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GIS Approach for Wind Power Plant Development in South Sulawesi, Indonesia: A Location Suitability Analysis

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Abstract. In Indonesia, one of the renewable energy sources which is promising to be developed for producing electricity at a certain region is wind energy. However, a suitable area for the wind farm is affected by various factors. Therefore, selecting the best site using a certain procedure is important to maximize the benefits obtained. This research has the focus to identify the optimal location in Jeneponto regency, South Sulawesi province based geographic information system (GIS) for developing wind power plant (WPP). Three step analyses using the scoring approach with 7 parameters in total were applied to determine the best location specifically. The adopted parameters which are considered affect decision in building WPP at particular place include wind potential, elevation, slope, land use type, soil condition, populated area, and distance to roads (access). In the first step analysis using 5 parameters for eleven sub-regencies in Jeneponto, it is obtained that area within Kelara sub-regency is the suitable location. To identify more detail, second step analysis using 5 parameters for 10 villages within Kelara sub-regency shown that there are three villages as candidates for the best location as indicated by the same highest scoring total. Next, final analysis for the three locations using all considered parameters shown in Tolo village is the best site with 127-hectare area. As applied procedure based GIS is capable in determining optimal location, presented results useful to increase more WPP particularly in South Sulawesi to follow electricity demand growth.

INTRODUCTION

Utilization of renewable energy sources (RES) for producing electrical energy is expected an increase from year to year to meet future load in one country. The usage of RES for electricity generation has many advantages compared to fossil fuel in some aspects such as more environmentally friendly and lower electricity production cost. Besides that, the efficiency of power generation is generally getting better due to technology advancement. These make RES increasingly attractive to be developed further for electricity production.

In Indonesia, one of RES which promising to be developed is wind energy as the wind potential at certain regions is relatively good. However, a suitable area for the wind farm is affected not only by wind potential in one place but also by other factors. Some the factors or parameters which influence the decision for a building of WPP at particular area included such as land use type, populated area, orography, soil type, access, and environmental impact [1,2]. Considering the factors are needed because of different reasons. In general, information such as land use type is to confirm whether the site can be used (permitted) for development WPP or not; populated area is to know suitable distance to wind farm site; orography data is to know surrounding condition which may affect wind characteristic; soil type is important for WPP construction, access is to ensure the availability of road for WPP

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development; meanwhile environmental aspect is to confirm the possible impact of the WPP in selected area such as disruption to the birds immigration path or electromagnetic interference [1]. Selecting the best site using a certain procedure which considered various parameters is important to get maximum benefits including reducing its effect concerning environmental aspect. Besides that, the cost for WPP project is relatively high, thus, feasibility study including finding the optimal location is ideally done [3]. Knowledge for best site and wind farm potential can be used for development plan and energy policy in one place [4]. However, selecting an appropriate location for WPP is not an easy task (a complex process) as it is affected by many factors [3]. With regards to this, one of the approaches that can be applied to identify and to assess suitability location for WPP in one place is using GIS. This general approach has been used successfully not only for WPP case but also in some other renewable energy applications [5].

Previous studies related to wind farm location analysis at certain areas in some different countries can be found in [2-11], namely in USA [2], in Jordan [3], in India [4,6], in Lebanon [5], in Poland [7], in Abu Dhabi Emirate [8], in Oman [9], in Cyprus [10], and in Thailand [11-12]. This present work has a focus to identify the optimal location in Jeneponto regency, South Sulawesi province, Indonesia for developing WPP. To get the best location, three-step analyses based GIS using general scoring technique are performed. Seven parameters in total were used in the wind site selection process.

Structure of this paper consists of four main parts. Part 2 describes the area study, used criteria and selection procedure for WPP location in Jeneponto. Part 3 presents the results regarding the optimal site for WPP in the observed area, and meanwhile in Part 4 is the conclusion and implication of the study.

AREA STUDY AND SELECTION PROCEDURE

Studied area for development WPP in Indonesia is focused on Jeneponto as seen in Fig. 1. Jeneponto which has eleven sub-regencies is one of the regencies in South Sulawesi province. It is located with the northern boundaries of Gowa and Takalar regencies, the eastern boundary with Bantaeng regency, the southern border with Flores sea, and the western boundary with Takalar regency with an area of 749.79 km^2. Average wind speed is generally above 5 m/s. Thus, the area within Jeneponto is potential enough for developing WPP and interesting to be observed in more detail.

