Carbon emission and sequestration on tin mined land: A case study in Bangka Belitung Province

U Haryati and A Dariah
Indonesian Soil Research Institute, Jl Tentara Pelajar No 12, Cimanggu, Bogor, West Java, Indonesia
Email: umiharyati@yahoo.com

Abstract. The research objective was to study emission rate and carbon sequestration in ex-tin mining land, with Bangka Belitung Province as the case site. Emission projections are carried out until 2040 based on historical emissions from 2000-2013. The results showed that in the period 2000 - 2013 there was an expansion of the tin mining area in the province covering an area of 22,642 ha, causing a decrease of 19,507,142 t of soil C stock and 10,056,896 t of plant C stock and emissions (sourced from plants only) of 36,908,808 t CO2 eq. There are two scenarios we propose here to reduce emissions: Scenario 1, avoid the opening of primary forest, primary and secondary swamp forests, and reclaim 80% of the tin mined land area by planting perennial crops such as plantation/estate crops or industrial forest. Scenario 2, equals Scenario 1 plus a reduction in the rate of secondary forest clearing for various uses by 50%. Scenario 1 will potentially able to reduce emissions by 8% and carbon sequestration by 8,000,000 t CO2 eq and scenario 2 reduced emissions by 26.97% with carbon sequestration 32,500,000 t CO2 eq.

1. Introduction
The largest tin mining area in Indonesia is in Bangka Belitung Province. Tin mining activities at this location had been going on for long time and had a negative impact on the environment. The negative impact of this activity mainly indicated by drastic changes in the physical and chemical properties of the soil, in addition this turbances to vegetation, animal and other natural ecosystem.

Mining causes major changes in the landscape and negatively impacts the ecology due to the loss of flora and fauna and decreases soil fertility, causes erosion and sedimentation of waterways and rivers, decreases water quality and destroys microbial communities (1; 2; 3; 4; 5; 6). Bangka Blitung is one of the provinces with the largest tin mining activity in Indonesia, amounting to 27.56% of the island's land area is the area of tin mining authority (KP =Kuasa Penambangan).

Tin mined land in Bangka and Belitung Islands is mostly classified as Unsuitable Current Class (Class N1 ) which is 64,255 ha (51%), Marginally Appropriate (Class S3) covering 37,294 ha (30%), and not suitable (Class N2) covering 11,144 ha (9%), and in the form of ponds of 124,838 ha (10%). (7; 8). The low carrying capacity of ex-mining land for plant growth is caused by soil physical and chemical properties damage (9; 10; 11) and the presence of heavy metal pollution and iron poisoning (12; 13).

The mining process also impacts on the loss (emission) of carbon stocks, both in the soil (below ground C-stock) and plants (above ground C-stock). Deforestation and changes in land use currently cause around 8-20% of carbon dioxide (CO2) emissions source from human activities at the global level - ranking second after burning fossil fuels (van der Werf 2009 and IPCC 2007 in 14). An international climate agreement recently emphasized the importance of Reduced Emissions from Deforestation and Degradation (REDD +) as key and relatively low-cost options for climate change.
mitigation; this strategy aims to maintain carbon storage (C) on land through financial incentives to protect forests (for example, carbon credits) (14). Therefore, in the era of climate change, rehabilitation measures for ex-mining land must also be aimed at re-sequestrating carbon as much as possible, so that it can contribute to climate change mitigation.

The concept of green mining is expected to create a balanced relationship between mining companies, the community and nature (15, 16). Although it is very difficult to make a choice between resource exploitation and ecological environmental protection (17). Land reclamation efforts need to be done to minimize the negative impacts of exploitation of natural resources and restore environmental functions. In order to contribute to climate change mitigation, the reclamation effort must also be aimed at reestablishing the lost C as optimal as possible. Based on the foregoing, this research aims to study the level of emissions caused by mining activities and carbon sequestration on ex-mining land, by taking a case study in the tin mining area in Bangka-Belitung Province.

2. Materials and methods
The study was conducted in a desk work at the Soil Research Institute office in 2016. The study area took a case in Bangka-Belitung Province. The materials and tools used in this study were:

- Indonesian Land Cover Map, scale 1: 250,000 in 2000 (18)
- Indonesian Land Cover Map, scale 1: 250,000 in 2013 (19)
- Abacus REDD module / software (20)
- GIS Software
- Soil C-organic content data in various land covers (secondary data)
- Carbon stock data on various forms of land use

The research was conducted in several stages, namely:
1. Clipping the study area (Bangka–Belitung Province) from the 2000 Indonesia land cover map and 2013 to get the Bangka Belitung Province land cover map in 2000 and 2013.
2. Geometry calculation of the land cover map of Bangka-Belitung Province in 2000 and 2013 to get an area of each land cover type in 2000 and 2013.
3. Overlaying of land cover map in 2000 and 2013 to find out land cover change from 2000 to 2013 using GIS software.
4. Based on the overlapping forest and land cover data in 2000 and 2013, a land cover and transition land cover (MPTPL) matrix was produced.
5. Calculation and tabulation of changes in land use types in Bangka Belitung Province in 2000 and 2013.
6. Calculation and tabulation of land cover changes to mining areas to determine the addition and distribution of mining land areas in Bangka Belitung Province in 2000 and 2013.
7. Calculation of carbon stock (C-stock) in the soil using the following formula (21; 22; 23):

\[ C_{\text{Stock tnh}} = \sum (L_i * D_i * BD_i * C_i) \]

Where,
- \( C_{\text{Stock tnh}} \) = soil carbon stock (t)
- \( L_i \) = land area (m²) of land use type no i
- \( D_i \) = soil depth (m) of land use type no i
- \( BD_i \) = Soil bulk density (t/m³) average of land use type no i
- \( C_i \) = Soil C organic content (%) of land use type no i

