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THE EVALUATION OF BULUSAN LANDFILL CAPACITY IN BANYUWANGI

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Abstract. *The Bulusan landfill of Banyuwangi has 1.5 ha to accommodate garbage from 13 districts with an input of 451.8 m^3 of garbage per day and controlled landfill methods are carried out as garbage management. This research aims to evaluate the capacity of the Bulusan Landfill in Banyuwangi. Arithmetic, geometric and least square method were selected by the highest correlation value. The projection result of the Bulusan landfill for 2018 has been declared overloaded, with the height of embankment was higher than the planned embankment and it has not been able to accommodate garbage. The projection for the next 15 years from 2017 to 2031 was predicted that Bulusan landfill will be overloaded at 1.172.185 m^3 of garbage volume. Financial and technical feasibility studies for candidates for the Bulusan landfill replacement need to be carried out so that the Bulusan landfill replacement project can be realized immediately.*

Keywords: Carrying Capacity, Landfill, Over Load, R square

1. INTRODUCTION

Solid garbage is consisting of organic materials and inorganic materials which are considered useless and must be managed so as not to endanger the environment and protect development investment. Solid garbage as a result of various activities in human life and the results of a natural process often cause serious problems in residential areas. With the increase in population, it will certainly produce garbage products that must be faced by the area and reduced land for processing garbage.

according to [1] The landfill generated from a city can be obtained by surveying measurements or direct analysis in the field with; Measuring directly the generation of garbage units from a number of samples (household and non-household) determined randomly at source for 8 consecutive days (SNI 19-3964-1995 and SNI M 36-1991-03), Measuring the amount (weight and / or volume) of garbage entering the TPS, High-volume analysis, and balance analysis material.

Research on handling landfills has been carried out, [2] predicting and analyzing landfills in the city of Padang, [3] evaluating domestic solid garbage management systems in Palembang. Whereas the determination of landfill is assessed by [4] wherein estimating the availability of landfills, data mining and linear regression algorithms are used. While [5] applies the Weight Aggregated Sum-Product Assessment (WASPAS) method and the Multi-Objective Optimization On Base of Ratio Analysis (MOORA) method to determine the landfill Site in Medan City.

Although the new landfill plan can be predicted, it is still necessary to estimate the projected capacity of the Bulusan landfill by determining the remaining capacity of the Bulusan landfill. To calculate cell landfill capacity, landfill planning dimension data is needed such as cell column length, cell pool width, cell pool bottom width, cell pool depth, cell pool edge slope, and cell pool base slope. Whereas for the process of analyzing land capacity and needs, it is necessary to calculate the area, planned depth/thickness, the generation rate of garbage generation, the density of garbage before compacting and after solidification, and the percentage of volume reduction after solidification.

2. METHODS

2.1. Data Collection

data consists of primary data and secondary data. The primary data is landfill dimension and the secondary data are the amount of garbage per year, landfill plan age, landfill area, facilities, infrastructure in landfill, the population of 13 sub-districts in Banyuwangi Regency from 2006 – 2016 which collected from Dinas Lingkungan Hidup (DLH) and Badan Pusat Statistik (BPS) of Banyuwangi.

2.2. Correlation Coefficient

The Correlation Coefficient (Eq.1) is used to find out the relationship between two variables (population and amount of garbage) and know how the relationship is going. This correlation aims to determine the three extrapolation methods (Arithmetic, Geometric and Least square methods), which method is suitable for calculating population projections and the amount of garbage.

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{\{n \sum x^2 - (\sum x)^2\}\{n \sum y^2 - (\sum y)^2\}}} \tag{1}$$

Where r is correlation coefficient value, x is the first variable value, y is a second variable value, and n is an amount of data.

2.3. Arithmetic Method

The Arithmetic Method (Eq.2) is generally used if the population growth is relatively constant each year. The equation used is:

$$p_{n=} p_{o+R.n} \tag{2}$$

Where p_n is the number of population in a year, p_o is the initial population, R is the amount of population growth each year, and n is the number of years projected.