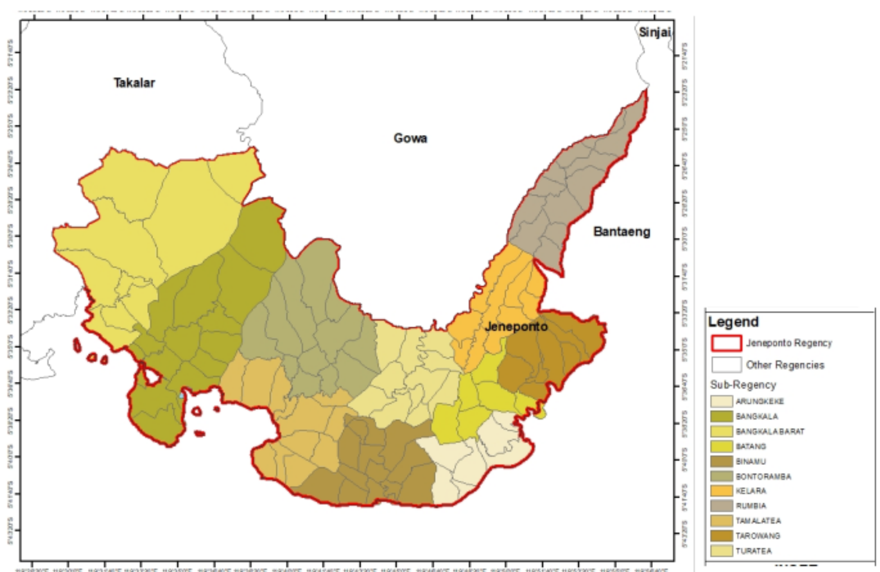

FIGURE 1. Location map of Jeneponto regency.

For selection criteria, adopted parameters which are considered affect decision in building WPP from literature [1,2] are wind potential, elevation, slope, land use type, soil condition, access, and populated area. Here, wind speed parameter is classified into 5 categories, namely very low (< 2 m/s), low (2–3 m/s), medium (3–4 m/s), high (4–5 m/s), and very high (> 5 m/s). For elevation (above sea level (ASL)), it is categorized into high (> 100 m), medium (50–100 m), low (0– 0 m). The slope is divided into 5 categories, namely very good (0–8°), good (9–15°), neutral (16– 25°), poor (25– 40°), and very poor (>40°). Land use is divided into 5 categories includes very good (non-forest area (NFA)), good (protection forest (PF)), neutral (production forest (PRF)), poor (limited production forest (LPR)), and very poor (hunting park (HP)). Soil type is divided into very good (hap-ustalfs), good (haplustults), neutral (ustropepts), poor (ustipsamments), and very poor (dystrandepts). For distance to roads (access), it is classified into very suitable (> 300 m, smooth asphalt), suitable (250-300 m, asphalt), neutral (150–250 m, smooth ground), unsuitable (50-150 m, non-smooth ground), and very unsuitable (0–50 m, rocky land). Meanwhile for populated area, it is divided into very suitable (> 300 m, very not crowded), suitable (250–300 m, not crowded), neutral (150– 250 m, medium), unsuitable (50–150 m, crowded), and very unsuitable (0–50 m, very crowded).

In this study, three-step analyses using the scoring approach with the seven parameters were applied to determine the best location for a wind farm. In the first step selection, analysis using 5 parameters for eleven sub-regencies in Jeneponto is done. In the second step, villages in the best sub-regency will be analyzed using 5 parameters to find some candidates for the best location based scoring total value. Next, the final analysis is done for candidate locations using all parameters to determine the best area specifically for placing WPP. The five parameters (weights in percent) for the first and the second step are wind potential (30%), elevation (20%), slope (20%), land use type (20%), and soil condition (10%). Meanwhile given weight values for seven parameters in the third step are 25% for wind speed, 20% for elevation, 20% for slope, 15% for land use type, 10% for soil condition, 5% for distance to roads or access, and 5% for a populated area. Next, giving scoring or rating for every category in each parameter is done. Final score for each step is based on the weights and scoring for parameters and categories. Score value for some parameters (wind speed, elevation, and slope) are shown in Table 1.