8. The soil depths that changes in organic C content in this calculation was assumed 1.00 m while the BD and soil C-organic content were obtained from some previous research results or assumptions /expert judgment (Table 1). It was also assumed that BD and C-organic content in the soil were the same in each layer to a depth of 1.00 m.
Table 1 BD and soil C-organic content of some landuse types

| Land use type                                      | BD* (t/m$^3$) | Source  | C-organic * (%) | Source |
|---------------------------------------------------|---------------|---------|-----------------|--------|
| Primary upland/dryland forest HLKP                | 1.0           | 24; 22  | 4.20            | 25; 26 |
| Secondary upland/dryland forest/logged-over land  | 1.0           | 24; 22; 28; 29; | 4.20 | 25; 26; 28; 27 |
| Primary mangrove forest                           | 1.0           | 24; 22  | 4.20            | 30     |
| Secondary mangrove forest / logged-over land      | 1.0           | 24; 22  | 4.20            | 30     |
| Primary swamp forest                               | 1.0           | 24      | 4.20            | 30     |
| Secondary swamp forest/logged-over land           | 1.0           | 24; 22  | 4.20            | 30     |
| Plantation/Garden                                 | 1.1           | 24; 22  | 3.20            | 24     |
| Upland/dryland Agriculture                        | 1.4           | 31; 34; 35 | 1.28          | 24; 32; 33; 31; 34; 35 |
| Upland Agriculture mixed bush/mixed garden       | 1.3           | **      | 1.28            | 24     |
| Shrub                                             | 1.2           | **      | 1.28            | **     |
| Swamp shrub                                       | 1.3           | **      | 1.28            | **     |
| Open field land                                   | 1.5           | **      | 0.50            | **     |
| Ex-mining land                                    | 1.4           | 36      | 0.53            | 36     |
| Paddy/Rice field                                  | 1.3           | 37; 38  | 0.84            | 37; 38 |

* average from the same land use type from some research results, **expert judgement (expert statement),

9. Calculation of plants carbon stock (C-stock) using the following formula (21; 23):

$$C\text{- Stock}_{\text{tan}} = \sum (L_i \times C\text{- Stock}_{-i})$$

(2)

where

- $C\text{- Stock}_{\text{tan}}$ = plant carbon stock (t)
- $L_i$ = area of land use type no i (m$^2$)
- $C\text{- Stock}_{-i}$ = plants C Stock (t/m$^2$) land use type no i (Table 2)

Table 2 Plant carbon stock each landuse type

| Landuse type                                      | Plant carbon (C) stock (t/ha)$^*$ |
|---------------------------------------------------|-----------------------------------|
| Primary upland/dryland forest (HLKP)               | 262                               |
| Secondary upland/dryland forest/logged-over land   | 239                               |
| Primary mangrove forest                            | 193                               |
| Primary swamp forest                               | 58                                |
| Secondary swamp forest/logged-over land            | 58                                |
10. Calculation and arrangement of Carbon-budget based on the data from calculation of carbon stock changes (soil and plants), emissions from peatlands and sequestration that occur due to land use changes (mining land rehabilitation process) conducted from 2000 to 2013.

11. The arrangement of emission reduction scenarios was based on the projected emissions and sequestration C in 2013 to 2039. Emission projections were based on land use change data specifically those that became mining areas from 2000 to 2013.

3. Results and discussion

3.1. Tin mined land areas distribution

The tin mining area in Bangka-Blitung Province was spread in almost all districts both on Bangka Island and Belitung Island (figure 1). These districts were West Bangka, Bangka, Central Bangka, South Bangka, Belitung, East Belitung, and Pangkal Pinang City. This distribution is on the same location, both in 2000 and 2013 while the difference was the increase in area in each of these districts. However, there were several regencies both on Bangka Island and on Belitung Island that were more dominant in terms of the size of this ex-tin mining land compared to other regencies, namely Bangka and West Bangka Regencies for Bangka Island and East Belitung Regencies for Belitung Island (table 3). The development of mining area in each regency on Bangka Island and Belitung Island, showed that almost all districts experience an increase in mining area except Pangkal Pinang City (Figure2).

---

| Land Use Type | Percentage |
|---------------|------------|
| Secondary mangrove forest / logged-over land | 141 |
| Plantation / Garden | 45 |
| Settlement/housing / developed land | 4 |
| Upland/dryland Agriculture | 1 |
| Upland Agriculture mixed bush / mixed garden | 43 |
| Shrubs | 43 |
| Swamp shrub | 43 |

* Source: 18; 19; 23

---

**Figure 1** Land use areas distribution map for tin mining in 2000 and 2013 in Bangka - Belitung Province
The addition of tin mining area from 2000 to 2013 in Belitung and East Belitung districts was more dominant than other districts (Table 1). In 2000 the area of tin mining in Bangka-Belitung Province was 79,670 ha and became 102,320 ha in 2013. Thus there had been an increase in the mining area of 22,650 ha or as much as 28.43% of the original mining area (2000) (Table 3). With the expansion of the mine area, the opportunity for emissions is greater than sequestration, because generally land use before mining has a higher carbon stock. Based on the data in Tables 1 and 2, it can be seen that C stock in both plants and soil in the mining area are lower than other types of land use.

Table 3 Percentage of additional tin mining area in each district in Bangka-Belitung Province from year 2000 - 2013

| District          | 2000 (x 1000 ha) | 2013 (x 1000 ha) | Additional area (%) |
|-------------------|------------------|------------------|---------------------|
| Bangka            | 16.78            | 19.74            | 2.96                | 17.63               |
| Bangka Barat      | 14.58            | 19.63            | 5.05                | 34.63               |
| Bangka Selatan    | 14.64            | 17.45            | 2.80                | 19.12               |
| Bangka Tengah     | 14.87            | 16.52            | 1.65                | 11.12               |
| Belitung          | 6.36             | 10.65            | 4.29                | 67.50               |
| Belitung Timur    | 9.12             | 15.01            | 5.90                | 64.65               |
| Kota Pangkal Pinang | 3.32             | 3.32             | 0.00                | 0.00                |
| **Amount**        | **79.67**        | **102.32**       | **22.65**           | **28.43**           |

*Proportion to initial mining area (year 2000)

3.2. Land use change

Types of land use in Bangka-Belitung Province in 2000 included primary dryland forest (HLKP), secondary/logged-over dryland forest (HLKS), primary swamp forest, secondary/logged-over swamp forest, primary mangrove forest, secondary mangrove forest / logged-over plantation, plantation/garden, shrub, swamp shrub, savanna/pasture, mixed dry-bush agriculture/mixed garden, paddy field, pond, settlement/developed land, airport/port, transmigration, open land, mining, body of water, and swamp. The extent of each type of land use has changed from 2000 to 2013 (Table 4), due to land use changes.