2.4. Geometric Method

The Geometric Method (Eq.3) is generally used if the population growth rate rises multiple or the population growth rate changes equivalent to the previous year's population. The equation used is:

$$p_{n=} p_{o\,(1+r)^n} \tag{3}$$

Where $p_n$is number of population in a year, p_o is initial population, r is a percentage of population growth each year, and n is the number of years projected.

2.5. Least Square Method

The Least Square Method (Eq.4) is used if the data regression line of past population development describes linear line trends, although population growth does not always increase. The equation used is:

$$y = A + B_{\cdot x} \tag{4}$$

$$A = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i \; Y_i)}{n \sum x_1^2 - (\sum x_1)^2} \tag{5}$$

$$B = \frac{n \sum X_i \; Y_i - (\sum X_i) \; (\sum Y_i)}{n \sum x_1^2 - (\sum x_1)^2} \tag{6}$$

Where y is total population, x is an additional amount of base year, $A, B$are Constants, and n is the amount of data.

2.6. Landfill capacity

The data required for Calculating cell landfill capacity are cell column length, cell pool width, cell pool bottom width, cell pool depth, cell pool edge slope, cell pool base slope. Landfill cells can be a parallelogram, triangle and trapezoidal shapes. To calculate the capacity of a cell landfill, the formula is used:

$$V = (a \times t) \times p \tag{7}$$
$$V = (0{,}5 \times la \times t) \times p \tag{8}$$
$$V = la + lb \times t \times p \tag{9}$$
$$Total\ volume = n \times v \tag{10}$$

Where *V* is volume of *cell landfill* (m³), *la* is wide up of *cell landfill* (m), *lb* is bottom width of *cell landfill* (m), *t* is depth of *cell landfill* (m), *p* is length of *cell landfill* (m), and *n* is lots of *cell landfill*.

2.7. Analysis of Land needs and capacity

The requirements according to the Ministry of Public Works (1995) as follows: Location area, Planned depth/thickness of the layer, Garbage generation rate, Density of garbage before compacting and after compacting, and Percentage of volume reduction after compacting. Calculation of land requirements for Sanitary Landfill uses the following formula:

$$V = \frac{R}{D}\left(1 - \frac{P}{100}\right) - C_v \quad (11)$$

$$V = \frac{V_N}{d} \quad (12)$$

Where V is a volume of solid garbage and overburden (m³/person/year), R is garbage generation rate per person per year (kg/person/year), The value of the rate of garbage generation is obtained from the amount of generation based on the classification of cities. D is density before solidified garbage that arrives at the landfill (kg / m³), the density value is obtained from the results of the assumptions of the determination of municipal garbage generation rates in Indonesia, (200 - 300 kg / m³). P is the percentage of volume reduction due to compaction with the tool (3 × trajectory) approximately 50% to 75% (provision). Cv is cover volume (m² / person / year). A is land area needed (m² / year), N is the number of population served, and d is high solid garbage and overburden.

Compaction ratio and calculation of land requirements of the landfill (Eq.13) is a reduction in the volume of garbage after undergoing a compaction process at the landfill. The assumption ratio of 1 part of overburden is compared to 4 parts of garbage (1: 4) with the formula:

$$V = 1{,}25\ \frac{R}{D}\ \left(1 - \frac{P}{100}\right) \quad (13)$$

3. RESULTS AND DISCUSSION

3.1. Amount of Garbage and Total Population

Bulusan landfill is located at Bulusan village, Kalipuro district, Banyuwangi regency. Founded in 1986, effective use in 1988 and re-inaugurated after the renewal of names in 2012. The landfill has 1.5 ha of land area with 15 years of economic age. The amount of garbage entering bulusan's landfill in 2006-2013 was a relatively small increase. While the biggest increase was in 2014 (46.28%). In detail, the amount of garbage entering each year is presented in Table 1, while the increase and decrease in the amount of garbage can be seen in Figure 1.

