Spatial analysis for the selection of landfill in Jepara Regency

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Spatial analysis for the selection of landfill in Jepara Regency

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1. Introduction

A landfill is a location for processing and returning waste safely to humans and the environment [1]. The selection of the landfill site is essential due to the enormous potential of environmental pollution and various technical, economic and environmental criteria which must be given proper attention.

In meeting the needs of solid waste facilities, Jepara Regency has three landfills, namely Bandengan, Gemulung, and Krasak. Bandengan is the central Landfill, while Gemulung and Krasak are the supporting Landfills. Bandengan currently uses a landfill system with a total area of 7.13 Ha. This is expected to be filled up in the next 1.68 years [2]. Gemulung landfill has an area of 0.9025 Ha while Krasak is only 0.708 Ha. Both of them use the open dumping system, and they were closed in 2013 according to Law No.18 of 2008. Due to the prolonging problems, it is necessary to plan a new landfill with sufficient capacity. The landfill should have sufficient capacity and must meet the standard environmental requirements.

The very first step of this planning is site selection. Improper site selection will lead to future environmental problems. Furthermore, if the landfill's operational activities conflict with the social interests of the surrounding community, there will be interferences [3]. In fact, to date, site selection activities are often constrained by land readiness issues. Therefore, the best option for the sites is on government lands because land readiness is the main determinant in choosing a development location.

The site selection operation is a long and complicated process. Hence, a method is needed to make the process easier and more straightforward. One method that can be successfully applied is the Geographic Information System (GIS). It can enter, store, integrate, manipulate, analyze, and display geographic reference data. The use of GIS will shorten the analysis time of various parameters of land suitability assessment for precise locations with high data accuracy [4].

Statistics say that it is necessary to conduct a research in determining the feasibility zone and alternative locations that can be recommended as a landfill in Jepara Regency. The results of the study are expected to be given due to the consideration in the preparation of new landfill planning

1.1. Problem Formulation
According to the described background, the problem statement is taken as follows
1. Which zone is suitable for use as a landfill location?
2. Which alternative sites can be recommended as the landfill locations?

1.2. Purpose and objective
The objective of this research is to select the best landfill location in Jepara. Therefore, the site should be environmentally sound and have great adequacy to be used as a facility to return waste to the environment for humans safely. Therefore, this study aims to:
1. Assess the most suitable zone for the landfill location.
2. Review alternative available sites that can be recommended as landfill.

2. Methods
2.1. Research Criteria and Data
This research begins with determining the location selection criteria according to SNI 03-3241-1994 regarding the Procedure for Selecting the location of landfill [5]. This was then followed by a literature review. The criteria based on SNI used in this study are as follows:
1. Criteria in the regional stage

This criterion is used to determine decent or inappropriate landfill zones. It consists of the following:

a. Geological factor; the geological factor consists of 2 criteria, namely 1) Not being located in the fault zone or Holocene fault. It is also not allowed to be located in the geologically dangerous zones or landslide-prone areas.

b. Hydro-geological factors which comprises of 3 criteria, which are 1) Not having a groundwater level of less than three meters, 2) not passing the soil permeability greater than 10^{-6} cm / second, 3) the distance to the source of drinking water must be greater than 100 meters downstream. In the event that there are no zones that meet the criteria above, technological input must be made.

c. Topographical factor, which means that the slope of the zone must be less than 20%

d. The distance from the airfield must be greater than 3,000 meters for turbo jet flights and must be greater than 1,500 meters for other types.

e. Must not be in a protected area/nature reserve and flood area with a 25-year return period.

2. The allowance stage criteria are used to select the best site from the output location generated based on regional criteria. These criteria can be seen in **Table 1**.