Land use areas that have decreased include primary dryland forest (HLKP), secondary dry land forest/logged-over (HLKS), primary swamp forest, secondary swamp forest/logged-over, secondary mangrove forest/logged-over forest, swamp shrub, savanna/meadows, fields, ponds, and swamps. The
swamps remained relatively unchanged (Table 4 and Figure 3). The land use of paddy fields, ponds and settlement/built land, airports/ports, transmigration, open land, water bodies and mining. The type of plantations/gardens, shrubs, dry land agriculture, mixed shrub/ mixed garden agriculture, settlement/built land, airports/ports, transmigration, open land, water bodies and mining. The type of land use that experienced the highest percentage increase compared to the previous area was transmigration (> 100%), because from none to there were. The land use of paddy fields, ponds and swamps remained relatively unchanged (Table 4 and Figure 3).

Table 4 Land use change in Bangka Belitung Province from Year 2000 - 2013

| Land cover/ Land use                        | Land area (ha) | Decrease (ha) | (%)   |
|--------------------------------------------|----------------|---------------|-------|
| Primary upland/dryland forest              | 743.59         | 617.62        | 125.98| 16.94 |
| Secondary upland/dryland forest /          |                |               |       |       |
| logged-over land                           | 181,381.81     | 127,044.72    | 54,337.09 | 29.96 |
| Primary mangrove forest                    | 19,565,27      | 1,202.65      | 18,362.61 | 93.85 |
| Secondary mangrove forest/ logged-over     | 60,784.93      | 50,559.94     | 10,224.99 | 16.82 |
| land                                       | 16,222.21      | 31,958.97     | -15,736.76 | -97.01 |
| Secondary swamp forest/ logged-over land    | 22,618.28      | 22,365.29     | 252.99 | 1.12  |
| Plantation / Garden                        | 113,645.42     | 123,301.33    | -9,655.91 | -8.50 |
| Shrub                                      | 355,885.65     | 365,423.75    | -9,538.10 | -2.68 |
| Swamp shrub                                | 55,397.05      | 53,986.06     | 1,410.99 | 2.55  |
| Savanna / pasture                          | 10,788.58      | 10,748.28     | 40.30  | 0.37  |
| Upland/dryland Agriculture                 | 53,466.96      | 53,703.01     | -236.05 | -0.44 |
| Upland Agriculture mixed                   |                |               |       |       |
| bush / mixed garden                        | 494,599.24     | 514,011.31    | -19,412.07 | -3.92 |
| Paddy field                                | 604.54         | 604.54        | 0.00  | 0.00  |
| Ponds                                      | 425.89         | 425.89        | 0.00  | 0.00  |
| Settlement / Built land                    | 28,361.16      | 28,435.26     | -74.10 | -0.26 |
| Air port / Port                            | 70.01          | 151.48        | -81.47 | -116.37 |
| Transmigration                             | -2,416.80      | -2,416.80     | >100.00 |        |
| Open land                                  | 78,812.25      | 83,675.63     | -4,863.38 | -6.17 |
| Mining land                                | 79,668.58      | 102,317.53    | -22,648.95 | -28.43 |
| Water bodies                               | 4,382.04       | 4,481.94      | -99.90 | -2.28 |
| Swamp                                      | 9,590.62       | 9,582.09      | 8.53  | 0.09  |

Amount 1,587,014.07 1,587,014.07 0.00 0.00

Note: negative signs (-) mean increase
In the period 2000 to 2013 there was an expansion of the tin mining area in Bangka Belitung with an area of 22,641.83 ha. The expansion of the mining area in this period mostly occurred on the Secondary Dry Land Forest (HLKS), which was 8,480.44 ha (37.45% of the total mining area) and Shrublands of 8,442.55 ha (37.29% of the total mining area) (Table 5).

Table 5  Land use type that change became tin mining area in Bangka - Belitung Province in the period 2000-2013

| Initial Land Use                                           | Became mining land area | Area (ha) | (%)  |
|------------------------------------------------------------|-------------------------|-----------|------|
| Primary upland/dryland forest                              | 0.02                    | 0.00      |
| Secondary upland/dryland forest / logged-over land         | 8,480.44                | 37.45     |
| Primary mangrove forest                                    | 286.91                  | 1.27      |
| Secondary mangrove forest / logged-over land               | 649.28                  | 2.87      |
| Primary swamp forest                                       | 171.60                  | 0.76      |
| Secondary swamp forest/logged-over land                    | 303.86                  | 1.34      |
| Plantation / Garden                                       | 336.63                  | 1.49      |
| Settlement / Built land                                    | 28.42                   | 0.13      |
| Upland/dryland Agriculture                                | 625.73                  | 2.76      |
| Upland Agriculture mixed bush / mixed garden              | 2,320.77                | 10.25     |
| Shrub                                                      | 8,442.55                | 37.29     |
| Swamp shrub                                                | 995.62                  | 4.40      |
| Total                                                      | 22,641.83               | 100.00    |

3.3. Soil carbon stock
Carbon stock is the amount of weight of carbon stored in an ecosystem at a certain time, either in the form of plant biomass, dead plants, or carbon in the soil (21). Based on the calculation, there was a decrease in soil carbon stocks in several types of land use (Table 6). This happened because there was a change in original land use type with higher C-organic soil content becomes less in its area to become a land use type with a lower C-organic content. Land use change significantly affects total soil organic matter. Forests have the highest total organic matter (3.75%), mixed gardens 2.84% and the lowest was in intensively managed by corn monoculture (2.27%) (24). Land use conversion from forests to coffee plantations (1 year old) reduced the total organic matter content of soils from 4.09%
to 1.87% (39). The condition of low soil organic matter on agricultural land compared to forests, is related to diversity, the amount of vegetation and soil litter deposition. According to (40), low amount and diversity of vegetation in an area on agricultural land causes low diversity in the quality of organic material input and the level of soil surface cover by litter layers.