Table 1. The amount of garbage entered in Bulusan landfill

No	Year	amount of garbage (m³)	garbage growth rate (m³)	the rate of garbage (%)
1	2006	27.621	5171	18,72
2	2007	32.792	(2359)	-7,19
3	2008	30.433	2619	8,61
4	2009	33.052	(406)	-1,23
5	2010	32.646	(3475)	-10,64
6	2011	29.171	1442	4,94
7	2012	30.613	267	0,87
8	2013	30.880	14292	46,28
9	2014	45.172	(1088)	-2,41
10	2015	44.084	440	1,00
11	2016	44.524	-	-
Total		380.988	16.903	58,95
Average		34.635	1.690	5,89

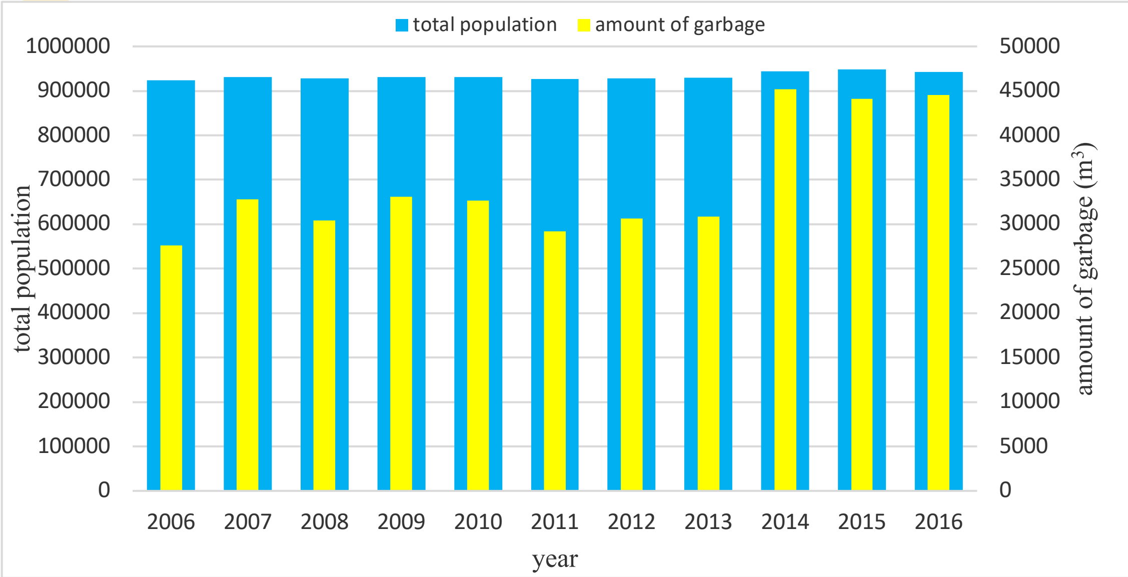

Figure 1. Graph of Population Growth and Garbage Rate (Analysis Results, 2018)

The Growth of population in 13 sub-districts showed a significant increase. The largest population is in 2015 with a population of 948,231. From 2006 to 2016, population growth increased by 1.98% or 18,257. From the calculation results, the average population growth is 932,881, the average percentage of population growth is 0.20% and the average amount of garbage is 34,635 m^3/day. The following is a recapitulation of population data from 13 sub-districts of Banyuwangi Regency as in Table 2.

