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# Environmental Design for the Reconstruction of PT X Ex-Mine Land Reclamation, Bombana Regency, Southeast Sulawesi Province

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## ABSTRACT

The study area is located in the IUP of PT X, which covers an area of ± 1,210 ha. Administratively located in Bombana Regency, Southeast Sulawesi Province. Spatial data analysis in mapping the potential success rate of reclamation and environmental design is carried out based on geological criteria and remote sensing so that the impact of risks in the mining industry can be minimized. This study aims to map the potential success rate of post-mining land reclamation and environmental design in the study area based on spatial analysis with the Analytical Hierarchy Process (AHP) method. The geological criteria used in this study are lithological units, seismicity, hydrology (catchment area), vegetation density distribution, and hydrothermal alteration (iron oxide alteration and clay minerals). The data used in this study are the Kolaka sheet regional geologic map, DEM SRTM, Landsat 8 imagery, and company reports (lithology, reclaimed land openings). The data were analyzed to produce evidence maps of lithology, ranginess, catchment area, and vegetation density distribution using the NDVI technique and hydrothermal alteration using the band ratio technique, then spatial analysis was carried out using the AHP method. The result of this research is a map illustrating the potential success rate of reclamation and environmental design in the study area which is divided into 3 classes, namely: high potential area of 407.52 Ha (36.68%), medium potential area of 360.81 Ha (32.48%), and low potential area of 342.54 Ha (30.84%) of the total area. Based on the validation test of the reclaimed land opening area of 28.63 Ha that corresponds to the area with the result of a high potential success rate of about 89% of the total validation land opening area the results of this modeling are statistically acceptable.

**Keywords:** environmental management; reclamation success; AHP; GIS; Landsat.

## INTRODUCTION

Mining activities have a positive impact on human civilization and a negative impact on the environment such as changes in environmental hue, disruption of flora and fauna habitat, and a decrease in groundwater quality.
Most open pit mining businesses are carried out without careful planning or are not in line with the plans that have been prepared. As a result, there are abandoned former mining lands and reclamation systems that tend to be random and have large budgets, so reclamation efforts should have started at the beginning of mining activities which are then continued with environmental governance.

Geographic Information System (GIS) is utilized as a useful software to integrate and combine several data (layers of data) of geological / earth and environmental sciences into an environmental design map on reclamation of ex-mining land.

Based on the description above, this research will model and map the success rate of reclamation using spatial data analysis of the Analytical Hierarchy Process (AHP) method at PT. X located in Bombana Regency, Southeast Sulawesi, based on data on lithology, slope, hydrology (catcment area), vegetation density, and hydrothermal alteration (iron oxide and clay minerals) obtained from semidetail geological maps, DEM SRTM and Landsat 8 images, then the data will be validated with the known distribution of reclamation land openings so that it is expected to get a model of the success rate of reclamation and environmental design and become a reference in the environmental governance system in the research area so as to minimize losses and optimize decision making.

## RESEARCH AND METHODS

### Regional Geology

Broadly speaking, according to Surono (2009), Sulawesi island is controlled by three main tectonics namely western volcanic belt, central metamorphic belt, and eastern ophiolite complex. The research area is located in the central metamorphic belt which is composed by the early Miocene aged Langkowala Formation (Tmls) consisting of shale, sandstone, conglomerate and the Pre Tertiary aged Pompangeo Complex (Mtpm) in the form of metamorphic rocks consisting of mica schist, metag limestone, metabatupas, quartzite, phyllite and slate. The Langkowala Formation is overlain by Miocene to Holocene age sediments or placer deposits. The Langkowala area where placer gold is found is characterized by undulating - flat morphology and cut by several large rivers including the Langkowala River, Watu-Watu River, Inotowonua River. The Langkowala area is located between Mount Mendoke to the north and Mount Rumbia to the south. The Langkowala area is underlain by the Langkowala Formation (Tmls). This formation is part of the Sulawesi Molasses, as described by Surono (2009). Mica schists and metasediments, especially meta-sandstones in the Pampangeo Complex, are usually characterized by the presence of quartz veins/veinlets with various widths up to 1 - 20 cm. The quartz veins/veinlets can be interpreted as a placer/paleoplacer gold source in the study area. The geological map of the study area is shown in Figure 1.

### Reclamation

Reclamation of ex-mining land is not only an effort to improve post-mining environmental conditions, but also to produce a good ecosystem environment and strive to be better than its initial hue.

Reclamation activities are the end of mining activities that are expected to return the land to its original state, even if it is possible to be better than the conditions before mining. Reclamation activities include restoring mined land to restore ecologically disturbed land and preparing ecologically improved mined land for further use. The ultimate goal of reclamation is to improve ex-mining land so that its condition is safe, stable and not easily eroded so that it can be reused.

In general, the outline of the stages of reclamation are:

1) Conservation of top soil
2) Landscaping
3) Sediment management and erosion control
4) Cover crop planting
5) Planting of pioneer plants
6) Heavy Metal Countermeasures

### Analytical Hierarchy Process (AHP) Method

Analytical Hierarchy Process or commonly abbreviated as AHP is one of the methods used to organize information and assessments in choosing the most preferred alternative (Saaty, 1993 in Saaty, 2000). Or in simple terms it can be said that AHP is a method that provides alternative problem solving in an organized framework, so that it can simplify and accelerate decision making on a complex matter.
AHP is often used as a problemsolving method compared to other methods for the following reasons:
- Hierarchical structure, as a consequence of the selected criteria, down to the deepest sub-criteria.
- Takes into account the validity up to the tolerance limit of inconsistency of the various criteria and alternatives selected by the decision maker.
- Taking into account the durability of the output of the decision-making sensitivity analysis.

