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GIS-based site analysis for selecting suitable sites of waste-to-energy plants in Pathumthani

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Abstract

In response to cumulative municipal waste problem in Pathumthani, a waste-to-energy electric power plant is selected as waste management approach. This study aims at assessing waste-to-energy power plant potential zones in Pathumthani using Geographic Information System (GIS). GIS data collection depends on all 12 factors considered in this study as follows: the distances from power plant site to communities, to industrial areas, to power lines, to power stations, to waterworks stations, to hospitals, to education institutes, to main water resources, to accessible roads, to railways, to airports and the risk of flooding. After multiple layers of information have been generated as a single map using GIS, the suitable power plant locations are defined on the basis of the ordered weighted averaging (OWA) technique. Color-coded symbology is applied to the maps to differentiate suitable/unsuitable areas for power plant establishment. Considering proportions of suitable areas of each of the seven districts to the total area of the province, the most suitable district is Klong Luang, followed by Nongsua, Lamlukka, Ladlumkaew, Muang Pathumthani, Thanyaburi, and Samkok districts, respectively. This analysis approach should be further developed and applied to other areas.

Keywords: Waste-to-energy power plant, Location suitability analysis, Pathumthani, GIS

1. Introduction

The domestic disposal of municipal solid waste is inappropriate such as uncontrolled incineration and open dumping leading to difficulties in recycling programs. These open-air disposal approaches cause hazardous air pollution associated with PM 2.5 exposure. According to the Waste Management Master Plan of Thailand (2016-2021), the sustainable reginal solid waste management in Thailand has planned to launch proper recycling project by 2021. Therefore, government and private sectors need to make implement the waste management technology.

Several big cities in Thailand are currently facing problems concerning a large quantity of garbage. Therefore, efficient garbage management solutions are required. One promising outcome relies on a conversion of garbage into electricity as the benefit of this strategy. In this case, Pathumthani, a metropolitan area, is a fast−growing city with continuously increasing number of population, resulting in increasing daily amount of waste. Pathumthani handles approximately 1,829 tons of garbage per day. About 70% of this amount is disposed in nearby provinces while the remaining 30% accumulates daily within the province. The management of substantial quantity of accumulated wastes is endorsed by central government policy for energy recovered from municipal solid wastes in different regions including Pathumthani. Criterion for siting a suitable solid waste incineration power plant is considered not only appropriate location, but also optimal one to avoid unnecessary loss caused by unexpected disaster and public dissatisfaction. Site selection for the waste−to−energy plant in Pathumthani, one of influencing factors is the region specified as the area for raw water source conservation for Metropolitan Waterworks Authority. A raw water pumping station located in Muang district in Pathumthani extracts raw water from the Chao Phraya River to produce and distribute tap water to eastern part of Bangkok.

Therefore, the result of suitability assessment for site selection of waste–to–energy power plant should be satisfied by all stakeholders.

This research conducted to evaluate potential site of waste–to–energy power plant for a moving grate incineration of solid waste in Pathumthani limits the scope of this investigation. The moving grate incineration technology is selected as energy recovery from municipal solid waste owing to less electricity consumption required for reduction of large waste volume. Selecting a possible location for construction of waste–to–energy plant in Pathumthani via geographic information system (GIS) analysis is applied by ranking of the area based on their weighted suitability score assigned to each factor such as distance to water sources, distance to electricity systems, distance to public water supply systems, distance to roads, and distance to the residential and etc. (Misra & Sharma, 2015). A decision making tool for suitability analysis of potential sites is geographic information system (GIS) due to its high capacity in collecting, displaying, and analyzing multiple datasets (Rikalovic, Cosic, & Lazarevic, 2014). The application of GIS and spatial data provided a set of attribute values is efficient for assessing potential candidate sites to construct waste–to–energy power plants based on the suitability score (Goyal, Sharma, & Joshi, 2017). The decision–making approach in site selection for waste–to–energy power plant in Pathumthani is the integration of Ordered Weighted Averaging (OWA) technique with GIS that the order weights assigned to a given criteria for all factors according to specific requirements and preferences are taken into account (Zahibi, et al., 2019).

2. Research objectives

1. To specify factors and criteria for selecting suitable locations of waste-to-energy power plants in Pathumthani based on GIS data

2. To determine appropriate sites of waste-to-energy power plants in Pathumthani using the Ordered Weighted Averaging technique

3. Methodology

The research methodology can be divided into two parts namely the part of data collection and the part of GIS-based data analysis as described below.