Table 2. The population of 13 districts and Bulusan landfill garbage

No	year	Total population	Growth Total population	Population Growth (%)	Amount of garbage (m^3/day)
1	2006	924.171	6.409	0,69	27.621
2	2007	930.580	(2.924)	-0,31	32.792
3	2008	927.656	3.246	0,35	30.433
4	2009	930.902	(503)	-0,05	33.052
5	2010	930.399	(4.307)	-0,46	32.646
6	2011	926.092	1.787	0,19	29.171
7	2012	927.879	1.793	0,19	30.613
8	2013	929.672	14.014	1,51	30.880
9	2014	943.686	4.545	0,48	45.172
10	2015	948.231	(5.803)	-0,61	44.084
11	2016	942.428	-	-	44.524
Total		10.261.696	18.257	1,98	380.988
Average		932.881	1.826	0,20	34.635

The relationship between population and the amount of garbage each year shows a very strong, consistent and reliable correlation (R^2 = 0.9585). That is, the greater the increase in population, the greater the addition of garbage entering the Bulusan landfill. This correlation can be seen in Figure 2.

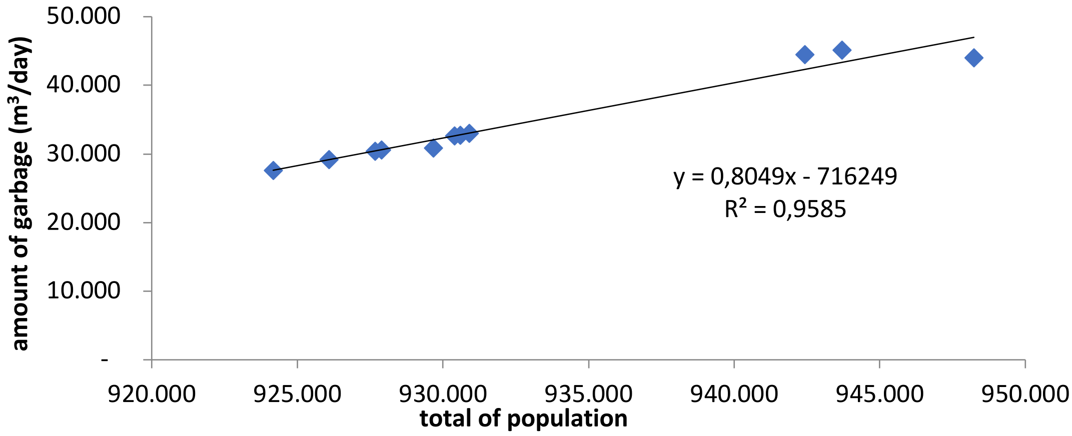

Figure 2. The coefficient of Correlation of Total Population with Amount of Garbage (Analysis Results, 2018)

3.2. Determination of The Correlation Method

This correlation aims to determine the three extrapolation methods (Arithmetic, Geometric and Least square methods) which are suitable to be used to calculate population projections and the amount of garbage. Determination of the method is obtained from the highest R^2 value. The results of the correlation calculation state that the suitable method used are the Geometric Method because it has the best correlation coefficient r among the three methods (Table 3). Furthermore, the data can be used as data to determine the projected population and the amount of garbage.

Table 3. Correlation results of various methods

Population Correlation Coefficient		The correlation coefficient of garbage	
Method	R^2	Method	R^2
Arithmetic	0,0008	Arithmetic	0,0131
Geometric	0,5941	Geometric	0,5827
Least Square	0,5431	Least Square	0,5292

3.3. Projection of Total Population and Amount of Garbage

To project the total population and the amount of garbage for the next 15 years in 13 districts, the geometric method was chosen. The projection of the total population in 2031 is 970,744 and amount of garbage is 105.125 m^3. This can be seen in Table 4 and Table 5.

