

## Determine Appropriate Post Mining Land Use in Indonesia Coal Mining Using Land Suitability Evaluation

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## Technical Report

**Determine Appropriate Post Mining Land Use in Indonesia Coal Mining Using Land Suitability Evaluation**Sri Maryati<sup>\*1,3</sup>, Hideki Shimada<sup>\*2</sup>, Akihiro Hamanaka<sup>\*2</sup>, Takashi Sasaoka<sup>\*2</sup>,  
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Coal mining industry gives many benefits for Indonesia including contribution in total Indonesian GDP. Most of coal mines in Indonesia are open pit mining method which disturbs large area of land. One of open pit mining impact is damage land and related to soil erosion occurrences it will degrade land by top soil loses. Indonesia Government has issued mine closure regulation to encourage mining industry provide post mining land use. Determination of post mining land use should be considering the physical land properties including soil properties, topography and climate properties. The land evaluation process using GIS enables effective, easy and systematic determination of post mining land use.

**1. Introduction**

Indonesia as a one of the big exporter coals in the world with total resources: 105.2 billion tons and total reserves: 21.13 billion tons<sup>1)</sup> gives many benefits for Indonesia including contribution in total Indonesian GDP. Coal resources and reserves is distributed in Sumatra Island, Kalimantan Island, Sulawesi Island, Papua Island also Java Island. Most of coal mines in Indonesia are surface mining. One of open pit mining impact is damage land and related to soil erosion occurrences it will degrade land by top soil loses.

Environmental impact of mining can be physical impact, hydrological impact, climate impact, biological and also health impact. The mining activities if not managed properly can lead several impacts including landscape change, erosion, sedimentation, soil movement land capability degradation, microclimate change, flora and fauna disturbance, aquatic habitat disturbance and public health problem<sup>2,3)</sup>.

The environmental impact of mining activities if not handled seriously not only generate environmental problem during mining operation but also will affect to reclamation success and sustainable post mining land use. Mine closure policy or regulation is needed to overcome this problem.

There are several regulations regarding post mining in Indonesia. On 2010 Indonesia government has issued new government regulation No 78/year 2010 regarding reclamation and post mining. This regulation stated obligation for mining company to implement reclamation and post mining, also regulate procedure of reclamation and post mining both open pit mining and also underground mining. The Indonesia minister of forestry has issued the Regulation of the Minister of Forestry P4/Menhut-II/2011 regarding guidelines for forest reclamation. This regulation intended to give reference/guidance in the forest reclamation activities in

order to be implemented in line with standard and criteria of forest restoration. Law of The Republic of Indonesia No 4/year 2009 concerning mineral and coal mining obligate that exploration and production mining permit must state environmental management, reclamation and post mining and also reclamation and post mining deposit funds<sup>2,4,5)</sup>.

Post mining land use should be in line with regional development plan and should consider community development and community empowerment. The post mining land use planning should be formulated by three development agent namely mining company, government and local community. Preparation of mine closure plan involving all stakeholders and approved by the government will be a guidelines in the implementation of mine closure<sup>6)</sup>.

Determination of post mining land use should be considering the physical land properties including soil properties (drainage, texture, coarse material, soil depth, thickness of peat, alkalinity, erosion risk, flood risk, acidity), topography properties (relief, elevation) and climate (rainfall, temperature, water availability). It can be done by land evaluation method<sup>7)</sup>.

Land evaluation is process to assess land potency when used for specified purpose including agricultural and non-agricultural use. This process consist of collecting land characteristic data regarding climate data, soil properties data, topography data and comparing/matching between requirement for specific land use with land characteristics. Type of the land use to be evaluated should consider physical condition, economy condition and social condition of the area<sup>8,9)</sup>.

**2. Indonesia Government Rule**

Indonesia government regulation No. 78/year 2010 regarding reclamation and post mining describe

principle of reclamation and post mining, procedure of reclamation and post mining, agreement reclamation and post mining. The spirit of this regulation is in order to achieve sustainable development where mining activities should be undertaken regard to environmental principles, transparency and public participation. Proper planning and implementation is a series of sustainable and environmentally mining management that will reduce the negative impacts of mining activities. Regarding this regulation implementation reclamation and post-mining shall comply with protection and management of environmental mining. This regulation also state that one of the principle of environmental protection and management of mining is appropriate post mining land use<sup>2)</sup>.

