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Integration of GIS modeling with Fuzzy Logic method for land optimization of post mining on coal mine in South Kalimantan province: A case study of PT Wahana Baratama Mining

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Abstract

Currently coal companies, especially in South Kalimantan, have not been yet or only slightly entered the post-mining stage, although part of the mining blocks have been totally exploited, so that the company should have been preparing for the development of other sectors (non-mining). It shows that optimization of coal resources from exploration, mining to post-mining land use is necessary to ensure sustainable mining and sustainable development in terms of meeting the conservation aspect. To meet all aspects of conservation, the achievement of optimization in a series of mining business activities is started from the potential optimization of the potential of the coal remain resources until the optimization of post-mining land use is absolutely required. This research has analyzed several alternative sectors outside mining, which will be selected for optimization of utilization or post-mining land use, including plantation, recreation, industry and conservation sectors. The analyzing process used several parameters to assess the selected sector including rainfall, slope and land use. Therefore, this study uses an approach of GIS-based methods (knowledge-driven), mainly fuzzy logic for post-mining land use planning. The selected mining area for this study belongs to PT. Wahana Baratama Mining company that has a Work Agreement for Coal Mining Exploitation. The result shows the suitability of plantation for the optimization of land use in all mining sites and also for conservation areas or protected forests.

Keywords: Optimization, Land use, Post-mining, Fuzzy logic.

Abstrak

Saat ini banyak perusahaan batubara terutama di Kalimantan Selatan belum ada atau hanya sedikit yang memasuki tahap pascatambang, walaupun sebagian blok tambang telah selesai dieksploitasi, sehingga perusahaan tersebut seharusnya sudah mempersiapkan pengembangan sektor lainnya (di luar sektor pertambangan).Hal tersebut menunjukkan tingkat optimalisasi sumber daya batubara mulai dari eksplorasi, penambangan sampai dengan pemanfaatan lahan pascatambang mutlak diperlukan untuk menjamin pertambangan berkelanjutan dan pembangunan berkelanjutan dalam memenuhi aspek konservasi. Jadi, pencapaian optimalisasi dalam suatu rangkaian kegiatan usaha pertambangan adalah mulai dari optimalisasi potensi sumber daya sisa batubara sampai dengan optimalisasi pemanfaatan lahan pascatambang mutlak dilakukan untuk memenuhi segala aspek konservasi. Penelitian ini telah menganalisis beberapa sektor alternatif di luar pertambangan yang akan dipilih untuk optimalisasi pemanfaatan atau penggunaan lahan pascatambang, termasuk sektor perkebunan, rekreasi, industri dan konservasi. Studi ini menggunakan beberapa parameter untuk menilai sektor yang akan dipilih meliputi faktor curah hujan, kemiringan dan penggunaan lahan. Sehubungan dengan hal ini digunakan pendekatan metode berbasis GIS terutama logika fuzzy untuk perencanaan penggunaan lahan pascatambang. Wilayah pertambangan yang dipilih untuk penelitian ini adalah milik PT. Wahana Baratama Mining, sebagai pemegang izin Perjanjian Karya Pengusahaan Pertambangan Batubara. Hasilnya menunjukkan kesesuaian perkebunan untuk optimalisasi penggunaan lahan di semua lokasi pertambangan dan juga sebagian kecil lahan untuk kawasan konservasi atau hutan lindung.

Kata kunci: Optimisasi, Penggunaan lahan, Paskatambang, Fuzzylogic.

1. Introduction

The management capability in optimizing coal resources, will ultimately influence the success of sustainable mining and sustainable development. One of these successes is that a company has considered factors for determining the purpose or direction of designation after reclamation [1,2, 3,4,5]. Therefore, it can be determined the steps of environmental management and monitoring activities in achieving the reclamation success after post-mining stage. This is also adapted to the socio-economic conditions of the communities surrounding coal companies in general that depend on the plantation and agriculture sectors based on a review of data from Central

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Bureau of Statistics.[6] It also encourages mining companies to give priority of the land use for the plantation area, which is the development of optimization modelling to illustrate the above series whose estuary, that is a series of conservation policies [1,2, 3,4,5]

The success of reclamation is very supportive to determine the allotment of post-mining land in accordance with the needs of the surrounding community of mining activities. While the success of the company in preparing communities around the mine, socially and economically contributes to the independence of the community.

