        | 1,714.4 | 37.1 |
|    | Total         | 4,421.8 | 100.0 |

3.1.5. Climate. According to the Schmidt-Ferguson classification, the Pedindang Sub-Watershed is included in the Climate Type C (slightly wet) with a ratio of dry months and wet months 0.428. The 5-year annual rainfall is quite fluctuating, 2899.8 mm in 2011, declining to 2017.5 mm in 2012, up again by 2844.6 mm in 2013, then falling to 1653.7 mm and 1519.7 mm in 2014 and 2015, respectively (see table 5).

Table 5. Rainfall data in 5 years (2011-2015) of Pedindang Sub-Watershed based on Depati Amir Station

| Month   | Year (mm) | Average (mm) | Maximum (mm) | Minimum (mm) |
|---------|-----------|--------------|--------------|--------------|
|         | 2011      | 2012         | 2013         | 2014         | 2015         |
| January | 253.1     | 185.6        | 202.6        | 218.2        | 168.8        |
| February| 309.9     | 466.2        | 304.5        | 59.4         | 98.0         |
| March   | 228.5     | 258.3        | 261.0        | 82.7         | 397.6        |
| April   | 356.2     | 126.9        | 190.1        | 311.1        | 222.3        |
| May     | 343.9     | 144.1        | 258.0        | 156.2        | 110.1        |
| June    | 271.6     | 165.0        | 119.9        | 96.8         | 82.8         |
| July    | 91.1      | 192.7        | 249.4        | 135.1        | 23.1         |
| August  | 43.6      | 4.0          | 84.5         | 128.5        | 13.7         |
| September| 78.6     | 13.5         | 235.1        | 0.8          | 0.0          |
| October | 301.9     | 46.1         | 198.3        | 38.6         | 32.4         |
| November| 351.9     | 215.6        | 335.1        | 135.8        | 135.0        |
| December| 268.5     | 199.5        | 406.1        | 290.5        | 235.9        |
|         | Total     | 2,898.8      | 2,017.5      | 2,844.6      | 1,653.7      |
|         | Average   | 241.6        | 168.1        | 237.1        | 137.8        |

3.2. Properties of Soil

The results of soil properties analysis which are considered as parameters for assessment of soil damage based on Government Regulation Number 150 in 2000 are presented in table 6.

The soil properties of tin mining showed quite remarkable differences as compared to the other three land uses. Soils in the tin mining area have higher soil bulk density, lower total soil porosity, lowest organic carbon content, the highest sand content, and the highest soil permeability compared to the other three land uses in all slope classes.

The increase in soil weight on ex-tin mining land was caused by compaction due to human activities and the use of heavy equipment for a long time during mining activities, this resulted in a decrease in soil porosity. The high sand content in the tin mining area due to mining activities separates sandy tail from clay so that the clay content gets lower and the residue has a very high sand content. The high sand content causes an increase in the value of soil permeability.
Table 6. Soil properties in Pedindang Sub-Watershed that indicating soil degradation based on Government Regulation Number 150 in 2000 [8].

| Slope Class (%) | Land Use | Permeability (cm/hr) | Bulk Density (cm³/g) | Porosity (%) | Sand (%) | Silt (%) | Clay (%) | C-organic (%) |
|-----------------|----------|----------------------|----------------------|--------------|----------|----------|----------|--------------|
| 0 – 8           | Tin Mining | 73.62 | 1.51 | 43.17 | 87.91 | 30.65 | 9.91 | 0.46 |
|                 | Conversion Forest | 27.22 | 1.23 | 53.58 | 69.54 | 14.39 | 16.08 | 2.19 |
|                 | Dry Land Farming Shrubs’ | 20.58 | 1.27 | 56.82 | 75.65 | 9.61 | 15.22 | 1.92 |
| 8 – 15          | Tin Mining | 67.68 | 1.53 | 41.58 | 89.33 | 7.15 | 3.52 | 0.08 |
|                 | Conversion Forest | 6.27 | 1.30 | 47.56 | 75.62 | 5.49 | 18.90 | 1.69 |
|                 | Dry Land Farming Shrubs’ | 7.60 | 1.31 | 50.48 | 79.27 | 4.40 | 16.34 | 1.56 |
|                 | Conversion Forest | 3.63 | 1.38 | 45.74 | 56.76 | 6.25 | 37.00 | 1.12 |
| 15 – 25         | Tin Mining | 60.96 | 1.44 | 45.02 | 88.36 | 1.08 | 10.56 | 1.07 |
|                 | Conversion Forest | 9.32 | 1.29 | 51.03 | 76.07 | 4.23 | 20.21 | 1.90 |
|                 | Dry Land Farming Shrubs’ | 24.93 | 1.32 | 48.00 | 79.98 | 2.78 | 17.24 | 1.51 |
| 25 – 40         | Tin Mining’’ | 29.81 | 1.37 | 46.78 | 67.97 | 20.90 | 11.14 | 1.18 |
|                 | Conversion Forest | 30.57 | 1.43 | 41.34 | 80.34 | 7.00 | 12.66 | 1.93 |
|                 | Dry Land Farming Shrubs’ | 25.85 | 1.13 | 57.43 | 3.34 | 94.36 | 2.30 | 0.48 |
| > 40            | Tin Mining’’ | 22.85 | 1.32 | 54.88 | 61.74 | 7.95 | 30.3 | 1.99 |

Remark: *there is no shrub except in the slope class of 8 – 15%  
**there is no tin mining in the class slope of 25 – 40% and >40%

3.3. Analysis of Soil Degradation Levels
The soil properties in Table 6 indicate that in the tin mining area of the Pedindang Sub-Watershed soil degradation has occurred. Some indications that support this statement are the occurrence of a large decrease in organic carbon, a large decrease in total porosity of the soil, a high increase in soil bulk density, clay washing so that the clay content remains extremely low and very high the sand percentage, and soil permeability increases drastically. Soil properties in the tin mining area in the Sub-Watershed region have exceeded the critical threshold of Government Regulation Number 150 in 2000, specifically soil bulk density, soil permeability, and sand content.

4. Conclusions
Practise of tin mining activities in the Pedindang Sub-Watershed have caused land degradation, as shown by the changing of some soil properties. Soil properties quality are below the critical threshold of Government Regulation Number 150 in 2000 are soil bulk density, soil permeability and sand content. Thus, soil degradation by tin mining activities resulted in decreased quality of the Pedindang Sub-Watershed. Restoration and rehabilitation are needed for the ex-tin mining area to restore the quality of soil and so that they can be used for agricultural areas or reforested.

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