## RESULT AND DISCUSSION

### Data Presentation

Data sources that will be used in making evidence maps in this study include: Regional Geological Map of Kolaka sheet, Landsat 8 image, DEM SRTM image and company report (PT. X) in the form

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of lithology data and land openings that have been reclaimed. These data are used in making evidence maps as a basis for determining maps of the success rate of reclamation and environmental design with spatial analysis using the AHP method.

**Evidence Map Generation**

The production of evidence maps in this study include: lithology unit evidence map, slope evidence map, hydrology evidence map (catcment area), vegetation distribution evidence map obtained by processing Landsat 8 images using NDVI technique and hydrothermal alteration evidence map (iron oxide alteration and clay minerals) obtained through band ratio technique (4/2 and 7/5). The six evidence map factors obtained will be used as the basis for determining the map of the success rate of reclamation and environmental design with spatial analysis using the AHP method.

Before calculating the NDVI and band ratio, the Landsat 8 image data in each band must first be atmospherically corrected. The stages of atmospheric correction are as follows:

**Stage 1. Calculating reflectance values from satellite data**

OLI spectral radiance data can also be converted to TOA (Top of Atmospheric) reflectance values using the reflectance coefficient provided in the Landsat 8 OLI metadata file. The following equation is used to convert DN values to TOA reflectance values:

$$\rho\lambda' = M\rho \times Qcal + A\rho \qquad (1)$$

Where:
$\rho\lambda'$ = TOA reflectance value
$M\rho$ = Band-specific multiplicative factor of the metadata file
$A\rho$ = Band-specific additive filtering factor of the metadata file
$Qcal$ = Quantized and calibrated standard product pixel value (DN).
After all variables are obtained from the metadata file, calculations are then carried out using a raster calculator.

**Stage 2. Correcting the TOA reflectance value (Atmospheric correction)**

The TOA reflectance value can be corrected using the local sun elevation. The following equation is used to correct the TOA reflectance value:

$$\rho\lambda = (\rho\lambda')/\sin\ \theta SE \qquad (2)$$

Where:
$\rho\lambda$ corrected reflectance value (atmospheric correction)
$\rho\lambda'$ = TOA reflectance value
$\sin\ \theta SE$ = the local sun angle (sun elevation) obtained from the metadata file
Similarly to stage 1, atmospheric correction is calculated using a raster calculator.

**Spatial Analysis with AHP Method**

Data sources that will be used in making evidence maps in this study include: Regional Geological Map of Kolaka sheet, Landsat 8 image, DEM SRTM image and company report (PT. X) in the form of lithology data and land openings that have been reclaimed. These data are used in making evidence maps as a basis for determining maps of the success rate of reclamation and environmental design with spatial analysis using the AHP method.

After calculating using the Raster Calculator function, it can be seen that the pixel value ranges from 2,335 - 6,797 as shown in Fig. 11, then the next step to get a map of gold mineralization potential is the reclassification process in ArcGIS 10.8. Then the final map of potential is divided into 3 potential classes, namely: high potential with a pixel value of 4,762 - 6,056, medium potential with a pixel value of 3,412 - 4,762, low potential with a pixel value of 2,08- 3,412, as seen in Fig. 12.

After obtaining a map of reclamation success in the study area using the AHP method, an effective and efficient environmental management design can also be made, namely for areas that have a high level of reclamation success can be utilized as plantation land, agro-tourism, ponds / reservoirs, for areas that have a medium level of success can be used as agricultural land and residential areas, while areas that have a low level of success can be used as endemic plantation land (cashew, cloves, bitti, etc.) and as an ecological conservation area as shown in Figure 14 and Figure 15.

### Validation

From the classification results obtained, testing is then carried out to determine the level of accuracy and accuracy of the success rate map that has been produced with the presence of validation points in the form of reclaimed land openings covering 28.63 Ha.

The validation point is overlaid with the reclamation success rate map generated from spatial analysis modeling using the AHP method, then the validation result of the reclamation success rate model is obtained.

Based on the validation test as shown in Fig. 12, it can be concluded that the map of reclamation success rate modeling results in this study is quite accurate in that there are 25.42 Ha validation points that correspond to areas with high potential from the modeling results or about 89% of the total validation area, so the validation test for this modeling result is statistically acceptable (meeting the requirement of deposit presence > 75%).

