RESEARCH ARTICLE

Sustainability of mangrove forest management in the former bauxite mining area on Bintan Island [version 1; peer review: 1 approved with reservations]

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Abstract

Background : The bauxite mining area on Bintan Island continues to expand into the mangrove forest area. Mangrove forests have ecological, economic, and social importance, which must be managed accordingly to maintain their sustainability. This research was conducted to examine the sustainability of mangrove forest management in the former bauxite mining area on Bintan Island.

Methods: The approach used is Multi Dimensional Scaling- Rapid Appraisal for Sustainability through the modified Rapfish ordinance software technique for the Mangrove Ecosystem. The type of data used is quantitative, covering five dimensions of sustainability, namely ecological, economic, social, legal and institutional as well as technology.

Results: The results showed that the sustainability index status of the ecological, social, legal and institutional dimensions was quite sustainable, while the sustainability index of the economic dimension was unsustainable, and the technological dimension was less sustainable. Attributes of levers that are sensitive to the sustainability of mangrove forest management are: 1) Mangrove density, 2) Substrate fraction, 3) sedimentation, 4) Mangrove importance index, 5) Bio-concentration factor, 6) Benefit value direct, 7) Indirect benefit value, 8) Dependence on mangrove forest as a source of livelihood, 9) Corporate Social Responsibility funding support, 10) Community income, 11) Community health level, 12) Community perception, 13) Legality of mangrove area and mining, 14) Pollution monitoring technology in ex-mining areas and 15) Mangrove rehabilitation technology.

Conclusions: The status of the mangrove forest sustainability index on Bintan Island is quite good. the economic and

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technological dimensions can be upgraded to sustainable status by carrying out management that is more focused on the lever attributes of the ecological, social, legal and institutional dimensions.

Keywords

Bintan Island, bauxite mine area, mangrove forest, sustainability

This article is included in the **Ecology and Global Change** gateway.

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Introduction

Bintan Island in the Riau Archipelago Province of Indonesia has a high potential for bauxite extraction. This particular advantage has encouraged many mining entrepreneurs, both local and foreign, who are interested in exploiting bauxite. The highest production was reported from 2001 to 2019 with an estimated 1.6 million metric tons extracted per year.¹ Bauxite mines that are still operating legally or illegally can be found in Tanjungpinang City and Bintan Regency, such as those in Koyang Island, Wacopek Village, and Tembeling. Land clearing for mining continues to expand into limited production forests and conservation forests, including mangrove forests.² It has been reported that in general, the bauxite mining activities on Bintan Island have not been carried out according to good mining practices, both during operation and post-mining. Although some mining activities have already stopped, the environmental damage sustained from these activities can still be observed in many ex-mining areas, especially the affected mangrove area in the coastal area of Bintan Island. There has been no effort to reverse the damage done to the mangrove forest around the mining site. Until now, only PT. Antam is the only mining company that carries out post-mining activities via reclamation and revegetation in the Bintan Regency, as well as corporate social responsibility (CSR) programs to restore the disturbed environment and accelerate the economic independence of communities around ex-mining areas.² However, all these activities are still limited to land areas, while mangrove forest restoration has still not been carried out optimally. The government has restored damaged mangrove areas through mangrove rehabilitation in collaboration with universities and private companies. However, they often experience growth failure.³ Consequently, there are still many areas of unrestored mangrove forest that have been damaged and lost due to bauxite mining. According to the Central Bureau of Statistics of the Riau Archipelago Province,⁴ there have been around 90 hectares of mangrove land in Tembeling District since 2010, which have been damaged due to land clearing for bauxite mining and have not been rehabilitated after the end of their operations. This condition has persisted for years. If left unchecked, the impact will not only result in ecological losses but also disturb the economic and social values of the people who depend on the existence of mangroves.

