Lesson Learned from Belitung Mangrove Park: Converting Inactive Tin Mining Area to Mangrove Tourism Park to Support Ecosystem Rehabilitation and Carbon Sequestration

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Abstract. Unconventional tin mining is devouring coastal forest and mangrove in Belitung Island. Thus, carbon emission from deforestation, loss of biodiversity, and increasing vulnerability of coastal communities are inevitable. TERANGI together with ICCTF initiated Belitung Mangrove Park (BMP) to convert inactive tin mining in Seberang Bersatu Community Forest, Belitung, into a mangrove tourism park. Local community were trained in ecotourism management, mangrove rehabilitation, ecosystem monitoring, tour guiding, promotion, and financial management. The total carbon stock in Juru Sebrang Community Forest equalled to 4,704.159 tonnes with unequal distribution. Mangrove rehabilitation was conducted over a 1.5 ha with current carbon stock of 3 tonnes. In order to support low-carbon ecotourism activities, two solar power electric generator were installed and able to reduce emissions of 872 kg CO\text{2}/year. The local community was able to develop, promote, and manage ecotourism activities independently, and increased their group assets, from IDR 698,014,118 to IDR 18,655,700,000 just within 18 months. Tourist visits increased from around 3,000 visits/month to 14,000 visits/month. The programme also involved stakeholders from programme development, area management plan, and research and monitoring, thus increasing the participation and supports from both the local and national stakeholders. The programme success and lesson-learned could also be replicated in other areas.

1. Introduction
Based on Statistic Indonesia[1], Bangka Belitung Province produced 15,403.86 tonnes of tin in 2013 alone, which decreased significantly from 47,723.20 tonnes in 2008. Such data did not reflect the true condition of tin mining in Bangka Belitung, since the source of data is PT. Timah, Tbk. According to Aspinal [2], the policy from PT. Timah Tbk, of giving permit to local people to mine from their previous concessions backfired, making their production declined, and gave rise to illegal and/or unconventional mining that produced around 42,000 tonne of tin. IDH Tin Working Group [3] estimates that the true production from Bangka Belitung is around 106,000 tonnes from various sources. The mining actually began from land but continued to coastal areas, devouring protected forest and marine ecosystems [4][5][6][7].

Beger et al. [8] considered Belitung Island as a conservation priority area within the coral triangle. Belitung Island has good representation of coastal ecosystem, such as coral reefs, sea grass beds, mangrove and coastal forest [8]. It is also an important area for fish spawning aggregation. Belitung Island is also an important nesting and feeding grounds for green turtles and hawksbill turtles [9]. Beger et al. [8] also considered that this area is important for mitigation of climate change. One of the important coastal ecosystems for climate change mitigation available in Belitung Island is mangrove and coastal forests. They provide important ecosystem goods and services to nature and society, and in
recent years, the carbon sequestration potential and protective role of mangrove forests from natural disasters is being highlighted as an effective option for climate change adaptation and mitigation [10]. Donato et al. [11] have also established that mangroves are among the most carbon-rich forests in the tropics. Sadly, there is an extensive land conversion from forest to tin mine in Belitung Island [7].

Mangrove and coastal forests in Juru Seberang Village situated in Belitung Island, has experienced similar problem. Mining started in the early 2000’s and in 2015 the Ministry of Environment and Forestry assigned the mangrove and coastal forest of Juru Sebrang Village as a community forest, where the local community have the rights to manage and utilise the resources in that particular area. Based on the Ministerial Decree no SK.79/MenLHK-II/2015, the community forest covers a 757 ha of coastal area. Local community formed a group named HKm Seberang Bersatu in order to manage the particular area and rehabilitate the mangrove and coastal forests. Inside the community forest, Yayasan TERANGI developed Belitung Mangrove Park (BMP) which is a land-based climate change mitigation strategy through mangrove rehabilitation of a former tin mining area and hence promoting ecotourism.

2. Method

Juru Seberang Community Forest is located in Belitung District, Belitung Island. It is geographically situated at 2.763455°S and 107.606039°E. The map of study area is shown in Figure 1.

Figure 1. Juru Seberang Community Forest.