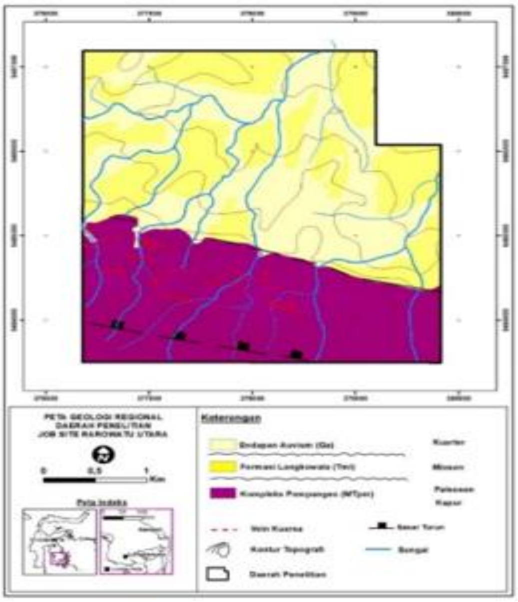

**Figure 1.** Geologic map of the study area (modified from Simandjuntak et al., 1993)

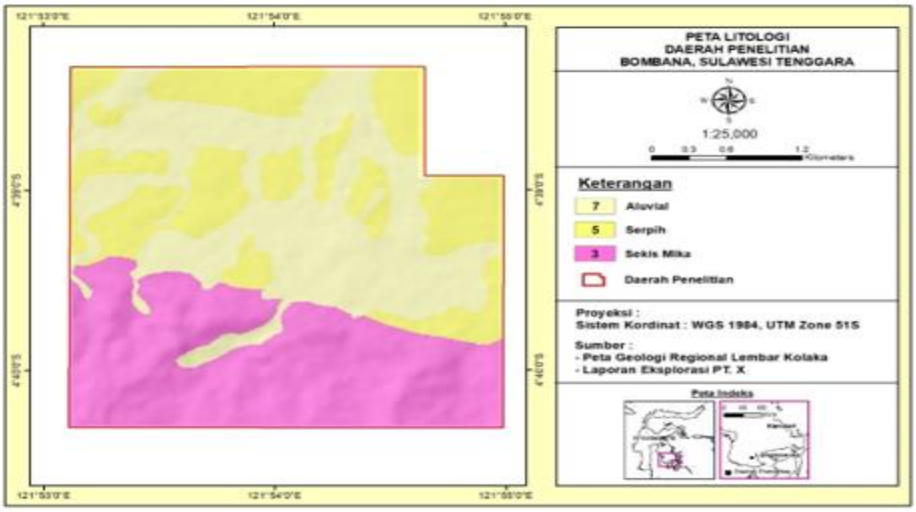

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**Figure 2**. Lithologic evidence map of the study area. Obtained from a combination of the regional geologic map of the Kolaka sheet with the exploration report of PT X.

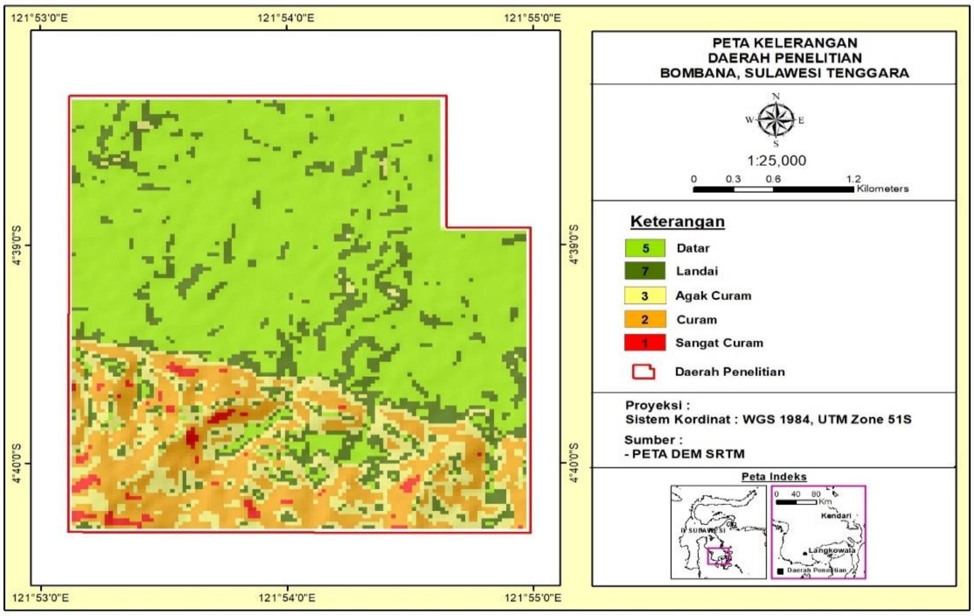


**Figure 3**. Slope map of the study area. Slope class based on percent with the source of guidelines for the preparation of land rehabilitation and soil conservation patterns, 1986.

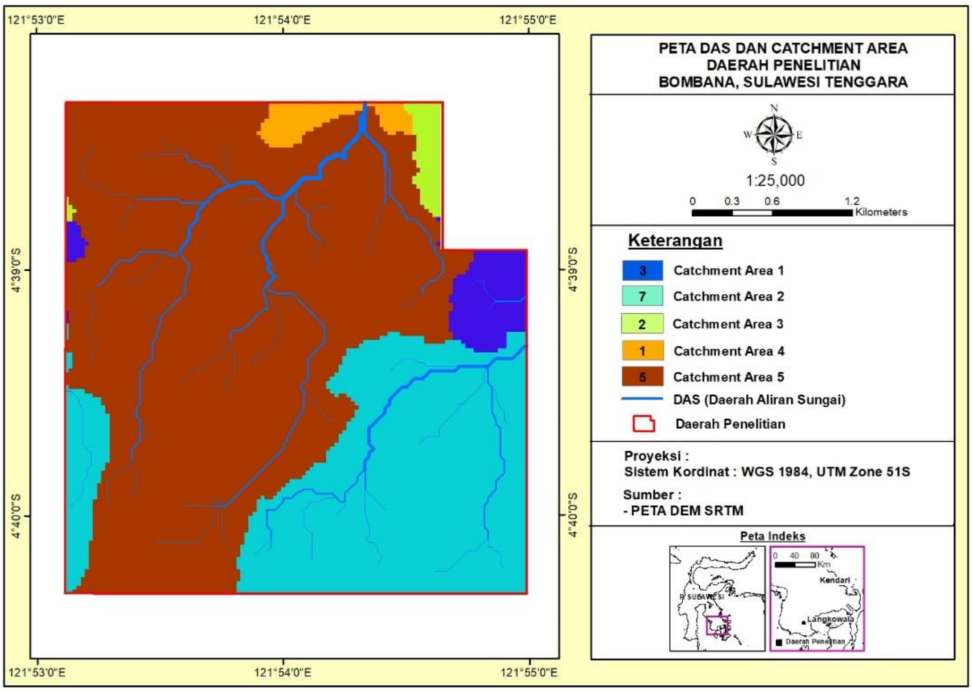


**Figure 4.** Hydrological map (catchment area) of the study area. After reclassification, 5 catchment areas were obtained where the map was extracted from the DEM SRTM map.