TABLE 1. Score value for wind speed, elevation, and slope parameters

Wind Potential:

Category	Range	Scoring
Very high	> 5 m/s	5
High	4 – 5 m/s	4
Medium	3 – 4 m/s	3
Low	2 – 3 m/s	2
Very low	< 2 m/s	1

Elevation (ASL):

Category	Range	Scoring
High	> 100 m	5
Medium	50 – 100 m	3
Low	0 – 50 m	1

Slope:

Category	Range	Scoring
Very good	0 – 8°	5
Good	9 – 15°	4
Neutral	16 – 25°	3
Poor	25 – 40°	2
Very poor	> 40°	1

Data for the observed area for analysis of Step 1 are summarized in Table 2. The wind speed information is taken from [13] and others derived from spatial data. For example, a potential map for elevation and slope can be seen in Figs. 2 and 3, respectively.

TABLE 2. Summary of parameter data for eleven sub-regency in Jeneponto

Sub-Regency	Parameter				
	Average Wind Speed (m/s)	Elevation (m ASL)	Slope (°)	Land Use	Soil Type
Bangkala Barat	7.9	20 – 250	25 – 40	HP	Haplustults
Tamalatea	7.9	50 – 120	0 – 8	NFA	Haplustults
Bontoramba	7.9	20 – 400	25 – 40	PF	Haplustults
Binamu	7.9	10 – 40	0 – 8	NFA	Haplustalfs
Turatea	7.9	30 – 90	0 – 8	NFA	Haplustalfs
Batang	7.9	10 – 120	9 – 15	NFA	Haplustalfs
Arungkeke	7.9	30	0 – 8	NFA	Haplustalfs
Tarowang	7.9	10 – 30	9 – 15	NFA	Ustropepts
Kelara	7.9	130 – 180	9 – 15	NFA	Haplustalfs
Rumbia	7.9	340 – 1400	16 – 25	NFA	Dystrandepts
Bangkala	7.9	10 – 330	25 – 40	PF	Ustipsamments

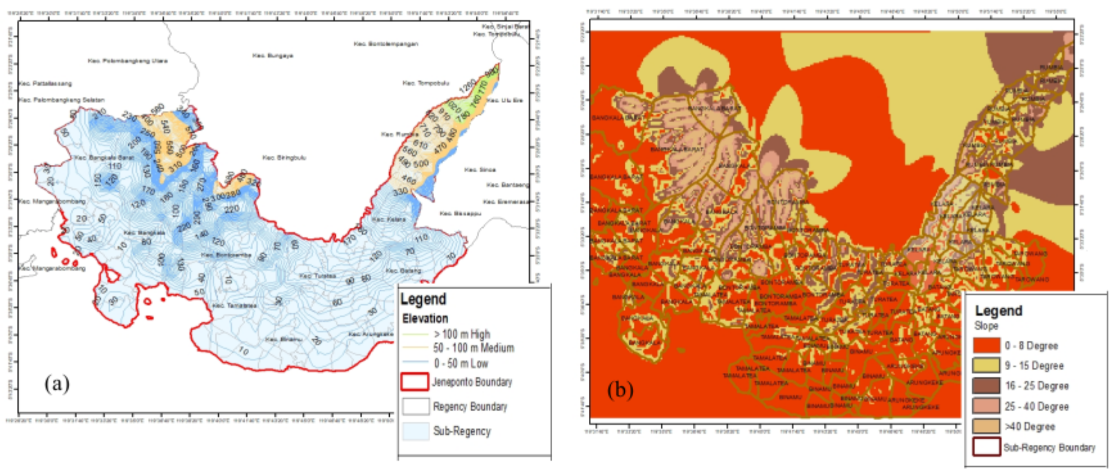

FIGURE 2. Potential map for Jeneponto: (a) elevation, (b) slope.

RESULTS AND ANALYSIS

Table 3 shows the results of the Step 1 selection process. From the results, it is found that among sub-regencies in Jeneponto, an area within Kelara is the appropriate location (grey color) as indicated by the obtained highest scoring total value (4.8). To identify more specific the suitable area, the second step analysis is performed by using five.