The first step was assessing the carbon stock in HKm Seberang Bersatu. Ground-based vegetation analysis was conducted in 63 sampling plots, of size 15 x 15 m² each. The ground-based biomass data of 4 carbon pools (barks, branches, leaves, and roots) were collected. Biomass was assumed from 46% of dried weight Error! Reference source not found.. The allometric equation used was based on Komiyama Error! Reference source not found., which take into account the wood density difference between species. Landsat 8 OLI TIRS Imagery acquired at date 2016-08-24 and time 02:55:06, path no = 122 and row no = 62 were used. Images were then analysed using SAGA GIS 2.3.2 and ArcGIS 10.5. OLI band data was then converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). The ground-based vegetation analysis data were then divided into two sets, the first set (34 sampling plots) were used to develop regression models of vegetation indices and carbon stocks of each pixel and the second set (20 sampling plots) were used for accuracy testing, while 9 plots were omitted due to sampling errors.
Each vegetation index vs. ground carbon stock model was then evaluated for correlation coefficient ($R^2$), where the highest would be used for predicting the total carbon stock of Juru Sebrang Community Forest.

The next step was community-based mangrove rehabilitation. The community members of HKm Seberang Bersatu were given training in mangrove rehabilitation. Based on the previous carbon stock mapping, areas with low carbon stock were plotted as priority rehabilitation areas, while areas with high carbon stock were plotted as the seed sources. All the seeds were acclimated in a nursery prior to be planted directly in the rehabilitation area. The species selected were *Rhizophora* spp., *Bruguiera* spp., *Terminalia catappa*, and *Casuarina equisetifolia*.

![Figure 2. Process in determining rehabilitation and seed collection areas (top), seed collection (bottom left), and mangrove nursery (bottom right).](image)

The community members were trained in ecotourism through a series of trainings, which included coastal ecosystem monitoring, ecotourism development and management, financial management for small scale enterprise, tourism product diversification, and conservation [15][16]. In order to support ecotourism activities, tourism facilities were also developed, such as solar-powered information centre (2400 watt per day), mangrove trek, solar powered watch tower (1200 watt per day), information panels, and sanitation facility.
3. Results

3.1. Carbon stock assessment

The density of trees in Juru Sebrang Community Forest is 571 individuals/ha and the species with the highest density was *Rhizophora apiculata* with 266 trees/ha. The mangrove condition is considered as degraded according to the Indonesian Standard for Mangrove Quality. The average aboveground biomass was 14.09 tonnes/ha while the average aboveground carbon stock was 6.62 tonnes/ha. The highest carbon stock was 32.756 tonnes/ha. The biomass was not distributed equally, the area near the coastline and ex mine pools had very low carbon stock (0 – 6 tonnes/ha) while difficult to reach areas tend to have higher carbon stocks. Based on the regression analysis of vegetation indices and carbon per pixel using Difference Vegetation Index (DVI), Normalized Difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Normalized Ratio Vegetation Index (NRVI), Transformed Vegetation Index (TVI), Corrected Transformed Vegetation Index (CTVI), Thiam’s Transformed Vegetation Index (TTVI), and Soil Adjusted Vegetation Index (SAVI), it is known that DVI gave the highest R² value of 64.59%, while other ranges from 59.79 to 60.19%

Based on that result, the DVI was then used for predicting the carbon stock value for Juru Seberang Community Forest. There were 31424 valid cells of data in Juru Seberang Community Forest covered by Landsat 8. The minimum carbon stock value was 0 tonne/pixel, while the maximum value was 0.503 tonnes/pixel. The mean value of carbon stock was 0.149 tonnes/pixel with standard deviation of 0.102 tonnes/pixel. The distribution of carbon stock is shown in Figure 3.

![CARBON STOCK DISTRIBUTION MODEL OF JURU SEBERANG COMMUNITY FOREST 2017](image)

**Figure 3.** Distribution of carbon stock in Juru Seberang Community Forest.

The total carbon stocks in Juru Seberang Community Forest was 4,704.158 tonnes with root means square error of ±5.813 tonnes/ha. Based on the calculation, Juru Seberang Community Forest is classified as very low carbon stock area. The mined area showed the lowest carbon stock, implying
that mining activities had severe consequences towards forest ecosystem in that particular area. Results from the image analysis were in line with field observations, where areas near the beach and other mined areas had lower carbon stocks. According to Error! Reference source not found., the below ground carbon stock for secondary mangrove forest was between 28.8 - 174.4 tonnes carbon/ha, hence the total below ground carbon stock in HKm Seberang Bersatu was Min = 28.8 x 757 = 21,801.6 tonnes carbon and Max = 174.4 x 757 = 132,020.8 tonnes carbon. Therefore, the total carbon (above and below ground) were between 26,505.758 – 136,724.958 tonnes carbon.