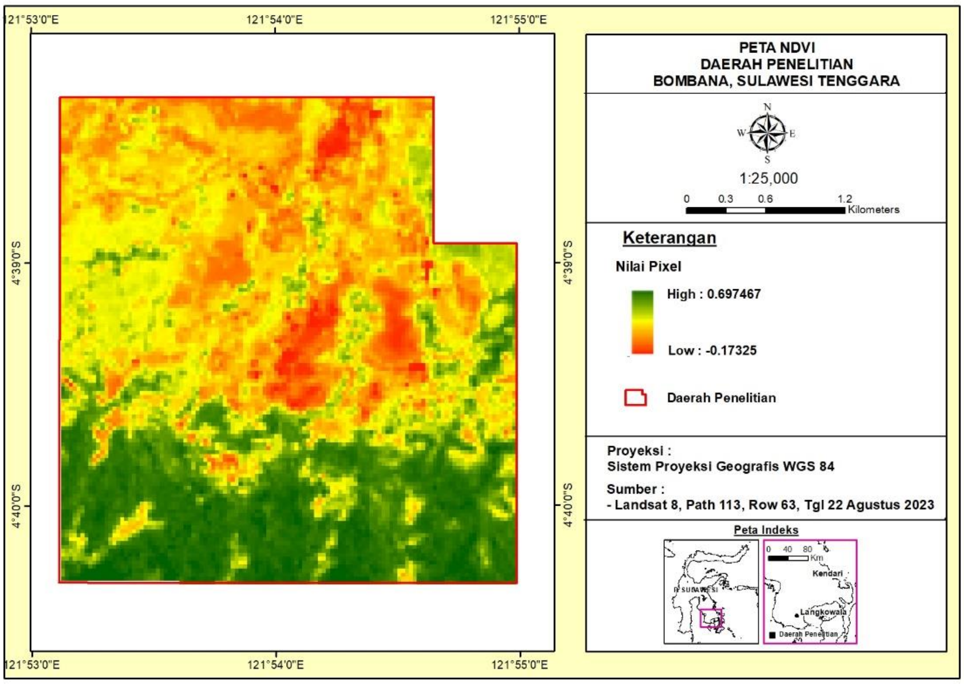


**Figure 5.** NDVI map of the study area. This map was extracted from the Landsat 8 image using the band ratio technique (5-4)/(5+4), green color is interpreted as dense vegetation and red color as sparse vegetation.

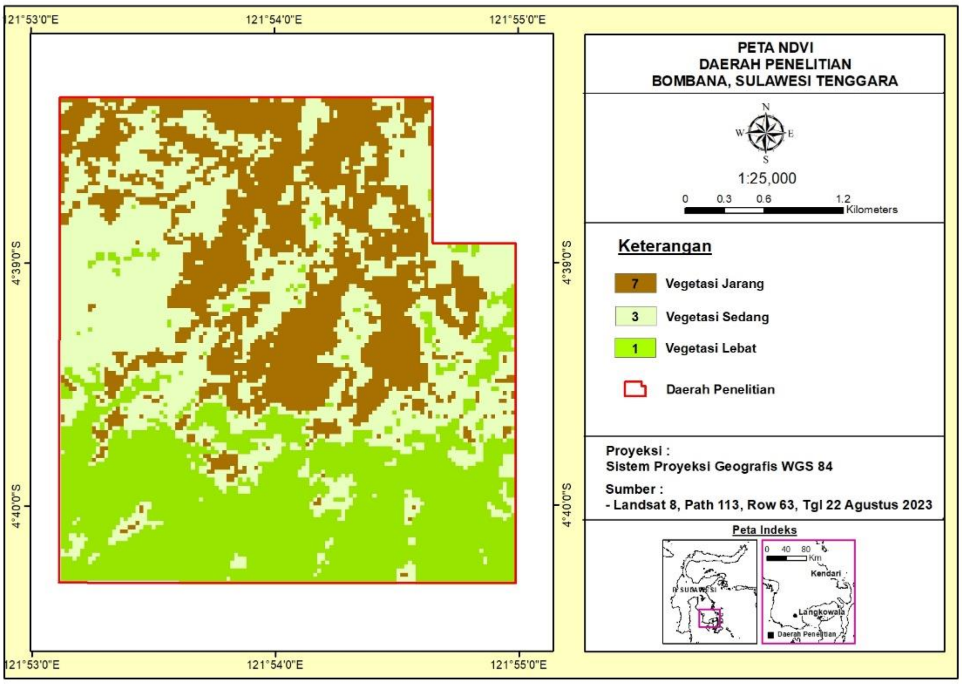


**Figure 6.** Map of reclassification results of vegetation distribution to gold mineralization points in the study area. Vegetation is sparse - medium so it is given a higher rank because it intersects the most with the reclamation land opening model in the field.