The existence of mangrove forests needs to be optimized so that they can continue to function as spawning grounds for fish, land protectors, a barrier to abrasion by waves and strong winds, filters for seawater entering the land, wildlife habitats, bird migration sites, and even helps in phytoremediation of heavy metal content and filtration of pollutants.⁵⁻⁷ Given that the benefits and functions of mangroves do not only present the ecological value but also the economic and social values, maintaining, preserving, and revitalizing the functions of the mangrove ecosystem around the former bauxite mining area must be carried out through a multidimensional approach. The mangrove ecosystems around the former bauxite mining area can only continue to function if the forest is maintained. Therefore, this study aimed to analyze the sustainability of mangrove forest management around the ex-bauxite mining area in Bintan Island on a multidimensional basis. It is hoped that the mangrove forests can restore the damaged environment in the former bauxite mining area and become a resource with multiple values for the residents of Bintan Island.

Methods

Location of study

The research was carried out from June to November 2021 in Bintan Regency (Tembeling Tanjung and Wacopek Villages) and Tanjungpinang City (Senggarang Village and Air Raja Village) as presented in [Figure 1](#). The location of the former bauxite mine is visible with reddish-yellow land openings with Mangrove ecosystem still found around the area.

Data collection

The data used in this study include primary and secondary data. Primary biophysical data were obtained directly through field observations, while economic, social, institutional, and technological data were obtained using a Focus Group Discussion (FGD) involving 17 respondents. The selection of key respondents was carried out using a purposive sampling technique, namely experts in the field such as the village head/Lurah, community leaders, community organizations, and the government. Secondary data were obtained from the Tanjungpinang City Government, Bintan Regency, and related literature. The dimensions and attributes of the analysis on the sustainability of mangrove forest management on Bintan Island are presented in [Table 1](#).

Data analysis

Sustainability analysis was carried out via the MDS (multidimensional scaling) approach using the software RAPFISH (Rapid Appraisal for Fisheries) 1.0⁸ which was modified into RApMEc (Rapid Appraisal for Mangrove Ecosystem) to evaluate the sustainability of mangrove forests in multidimensionality. The sustainability index value of each dimension can be visualized in the form of a kite diagram and analyzed multidimensionally to determine the point or position of the sustainability of mangrove forest management. The grouping of sustainability index values is presented in the range of 0 (bad) to 100 (good), which consists of 0-25 (bad), 25-50 (poor), 51-75 (enough), and 76-100 (good).⁹ Leverage analysis was used to determine the leverage factor while Monte Carlo analysis was used to see the effect of errors in the scores of each attribute.¹⁰

Figure 1. Map of research sites on Bintan Island.

Table 1. Dimensions and attributes of mangrove sustainability.

Dimension	Attributes
Ecology	(1) The level of water pollution ^{6,7} ; (2) Environmental pollution load ^{7,8} ; (3) Metal Geoaccumulation Index ^{7,9} ; (4) Substrate fraction ⁷ ; (5) Sedimentation rate ⁸ ; (6) Mangrove density level ⁶ ; (7) Bioconcentration of heavy metals in mangroves ¹⁰ ; (8) The level of health of mangrove forests ¹¹ ; (9) Important Value Index ¹²
Economy	(1) Community income ¹³ ; (2) Dependence on mangrove ecosystems as a source of livelihood ¹³ ; (3) The value of direct benefits of mangroves ¹⁴ ; (4) The value of indirect benefits of mangroves ¹⁴ ; (5) CSR funding support ¹⁴
Social	(1) Knowledge of mangroves ¹⁵ ; (2) The level of public health around the ex-mining area ¹⁸ ; (3) Potential social conflict in the use of mining land around mangrove forests ¹⁷
Law and Institutional	(1) Availability of management regulations ¹⁷ ; (2) Institutional ¹⁷ ; (3) Involvement of community institutions ¹⁷ ; (4) The legality of mangrove areas ^{14,17} ; (5) Law enforcement ¹⁴
Technology	(1) Mangrove rehabilitation technology ¹⁴ ; (2) Monitoring technology for environmental pollution in ex-mining areas ^{14,18}