Setiabudi and Hutamadi (2003) stated that the Conservation of Minerals Materials (COMM) is essentially a safeguard, repair and use of mined materials wisely that can provide high economic and social benefits, preserve the function of the environment, and ensure the sustainability of development for the community.

Optimization of land use related to the achievement of sustainable development is indicated by the level of reduction of dependence on the mining sector and the development of other sectors for the growth of new economic areas in post-mining land. The development of sectors outside the mine can be evaluated with common parameters such as land use, slope and rainfall that can influence the sustainable development with reference to the recommended parameters of previous studies.

This study analyzes the suitability of land for land use optimization and also by considering used several parameters to assess, which a sector will be selected, including rainfall, slope and land use factors. [8,9,10] This study is limited in the analysis of optimization of conformity or land use using several criteria. Some of the main criteria comprise such as rainfall, slope and limits of land administration/infrastructure. In this analysis, it must first determine the output, because this study aims to optimize the mining area for sectors outside mining activities or sustainable development, then the output selected according to related statistics in the area of plantation, recreation, industry and conservation.

Fuzzy logic method has been widely used to assist in decision-making process. Fuzzy set was first developed in 1965 by Prof. Lotfi A. Zadeh. This theory has been widely developed and applied in various real problems. This method often begins with and developed based on a number of rules defined by decision makers. [11]

2. Methodology

This study developed a model for the determination of land suitability (plantation, industry, conservation/ protected forest, and recreational land) using the above-described theories of fuzzy logic. The object of this research took a case study at several coal companies that had mining licenses of Work Agreement for Coal Mining Exploitation (*Perjanjian Karya Pengusahaan Pertambangan Batubara*/PKP2B) in South Kalimantan.

Several coal mining companies included in PKP2B (Contract of Work) are still active in South Kalimantan (about 14 companies), in which PT Wahana Baratama Mining (PT WBM) was selected for this study. The company site is PKP2B Second Generation located in Sungai Cuka Village, Kintap, Tanah Laut Regency and Bukit Baru Village, Satui, Tanah Bumbu Regency, South Kalimantan. The company has 7811 Ha but only one main pit is active in the western part of the PKP2B Concession still in Kintap, Tanah Laut regency but only one main pit is active in the western part of concession still in Kec. Kintap, Tanah Laut Regency. Location PT WBM can be reached by using regular Jakarta - Banjarmasin for approximately 90 minutes. Furthermore, through the Banjarmasin

Figure 1. Location of PT Wahana Baratama Mining mining site in South Kalimantan

- Kintap highway, this location can be reached for approximately 3 hours with a distance of about 150 km. To reach the working area of PT. Wahana Baratama Mining can be reached by four-wheeled vehicles through a paved road more or less 5 km from the company basecamp (Figure 1).

Optimization of the suitability of land/land use in this study is directed to the use of plantation/agricultural and conservation areas, whereas the determination of the criteria optimization of land use can be seen in Table 1. While the criteria on the table refers to the rules that set by the government and refers to the Guidelines for the Spatial Layout (RTRW) of the Regency (Law No. 26 Year 2007 on Spatial Planning) Such the law was issued by the National Spatial Planning Coordinating Agency of the Republic of Indonesia. [11]

The criteria (as well as sub-criteria) determination of land use calculation must be referred to the above laws and regulations, so that it cannot be done arbitrarily. [11] In this case, to make the determination of fuzzy logic calculation criteria was used the criteria and sub-criteria of land suitability determination that include:

- availability of water (rainfall, humidity, drainage, surface area of aquifer);
- availability of oxygen (drainage, slope);
- landscape/morphology (physiographic, slope inclination, erosion sensitivity, erosion rate);
- type of vegetation (forest, rice field);
- road network (primary, secondary).