3.2. Mangrove rehabilitation
A total of 15,000 seedlings were planted with plantation distance of 1 x 1 m based on [18], and thus the total rehabilitated area was 1.5 ha. Species planted include Rhizopora apiculata, R. mucronata, Bruguiera gymnorrhiza, Nypa fruticans, and Terminalia cattappa. The rehabilitation area was selected based on the low carbon area suggested by the carbon stock model. For the first year, 1.5 ha of seedlings contributed to 3 tonnes of CO₂ equivalent with assumption of 2 tonnes CO₂-equivalent/ha.

3.3. Ecotourism
The local communities were able to develop several ecotourism activities that have increased the total monthly visits from between 3 to 4 thousand to 14 thousand tourists. Activities developed including mangrove trekking, river tracking, bird watching, bedulang feast (culinary from sea food from aquaculture), and excursion study. More incomes were generated due to ticketing for mangrove trekking. The local communities were also able to create selfie spots to increase site attractiveness. They were also able to increase their group assets, from IDR 698,014,118 to IDR 18,655,700,000 in just 18 months. Solar energy in the information centre and the watch tower was sufficient to support most ecotourism activities and monitoring in BMP. Solar power also provided emissions reduction of 872 kg CO₂/year.
Figure 5. Mangrove trekking and river tracking (top) developed by the members of HKm Seberang Bersatu that has increased the total monthly visits.

4. Discussion

4.1. Carbon stock assessment

Even though it has been years after tin mining was closed, the vegetation has not recovered. Nurtjahya [19] observed that, in Bangka Island, tin mining decreases soil quality and changed the content of the sand to 97%. Further research by [20] also found that the water and sediments from the second step brought acidic substances that gave negative effect towards soil flora and fauna. Therefore, the effect of mining was still visible from both ground surveys and satellite imageries. Based on the results, vegetation indices could be used to estimate carbon stocks in HKm Seberang Bersatu. Similar conclusion was also obtained by [21], where EVI and TVI had the correlation coefficient of 72 and 63% respectively. This study however, found that DVI performed better than any other indices, including NDVI, even though it was the most used vegetation index for spatial ecology [22]. DVI performed better for estimating vegetation cover in sparsely vegetated areas.

Reference source not found. Juru Sebrang Community Forest is a degraded forest with only 571 trees/ha, and since the trees grew sparsely, DVI could performed better than other indices.

4.2. Mangrove rehabilitation

Belitung is more arid than Java, thus during the month of September and October 2017, there were no rain for several weeks. Therefore, some of the seedlings could not survive. Previously in the planning, it was assumed that the rainy season would start from September, and hence provided fresh water and shading to the seedlings. The use of polybags in the nursery has added stress to the seedlings. A polybag is thin and hence allowed the seedling roots to penetrate through and settled on the substrate in the nursery. While transporting the seedlings to the rehabilitation area, the roots were injured, and
thus reduced plant fitness. The use of polybags should be replaced with harder containers, such as plastic cups, so that the plant roots would not be injured.

4.3. Ecotourism
The increase of visit can be attributed to two factors, the availability of various ecotourism activities and better management of tourism site. These factors were achieved through several consideration based on the Department of National Parks, Sport, and Racing[24].

Since the management was performed by the local community, Yayasan TERANGI has facilitated the development of the park management plan using participatory prospective analysis that ensure long-term community partnership and economic benefits [25][24]. During this process, the local community identified and analysed key variables and developed scenarios and actions needed to address each scenario [26][27]. They developed sites layouts, designed that blended into the landscape, and construction that was also simple and had minimal impacts towards the environment [24]. There is a current trend that tourists tend to be selfie tourists [28]. Therefore, by establishing selfie spots, the local community had attracted more tourists than the previous years.

Solar power was sufficient for supporting information centre activities, such as display, information and announcement, entertainment, and administration. The watch tower was also used for monitoring illegal tin mining activities, and the energy generated was enough for lighting and communication. In addition, since solar power gave little emission, this approach could be replicated in other tourism activities/sites.

5. Conclusion
This study concluded that forest is in degraded state due to mining, where the carbon stock is very low. The distribution of carbon stock was not equal to the areas near the coastline and ex mines where they were the most degraded. Differential Vegetation Index gave the highest correlation coefficient for sparsely vegetated area. Mangrove rehabilitation need to focus on low carbon area based on carbon stock distribution model. Finally, community support is an essential part of the programme and financial sustainability.

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