As shown in **Table 1**, SNI 19-3241-1994 is a rule used in site selection, and this was made 24 years ago (1994). For reference addition, it is vital to look at the latest literature. The literature review consists of 11 studies on the topic of choosing landfill sites. The study was conducted by 1) Colvero et al., 2018 [6], 2) Khan et al., 2017 [7], 3) Setyarini, 2016 [8], 4) Rahmat et al., 2016 [9], 5) Bahrani et al., 2016 [10], 6)

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Torabi-Kaveh et al., 2016 [11], 7) El Maguiri et al., 2016 [12], 8) Djokanovic et al., 2016 [13], 9) Chabuk et al., 2016 [14], 10) Hanine et al., 2016 [15] and 11) Donevska et al., 2012 [16]. The criteria used in the study of landfill site selection are 23 as seen in **Figure 1**.

Table 1. Allowance Criteria for site selection

No.	Parameter
I	**Public**
1	Administrative Limits with Weights 5. The criteria and scores are (1) within the administrative boundary = 10, (2) outside the administrative boundary but in an integrated landfill management system = 5, (3) outside the administrative boundary and outside the management system integrated garbage = 1, (4) outside the administrative boundary = 1
2	Ownership of the land with weight 3. The criteria and scores are (1) local / central government = 10, (2) personal (one) = 7, (3) private / company (one) = 5, (4) more than one owner of rights and / or ownership status = 3, (5) social / religious organization = 1
3	Land capacity with weight 5. The criteria and scores are (1)> 10 years = 10, (2) 5 years - 10 years = 8, (3) 3 years - 5 years = 5, (4) less than 3 years = 1
4	Number of landowners with weight 3. The criteria and scores are (1) one (1) kk = 10, (2) 2 - 3 kk = 7, (3) 4 - 5 kk = 5, (4) 6-10 kk = 3, (5) more than 10kk = 1
5	Community participation with weight 3. The criteria and scores are (1) spontaneous = 10, (2) driven = 5, (3) negotiation = 1
II	**Physical Environment**
1	Land (above ground level) with weight 5. The criteria and scores are (1) the permeability score $<10^{-9}$ cm / sec = 10, (2) the permeability score is 10^{-9} cm / sec - 10^{-6} cm / sec = 7, (3) Permeability score > 10^{-6} cm / sec reject (unless there is technology input) = 0
2	Groundwater with weight 5. The criteria and scores are (1) depth> 10 m with permeability $<10^{-6}$ cm / sec = 10, (2) depth <10 m with permeability $<10^{-6}$ cm / sec = 8, (3) depth = 10 m with a passing of 10^{-6} cm / sec - 10^{-4} cm / sec = 3, (4) Depth <10 m permeability 10^{-6} cm / sec - 10^{-4} cm / sec = 1
3	Groundwater flow system with weight 3. The criteria and scores are (1) discharge area / local = 10, (2) recharge area and local discharge area = 5, (3) recharge regional and local areas = 1
4	Relation to groundwater utilization with weight 3. The criteria and scores are (1) the possibility of low utilization with hydraulic limit = 10, (2) projected to be used with hydraulic limit = 5, (3) projected to be used without hydraulic limit = 1
5	Flooding danger risk with weight 2. The criteria and scores are (1) there is no danger of flooding = 10, (2) the possibility of flooding> 25 years = 5, (3) the possibility of flooding <25 years reject (unless there is technology input) = 0
6	Soil cover with weight 4. The criteria and scores are (1) sufficient soil cover = 10, (2) soil cover up to half the age of use = 5, (3) No. soil cover = 1
7	Rainfall intensity with weight 3. The criteria and scores are (1) below 500 mm per year = 10, (2) between 500 mm to 1000 mm per year = 5, (3) above 1000 mm per year = 1
8	Road to location with weight 5. The criteria and scores are (1) flat with good conditions = 10, (2) flat with bad conditions = 5, (3) up / down = 1
9	Waste transport (one road) with weight 5. The criteria and score are (1) less than 15 minutes from the garbage centroid = 10, (2) between 16 minutes - 30 minutes from the garbage centroid = 8, (3) between 31 minutes - 60 minutes from the centroid garbage = 3, (4) more than 60 minutes from the centroid garbage = 1
10	Entrance with weight 4. The criteria and scores are (1) garbage trucks not through residential areas = 10, (2) garbage trucks through medium density residential areas (≤ 300 people / ha) = 5, garbage trucks through high density residential areas (≥ 300 people / ha) = 1
11	Traffic with weight 3. The criteria and scores are (1) located 500 m from public roads = 10, (2) located <500 m in low traffic = 8, (3) located <500 m in medium traffic = 3, (4) located in high traffic = 1
12	Land use with weight 5. The criteria and score are (1) having a slight impact on surrounding land use = 10, (2) having a moderate impact on surrounding land use = 5, (3) having a large impact on land use around = 1
13	Agriculture with weight 3. The criteria and scores are (1) located on unproductive land = 10, (2) there is no impact on agriculture around = 5. (3) there is a negative influence on agriculture around = 1, (4) Located on productive agricultural land = 1
14	Protected area / nature reserve with weight 2. The criteria and scores are (1) there is no protected area / nature reserve around it = 10, (2) there is a protected area / nature reserve around it which is not negatively affected = 1, (3) There is a negative effect for protected area / nature reserve around it = 1
15	Biological with weight 3. The criteria and scores are (1) low habitat value = 10, (2) high habitat value = 5, (3) critical habitat = 1
16	Noise, odor with weight 2. The criteria and score are (1) there is a buffer zone = 10, (2) there is a limited buffer zone = 5, (3) there is no buffer zone = 1
17	Aesthetics with weight 3. The criteria and scores are (1) the hoarding operation is not visible from the outside = 10, (2) the hoarding operation looks slightly from the outside = 5, (3) the hoarding operation looks from the outside = 1