Results and discussions

Environmental conditions of the former mining area on Bintan Island

Bauxite mining activities on Bintan Island have continued to grow, reaching 1.1 million metric tons in 2013 and 1.6 million metric tons in 2019.¹ The general characteristics seen in ex-bauxite mining areas include severe land damage, missing soil layers, and a soil structure, texture, and density that does not support the development of root systems, thereby interfering with plant growth.¹¹ Pollutants detected in bauxite mines on Bintan Island typically include minor elements, namely Fe and Mn. In addition, the trace elements found in the area include Cu, Cr, Cd, Pb, Ni, and Zn. The reported values obtained from the analysis of metal contents in the area indicated non-compliance with the environmental quality standard.¹² The results from the previous study¹³ showed that the environmental conditions around the former bauxite mining area on Bintan Island are not polluted but have been contaminated with heavy metals from mining activities. The conclusion was derived based on the Pollutant Load Index (PLI) value which was <1 for Pb and Cr, and the Geo-Accumulation Index (I_{geo}) which was $0 < I_{geo} < 1$ for Pb and Cr. On the other hand, it was reported that the sediment fraction in Karang River, Tanjungpinang City is dominated by sand (74.65-97.7%), while the Tembeling Tanjung and Wacopek in Bintan Regency are dominated by gravelly sand to slightly gravelly sand.¹⁴

Mangrove biophysical condition

The survey¹³ found 11 mangrove species at the site, namely *Avicennia alba*, *A. marina*, *Rhizophora apiculata*, *R. mucronata*, *Ceriops tagal*, *Bruguiera gymnorhiza*, *B. cylindrical*, *Sonneratia alba*, *Xylocarpus granatum*, *X. mollucensis*, and *Lumnitzera littorea*. The most dominant species were *R. mucronata*, *R. apiculata*, and *A. marina* with mangrove density values classified as moderate (1300 trees/Ha) to damaged (678 trees/Ha). Assessment of the damage level in mangrove trees revealed that 43.5% of the trees in the samples were found damaged with the remaining 56.5% found as healthy. The mangrove tree species with the largest Significance Index determined in the tree, sapling, and seedling strata was *R. mucronata*.

Based on the results from a study,¹³ the accumulation of heavy metal, Pb, in the sediment was found between 0.06 and 0.24 ppm. Besides, the concentration of Pb found in the leaves of *R. mucronata* was between 0.04 and 0.37 ppm, 0.05-0.71 ppm in the stems, and 0.08-0.87 ppm in the roots. On the other hand, the concentration of Cr in sediment was found between 0.01 and 0.04 ppm, with the concentration of Cr in the leaves of *R. mucronata* found between 0.02-0.09 ppm, 0.01-0.09 ppm in the stems, and 0.01-0.10 ppm in the roots.

Sustainability index

A Sustainability Index of 52.48 was obtained from an analysis using RApMEc, which was carried out based on 27 attributes. This value reflects the sustainable management of mangrove forests in the former bauxite mining area in a multidimensional manner. Sustainability index values for each dimension, stress value, and R^2 are presented in Table 2.

Table 2 shows that the small difference between the index values obtained from the MDS analysis and that of the Monte Carlo analysis indicates the relatively small scoring errors, relatively small variation in opinions, a stable repeated analysis process, and errors in data entry or lost data can be avoided. The results confirmed the validity of the MDS used in assessing the sustainability of mangrove forest management on Bintan Island. The validity of the results obtained from the MDS analysis was also demonstrated by the Goodness of Fit value, which was represented by the stress value and the coefficient of determination (R^2) at the 95% confidence level. Table 2 shows that the stress value was less than 0.25 and the R^2 value was close to 1, demonstrating the statistically valid results obtained from the analysis and the sufficient number of attributes used which represented the actual condition adequately. The attributes used in the analysis were sufficient to assess the sustainability of mangrove forests, whereby the results demonstrated a high level of confidence in the RApMEc analysis. The multidimensional sustainability indices are shown in Figure 2.