3.1 Data collection for each factor

This research has collected data of influencing on suitability of waste-to-energy power plant sites from three main governmental organizations namely Department of Public Works and Town & Country Planning (DPT), Provincial Electricity Authority (PEA), and Provincial Waterworks Authority (PWA). Based on the acquired data, there were 12 factors for assessing site suitability using the selected criteria by environmental experts for assigning weights and scores as shown in Table 1.

Table 1. List of decision factors and their associated criteria, weights, and scores for suitability analysis of waste–to–energy power plant sites

No.	Analyzed factors (variables)	Criteria	Weight	Score	Data source
1	Distance from urban areas and community centers	Over 5 km away from communities	15	3	Using munisan_a dataset of DPT
		3-5 km away from communities		2	
		< 3 km from communities		1	
2	Distance from industrial areas	< 0 km from industrial areas	10	3	Extracting features with codes 3000-3800 from Landsum_a dataset of DPT
		1-3 km away industrial areas		2	
		Over 3 km away from industrial areas		1	
3	Distance from power lines	< 50 m from power lines	10	3	Using LB_Centertline dataset of PEA
		50-100 m from power lines		2	
		Over 100 m from power lines		1	
4	Distance from power stations	< 50 m from power stations	12	3	Using DS_T_Station dataset of PEA
		50-100 m from power stations		2	

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No.	Analyzed factors (variables)	Criteria	Weight	Score	Data source
		Over 100 m from power stations		1	
5	Distance from waterworks stations	Over 100 m from waterworks	12	3	Merging district-level data of PWA to derive PWA_merged dataset
		50-100 m from waterworks		2	
		< 50 m from waterworks		1	
6	Distance from hospitals	Over 5 km away from hospitals	7	3	Extracting features with codes 6500-6580 from Landsum_a dataset of DPT
		2-5 km from hospitals		2	
		0-2 km from hospitals		1	
		Overlapping hospitals		0	
7	Distance from education institutes (academies)	Over 3 km away from academies	6	3	Extracting features with codes 6100-6180 from Landsum_a dataset of DPT
		1-3 km from academies		2	
		0-1 km from academies		1	
		Overlapping academies		0	
8	Distance from main water resources	Over 1 km away from water resources	12	3	Extracting features with codes 9511 (rivers) and 9512 (canals) from Landsum_a dataset of DPT
		0.5-1 km from water resources		2	
		10 m - 0.5 km from water resources		1	
		Overlapping or within 10 m from water resources		0	
9	Accessible roads	3-300 m away from roads	7	3	Using roadedge_a dataset of DPT
		300-800 m from roads		2	
		Over 800 m away from roads		1	
		Overlapping or within 3 m from roads		0	
10	Flood risk levels	Low level of flood risk	9	3	Using F-DWR2 dataset of Department of Water Resources
		Moderate level of flood risk		2	
		High level of flood risk		1	
11	Railways	Overlapping railways or within 20 m away from railways	0	0	Using railedge_a dataset of DPT
12	Airports	Overlapping airport areas	0	0	Using airport_a dataset of DPT
		Total weight	**100**		

Note: The factors and their criteria weights, and scores were derived from relevant literatures and communication with domain experts.

3.2 Data analysis procedures

The data analysis consists of the following procedures.

a. Make the dataset of each factor containing distance information according to the specified criteria by using the Multiple Ring Buffer command of ArcGIS and editing the output attribute table to obtain value fields associated with their weights and scores as shown in Figure 1. To indicate relative suitability levels of the set of ordered weighting factors, scores ranging from 1 to 3 are given as follows: 1 refers to low suitability, 2 refers to moderate suitability, and 3 refers to high suitability levels. The sum of percentage weight factors equals 100. In case of two overlap datasets, a score of the

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features is specified to be 0 based on the overlap criterion when overlapping is not allowed.

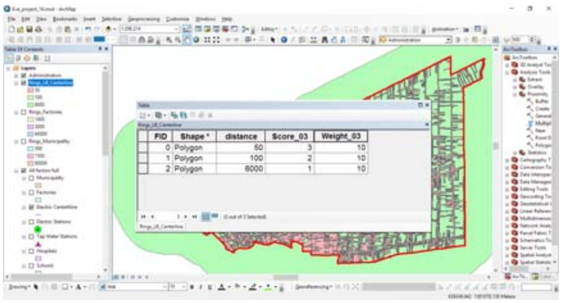

Figure 1. An example of scores and weights given using the Multiple Ring Buffer command with its attribute table

b. Use the Clip function with the output feature of the Multiple Ring Buffer command in order to obtain a dataset coverage equal to the area of the province of Pathumthani as shown in Figure 2.