In detail, the above criteria for land types cover plantation, conservation, recreation and industry landscape considers the fulfillment of criteria with the characteristics shown in table 1.

Analysis of land suitability for post-mining land use optimization was conducted through a system of fuzzy logic. This research used a Mat lab software to solve a complex calculation of fuzzyfication from related graphical method. The analysis of fuzzyfication deals with the necessary steps to convert bivalent values into specific membership values. [11]

Triangular membership functions actually have some other

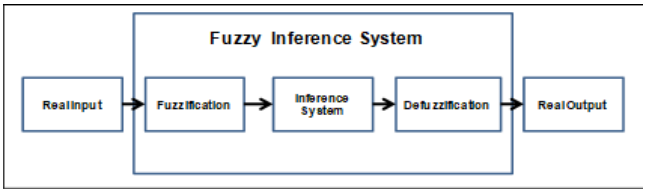

Figure 2. The scheme of the system of analysis Fuzzy Logic

Table 1.The criteria of optimal value for the selection of four alternative land use

Criteria	Land Use			
	Plantation	Conservation	Recreation	Industry
Slope				
0 - 8 %				
8 - 15 %				
15 - 25 %				
25 - 45 %				
> 45 %				
Rain Fall				
0 - 100 mm				
100 - 200 mm				
200 - 300 mm				
300 - > 600 mm				
Distance to Road				
1 - 3 km				
3 - 5 km				
> 5 km				
Distance to Settlement				
1 - 3 km				
3 - 5 km				
> 5 km				
Distance to River				
1 - 3 km				
3 - 5 km				
> 5 km				

Law No. 26/2007 on Spatial Planning of the District (Nugroho and Hartati, 2012)

membership functions, such as Gen Bell, Sigmoid, Phi, Trapezoidal, Gaussian, Piece Wise Linear, and so on. This study uses Triangle membership function in this analysis. Thus, the formula for calculating the degree of membership used is as follows. [11]

$$\mu - \text{triangular}(x, a, b, c) \begin{cases} 0, x < a, x > c \\ (x-a)/(b-a), a < x < b \\ -(x-c)/(c-b), b < x < c \end{cases}$$

3. Results and Discussion

The analysis of the land suitability for the land use is the basis of the environmental management of the coal company. As described in the previous chapter, fuzzy logic analysis includes three important steps, namely, inference and defuzzyfication. In this research, the series of analysis can be applied to the company that has PKP2B licence through three stages of fuzzy logic analysis. The first stage is fuzzyfication, that perform to changing the firm or crisp/bivalent values into the values of the more specific natural fuzzy membership (Fuzzification) for all inputs using the Mat lab software (Figure 3.). As for determining the most optimal output (land suitability) used several criteria such is with the following parameters or conditions:

- tilt slope with a certain class distance;
- rainfall at certain periods with reference intervals accordingly;
- administrative map in the form of the distance from the highway;
- administrative map in the form of the distance from settlement e.g. village;
- administrative map in the form of the distance from the main river.

This criterion refers to the rules that have been regulated by the government and refers to the Guidelines for Spatial Layout (RTRW) of the Regency (Law No. 26 Year 2007 on Spatial Planning) issued by the National Spatial Planning Coordinating Agency of the Republic of Indonesia.[11] The above criteria parameters must be generally inputted without a specific limitation according to the class distance and determined by reference or field research data, e.g. drought slope and rainfall map. The result of this series of analysis stages is shown in Figure 3.

After completing related main criteria inputs, the next step is the fuzzy set inference rules.[11] Based on the reference guide of rainfall map, slope and land administration/land use and related reference then arranged fuzzy inference rules according to predetermined output objectives. The process does not only take into consideration some of the detailed analyzied criteria, but in this research also select the suitable area for land optimization such as plantation land, conservation sites, recreational lands and industrial land. Those can be determined based on the overlay map land unit map by fuzzy logic determination method and GIS modeling approach.