The sustainability of the ecological dimension is an indicator of the biophysical sustainability of mangrove forests related to environmental aspects such as physical, chemical, and biological. A sustainability index of 69.94 was obtained for the ecological dimension indicating quite a sustainable management in this aspect. This finding also demonstrates that the ecological dimension is sufficient to prove the sustainability in the mangrove forest management around the former bauxite mining area on Bintan Island. On the other hand, the leverage analysis revealed the five attributes related to the sustainability of the ecological dimension, namely 1) mangrove density, 2) substrate fraction, 3) sedimentation, 4) mangrove importance value index, and 5) metal bioconcentration factor. These attributes are presented in Figure 3.

The density level of various mangrove tree species deserve attention and should ideally be increased because they greatly affect the health of the mangrove forest, and consequently, the sustainability of the mangrove forest ecosystem on Bintan Island. Although the emergence of seedlings and saplings has been reported in the area, the Important Value Index indicates a disturbance in the mangrove community.¹³ The growth of mangrove seedlings and saplings must be preserved to maintain the availability of seeds for mangrove forest regeneration.

Table 2. Results from MDS, Monte Carlo, and statistics analysis.

Dimensions	Sustainability index		Difference	Statistic		Iteration
	MDS	Monte Carlo		Stress	R^2	
Multidimension	52.48	51.39	1.09	0.175	0.927	2
Ecological dimension	69.94	68.66	1.28	0.134	0.947	2
Economic dimension	17.62	16.43	1.19	0.153	0.939	2
Social dimension	65.40	65.34	0.06	0.188	0.927	2
Legal and institutional dimension	59.94	56.87	3.07	0.168	0.932	2
Technological dimension	49.52	49.65	-0.13	0.236	0.891	2

Figure 2. Kite diagram of the five dimensions of RAPMEc showing the mangrove management status score.

Figure 3. Leverage of sustainability attributes ecological dimension.

Sedimentation that occurs around the former bauxite mining area has been reportedly low. Sedimentation has resulted in the formation of red mud sediment in the mangrove area, indicating a very low organic content in the soil. Therefore, it is necessary to prevent the rate of erosion and sedimentation so the quality of the water and sediments in the former bauxite mining area can be improved, which consequently supports the life of the surrounding mangroves.

Based on the results from the analysis of the Bioconcentration Factor (BCF), it was found that *R. mucronata* and *A. marina* can absorb heavy metals, namely Pb and Cr present in the environment. Although the metal accumulation value was reportedly low, a test on the metal absorption mechanism revealed that *R. mucronata* is a hyperaccumulator of metals while *A. marina* was found the opposite.¹³ The BCF revealed the potential use of mangrove species for the accumulation of heavy metals from the former bauxite mining area to eliminate pollution.

A value of 17.62 was obtained to represent the sustainability status of the mangrove forest around the ex-bauxite mining area on Bintan Island, indicating unsustainability (bad). This value demonstrates that the management of mangrove forests around the former bauxite mining area has been experiencing pressure from an economic standpoint. This pressure could be due to the poor ability of mangrove natural resources and the surrounding ecosystems to provide environmental benefits and services. The results obtained from the leverage analysis showed that all attributes are the levers that require attention in the management of mangrove forests. The graph of economic dimension leverage is presented in Figure 4.

The values obtained for direct and indirect benefits of mangrove forests around the former bauxite mining area revealed that the current utilization of mangrove forests is not optimal.¹² Therefore, there is an immediate need to increase the economic value of mangrove forests, either directly or indirectly, so that people can also benefit from healthy mangrove forests. The status of the mangrove forest area around the former bauxite mining area does not prohibit its development based on usefulness values, especially for fisheries and environmental services.¹⁶

The dependence of the community around the mangrove forest is still very low as some people choose to be entrepreneurs. Fishermen are the only group of people in the community whose livelihood depends on mangrove forests. Moreover, the community does not view the mangrove forests as an asset in supporting their household economy. Awareness of the importance of mangrove forests must be raised so the community can benefit from the forests economically, either directly or indirectly.