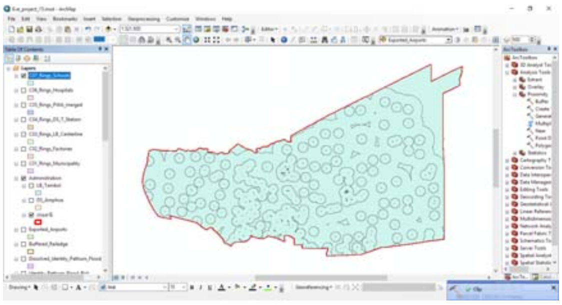

Figure 2. An example of output coverage corresponding to marked geometry of Pathumthani province with the given input dataset

c. Combine multiple datasets of the 12 factors together by using the Union command as shown in Figure 3.

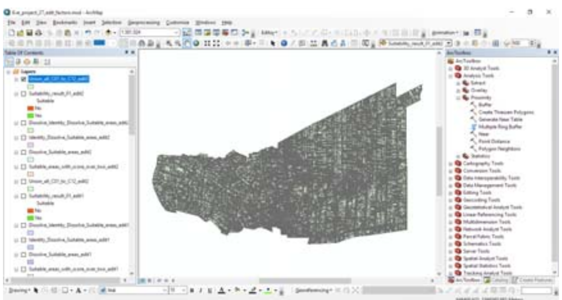

Figure 3. The resulting dataset by combining layers of spatial data and attribute data of all factors

d. Calculate the suitability value of each of resulting feature of the dataset based on the original weights and scores assigned to each factor as shown in Figure 4.

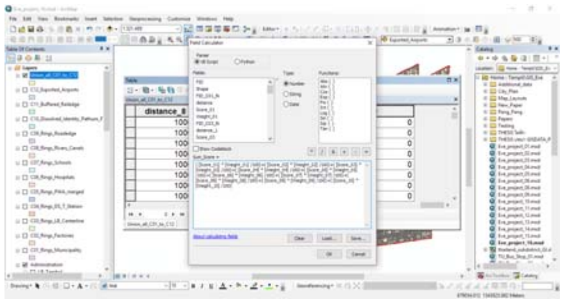

Figure 4. The command and the formula for calculating suitability values of the resulting dataset based on the previously given weights and scores

e. Select features that represent suitable areas for construction of waste-to-energy power plants based on the following criteria: 1) area outside the edge of the province of Pathumthani to avoid the overlapping (areas with original score of 0); and 2) the resulting total score greater than 2.00 indicating the moderately suitable level as shown in Figure 5. Using symbol colors for suitability classification, green is assigned to suitable areas while red is assigned to unsuitable areas as shown in Figure 6.

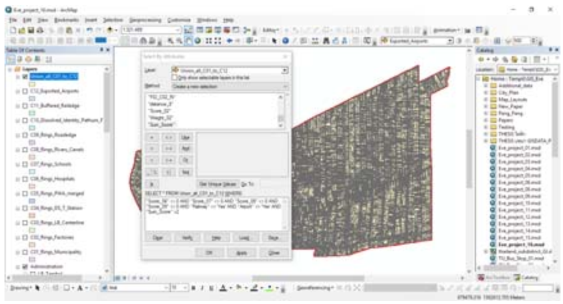

Figure 5. Parameters for selecting suitable areas to build waste-to-energy power plants to meet the criteria for a score of 2.00.

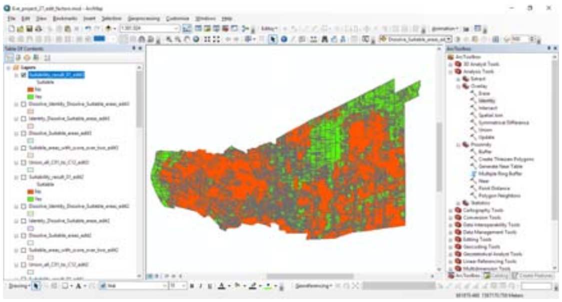

Figure 6. Classification of area suitability for waste-to-energy power plants using symbol colors (green represents suitable areas and red represents unsuitable areas.).

f. Analyze suitable/unsuitable areas of each district in Pathumthani province to generate the output layer by combining the features of the dataset of districts and the output dataset obtained from step (e) using the Identity function.