The highest decrease in carbon stock (93.83%) occurred in the primary swamp forest land use type, because the use type was reduced by 93.83% from the original area to other land use types (mixed bush/dry land agriculture, settlement/land built, and open land). On the other hand an increase in soil carbon stocks occurred in several types of land use including primary mangrove forests, plantations, shrubs, dry land agriculture, mixed gardens, open land and mining land (Table 6). The highest increase in soil carbon stock (97.01%) occurred in the type of primary mangrove forest land use. This was also due to the addition of the area of land use types from other types of land use (primary dry land forest, plantations/gardens, shrubs, swamp shrubs, dry land agriculture, mixed upland agriculture/mixed gardens, settlements/built land, open land, mining and water bodies) became primary mangrove forests. Primary mangrove forest has a soil carbon stock of 446.2 Mg ha\(^{-1}\) (± 36.9) (30), so that it will contribute to a large amount of soil carbon stock. The calculation results showed that overall there had been a decrease in soil carbon stock by 19,507,141.84 t (371,978,939.4 t - 352,471,797.6 t) or as much as 5.24% of the original carbon stock (Table 6). Carbon stores in the soil are strongly influenced by land use activities. Soil carbon content varies across landscapes and is mainly influenced by climate, soil type, and land use (Dadal and Meyer, 1986 in 41). While soil carbon sequestration rate varies with the type of soil and management system applied to plants (US EPA, 2006 in 41). Carbon content in both Ferralsols and Acrisols was generally controlled by soil density, the higher the soil density (BD), the lower the soil C content. The potential for soil carbon storage in Ferralsols was greater than that of Acrisols and was significantly different at depths of 0-30 cm, namely 74.72 t ha\(^{-1}\) and 64.39 t ha\(^{-1}\), respectively (41).

| Land use type                      | BD (g/cm\(^3\)) | C-org (%) | Area (ha) 2000 | Area (ha) 2013 | Soil C-stock (t) 2000 | Soil C-stock (t) 2013 | Decrease (%) |  
|-----------------------------------|-----------------|-----------|----------------|-------------------|-----------------------|---------------------|--------------|  
| Primary upland/dryland forest     | 1.00            | 4.20      | 743.59         | 617.62            | 312,308,52.11         | 259,398,59.11       | 16.94        |  
| Secondary upland/dryland forest / | 1.00            | 4.20      | 181,381.81     | 127,044.72        | 76,180,359.87         | 53,358,780.79       | 29.96        |  
| logged-over land                  |                 |           |                |                   |                       |                     |              |  
| Primary mangrove forest           | 1.00            | 4.20      | 16,222.21      | 11,958.97         | 8,613,329.369         | 13,422,768.37      | -97.01       |  
| Secondary mangrove forest / logged- | 1.00            | 4.20      | 22,618.28      | 22,365.29         | 9,499,677.028         | 9,393,420.246      | 1.12         |  
| over land                         |                 |           |                |                   |                       |                     |              |  
| Primary swamp forest              | 1.00            | 4.20      | 19,565.27      | 1,202.65          | 8,217,411.806         | 505,114,67.58      | 93.85        |  
| Secondary swamp forest/logged-over | 1.00            | 4.20      | 60,784.93      | 50,559.94         | 25,529,670.2          | 21,235,173.71      | 16.82        |  
| land                              |                 |           |                |                   |                       |                     |              |  
| Plantation / Garden               | 1.10            | 3.20      | 113,645.42     | 123,301.33        | 40,003,186.92         | 43,402,066.87      | -8.50        |  
| Settlement / Built land           | 1.40            | 0.80      | 28,361.16      | 28,435.26         | 3,176,449.824         | 3,184,748.631      | -0.26        |  
| Upland/dryland Agriculture        | 1.30            | 1.28      | 53,466.96      | 53,703.01         | 8,896,902.208         | 8,936,181.229      | -0.44        |  
| Upland Agriculture mixed bush / mixed garden | 1.30  | 1.28 | 494,599.24 | 514,011.31 | 82,301,313.79 | 85,531,482.33 | -3.92 |  
| Shrubs                            | 1.20            | 2.25      | 355,885.65     | 365,423.75        | 96,089,125.93         | 98,664,413.79      | -2.68        |  
| Swamp shrub                       | 1.20            | 2.25      | 55,397.05      | 53,986.06         | 14,957,203.96         | 14,576,235.33      | 2.55         |  
| Total                             |                 |           | 1,404,671.569  | 1,374,622.9       | 371,978,939.4         | 352,471,797.6      | 5.24         |  

Note : negative signs (-) mean an increase
3.4. Plant carbon stock/above ground carbon stock

Plant carbon stock is the amount of weight of carbon stored in the ecosystem at a certain time, either in the form of plant biomass, dead plants, or carbon in the soil (21).

Plant biomass (plant tissue that still lives above the soil surface and plant roots) is one of the most important carbon pool (C). In addition in biomass, carbon is also stored in dead plant tissue called necromas and in the soil as soil organic carbon (43; 42; 21).

In the various deposits, the largest amount of C-stock for mineral land is above ground biomass, especially for forests and plantations and agroforestry lands. Biomass carbon data in plant roots is usually assumed to be about one third of the carbon in biomass above ground level, although this figure varies greatly depending on plant species, soil fertility and local climate (42).

Based on the calculation, there was a decrease in plant carbon stocks in several types of land use (Table 7). This happened because there was a change in land use, so the original land use type with a higher C-organic content of the plant became less in its area to become a land use type with a lower C-organic content. The highest decrease in plant carbon stock (93.85%) occurred in the primary swamp forest land use type, because this type of land use decreased by 93.85% from the original area to another land use type (mixed bush/dry land agriculture), settlements/land built, and open land). The results of (27) showed that carbon stock in primary forests was 168.27 t ha\(^{-1}\) C, almost 4 times greater than logged-over forests of 47.95 t ha\(^{-1}\) C.