Table 4. Projections of Total Population

year	Planning period	Least Square Constant		Projection of Total Population		
		$A = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i \; Y_i)}{n\sum x_1^2 - (\sum x_1)^2}$	$B = \frac{n \; \sum X_i \; Y_i \; - \; (\sum X_i) \; (\sum Y_i)}{n\sum x_1^2 - (\sum x_1)^2}$	Least Square	Geometric	Arithmetic
	n			$Pn=(A+B.x)$	$Pn=Po(1+r)^n$	$Pn=(Po+R.n)$
2017	1	923,280	1,904	925,184	944,290	944,254
2018	2	923,280	1,904	927,088	946,155	946,079
2019	3	923,280	1,904	928,992	948,024	947,905
2020	4	923,280	1,904	930,896	949,897	949,731
2021	5	923,280	1,904	932,800	951,774	951,556
2022	6	923,280	1,904	934,705	953,654	953,382
2023	7	923,280	1,904	936,609	955,538	955,208
2024	8	923,280	1,904	938,513	957,425	957,034
2025	9	923,280	1,904	940,417	959,317	958,859
2026	10	923,280	1,904	942,321	961,212	960,685
2027	11	923,280	1,904	944,225	963,111	962,511
2028	12	923,280	1,904	946,129	965,013	964,336
2029	13	923,280	1,904	948,034	966,920	966,162
2030	14	923,280	1,904	949,938	968,830	967,988
2031	15	923,280	1,904	951,842	970,744	969,813

Table 5. Projection Amount of Garbage

year	Planning period	Least Square Constant		Projection Amount of Garbage (m^3)		
		$A = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i \quad Y_i)}{n \sum x_1^2 - (\sum x_1)^2}$	$B = \frac{n \quad \sum X_i \quad Y_i \quad - \quad (\sum X_i) \quad (\sum Y_i)}{n \sum x_1^2 - (\sum x_1)^2}$	Least Square	Geometric	Arithmetic
	n			$Pn=(A+B.x)$	$Pn=Po(1+r)^n$	$Pn=(Po+R.n)$
2017	1	26.740	1.563	28.304	47.149	44.530
2018	2	26.740	1.563	28.305	49.928	44.536
2019	3	26.740	1.563	28.306	52.871	44.542
2020	4	26.740	1.563	28.307	55.987	44.548
2021	5	26.740	1.563	28.308	59.288	44.553
2022	6	26.740	1.563	28.309	62.783	44.559
2023	7	26.740	1.563	28.310	66.483	44.565
2024	8	26.740	1.563	28.311	70.402	44.571
2025	9	26.740	1.563	28.312	74.552	44.577
2026	10	26.740	1.563	28.313	78.947	44.583
2027	11	26.740	1.563	28.314	83.601	44.589
2028	12	26.740	1.563	28.315	88.529	44.595
2029	13	26.740	1.563	28.316	93.747	44.601
2030	14	26.740	1.563	28.317	99.273	44.607
2031	15	26.740	1.563	28.318	105.125	44.612

3.4. Landfill Capacity

It was Known that;

Landfill land area = 9.514 m^2
The height of plan pile = 15 m
Age of plan = 15 years
Solid factor = 2.5
So, the Capacity = 9.514 m^2 x 15 m^2= 142,710 m^3

3.5. Capacity Effectiveness of Machinery

The machinery owned by Bulusan landfill includes 1 excavator, 1 bulldozer and 1 loader. The loader is still in the repair stage so it cannot be operated. The volume of garbage entering the Bulusan Landfill on average each month is ± 3987.1 m^3, while the volume of garbage entering every day is ± 125-130 m^3 / day. According to the manager of the Bulusan landfill, the Excavator with a capacity of 1.20 m^3 per hour is able to efficiently garbage 103 m^3, while for the Bulldozer operations with a capacity of 3.18 m^3 it is able to efficiently garbage up to 120 m^3 / hour. Calculation of the effectiveness of the machine as follows.