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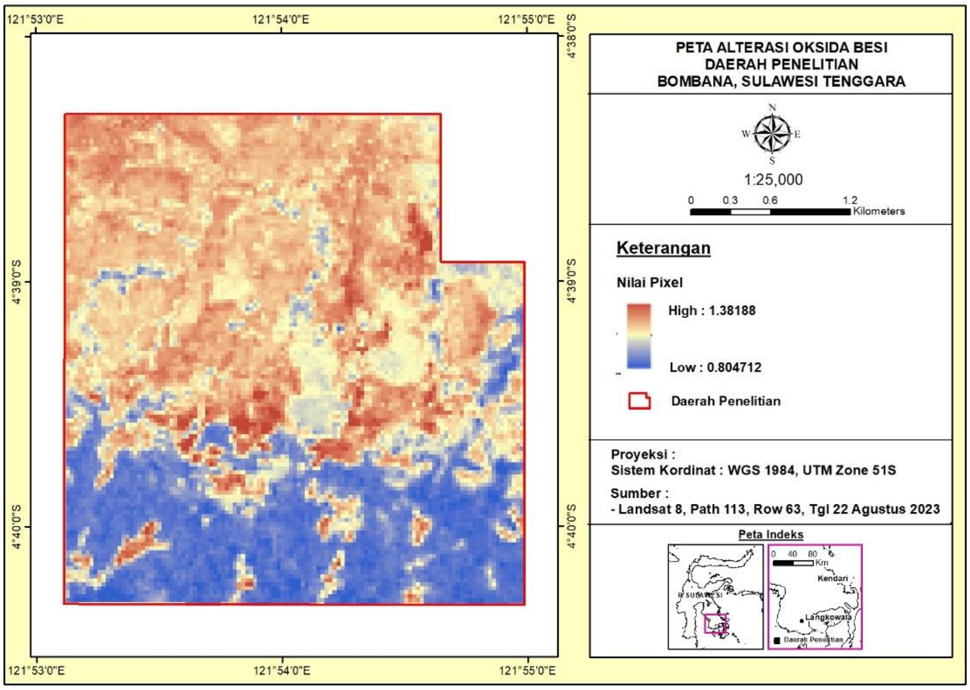


**Figure 7.** Landsat 8 image using the band ratio 4/2 technique, the image shows areas where iron oxides (hematite, goetite, limonite, jarosite etc.) are abundant shown in dark red.

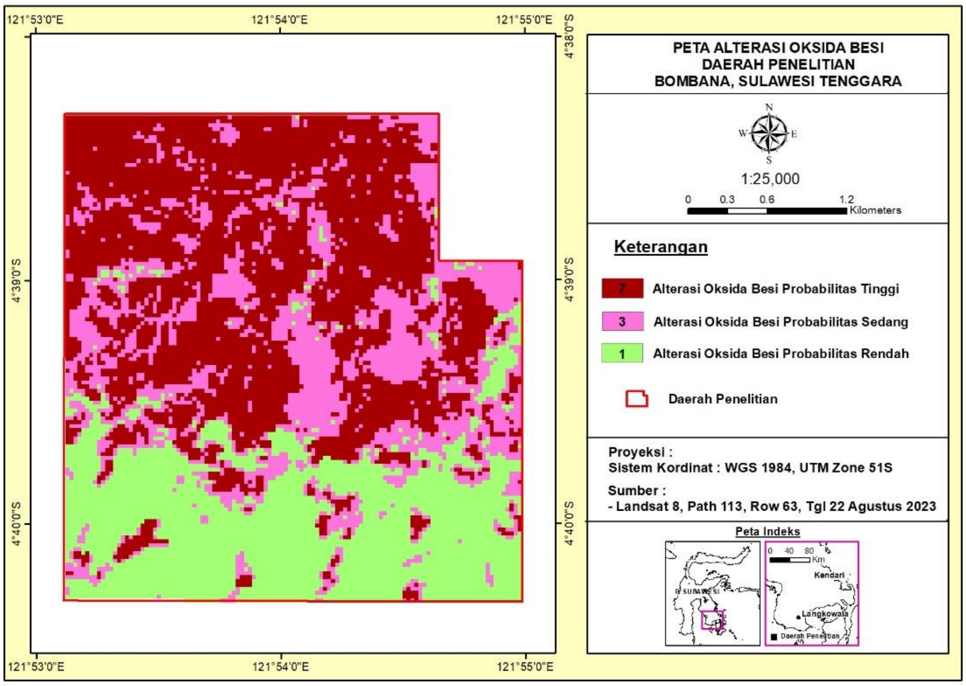


**Figure 8.** Reclassified map of iron oxide alteration against reclaimed land in the study area. Dark red color indicates iron oxide alteration with high probability. iron oxide minerals as field clues in determining the success rate of reclamation.

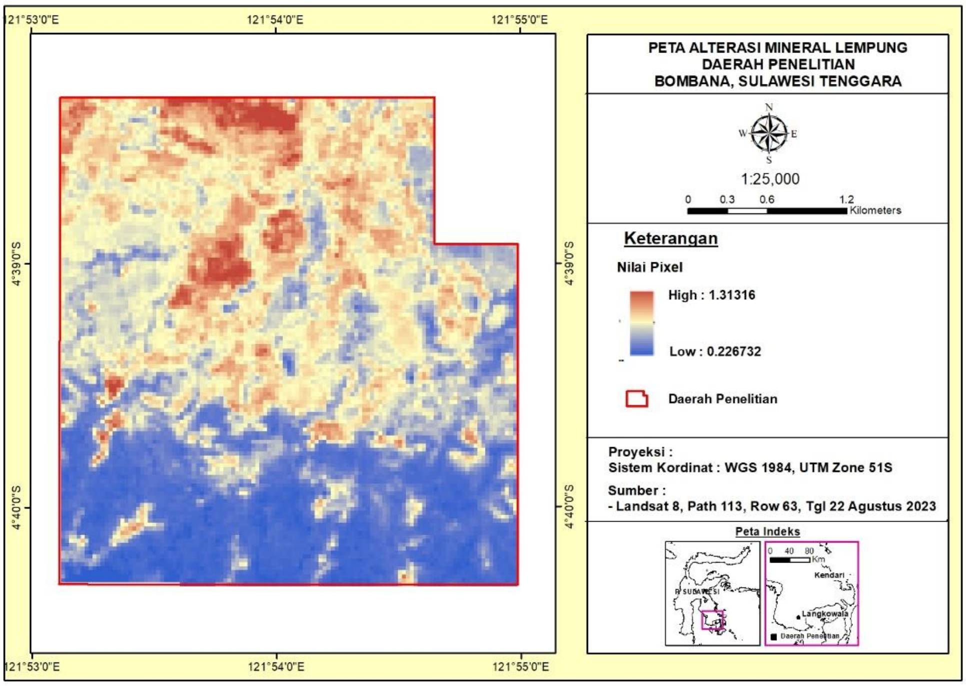


**Figure 9.** Landsat 8 band 7/5 image shows clay minerals, such as illite, kaolinite and montmorillonite, the abundant clay minerals are shown in dark red.