On the other hand there was an increase in soil carbon stocks in several types of land use including primary mangrove forests, plantations, shrubs, dryland agriculture, mixed gardens, open land and mining land (Table 7). The highest increase in carbon stocks (97.01%) occurred in the type of primary mangrove forest land use. This was also due to the addition of the area of land use types from other types of land use (primary dry land forest, plantations / gardens, shrubs, swamp shrubs, dry land agriculture, mixed upland agriculture/mixed gardens, settlements/built land, open land, mining and water bodies) became primary mangrove forests. The research results in the Siberut Subelen River, West Sumatra show ed that biomass and carbon content of mangrove forests were relatively low water bodies) became primary mangrove forests. The research results in the Siberut Subelen River, West Sumatra showed that biomass and carbon content of mangrove forests were relatively low consistent of R. apiculata Blume, R. mucronata Blume, and B. gymnorrhiza (L) types. Savigny is 49.13 t ha\(^{-1}\) or 24.56 t C ha\(^{-1}\) equivalent to the loss of carbon dioxide (CO\(_2\)) 90.16 t CO\(_2\) ha\(^{-3}\) (44). According to (14) mangrove was one of the forests with the highest carbon stock in the tropics (1,023 Mg C ha\(^{-3}\) ± 88) with above ground stock average of 159 Mg C ha\(^{-1}\), maximum 435 Mg C ha\(^{-1}\) while (30) showed that mangrove forests were land with the densest carbon plant stock of 146.8 Mg C ha\(^{-1}\) (± 10.2). According to (48) anthropogenic activities have reduced the ecological, economic and socio-cultural role of mangrove ecosystems, therefore restoration efforts are needed. A fairly successful restoration effort took place in Banggi Market, Kab. Rembang, Central Java because of the community participation in its management.

Overall, due to the change in land use into tin mining area in Bangka, there had been a decrease in plant carbon stocks by 10,056,896.28 t (98,759,328.12 t - 88,702,431.84 t) during 13 years (2000-2013) or 10.18% of the original carbon stock (Table 7).

Table 7 Plants carbon stock change due to landuse change become tin mining area in Bangka Belitung Province in the periode 2000 – 2013

| Land use type                                      | C- stock (t/ha)* | Area (ha) | Plant C-stock (t) | Decreaseement (%) |
|---------------------------------------------------|------------------|-----------|-------------------|-------------------|
|                                                   |                  | 2000      | 2013              | 2000              | 2013               |
| Primary upland/dryland forest                      | 262              | 743.59    | 617.62            | 194,821.03        | 161,815.31         | 16.94              |
| Secondary upland/dryland forest / logged-over land | 239              | 181,381.81| 127,044.72        | 43,350,252.40     | 30,363,687.17      | 29.96              |
| Primary mangrove forest                            | 193              | 16,222.21 | 31,958.97         | 3,130,887.07      | 6,168,081.66       | -97.01             |
| Secondary mangrove forest / logged-over land       | 141              | 22,618.28 | 22,365.29         | 3,189,177.29      | 3,153,505.37       | 1.12               |

\* Measured in Mg C ha\(^{-1}\)
Land use priorities must focus on land with low carbon / C stock such as shrubs. Land use which were very different (Table 8). Therefore to able to reduce emissions in the future, resulting emissions was very different. This was due to the carbon stocks between the two types of stocks above the ground level (above ground C-stock) in the period 2000 - 2013 were 9,821,587.09 t CO₂. Emission due to tin mined land expansion in Bangka-Belitung Province in the periode 2000 - 2013.

Table 8 CO₂ emission (source from above-ground C-stock release) due to landuse change into tin mining area in Bangka Belitung Province in the periode 2000 – 2013.

| Land use type that change to tin mined land | C₇ stock (t/ha)* | Emission (t CO₂ eq./year) | Emission Proportion (%) |
|------------------------------------------|-----------------|---------------------------|-------------------------|
| Primary upland/dryland forest | 262 | 19.21 | 0.00 |
| Secondary upland/dryland forest / logged-over land | 239 | 7,431,692.25 | 75.67 |
| Primary mangrove forest | 193 | 61,016.19 | 0.62 |
| Secondary mangrove forest / logged-over land | 58 | 121,435.60 | 1.24 |
| Primary swamp forest | 58 | 157,095.62 | 1.60 |
| Secondary swamp forest/logged-over land | 141 | 138,080.21 | 1.41 |
| Plantation / Garden | 45 | 55,543.95 | 0.57 |
| Sett kement / Built land | 4 | 416.83 | 0.02 |
| Upland/dryland Agriculture | 1 | 2,294.34 | 0.02 |
| Upland Agriculture mixed bush / mixed garden | 43 | 365,908.07 | 3.73 |
| Shrub | 43 | 1,331,108.72 | 13.55 |
| Swamp shrub | 43 | 156,976.09 | 1.60 |
| TOTAL due to tin mined land expansion | 9,821,587.09 | 100.00 |

*Source : 45 ; 23

3.5 Emission

The total CO₂ emissions from the tin mining area in Bangka-Belitung sourced from changes in carbon stocks above the ground level (above ground C-stock) in the period 2000-2013 were 9,821,587.09 t CO₂ eq. around 75% of them (7,431,644 t CO₂ eq.) sourced from the opening of sevondary dry land forest and around 15% (1,331,109 t CO₂ eq.) sourced from the opening of shrubs (Table 8). Although the total area of sevondary dry land forest and shrubs was not so much different, the impact on the resulting emissions was very different. This was due to the carbon stocks between the two types of land use which were very different (Table 8). Therefore to be able to reduce emissions in the future, land use priorities must focus on land with low carbon / C stock such as shrubs.
The risk of potential soil emissions is high if land changes occur on peatlands. In the period 2000-2013 the area of peat forest cleared and used for mining in Bangka-Belitung Province was around 475 ha, and produced CO$_2$ emissions of 315,229.17 t CO$_2$ eq. or 3% of total emissions due to mining expansion (Table 9).

Table 9 Emission from above-ground C-stock release and below-ground C-stock due to landuse change into tin mining area in Bangka Belitung Province in the periode 2000 – 2013

| Source of emission                  | Total of Emission (t CO$_2$ eq.) | Proportion (%) |
|-------------------------------------|----------------------------------|---------------|
| Above-ground C-stock release        | 9,821,587.09                     | 97            |
| Below-ground C-stock release        | 315,229.7                        | 3             |
|                                     | 10,136,815.26                    | 100           |

Note: emission from mineral soil was assumed 0, emission from peatlands without vegetation 51 t CO$_2$ eq.ha$^{-1}$ year$^{-1}$

3.6. Emission and sequestration- C projection (2013 - 2040)

The scenario of reducing emissions must focus on reducing the land use of high C-stock, namely primary forests and peat forests. The proportion of secondary forest use must also be avoided if significant emissions reductions are to be achieved. CO$_2$ gas as one of the biggest green house gas (GHG) compilers in the air can be absorbed by trees through photosynthesis and converted to C-organic in the form of biomass (46). Information about the carbon content of a vegetation or forest stand can be obtained by estimating the vegetation biomass. According to Brown (1997 in 47) nearly 50% of the biomass of a forest vegetation is composed of carbon elements.