In conducting analysis of suitability optimization or land utility, this research uses criteria map. Some of the main criteria such as the rainfall map around concession of PT. Adaro Indonesia and the slope map give significant contribution for decision optimization of land suitability. Analysis of GIS modeling for suitability optimization uses the criteria above and guidance of reference (Figure 7) based on the criteria as follows:

- slope, in the research area is generally 0-25% for plantation and over 25% for conservation land;
- rainfall, generally over 100 mm;
- distance from street, close enough around about 1 km;
- distance from settlement, close enough about 1 km;
- distance from river, close enough about 1 km.

Referring to Nugroho and Hartati (2012), the determination of fuzzy logic above was based on land suitability optimization criteria. The inference process for this fuzzy logic method can manually be performed either by Mamdani or Sugeno methods. One example for this analysis is the rainfall criterion (Figure 4) with certain subcriteria such as high (>100 mm) and low rainfall (<100 mm). Application of the sample analysis, this research used the Mamdani model (Nugroho and Hartati, 2012) as follows:

- If Rain_Fall Is Low Or Medium THEN Characteristic _Land Is Land_Recreation;
- IF Rain_Fall Is High Or Very high THEN Characteristic_Land

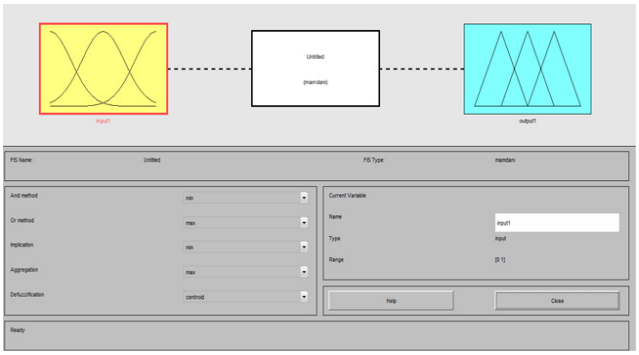

Figure 3. The Fuzzification Stages inputs all the criteria and output data

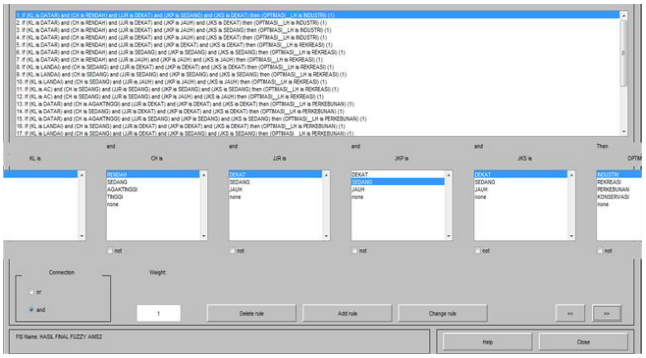

Figure 4. Input data in the form of rules

Figure 5. The process of defuzzification stage for plantation output

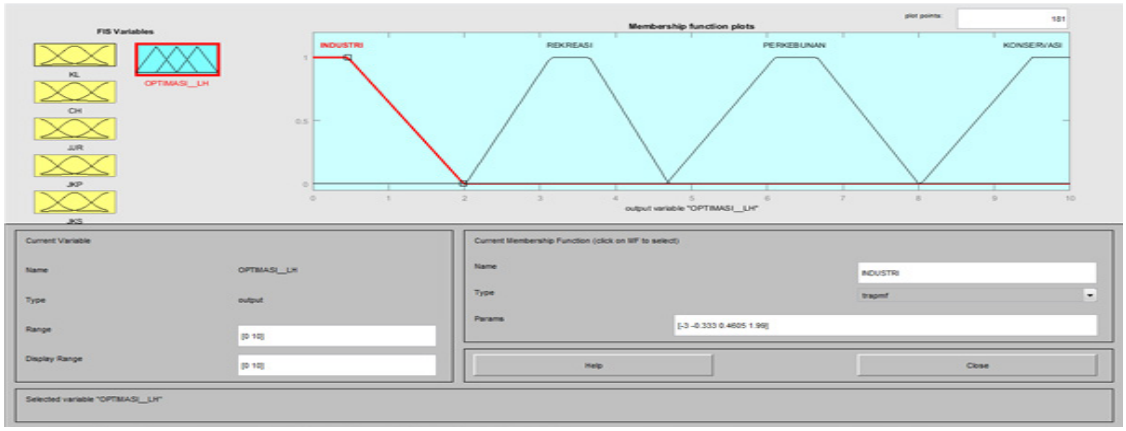

Figure 6. Results for the plantation output of the defuzzification process

Is Land_Conservation;

- IF Rain_Fall IS Low THEN Characteristics_Land IS Land_Industry;
- IF Rain_Fall IS Low Or Medium Or High THEN Characteristic_Land Is Lahan_Plantation.

The next step of the fuzzy logic analysis or deffuzyfication stage is to return the results of the inference analysis to the firmly return value to determine the highest output value. The result of the above analysis at PT. Adaro showed the limit criteria indicator after the defuzzyfication. The results of this analysis is shown in Figure 5 and Figure 6.

After a series of fuzzy logic analyzes, simultaneous and integrated GIS analysis is overlaid using spatial operations and then converted into vector-based GIS databases, since the entire overlay process is completed in a vector format shape file. [12] The stages are done by input data into fuzzy logic devices in GIS, including input criteria e.g. slope map, rainfall map, distance map from highway, distance map of settlement and distance map from river. Then for the selection of alternative land use (conservation, plantation, recreation and industry) as output data. [11]

The result can be seen that the role of the predictor map can produce the land unit map that must be analyzed again by fuzzy logic analysis of course through several series of analysis process. [12]