Source: *SNI 03-3241-1994*

Of the 23 criteria in **Figure 1**, there are 6 criteria that have a percentage of more than 50%. These criteria are 1) distance to road, 2) slope of the land, 3) distance to a residential area, 4) land use, 5) depth of groundwater, 6) distance to the water source. This will be included in the regional stage criteria issued by SNI to add relevance to the situation and conditions in the election. Of the 6 criteria, there are 3 that are the same as those in regional stages, namely 1) distance to rivers and water bodies, 2) depth of groundwater

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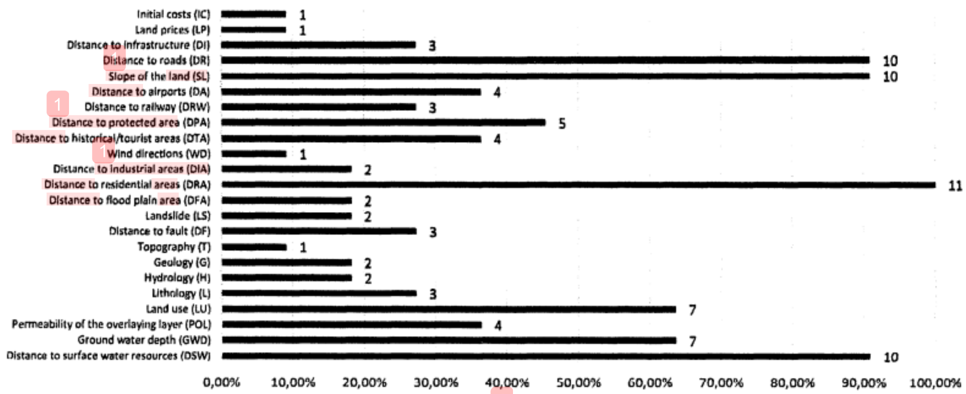
level and 3) slope of the land. Only three criteria are based on the literature review added at the regional stage, namely 1) distance to the road, 2) distance to settlements and 3) land use. Hence this study established 34 criteria for site selection. They were then grouped into two, namely 12 regional criteria and 22 criteria for elimination.



Source : Colvero et al., 2018, Khan et al., 2017, Setyarini, 2016, Rahmat et al., 2016, Bahrani et al., 2016, Torabi-Kaveh et al., 2016, El Maguiri et al., 2016, Djokanovic et al., 2016, Chabuk et al., 2016, Hanine et al., 2016 and Donevska et al., 2012

Figure 1. Amount and Percentage of Use of Landfill Site Selection Criteria

2.2. Stages of Analysis

After the relevant results were collected, data analysis was carried out. The method used was multi-criteria spatial analysis. It included the analysis of spatial data performed on many criteria using ArcMap software. Some data required preceeding process to fit the existing criteria which will eventually produce new data and the information is referred to as geoprocessing (spatial analysis). The spatial analyses used consist of buffering, overlay, query, interpolation, and the shortest path.