Land reclamation by planting relatively high carbon stock plants such as industrial plantations or plantations will also reduce the total emissions. To reduce emissions to be smaller than business as usual (BAU) emissions, two scenarios are made as follows:

- Scenario 1 is to avoid clearing primary forests, primary and secondary swamp forests, and as much as 80% of the area of tin mining has been reclaimed, by planting annual crops such as estate crops or industrial plantar forest (HTI) with an average C-stock 40 t ha$^{-1}$.

- Scenario 2 is scenario 1 plus a reduction in the rate of secondary forest clearance for various uses as much as 50%.

Based on the two scenarios, under scenario 1 in 2039 emissions would decrease only 6.64%, whereas with scenario 2 the emission reduction would be 26.97% (Figure 4). Thus, in scenario 1 a carbon sequestration of 8,000,000 t CO$_2$ eq has occurred (6.64% of BAU emissions) and scenario 2 totaling 32,500,000 t CO$_2$ eq. (26.97% of BAU emissions).

![Figure 4](image-url) Emissions reduction up to 2039 based on BAU trends with 2 scenarios
Carbon sequestration is the process of carbon sequestration from the atmosphere to certain carbon stock such as soil and plants. The main process of carbon sequestration is photosynthesis (23). Thus in order carbon sequestration to occur as fully as possible, the thing to do is reclaiming low carbon stock land by increasing carbon stocks in the soil and planting the land with plants that have high carbon stocks. Forests have a much greater carbon sequestration capacity (302.49 t ha\(^{-1}\)) compared to agricultural systems, given the very high density of trees/vegetation (25). The results research of Tomich \textit{et al.} (1998 in 25) showed that natural forest land can store 497 t ha\(^{-1}\) carbon. After being converted into vanilla agroforestry land and cocoa plants which are usually accompanied by protection plants, carbon sequestration decreased by 275.89 kg ha\(^{-1}\) and 292.81 kg ha\(^{-1}\) respectively, while the research results, the conversion of natural forests into rubber agroforestry caused carbon loss of 290 kg ha\(^{-1}\) and when converted to sengon HTI around 370 kg ha\(^{-1}\) (Tomich \textit{et al.} 1998 in 25).

Emission trends up to 2080 show that net emissions always have a higher value in each period compared to scenario 1 and scenario 2 (Figure 5). Scenario 1 produces carbon sequestration of 16 million t CO\(_2\) eq. t ha\(^{-1}\), while scenario 2 is + 40 million t CO\(_2\) eq. t ha\(^{-1}\). Thus scenario 2 is more effective in reducing emissions and increasing carbon sequestration.

![Figure 5](image)

**Figure 5** Emission trend up to year 2080 base on net emission, scenario 1 and scenario 2 on ex-tin mining land in Bangka Belitung Province

### 3.7. Carbon budget

Carbon budget is a balance of carbon transfer from one carbon pool to another in a carbon cycle, for example between the atmosphere and biosphere and soil (21). The results of the carbon balance calculation showed that there had been a decrease in carbon stocks of 29,564,038.1 t C or 6.28% of the original carbon stock (in 2000) sourced from land and plants in the period 2000 - 2013 (Table 10). Emissions that occurred in that period were 10,136,815.3 t CO\(_2\) eq. (or 2,764,586.0 t C) and the predicted sequestration in the period 2013-2040 is 8 million t CO\(_2\) eq. (or 2,181,818.0 t C) for scenario 1 and 32.5 million t CO\(_2\) eq. (or 8,863,636.0 t C) for scenario 2.

| Table 10 | Carbon balance/budget on ex-tin mining land in Bangka Belitung Province in the period 2000 – 2013 |
|-----------|-------------------------------------------------------------------------------------------------|
| Carbon storage | 2000 | 2013 | 2000 - 2013 | Note |
| Carbon stock | (t C) | (t C) | (t C) | (%) |
| Soil | 371,978,939.4 | 352,471,976 | 19,507,141.0 | 5.24 | reduction |
| Plant | 98,759,328.1 | 88,702,431.8 | 10,056,896.3 | 10.18 | reduction |
| Amount | 470,738,277.5 | 441,174,229.4 | 29,564,038.1 | 6.28 reduction |
|--------|---------------|---------------|---------------|----------------|
| Emission ** | 2,764,586.0* | -             |               |                |
| Sequestration ** | 2013-2040 |                |               |                |
| Scenario 1 | 2,181,818.0  | 8.00 Presentage |               |                |
| Scenario 2 | 8,863,636.0 | 26.97 from BAU emission | | |

Note: * with below ground emission from peatlands, **BM C/BM CO$_2$ x t CO$_2$ eq.

4. Conclusion
The tin mining area in Bangka-Belitung Province is spread in almost all districts and the dominant ones are in Bangka, West Bangka and East Belitung Regencies. In the period from 2000 to 2013 there was an expansion of the tin mining area in the province covering an area of 22,650 ha or 28.43% of original mining area.

The mining area mostly occurs in the Secondary Dry Land Forest, which is as much as 8,480.44 ha (37.45% of the total mining area) and Shrub as much as 8,442.55 ha (37.29% of the total mining area). Tin mining area expansion causing a decrease of 19,507,141.84 t C stock of soil (5.24%) and 10,056,896.28 t plant C-stock (10.18%) and emissions (source from plant only) of 36,908,808 t CO$_2$ eq. for 13 years.

There are two scenarios we propose to reduce emission: scenario 1 avoid the opening of primary forest, primary and secondary swamp forests, and reclaim 80% of the tin mined land area by planting perennial crops such as plantation/estate crops or industrial forest. Scenario 2, equals scenario 1 plus a reduction in the rate of secondary forest clearing for various uses by 50%.

The predicted emissions for the 2013-2040 period are 120,000,000 t CO$_2$ eq. Scenario 1 will potentially able to reduce emissions by 8% and carbon sequestration by 8,000,000 t CO$_2$ eq. and scenario 2 reduced emissions by 26.97% with carbon sequestration 32,500,000 t CO$_2$ eq.