Currently, the mangrove forest rehabilitation activities have mostly been funded by the CSR organizations located on Bintan Island such as the Ecology Foundation and Banyantree, PT. Various Mines. To date, such support still prevails on the island but is not yet optimally available. Furthermore, the support from CSR funding also influences the sustainability of mangrove forests on Bintan Island in terms of economic dimension. When funding is available, the management and utilization of mangrove forests by the community and the authority will run well.¹⁵

Figure 4. Leverage analysis of sustainability attributes in the economic dimension.

To improve the sustainability of the economic dimension in the mangrove forest management around the former bauxite mining area on Bintan Island, it is important to develop the economic values of the mangrove forests for community use and plan for integrated mangrove forest rehabilitation activities with various parties. The attribute of community dependence on the role of mangrove forests as a source of livelihood can be used as social capital to encourage communities to participate in the sustainable management of mangrove forests.^{16–18}

A value of 65.40 obtained from the analysis of the sustainability status of mangrove forests based on the social dimension indicated sustainability in the management. The level of public health and public perception of mangrove management were the two attributes that are sensitive and can greatly affect the social dimension. The graph of the leverage identified in the social dimension is presented in [Figure 5](#).

The level of public health and public awareness in the management of an area are both very important for the success of any efforts in managing the area. The perception of the coastal community greatly determines the level of understanding among the community about the importance of the mangrove area and its sustainable management for the survival of the community.^{19–22}

A value of 54.95 obtained from the analysis of the sustainability index for the legal and institutional dimensions indicated sustainability in the management. Based on the leverage analysis, only one of the five attributes, namely the legality of the mangrove forests and the bauxite mine was identified as the lever in the legal and institutional dimensions. The graph of the leverage is presented in [Figure 6](#).

The legality of mangrove forests and bauxite mining areas is necessary for resource management on Bintan Island. Within the mangrove ecosystem, many resources such as mangrove forests, fisheries, waters, and non-aquatic biota must be managed to ensure sustainability. In addition, Bintan Island is also rich in bauxite, one of the mineral resources.^{23,24} The potential value of bauxite minerals can be exploited to support the economy of the locals. To avoid overlapping, it is necessary to make clear arrangements regarding area zoning, forms of utilization, and management efforts according to the laws or regional regulations. This attribute should be given great attention in the implementation of mangrove forest management policies, considering the influence of these attributes on the sustainability of the management of mangrove forest and ex-bauxite mining areas.

A value of 49.52 was obtained for the sustainability index of the technological dimension, indicating a lack of sustainability in the management. The value indicates the condition of the mangrove forest around the former bauxite mining area on Bintan Island, which is currently under pressure from the technological aspect. Based on leverage analysis, all attributes were identified as the levers. The chart of the leverage analysis is presented in [Figure 7](#).

The technology for monitoring environmental pollution around the bauxite mining area is still inadequate in anticipating the impacts of erosion, abrasion, water quality degradation, and metal accumulation. Although the available mangrove

Figure 5. Leverage attributes in the social dimension.

Figure 6. Leverage attributes legal and institutional dimensions.

Figure 7. Leverage attributes in the technological dimension.

rehabilitation technology is still simple, namely planting with a seed and fruit system and embroidery techniques, this technology has not been able to reduce threats that can reduce the factors and intensity of threats to the mangrove ecosystem around the former bauxite mining area on Bintan Island.⁶ One of the reasons is the absence of integration programs between local and central governments (cross-sector). In addition, the miners have also not practiced environmentally friendly mining techniques (good mining practice) as mining activities are still carried out with an open mining system without the implementation of any post-mining restoration efforts. These two in the technological dimension need great attention for the implementation of mangrove forest management policies to support the sustainability of mangrove forest management in the future.

Conclusion

In general, the mangrove forest management around the ex-bauxite mining area on Bintan Island was found quite sustainable (52.48) based on the multidimensional dimension. On the other hand, the management was found moderately sustainable based on the ecological (69.94), social (65.40), and legal and institutional (59.94) dimensions, less sustainable (49.52) based on technological dimension, and unsustainable (17.62) based on the economic dimension. Findings made in this research revealed the attributes in each dimension, which are the determining factors that can also be used as a reference for the implementation of mangrove ecosystem management programs in the former bauxite mining area on Bintan Island.