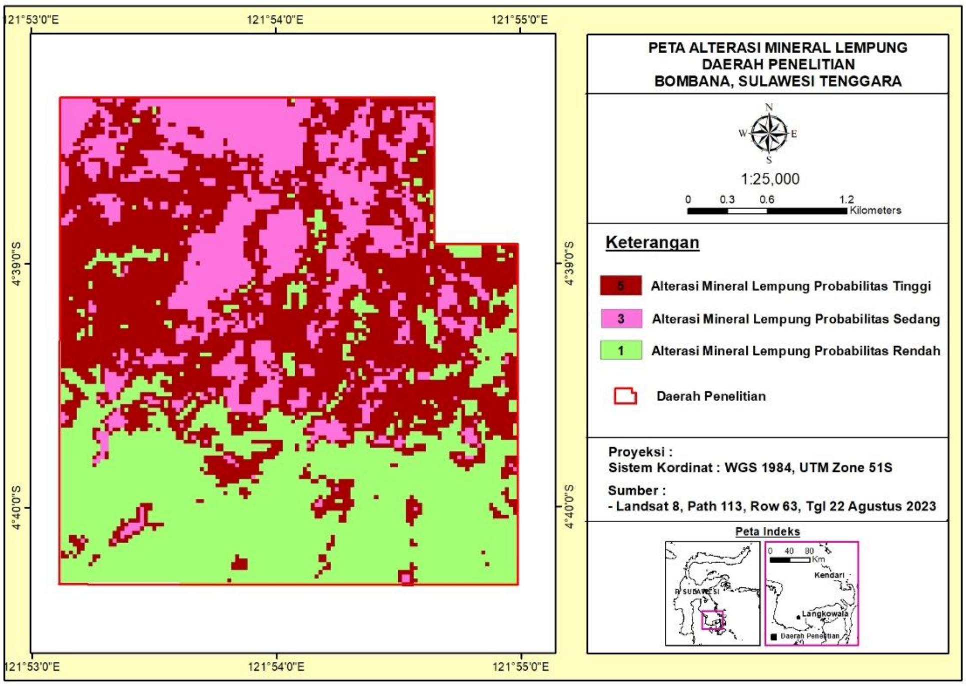


**Figure 10.** Map of clay mineral alteration reclassification results in the study area. Dark red color indicates clay mineral alteration with a high probability level. reclassification using the Natural Breaks method and then given a weighted value (ranking) based on the analysis of clay mineral alteration on reclaimed land openings.

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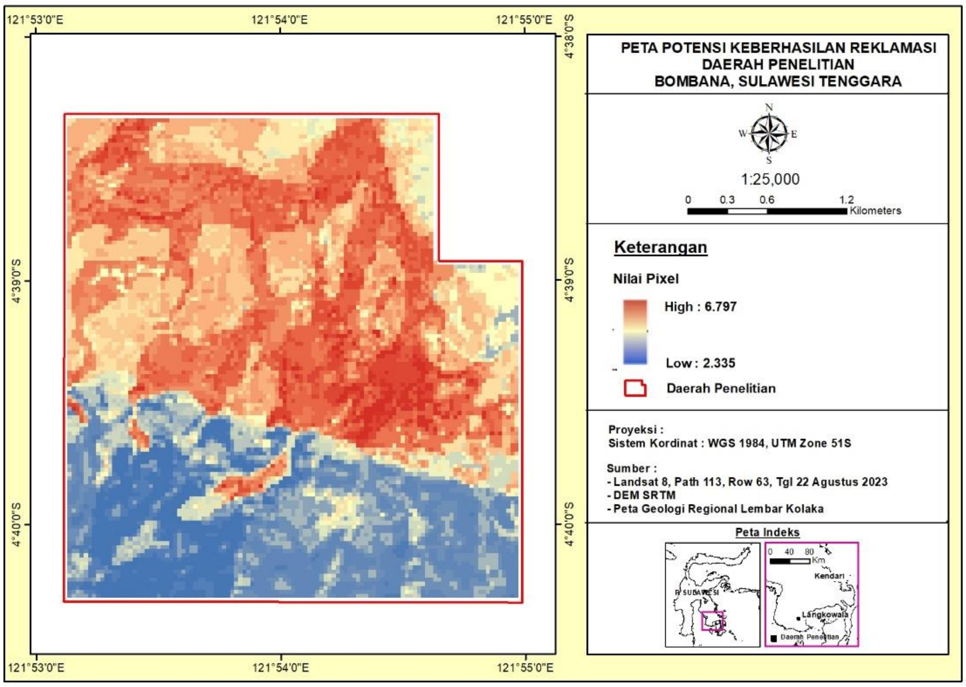


**Figure 11.** The result of calculating the potential success rate of reclamation using the Spatial Analysys Tools - Raster Calculator function. High potential is shown in dark red while low potential is shown in light blue.