5. References
[1] Tanpibal Vand Sahunalu P 1989 Characteristics and management of tin mine tailing in Thailand J Soil Technology (2) 17-26
[2] DubeyK, Singh V K, Mishra C M and Kumar A 2006 Use Of Biofertilizer For Reclamation Of Silica Mining Area Symp. Billings Land Reclamation
[3] Simarmata T 2007 Revitalisasi Kesehatan Ekosistem Lahan Kritis Dengan Memanfaatkan Pupuk Biologis Mikoriza Dalam Percepatan Pengembangan Pertanian Ekologis Di Indonesia J VISI 15 (3) 289 – 306
[4] Dariah A, Abdurachman A and Subardja D 2010 Reklamasi Lahan Eks-Penambangan untuk Perluas Areal Pertanian J Sumberdaya Lahan 4(1) 1-12
[5] Setiawaty P, Susi 2012 Valuasi Ekonomi Pertambangan Selaras Lingkungan Lestari Studi Kasus : Pertambangan Emas Pongkor J Green Growth dan Manajemen Lingkungan 1 (December edition) 49 - 60
[6] Sukarman and Husnain 2016 Karakteristik Lahan Bekas Tambang dan Permasalahanannya di Bangka Belitung dan Pulau Buru ed Pasandaran et al (Jakarta : IAARD Press) pp 54 – 71
[7] Sukarman and Agustian A 2016 Survai Pemetaan Lahan dan Analisis Sosial Ekonomidi Bekas Tambang (Bogor: Laporan Akhir Rencana Operasional Penelitian Balai Besar Litbang Sumberdaya Lahan Pertanian)
[8] Sukarman and Gani R A 2017 Lahan Bekas Tambang Timah di Pulau Bangka dan Belitung, Indonesia dan Kesesuaiannya untuk Komoditas Pertanian J Tanah dan Iklim 41 (2) 21-33
[9] Subardja D, Kasno A and Suryani E 2010a Teknologi Pemulihan Lahan Bekas Tambang Timah untuk Pertanian di Bangka Belitung Proc Seminar Nasional Teknologi Pemupukan dan Pemulihan Lahan Terdegradasi (Jakarta: Badan Penelitian dan Pengembangan Pertanian) pp 369-382
[10] Subardja D, Kasno A, Sutono and Sosiaawan H 2010b Identifikasi dan karakterisasi lahan bekas tambang timah untuk pencetakan sawah baru di Perlang, Bangka Tengah. Proc Seminar Nasional Sumberdaya Lahan Pertanian (Bogor) pp 109 -122
[11] Subardja D, Kasno A, Sutono 2012 Teknologi pencetakan sawah pada lahan bekas tambang timah di Bangka Belitung Proc Seminar Nasional Teknologi Pemupukan dan Pemulihan Lahan Terdegradasi ed Wigena et al (Bogor: Badan Penelitian dan Pengembangan Pertanian) pp111-122
[12] Asmarhansyah, Rusmawan D and Muzammiil 2012 Soil chemistry and yield of maize as influenced by different levels of fertilizer in ex-tin land Central Bangka, Kepulauan Bangka Belitung Int Maize Conference Agribusiness of Maize- Livestock Integration (Gorontalo ) pp 205 – 208
[13] Asmarhansyah 2015 Characteristic of physical and chemical properties of former-tin mining areas for crop production in Bangka Island Proc.Nasional Sistem Informasi Dan Pemetaan Sumberdaya Lahan Mendukung Swasembada Pangan ed Rejkiningrum et al (Jakarta: Badan penelitian dan pengembangan pertanian) pp 181-190
[14] Donatoa D C, Kauffmanb J B, Murdiyarso D, Kurnianto S, Stidhamd M and Kanninen M 2012 Mangroves among the most carbon-rich forests in the tropics Nature geoscience vol 4 pp 293-297
[15] Yin, Ming L, Zhen-fang Z and Xing M 2009 Study on incentive mechanisms of coal green mining J Procedia Earth and Planetary Science 1 211–218
[16] Sari D P, Buchori I 2015 Efektivitas Program Reklamasi Pasca Tambang Timah Di Kecamatan Merawang Kabupaten Bangka J Pembangunan Wilayah & Kota 11(3) 299-312
[17] Dong-sheng Z, Wei F G, Li-qiang M, An W and Yu-de L 2009 Harmony of largescale underground mining and surface ecological environment protection in desertdistrict - a case study in Shendong mining area, northwestern of China Procedia Earth and Planetary Science 1 pp 1114–1120
[18] Balai Pemantapan Kawasan Hutan (BPKH) 2000 Peta tutupan Lahan Indonesia skala 1:250.000 (Jakarta: Dirjen Planologi Kehutanan dan Tata Lingkungan. Kementrian Lingkungan Hidup dan Kehutanan)
[19] Balai Pemantapan Kawasan Hutan (BPKH) 2013 Peta tutupan Lahan Indonesia skala 1:250.000 (Jakarta: Dirjen Planologi Kehutanan dan Tata Lingkungan Kementrian Lingkungan Hidup dan Kehutanan)
[20] ICRAF 2015 Abacus REDD module / software. ICRAF. Bogor
[21] Agus F, Hairiah K, Mulyani A 2011 Petunjuk Praktis Pengukuran Cadangan Karbon Tanah Gambut (Bogor : ICRAF- BBSDLP) p 58
[22] Widiatmaka, Ardiansyah Mand Ambarwulan W 2012 Perubahan Cadangan Karbon Organik Tanah Dalam Konteksks Perubahan Penggunaan Lahan Selama 2 Dekade: Studi Kasus Kabupaten Bogor, Provinsi Jawa BaratJ Globe 14 (2) 170 - 177
[23] Agus F, Santosa I, Dewi S, Setyanto P, Thamrin S, Wulan Y C,Suryaningrum F 2014 Pedoman Teknis Perhitungan Baseline Emisi dan Serapan Gas Rumah Kaca Sektor Berbasis Lahan Buku I Landasan Ilmiah (Jakarta: Badan Perencanaan Pembangunan Nasional Republik Indonesia)
[24] Simanjuntak B H 2005 Studi Alih Fungsi Lahan Hutan Menjadi Lahan Pertanian Terhadap Karakteristik Fisik Tanah Studi Kasus DAS Kalitundo, Malang J AGRIC 18 (1) 85-101
[25] Monde A, Sinukaban N, Murtialaksono K and Pandjaitan N 2008 Dinamika karbon (C) Akibat Alih Guna Lahan Hutan Menjadi Lahan Pertanian J Agroland 15 (1) 22 – 26
[26] Monde A 2009 Degradasi Stok Karbon (C) Akibat Alih Guna Lahan Hutan Menjadi Lahan Kakao Di DAS Nopu, Sulawesi Tengah J Agroland 16 (2) 110 - 117
[27] Hanafi N, Bernardianto R B 2016 Pendugaan Cadangan Karbon Pada Sistem Penggunaan Lahan di Areal PT. Sikatan Wana Raya (Palangkaraya: Jurnal Kehutanan Faperta Univ. PGRI Palangka Raya dan Jurusan Pendidikan Geografi FKIP Univ. PGRI Palangka Raya)
[28] Rusdiana O and Lubis R S 2012 Pendugaan Korelasi antara Karakteristik Tanah terhadap Cadangan Karbon (Carbon Stock) pada Hutan Sekunder J Silvikultur Tropika 03 (01) 14 – 21