After obtaining the spatial analysis data, this result can be directly examined at the regional stage. At this stage, the analysis was performed on 12 criteria according to SNI and literature review, namely 1) distance to faults, 2) landslide-prone zones, 3) distance to airports, 4) protected area zones, 5) flood-prone zones, 6) soil permeability, 7) distance to river, 8) depth of groundwater table, 9) slope of land, 10) distance to road, 11) distance to settlements and 12) land use. The twelve criteria are overlaid which produce a zone map of a possible area that is not feasible for landfill. Analysis at the regional stage raised the output of prospective landfill sites. From those candidates, a report is needed at the stage of elimination. Therefore, the best output alternative location can be produced. The elimination stage has 22 criteria that will be analyzed through scoring. The total score in the allowance stage was used as the final score in ranking alternative landfill locations. The ranking was made up of alternative sites sorted from the highest to the lowest scores.

3. Results and Discussions

3.1. Regional Level Analysis

Regional stage analysis was conducted to discover the best location corresponding to SNI 03-3241-1994 and literature review. In the regional stage, spatial analysis was performed on 12 criteria as stated at the analysis stage. The 12 criteria in the overlay produced a suitable and unsuitable area zone map. To facilitate the analysis, the 12 analysed unsuitable zones were combined using union techniques. Hence, a combined zone map presented the unsuitable locations. The map of the small zone was then overlaid again with the