Law of the Republic of Indonesia No 4/year 2009 concerning mineral and coal mining obligate that exploration and production mining permit must state environmental management, reclamation and post mining and also reclamation and post mining deposit funds. Implementation of reclamation and post-mining activities carried out in accordance with appropriate post-mining land use and specified in the agreement between the holders of IUP (Izin Usaha Pertambangan- Mining Business License) or IUPK (Izin Usaha Pertambangan Khusus- Special Mining Business License) and holders of the land rights. Guidance and supervision of the reclamation post-mining land became one of the governments of the district authority in the management of mineral and coal mining<sup>5)</sup>.

The Minister of Forestry of the Republic of Indonesia Regulation no P.4/Menhut-II/2011 concerning the guidelines for the forest reclamation has an important meaning to the post-mining activities, because reclamation preparation is crucial step which is determining the success / sustainability of the post mining land use. This guideline provides a reference for the forest reclamation activities in the area of forest use in order to follow the general pattern, standards and criteria in the forests restoration. Implementation of the forest reclamation in accordance article 31 includes land preparation, erosion and sedimentation control, re-vegetation and maintenance. Forest reclamation planning is prepared into 5-year reclamation plan and derived into annual reclamation plan<sup>4)</sup>.

### 3. Land Evaluation Framework

FAO on 1976 released 'A Framework for Land Evaluation'; this framework is released regarding need international standard on land evaluation. FAO defined land evaluation as 'The assessment of land performance when used for specified purpose, involving the execution and interpretation of basic surveys of climate, soil and other aspect of land in term of the requirements of alternative form of land use'<sup>8)</sup>.

The basic principles of Land Evaluation FAO (1976) are as follows<sup>8)</sup>:

- Land suitability is assessed and classified with respect to specified kinds of use
- Evaluation requires a comparison of the benefits obtained and the inputs needed on different

types of land

- A multidisciplinary approach is required
- Evaluation is made in terms relevant to the physical, economic and social context of the area concerned
- Suitability refers to use on a sustained basis
- Evaluation involves comparison of more than a single kind of use

Based on FAO 1976, land evaluation as a part of land use planning should answer the following questions<sup>8)</sup>:

- How is the land currently managed, and what will happen if present practices remain unchanged?
- What improvements in management practices, within the present use, are possible?
- What other uses of land are physically possible and economically and socially relevant?
- Which of these uses offer possibilities of sustained production or other benefits?
- What adverse effects, physical, economic or social, are associated with each use?
- What recurrent input is necessary to bring about the desired production and minimize the adverse effects? What are the benefits of each form of use?

Land suitability is degree of suitability of land to be used for specific land use. There are two kind of land suitability: actual land suitability and potential land suitability. Actual land suitability is degree of suitability based on actual condition of land. Potential land suitability is degree of suitability after land improvement<sup>7,8)</sup>.

The land suitability classification, using the guidelines of FAO (1976) is divided into Order land suitability, Class, Sub Class land suitability and Unit land suitability. Order is the global land suitability group. Land suitability Classes represent degrees of suitability in order land suitability. Land Suitability Subclasses represent types of limitations or type of improvement needed. Land suitability units represent subdivisions of a subclass which describe small differences needed in management of sub classes. Structure of the land suitability classification is schematically figures on Figure 1<sup>8,9)</sup>.

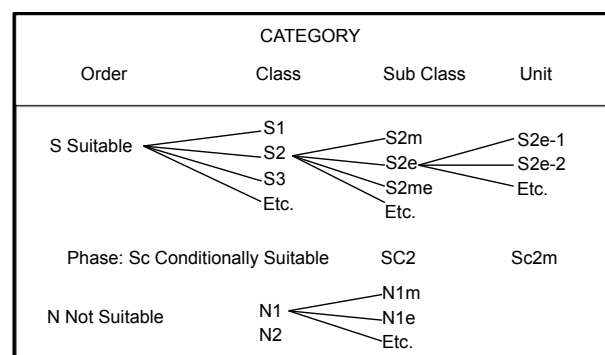


Fig. 1 FAO Structure of the Land Suitability Classification<sup>8)</sup>.

### 4. Land Evaluation Process

Land evaluation is a systematic process starts with identifying land characteristics and collecting data concerning the land characteristics, determining the type

of the land use or types of crops that will be evaluated, determining the land use requirement/ crop requirement, matching process between the land characteristics and the land use requirements /crop requirements, comparing between matching result and the actual land use to obtain recommendation for land use <sup>7,8)</sup>.