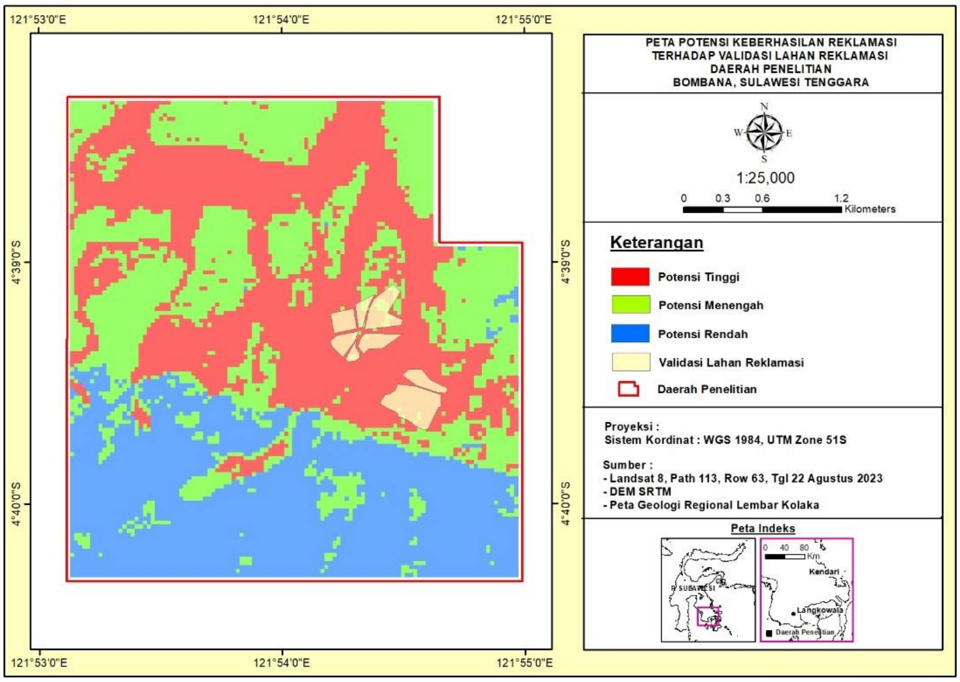


**Figure 12.** Map of reclamation success rates in the study area resulting from reclassification of reclaimed land openings. There are 3 categories of potential results from modeling the potential success rate of reclamation using the AHP method, namely high potential, medium potential and low potential.

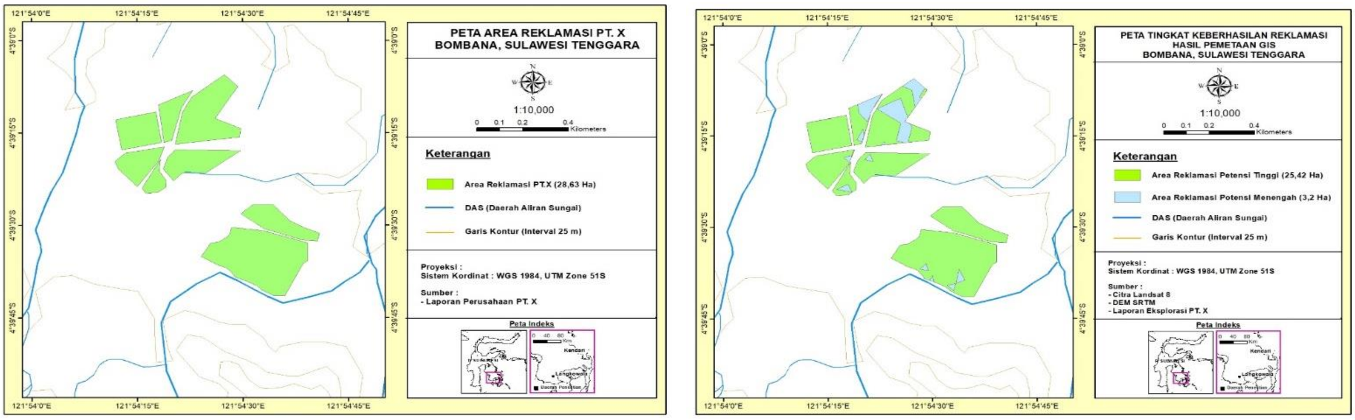


**Figure 13.** Comparison map of reclamation area. a) map of PT.X reclamation area; b) map of reclamation success rate from GIS mapping using AHP method.