[29] Qirom M A, Lazuardi D and Kodir A 2015 Keragaman Jenis dan Potensi Simpanan Karbon Hutan Sekunder di Kotabaru Kalimantan Selatan J Indonesian Forest Rehabilitation 3 (1) 49-66

[30] Jones T G, Ratsimba H R, Ravaoaarorotsihoarana L, Cripps G and Bey A 2014 Ecological Variability and Carbon Stock Estimates of Mangrove Ecosystems in Northwestern Madagascar. J Forests 5(1) 177-205

[31] Haryati U 2010 Peningkatan Efisiensi Penggunaan Air Untuk Pertanian Lahan Kering Berkelanjutan Melalui Berbagai Teknik Irigasi Pada Typic Kanhalpludult Lampung (Bogor: Sekolah Pascasarjana Institut Pertanian Bogor) p 131

[32] Supriyadi S 2008 Kesuburan Lahan Kering Madura J Embryo 5 (2) 124 – 131

[33] Supriyadi S 2008 Keragaman Jenis dan Potensi Simpanan Karbon Hutan Sekunder di Kotabaru Kalimantan Selatan J Embryo 5 (2) 176 – 183

[34] Hartatik W, Wibowo H, Purwani J 2015 Aplikasi Biochar dan Tithoganic dalam Peningkatan Produktivitas keladi (Glycine max L.) pada Typic Kanhalpludult Lampung Timur J Tanah dan Iklim 39 (1) 51- 62

[35] Haryati U, Surono, Tala'ohu S H and Subagyo K 2016 Peranan Mulsa Untuk Efisiensi Penggunaan Air Tanaman Cabai (Capsicum annum) Dengan Berbagai Teknik Irigasi pada Typic Kanhalpludult Lampung Timur Jurnal Tanah dan Iklim 43 (2): 123-134

[36] Haryati U, Supriyadi S, Subikoja I G M 2019 Pengaruh Amelioran terhadap Perbaikan Sifat Tanah dan Produksi Cabai Rawit (Capsicum frutescens) pada Lahan Bekas Tambang Timah. Jurnal Tanah dan Iklim 36 (2) 70 – 93

[37] Rahayu A, Utami S R, Rayes M L 2014 Karakteristik dan Klasifikasi Tanah pada Lahan Kering dan Lahan yang Disawahkan di Kecamatan Perak Kabupaten Jombang J Tanah dan Sumberdaya Lahan 1 (2) 79-8

[38] Suprayogo D, Widianto, Purnomosidi P, Widodo, Rusiana F, Aini Z Z, Khasanah Nand Kusuma Z 2004 Degradasi Sifat Fisik Tanah Sebagai Akibat Alih Guna Lahan Hutan Menjadi Sistem Kopi Monokultur: Kajian Perubahan Makroporositas Tanah J Agrivita 26 (1) 60-67

[39] Haryiah K, Suprayogo D, Widianto, Berlian, Suhara E, Mardiastuning A, Widodo R H, Prayogo C and Rahayu S 2004 Alih Guna Lahan Hutan Menjadi Lahan Agroforestri Berbasis Kopi : Ketebalan Seresah, Populasi Cacing Tanah dan Makro Porositas Tanah. J Agrivita 26 (1) 68-80

[40] Siringoringo H H 2007 Potensi Simpanan Karbon Pada Jenis Tanah Acrisols dan Ferralsols di Hutan Tanaman Acacia mangium Willd. dan Shorea leprosula Miq. Kabupaten Bogor J Penelitian Hutan dan Konservasi Alam 1V (5) 511-530

[41] Haryiah K, Dewi S, Agus F, Velarde S, Ekadinata A, Rahayu S and Noordwijk M V 2011 Measuring Carbon Stocks Across Land Use Systems: A Manual (Bogor: ICRAF) p 154

[42] IPCC (Intergovernmental Panel on Climate Change) 2013 Drained inland organic soils, Chapter 2 in Wetland Supplement of IPCC Good Practice Guidelines (Hayama: IPCC, IGES Institute for Global Environmental Strategies)

[43] Bismark M, Subiandono E, and Heriyanto N M 2008 Keragaman Dan Potensi Jenis Serta Kandungan Karbon Hutan Mangrove di Sungai Subelen Siberut Sumatera Barat J Penelitian Hutan dan Konservasi Alam 3 297-306
[45] Balai Pemantapan Kawasan Hutan (BPKH) 2015 *Peta tutupan Lahan Indonesia skala 1:250.000* (Jakarta: Dirjen Planologi Kehutanan dan Tata Lingkungan Kementrian Lingkungan Hidup dan Kehutanan)

[46] Hairiah K, Rahayu S 2007 *Pengukuran Karbon Tersimpan di Berbagai Macam Penggunaan Lahan* (Bogor : ICRAF)

[47] Purba K D, Riswan R 2013 *Pendugaan Cadangan Karbon Above Ground Biomass (AGB) pada Tegakan Sawit (Elaeis guineensis Jacq.) di Kabupaten Langkat* (Sumatera Utara: Program Studi Kehutanan, Fakultas Pertanian, Universitas Sumatera Utara) pp 39-46

[48] Setyawan A D and Winarno K 2006 *Pemanfaatan Langsung Ekosistem Mangrove di Jawa Tengah dan Penggunaan Lahan di Sekitarnya; Kerusakan dan Upaya Restorasinya* *J Biodiversitas* 7(3) 282-291