Identification of land characteristic is based on land use requirement. Generally land characteristics consist of climate characteristics, soil properties and topography characteristics. Climate characteristics consist of average annual rainfall, annual average temperature and number of dry months in a year which is obtained from rainfall station/ weather station. Based on the crop requirement/ land use requirement in Guidelines Land Suitability Evaluation<sup>7)</sup>, soil properties include of soil drainage, texture, coarse material, soil depth, peat properties, CEC clay, base saturation, pH H<sub>2</sub>O, % C-Organic, salinity, alkalinity, sulfidic contents, erosion risk, flood risk and surface outcrops. Soil properties are generated by soil laboratory analysis, description of soil in the fields and also from soil map. Topographic characteristics consist of relief and slope which are generated either from the contour data, digital elevation model or from land surveying.

Determining the type of land use or types of crops that will be evaluated should consider the land capability, regional development plans, potential community, local socioeconomic condition and should involve community participation.

Land use/crop requirements is requirement for the crops to growth well and requirement for sustain land use. The requirement can be obtained from the available literature such as from Food and Agriculture Organization, World Agroforestry Center and Indonesian Soil Research Institute, Indonesian Center for Agricultural Land Resources Research and Development (ICALRD).

Matching process is process of comparison between

land characteristics and land use/crop requirements. This process can be carried out computerized or manually. This process can be executed quickly by computerized system, also can be done manually if only a few points are to be evaluated but can be very time consuming. The result of matching process should be compared with the actual land use, regional development plan and local potency to obtain the final recommendation land use<sup>6,7)</sup>.

The land evaluation process is feasible carried out in coal mine reclamation area. Land characteristics used in this process namely climate characteristic, soil properties and topography characteristic are parameters that routinely monitored in mining operation. Climate properties including daily rainfall data and temperature were measured every day at rainfall stations spread over the mine area. Based on these data, the data interpolation of rainfall and temperature for each rainfall station can be done to obtain temperature data, rainfall and number of dry months in the area to be evaluated.

Soil properties data can be obtained from soil maps also can be obtained by analyzing soil samples in the laboratory. Topographic properties data including relief and slope obtained from contour maps carried out by a routine survey in mining operations. After all the data to be used in the process of land evaluation collected the matching process can be done between land characteristics and desired land use requirements / crop requirements.

### 5. Land Evaluation Using Geographic Information System (GIS)

Geographic information system (GIS) is a computer-based system consisting of hardware, software and brain ware to process and analyze geographic data<sup>10,11)</sup>. Because its ability to process spatial data as well as attribute data of geographic phenomena have been utilized extensively by

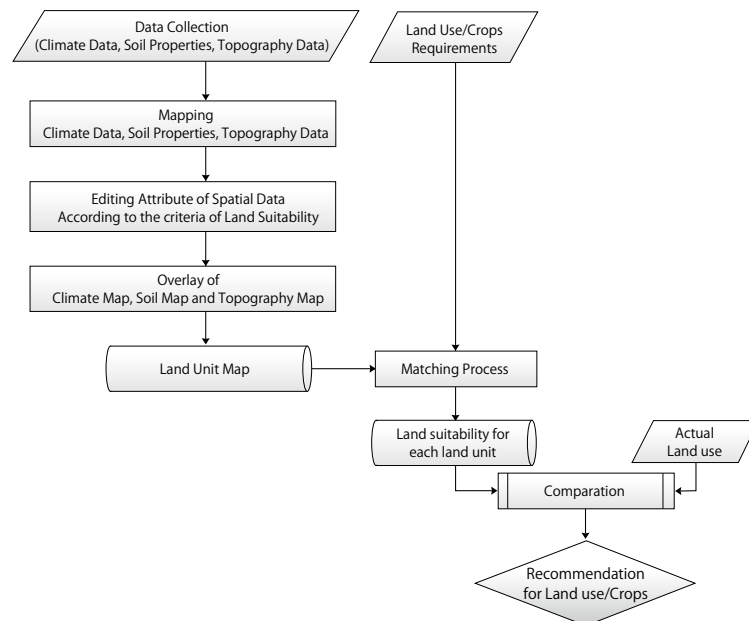


Fig. 2 Flowchart of Land Evaluation using GIS.

a variety of fields such as management of land resources, forestry, agriculture, marine and fisheries, infrastructure, tourism, plantation, mining and economic field.

GIS application for the land evaluation had applied in many countries for the various land use. An application of land suitability evaluation using GIS for example determine the land suitability for rice crop, land suitability evaluation for sorghum crop, land evaluation on afforestation spatio-temporal decision support and analysis for hillside development <sup>12,13,14</sup>.

Using of GIS for the land suitability evaluation in line with step of land evaluation, as can be seen in Figure 2, the steps are as follows

1. Data collection of climate data, soil properties and topography data
2. Mapping climate data, soil properties and topography data
3. Editing attribute of spatial data according to the criteria of land suitability
4. Overlay of climate map, soil map and topography map to generate land unit map
5. Matching process between land unit map and land use/crops requirement to generate land suitability for each land unit
6. Comparing between land suitability for each land unit and actual land use to get the recommendation for land use or crops.