The identified leverage attributes that are sensitive to the sustainability of mangrove forest management in the ex-bauxite mining area on Bintan Island are 1) mangrove density, 2) substrate fraction, 3) sedimentation, 4) mangrove importance index, 5) bioconcentration of metal factors, 6) the value of direct benefits, 7) the value of indirect benefits, 8) dependence on mangrove forests as a source of livelihood, 9) CSR funding support, 10) community income, 11) community health level, 12) community perception, 13) the legality of mangrove areas and mining, 14) technology for monitoring pollution of ex-mining areas, and 14) technology for mangrove rehabilitation. All of these attribute levers must be prioritized by the government and relevant stakeholders in preparing and implementing appropriate policies to ensure sustainable mangrove forest management on Bintan Island.

Data availability

All data concerning the results are available as part of the article and no additional source of data is required.

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References

1. **Report of a specific working visit of Commission VII DPR RI to the Riau Islands province. Overview of Tanjung Uban Oil Fuel Terminal PT. Pertamina (Persero) and Bauxite Mine Inspection PT. Mount Bintan Abadi In Bintan Regency.** March 8-10, 2019.
2. Kunjana G: 2011.
[Reference Source](#)
3. Firdaus LN, Wulandari S, Mulyeni GD: **Growth of Rubber Plant Roots on Ex-Bauxite Mine Soil With Application of Organic Materials.** *Biogenesis*. 2013; **10**: 53–63.
4. The Central Bureau of Statistics of the Riau Islands Province: **Riau Islands in Numbers**. 2020.
5. Heriyanto NM, Subiandono E: **Absorption of heavy metal pollutants (Hg, Pb and Cu) by mangrove species.** *J. Forest Res. Nature Cons.* 2011; **8**: 177–188.
6. Deswati H, Pardi HS, Rahmi I: **Adsorptive stripping voltammetry for the simultaneous determination of Cd, Cu, Cr, and Pb in water samples using Fluorexon: An optimization single factor.** *Anal. Bioanal. Electrochem.* 2018; **10**: 1491–1505.
7. Deswati H, Suyani AK, Muchtar EF, *et al.*: **Copper, iron and zinc contents in water, pakcoy (*Brassica rapa* L.) and tilapia (*Oreochromis niloticus*) in the presence of aquaponics.** *Rasayan J. Chem.* 2019; **12**: 40–49.
[Publisher Full Text](#)
8. Kuvaini A, Hidayat A, Kusmana C, *et al.*: **A multidimensional assessment technique to evaluate the sustainability of mangrove forests on Kangean Island, East Java Province.** *Regional Environ. J.* 2019; **7**: 137–152.
9. Safe'I R, Kasykoyo H, Darmawan A: *Analysis of Tree Health Using the Forest Health Monitoring Method (Case Study on Three Forest Functions in Lampung Province.)*. SemNASN MAPIAUB; 2020.
10. Fauzi A: *Sustainability Analysis Techniques*. Gramedia Pustaka Utama: Jakarta; 2019.
11. Putra RD, Apriadi T: **Study of Post-Bauxite Mining Heavy Metal Contamination (Pb and Cr) as Potential Locations for Aquaculture Activities.** *J. Aquacul. Intek.* 2018; **2**: 1–15.
12. Zulfikar A: **Analysis of Metal Content in Bauxite Mine Tailings Waste (Red Mud).** *Journal of Maritime Dynamics*. 2015; **5**. UMRAH PRESS.
13. Azizah D: **Phytoaccumulation of Pb and Cr Heavy Metals in *Rhizophora mucronata* Around the Former Bauxite Mine Area, Bintan Island.** *Indonesian Environ. Dynam.* 2021; **8**: 121–147.
[Publisher Full Text](#)
14. Yolanda OAP, Melani WR, Muzammil W: **Characteristics of Sediment in Sei Carang Waters, Tanjungpinang City - Indonesia.** *Habitat Aqua*. 2020; **1**: 11–20.
[Publisher Full Text](#)
15. Suryawan A: **Mangrove Rehabilitation on Alo Beach (Karakelang Island, Talaud) Using Propagules *Rhizophora mucronata* Lamk.** *Research and Development Center for Environment and Forestry Manado, North Sulawesi.* *WASIAN J.* 2017; **4**: 69–78.
[Publisher Full Text](#)
16. Pardi H, Deswati HS, Widya Edelwis T: **Cathodic stripping voltammetric determination of essential element (Copper and zinc) in drinking water.** *Anal. Bioanal. Electrochem.* 2019; **11**: 691–702.
17. Deswati H, Suyani IR, Pardi H: **Application of central composite design optimization technique for determination of copper in fruit and vegetable samples with adsorptive stripping voltammetry in the presence of calcein.** *Rasayan J. Chem.* 2017; **10**: 1359–1367.
18. Ministry of Environment of the Republic of Indonesia: *Decree of the Minister of the Environment Number 51 of 2004 Appendix III concerning Quality Standards for Marine Biota*. 2004.
19. Parizanganeh AH, Bijnavand V, Zamani AA, *et al.*: **Concentration, Distribution and Comparison of Total and Bioavailable Heavy Metals in Top Soil of Binab District in Zanjan Province.** *J. Soil Sci.* 2012; **02**(2012): 123–132.
20. Sham TM, Ray S, Kabir T, *et al.*: **Assessment of heavy metals contamination in incinerated medical waste.** *ARPJ. Sci. Technol.* 2012; **2**: 904–911.
21. Heriyanto NM, Subiandono E: **Absorption of Heavy Metal Pollutants (Hg, Pb and Cu) by Mangrove Types.** *J. Forest Res. Nature Cons.* 2011; **8**: 177–188.
22. Paringsih NC, Setyono P, Sunarto.: **TRM-Based Mangrove Conservation (Tanam Rawat Monitoring) To Protect Marine Resources In Cengkong, Trenggalek.** *J. Bioexperiments.* 2018; **4**(2018): 22–34.
23. Olfie LS, Jean T, Rin K, *et al.*: **Economic Valuation of Mangrove Forest Resources in Palaes Village, Likupang Barat District, North Minahasa Regency.** *ASE.* 2011; **7**: 29–38.
24. Rismika T, Purnomo EP: **Marine Ecosystem Management Policy Due to Tin Mining in Bangka Belitung Province.** *J. Publication.* 2019; **4**: 23–33.
25. Sari SP, Rosalina D: **The Success Rate of Mangrove Planting on Land Post Tin Mining in South Bangka Regency.** *Maspajj.* 2014; **6**: 71–80.