4. Results

The site suitability assessment areas for waste-to-energy power plants using GIS–OWA technique were used to achieve the suitable/unsuitable area sizes in each district of Pathumthani province as shown in Figure 6 and Tables 2 and 3.

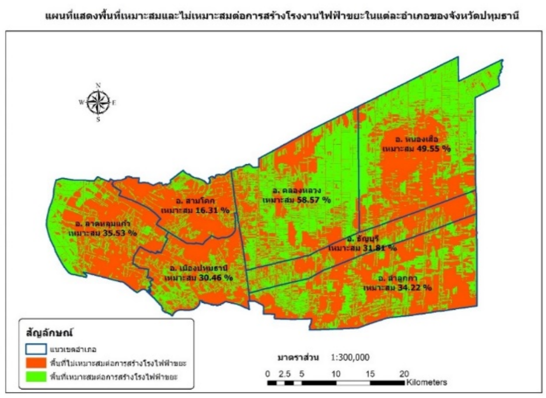

Figure 7. Site suitability analysis for waste-to-energy power plants in each district of Pathumthani province

Table 2. The percentage of suitable/unsuitable areas in Pathumthani province for construction of waste-to-energy power plants

Province/category	Area (rai)	Percent
Pathumthani	950,036.74	100.00
Unsuitable class	562,966.31	59.26
Suitable class	387,070.43	40.74

The analysis result at the provincial level reveals that the total area of Pathumthani of 950,036.74 rai, about 60% is suitable and 40% is unsuitable for construction of waste-to-energy power plant as shown in Table 2.

Table 3. Percentage of suitable/unsuitable areas for construction of waste-to-energy power plants in each district of Pathumthani province with the total area of 950,036.74 rai

District/category	Area (rai)	Percentage of area suitability for each district (%)	Percent area of the province
Pathumthani	**950036.74**		**100.00**
Muang Pathumthani	**89287.55**	**100.00**	**9.40**
No	62093.81	69.54	6.54
Yes	27193.74	30.46	2.86
Klong Luang	**189759.28**	**100.00**	**19.97**
No	78619.27	41.43	8.28
Yes	111140.00	58.57	11.70
Thanyaburi	**71788.83**	**100.00**	**7.56**
No	48953.83	68.19	5.15
Yes	22835.00	31.81	2.40
Ladlumkaew	**122316.25**	**100.00**	**12.87**
No	78859.89	64.47	8.30
Yes	43456.36	35.53	4.57
Lamlukka	**190125.99**	**100.00**	**20.01**
No	125059.40	65.78	13.16
Yes	65066.59	34.22	6.85
Samkok	**74327.07**	**100.00**	**7.82**
No	62202.87	83.69	6.55
Yes	12124.19	16.31	1.28
Nongsua	**212431.77**	**100.00**	**22.36**
No	107177.23	50.45	11.28
Yes	105254.54	49.55	11.08

No refers to unsuitable area and Yes refers to suitable area.

As illustrated in Table 3, the suitability rating of the potential areas for construction of waste-to-energy power plants on a scale from high to low is Klong Luang (11.7%), followed by Nongsua (11.08%), Lamlukka (6.85%), Ladlumkaew (4.57%), Muang Pathumthani (2.86%), Thanyaburi (2.4%), and Samkok (1.28%).

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5. Conclusion and discussion

The site selection for waste-to-energy power plants in Pathumthani was conducted by the GIS–OWA based suitability analysis with specific range of selection criteria. The result of area suitability analysis revealed that approximately, 60% of total area of Pathumthani was under suitable areas. At the district level, Klong Luang was classified as very highly suitable area, followed by Nongsua. This finding is in agreement with opinions of the inquiring experts and many experienced field operators.

6. Recommendations

The methodology of this study in selecting factors and analyzing the collected data can be further improved and applied to other studied areas by taking into account the physical characteristics of the land and garbage management policy.

7. Acknowledgement

This work would not have been possible without the information provided by Provincial Electricity Authority, Provincial Waterworks Authority and Government office in Pathumthani. The author would like to express our sincere gratitude to the School of Engineering, Thammasat University for the support of the Faculty Research Grants.

8. Conflict of Interest

This research was conducted without any conflicts of interest.

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