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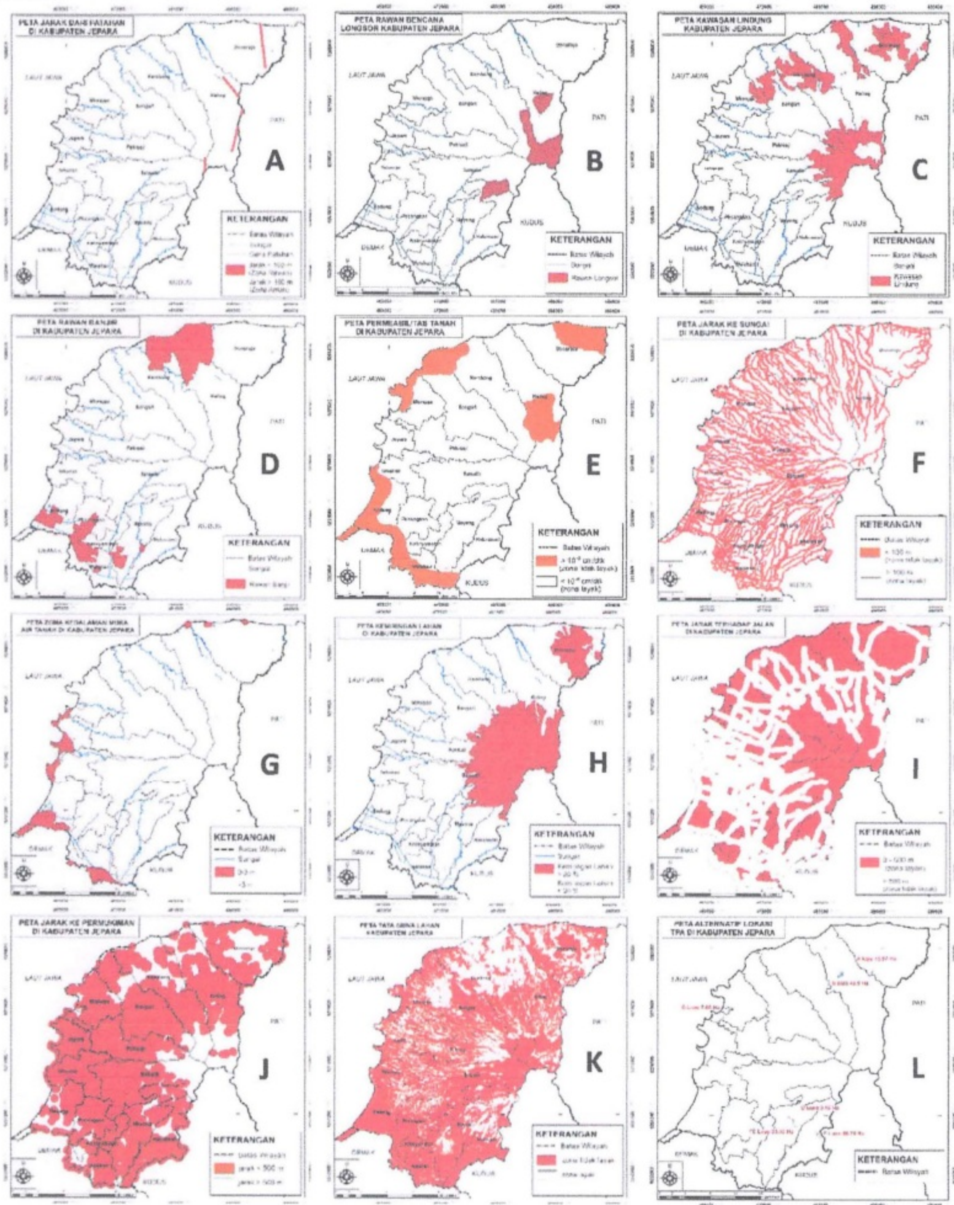
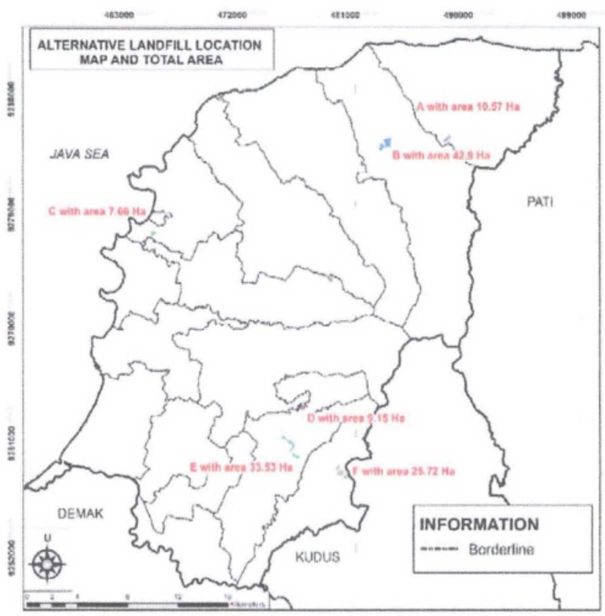
official map so that an empty zone that was not covered by the unsuitable zone map appeared. The empty zone is a decent zone for the landfill location. The analysis process at the regional stage can be seen in **Figure 2.**



Source: Analysis of The Researcher. Information: A. Distance with Fault Map, B. Landslide Hazard Map, C. Map of Protected Areas, D. Flood-Prone Map, E. Soil Permeability Map, F. Distance to River Map, G. Map of Groundwater Face Depth Zone, H. Slope Map, I. Distance for Roads Map, J. Distance to Settlements Map, K. Land Use Map, L. Regional Phase Analysis Output Maps.

Figure 2. Analysis process of regional stages

The various locations in the feasible zone were selected as alternative points. The area of the material is one of the most essential criteria that can be used as the material for consideration in choosing an alternative. The area of a polygon in a decent zone that is quite spacious can be chosen as an alternative, while the small ones can be ignored. Of the 12 polygons in the feasible zone, there are 6 locations which are considered to be quite spacious (having an area of more than 5 hectares) and can be chosen as the alternative location. The location points chosen and determined as alternative locations can be seen in **Figure 2**. The calculator field calculated the land area of each alternative location in the table of alternative location layer attributes. From these calculations, it was known that the entire feasible zone for alternative landfill sites is 129.53 Ha or 0.13% of the total area of Jepara Regency. The output from the allowance stage analysis can be seen in **Figure 3**.