Detail procedure to perform land suitability evaluation using GIS can be seen in Figure 3. It is starting with data collection of land characteristics includes climate data, soil properties data and topography data. All land characteristic data were mapped to generate spatial data.

Climatology data including rainfall and temperature data mapped by interpolation to produce isohyet map and isotherm map, also can be mapped by creating a polygon Thiessen map to map the area of influence of each rainfall station. Figure 4 shows the example of polygon Thiessen map, it displayed using ArcMap Arc GIS 9.3 Software. Polygon Thiessen describe the area of influence of a rainfall station point. This map contains information about climate including name of rainfall station, temperature, rainfall, number of dry months and air humidity.

Data on soil maps can be mapped based on the soil map or based on land units. Figure 5 shows exploration soil map-Pontianak (MA49) as the example of Indonesia soil map<sup>15</sup>). Topography data includes relief and slope can be mapped with elevation data interpolation to generate contour maps and processed with the 3D Analyst extension to produce slope map and relief. Figure 6 shows the contour map, one of topography data, it displayed using ArcMap Arc GIS 9.3 Software. Contour map can be used as input data to generate other topography data including slope map and relief map.

After completion the data collection and editing the attribute data adjusted to the criteria of land suitability, followed by map overlay process of all land characteristics to produce an overlay map which the attribute data contains all columns from the attribute data of input maps. The next process is matching process between the attributes of land characteristic with land suitability criteria using query analysis. After the matching process is complete it will acquired land suitability of each land units. Due to the overlay process involves a lot of land

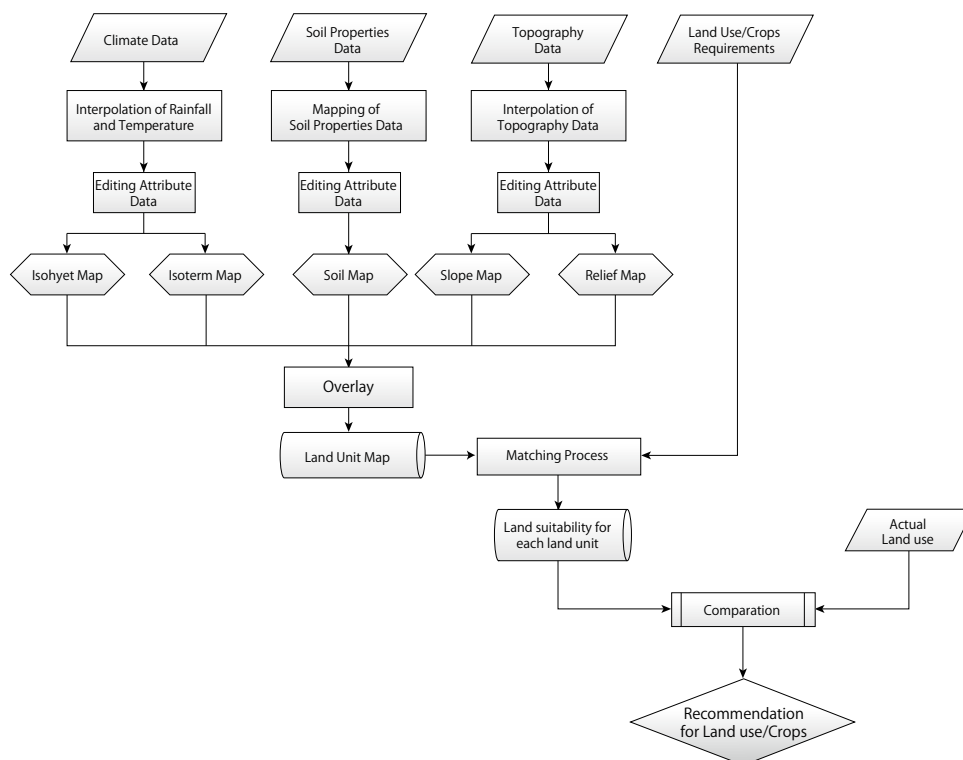


Fig. 3 Detail Procedure of Land Evaluation using GIS.