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On abstract:

In the method section, please explain how to determine the sample and how many there are.

In the results section, the attributes of the levers are grouped by dimension.

In the conclusion section, how can you conclude that the sustainability index is quite good, even though from the 5 dimensions analyzed, 2 dimensions are unsustainable. Then how is it possible, to increase the sustainability of the economic and technological dimensions, by carrying out management that focuses more on the attributes of levers? From the ecological, social, legal and institutional dimensions. This does not make sense.

Methods:

At the study site, the explanation does not match the picture 1. In picture one everything must be in English.

Need to be given clear boundaries "in the former bauxite mining area" is this the area of the ex-mining point, or the area outside the ex-mining point but around it?

In Table1. please explain how to give an assessment or score for each attribute.

Results and discussions:

The findings on the environmental conditions of the former mining area on Bintan Island, the sediment fraction is dominated by sand and gravel, does this support the life of mangrove vegetation? Considering the findings of the leverage factor, the mangrove density is high. What is the explanation?

Regarding water quality, which quality is used for human needs or vegetation needs? All of that has not been explained in the measurement or scoring on all the attributes used. (see in table 1.)

The sustainability value of the ecological dimension is quite good (69.94), what does this have to do with the fact that the environmental conditions of the former mining area does not support the development of root systems? (a contradictory research finding, and no explanation yet).

Overall, the results and discussion require a more in-depth discussion, therefore it is necessary to read several articles related to reforestation of the mangrove ecosystem.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Coastal resource economy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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