Source: Analysis of The Researcher

Figure 3. Alternative landfill location

3.2. Analysis of the stage of removal

Analysis of the allowance stage was performed to produce the most suitable location. The data on 6 alternative locations that have been generated at the regional stage was used. The elimination stage has 22 criteria that will be used for analysis. Each criterion has a different score and weight by SNI. At this stage, data has been processed and was classified according to their weight and value. This was carried out by scoring as a whole by multiplying the weight with the score of each criterion. The data obtained from the analysis are the scores of each alternative landfill location with a maximum total score of 790. The scores of each alternative result of the analysis can be seen in **Table 3**. The score can be calculated for finding the suitability of the alternative locations. The results of this scoring are used to see the level of location feasibility. From **Table 3** it can also be seen that the most suitable alternative location is location B with a score of 561 and a suitability level of 71%. Conversely, alternative locations with the lowest level of suitability (53%) are A with a score of 420. According to this rating, the most feasible alternative location recommendations appeared as the location B in Keling Village, Keling District, location E in Datar, Pule and Buaran Villages, Mayong District and location F in Ngetuk Village, Nalumsari District.

Table 2. Assessment of alternative landfill locations at the stage of elimination

No.	Criteria	Ideal score	alternative Location					
			A	B	C	D	E	F
B	Stage of Allowance							
I.	GENERAL							
1	Administrative Limits	50	50*	50*	50*	50*	50*	50*
2	Ownership of land	30	9	15*	9	9	9	9
3	Land capacity	50	5	25*	5	5	25	25*
4	Number of land owners	30	3	30*	3	3	3	3
5	Society participation	30	15*	15*	15*	15*	15*	15*
II	PHYSICAL ENVIRONMENT							
1	Soil	50	35*	35*	35*	35*	35*	35*
2	Groundwater	50	40	40	40	50*	50*	40
3	Groundwater flow system	30	30*	30*	30*	15	15	15
4	Relation to groundwater utilization	30	15	15	15	30*	30*	30*
5	Flood Hazards	20	20*	20*	20*	20*	20*	20*
6	Land cover	40	20*	20*	20*	20*	20*	20*
7	Rain intensity	30	3*	3*	3*	3*	3*	3*
8	Road to location	50	25	50*	50*	5	50*	50*
9	Garbage transport	50	15	40*	40*	40*	15	15
10	Entrance	40	20*	20*	20*	20*	20*	20*
11	Traffic	30	24*	3	24*	24*	24*	24*
12	Land use	50	25	50*	25	25	25	25
13	Agriculture	30	3	15*	3	15*	15*	15*
14	Protected Area	20	20*	20*	20*	20*	20*	20*
15	Biological	30	30*	15	30*	15	15	15
16	Noise, smell	20	10	20*	10	20*	20*	20*
17	Aesthetics	30	3	30*	3	30*	30*	30*
	Scoring Stage Score	790	420	561	470	469	509	499
	Allowance Stage Rating		6	1	4	5	2	3
	Level of Convincing Stage Suitability		53%	71%	59%	59%	64%	63%

Source: Analysis of The Researcher
Description: * sign shows the highest value among alternative landfill locations

4. Conclusion

This research was carried out to discover the most suitable landfill location in Jepara Regency as a substitute for the existing landfill. The criteria used in this research are by SNI 03-3241-1994 regarding the Procedure for Selection of Landfill Waste Sites and literature review. Hence, site selection analysis used a multi-criteria spatial analysis method, with a geographic information system device in the form of ArcGIS. The feasible zone for the landfill site has an area of 129.53 ha or 0.13% of the total area of Jepara Regency. The recommended location, ranked based on the scoring presented a result where the first location is Keling Village, Keling Subdistrict, the second location is in Datar, Pule and Buaran Villages, Mayong District, and the third location is in Ngetuk Village, Nalumsari District.

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