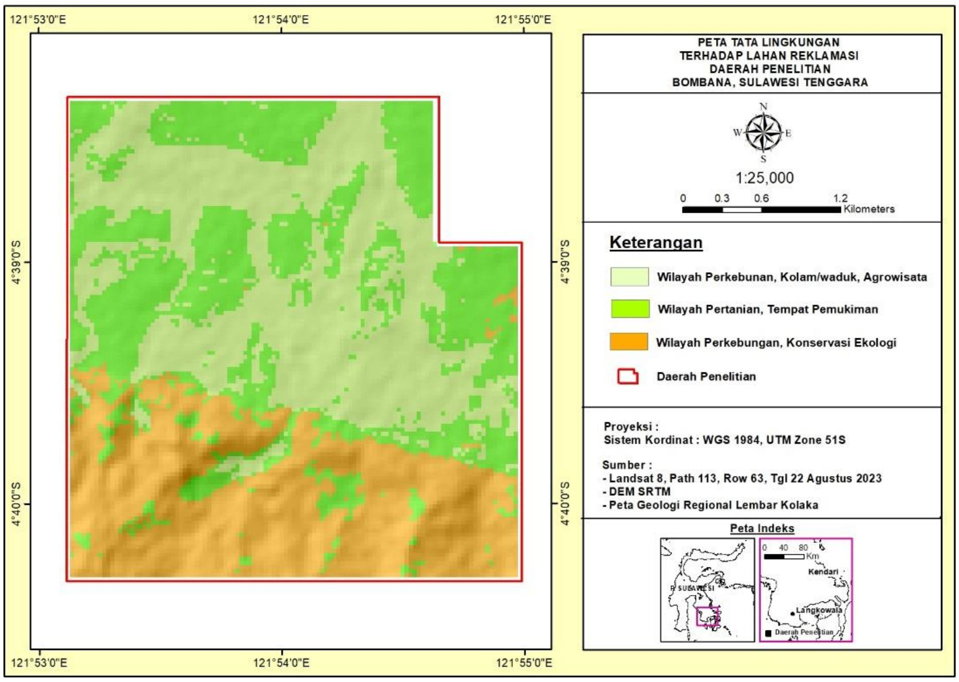


**Figure 14.** Environmental design map of the reclaimed land of the study area.

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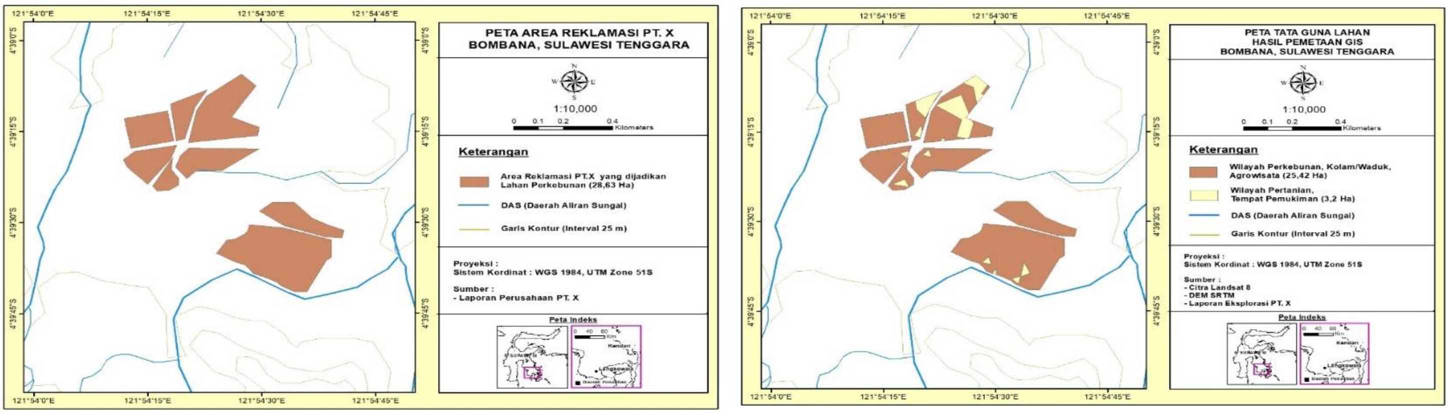


**Figure 15.** Land use comparison map. a) map of PT.X's reclamation area which is used as plantation land; b) land use map mapped with GIS.

**Table 1.** Parameters processed as evidence maps for spatial analysis

| Criteria (Geological Factors) | Weight | Sub Criteria | Value |
|---|---|---|---|
| Lithology | 0.390 | Alluvial | 7 |
| | | Shale | 5 |
| | | Mica schist | 3 |
| Rarity | 0.156 | Flat | 5 |
| | | Ramps | 7 |
| | | Somewhat Steep | 3 |
| | | Steep | 2 |
| | | Very Steep | 1 |
| Hydrology (Catchment Area) | 0.139 | Catchment Area 1 | 3 |
| | | Catchment Area 2 | 7 |
| | | Catchment Area 3 | 2 |
| | | Catchment Area 4 | 1 |
| | | Catchment Area 5 | 5 |
| Vegetation | 0.111 | Sparse Vegetation | 7 |
| | | Medium Vegetation | 3 |
| | | Dense Vegetation | 1 |
| Iron Oxide Alteration | 0.105 | Iron Oxide Alteration High Probability Level | 7 |
| | | Iron Oxide Alteration Medium Probability Level | 5 |
| | | Iron Oxide Alteration Low Probability Level | 1 |
| Clay Mineral Alteration | 0.098 | Clay Mineral Alteration High Probability Level | 5 |
| | | Clay Mineral Alteration Medium Probability Level | 3 |
| | | Clay Mineral Alteration Low Probability Level | 1 |

**Table 1.** Area of each class in the reclamation success rate map.

| Modeling Result Criteria | Area (Ha) | Percentage (%) |
|---|---|---|
| High Potential | 407,52 | 36,68 |
| Medium Potential | 360,81 | 32,48 |
| Low Potential | 342,54 | 30,84 |
| **Total** | **1.110,87** | **100** |

**Table 3.** Validation results of reclamation success rate modeling.

| Modeling Result Criteria | Area of Reclaimed Land Opening Validation (Ha) | Percentage (%) |
|---|---|---|
| High Potential | 25,42 | 89 |
| Medium Potential | 3,20 | 11 |
| Low Potential | 0 | 0,00 |
| **Total** | **28,63** | **100** |

## CONCLUSION

From the results of spatial analysis using the AHP method on the geological and environmental parameters used, it is found that the class of reclamation success rate in the study area is divided into 3 classifications, namely the high potential classification which covers an area of 407.52 Ha or 36.68%. The medium potential classification occupies an area of 360.81 Ha or 32.48% and the low potential classification covers an area of 342.54 Ha or 30.82% of the entire study area. Based on the map of reclamation success in the study area using the AHP method, an effective and efficient environmental management design can also be made, namely for areas that have a high reclamation success rate can be utilized as plantation land, agro-tourism, ponds / reservoirs, for areas that have a medium success rate can be utilized as agricultural land and residential areas, while areas that have a low success rate can be utilized as endemic plantation land (cashew, cloves, bitti, etc.) and as an ecological conservation area.

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