TABLE 3. Scoring value for Step 1 analysis

Sub-Regency	Parameter					Total
	Wind Speed	Elevation	Slope	Land Use	Soil Type	
Bangkala Barat	1.5	0.2	0.4	0.2	0.4	2.7
Tamalatea	1.5	0.2	1.0	1.0	0.4	4.1
Bontoramba	1.5	0.2	0.4	0.8	0.4	3.3
Binamu	1.5	0.2	1.0	1.0	0.5	4.2

TABLE 3. Continued

Sub-Regency	Parameter					Total
	Wind Speed	Elevation	Slope	Land Use	Soil Type	
Turatea	1.5	0.2	1.0	1.0	0.5	4.2
Batang	1.5	0.2	0.8	1.0	0.5	4.0
Arungkeke	1.5	0.2	1.0	1.0	0.5	4.2
Tarowang	1.5	0.2	0.8	1.0	0.3	3.8
Kelara	1.5	1.0	0.8	1.0	0.5	4.8
Rumbia	1.5	1.0	0.8	1.0	0.1	4.4
Bangkala	1.5	0.2	0.4	0.8	0.2	3.1

TABLE 4. Scoring value for Step 2 analysis

Village in Kelara	Parameter					Total
	Wind Speed	Elevation	Slope	Land Use	Soil Type	
Tolo	1.5	1.0	1.0	1.0	0.5	5.0
Tolo Barat	1.5	1.0	1.0	1.0	0.5	5.0
Tolo Selatan	1.5	1.0	1,0	1.0	0.5	5.0
Tolo Timur	1.5	0.2	0.8	0.6	0.4	3.5
Tolo Utara	1.5	0.2	0.4	0.8	0.4	3.3
Bonto Lebang	1.5	1.0	0.8	0.6	0.5	4.4
Samataring	1.5	0.6	0.4	0.6	0.5	3.6
Bonto Nompo	1.5	0.2	0.4	0.6	0.4	3.1
Gantarang	1.5	1.0	0.4	0.6	0.4	3.9
Tombolo	1.5	0.2	0.4	0.6	0.2	3.2

TABLE 5. Scoring value for final analysis (Step 3)

Village	Parameter							Total
	Wind Speed	Elevation	Slope	Land Use	Soil Type	Access	Populated Area	
Tolo	1.25	1.0	1.0	0.75	0.5	0.25	0.25	5.00
Tolo Barat	1.25	1.0	1.0	0.75	0.5	0.25	0.20	4.95
Tolo Selatan	1.25	1.0	1.0	0.75	0.5	0.25	0.20	4.95

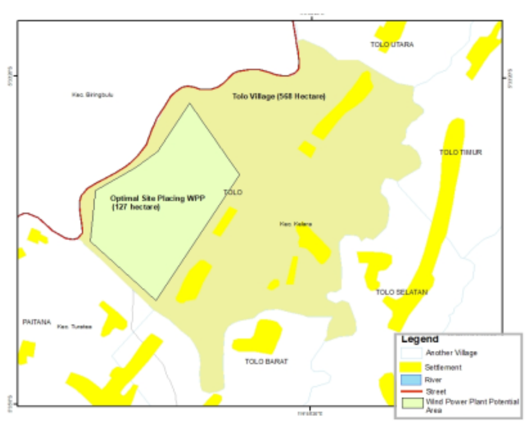

FIGURE 3. Best location for placing WPP in Tolo village.

parameters for selection. As results, among villages in Kelara, there are three villages which have the same highest scoring total (5), namely Tolo, Tolo Barat, and Tolo Selatan as seen in Table 4. This means the three villages are candidates for the best location. Next, final selection using all considered parameters for the three locations shown that area within Tolo village is the best site for placing WPP. Moreover, WPP operation in the site will not interrupt with the immigration routes of birds as well. The area of Tolo village is 568 hectare. Based on the existing condition, a potential site for placing a wind turbine in Tolo is around 127 hectare. The location for the optimal site of the WPP in Jeneponto is shown in Fig. 3. As the Indonesian government declares to increase the usage of power plant based RES, therefore, utilization of wind energy for WPP in Tolo village, Jeneponto is meaningful. It can increase the usage energy alternative to meet electricity needs in South Sulawesi besides Sidrap wind farm, and a wind farm in Kayuloe village - Jeneponto in the next few years.

CONCLUSION

This research presents a location suitability analysis for placing WPP particularly in Jeneponto regency, Indonesia based GIS. Scoring approach with three-step analyses was applied to find the best location specifically using 7 criteria or parameters. It is concluded from results that area in Tolo village is the best site for building a wind farm in Jeneponto with 127-hectare area. The implemented procedure using GIS approach is capable in determining suitable site specifically for placing wind farm in Jeneponto. Therefore, presented information will useful to enhance the usage of WPP for electricity production or for sustainable energy development in South Sulawesi, Indonesia to follow load growth.

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