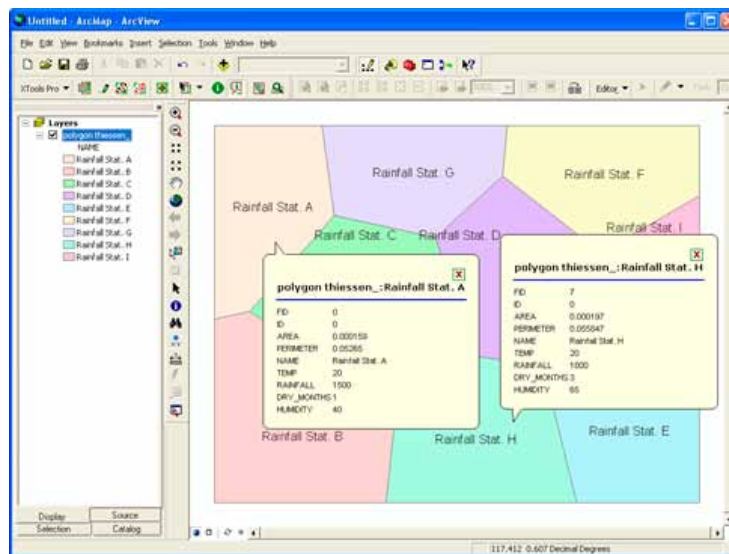


Fig. 4 Example of Polygon Thiessen Map.

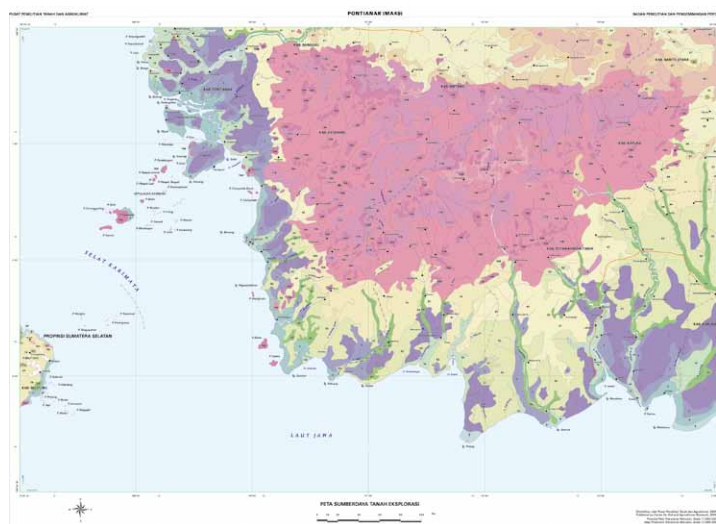


Fig. 5 Exploration Soil Map-Pontianak (MA49)<sup>15)</sup>.

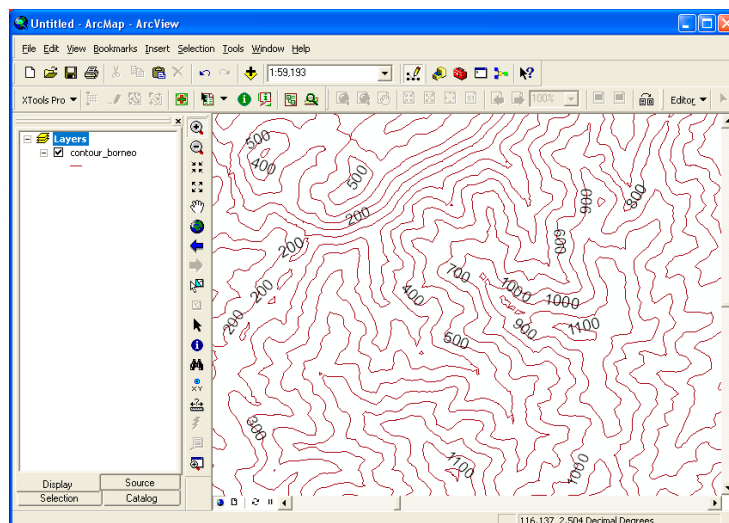


Fig. 6 Contour Map.

characteristics maps will be generated many small land units; therefore it is necessary to dissolve to merge the land units that have the same degree of land suitability.

Land suitability evaluation using GIS has many advantages such as producing maps that describe each of land unit spatially, analysis which integrates spatial data and attribute data, attribute data is easily manipulated and analyzed based on the purpose and objective, the results can be displayed as a map, table, diagram and report.

Land suitability evaluation process using GIS in mining operation is feasible to do, it would be easier process considering all the physical parameters of land used in the evaluation process is usually mapped using GIS for various purposes in mining operations, including as a regular report to the local government and environmental agency.

## 6. Conclusions

Indonesia Government obligate mining company provides post mining activities plan. A land evaluation method enables determination of post mining land use in appropriate result. This process can be carried out computerized or manually. The land evaluation process using GIS enables effective, easy and systematic determination of post mining land use.

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