The results of the analysis also show that the other allotment is land use for conservation areas of only about 0.08% of the total concession area compared to the plantation area and about 1.46%, which is not potential outside the two areas. The results of the anal-

ysis also show that the environmental performance has the potential to directly impact the environmental management performance of PT. Wahana Baratama Mining, which has long been in the operational stage of production. [9, 10, 11]

This study has analyzed the potential of plantations based on the local statistical data to contribute significantly beyond the mining sector. The analysis result shows that the prepared criteria suggest the optimum output of land to the plantation sector. [15] It can be shown that the plantation sector contributes to the sustainable development data from Central Bureau of Statistics. [6] Therefore, the data for the output criteria for the plantation sector should have been considered for preparing PT. Wahana Baratama Mining's future corporate reclamation plan. [9, 10, 11]

Based on the local government statistic central data, the analysis of land suitability optimization in PT.WBM is proposed since the post mining activity which is expected to be returned to the original function (rubber plantation area) (figure 7). This is in accordance with the social need and encourage economic level in Tanah Laut and Tanah Bumbu Regencies, where there has been rubber plantation processing plant. The result of this analysis shows that social-economic performance of the society is dominant enough data from Central Bureau of Statistics. [6]

The analysis result also indicated that the environmental performance does not always affect directly because the performance of the processing surrounding PT. Wahana Baratama still in the early stage. The result of analysis suggested that PT.Wahana Baratama Indonesia should manage its environment (reclamation and revegetation) into the plantation sector such a sector will give a socio-economic advantage besides the mining sector. [15]

The plantation sector will give a significant contribution to the sustainable development. Therefore, the selected plantation sector should be considered to the post mining plan of PT. Wahana Baratama Mining (Figure 7). The company has also an area of approximately 97.7%, which is feasible and significant to be diverted to other sectors outside mining activities in order to achieve complete sustainable development above (Figure 7).

4. Conclusion

The variables of land use are the important factor to determine the optimization of land use suitability within the framework of sustainable development, as shown below:

result of GIS modeling integration approach (overlay) and fuzzy logic analysis shows that the land use is based on the employed criteria such as infrastructure map, rainfall and slope;

the optimization of the suggested land is plantation area (about 97.7%) or agriculture and the rest is conservation areas (about 0.08%).

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