It's Known :

Excavator / hour heavy equipment operations = 103 m^3
Bulldozer / hour machine operation = 120 m^3
Effective working hours = 6 hours

The result of the assumption:

Operations/excavator days = Operational per hour × Effective working hours
= 103 m^3 × 6 hours = 618 m^3 / day
Operational / bulldozer day = Operational per hour × effective working hours
= 120 m^3 × 6 hours = 720 m^3 / day
Operational / year excavators = Operations per day × (1-day work time)
= 618 × (365 days - 96 days)
= 166242 m^3 / year
Operational / bulldozer year = Operations per day × (1-day work time)
= 720 × (365 days - 96 days)
= 193680 m^3 / year
The work volume of excavators and bulldozers = ((618 m^3/day + 720 m^3/day)) / (6 hours)
= 223 m^3/ day, or
= 59987 m^3/year

It is known that the monthly Bulusan landfill garbage data = 3987 m^3/month, or 47845 m^3/year. So the optimization coefficient of garbage volume is = 59,987 / 47,845 = 1.25.

The calculation of the capacity of machinery aims to determine the projection of the capacity of the Bulusan landfill with garbage efficiency through the operation of heavy equipment. The volume of garbage per year is reduced by the volume of excavators and bulldozers operations which is equal to 59987 m^3 or 1.25 of efficiency.

To further optimize the efficiency of reducing the volume of garbage in the Bulusan Landfill, additional machinery is needed, namely: Excavators and Bulldozers. Calculation for adding machine units:

The number of excavator units needed;

n = (largest production equipment) / (Production of tools)
= (223 m³ / day) / (103 m³ / hour)
= 2.16 (2 units)

The number of bulldozer units needed;

N = (largest production equipment) / (Production of tools)
= (223 m³ / day) / (120 m³ / hour)
= 1.89 (2 units)

3.6. Projection of Bulusan Landfill Capacity

From the projection of the capacity of the Bulusan TPA for 2018 the capacity has been overloaded with a height of 16.03 m and has been unable to accommodate 9,810 m^3 of garbage. Whereas in the next 15 year projections from 2017 to 2031, the Bulusan landfill is predicted to have overloaded 326.164 m^3 with embankment height of 49.28 m from the planned embankment height of 15 m, so that it has exceeded the planned capacity of 142,710 m^3 (overload). From the results of measurements in 2017 the height of landfill in the field reaches ± 13-14 meters, and in 2018 the heap height reaches ± 16-17 meters and according to the projection results, the embankment height has reached 16.03 meters. So the planned capacity has been exceeded, and it can be said that the capacity of the Bulusan landfill is dead and a replacement for the landfill site is needed. The projection of the capacity of the Bulusan landfill is presented in Table 6.

Table 6. Projections for Bulusan Landfill Capacity with Garbage Efficiency through Machinery Operations

year	Total populations	garbage (m^3)	Optimization of garbage Compaction (m^3)	Cumulative garbage Volume (m^3)	capacity (m^3)	Heap height (m)	Rest of capacity (m^3)
2006	924.171	27.621	22.030	22.030	8.812	0,93	133.898
2007	930.580	32.792	26.155	48.185	19.274	2,03	123.436
2008	927.656	30.433	24.273	72.458	28.983	3,05	113.727
2009	930.902	33.052	26.362	98.820	39.528	4,15	103.182
2010	930.399	32.646	26.038	124.858	49.943	5,25	92.767
2011	926.092	29.171	23.267	148.125	59.250	6,23	83.460
2012	927.879	30.613	24.417	172.541	69.017	7,25	73.693
2013	929.672	30.880	24.630	197.171	78.868	8,29	63.842
2014	943.686	45.172	36.029	233.200	93.280	9,80	49.430
2015	948.231	44.084	35.161	268.361	107.344	11,28	35.366
2016	942.428	44.524	35.512	303.873	121.549	12,78	21.161
2017	944.290	47.149	37.605	341.478	136.591	14,36	6.119
2018	*946.155*	*49.928*	*39.822*	*381.300*	*152.520*	*16,03*	*(9.810)*
2019	948.024	52.871	42.169	423.470	169.388	17,80	(26.678)
2020	949.897	55.987	44.655	468.125	187.250	19,68	(44.540)
2021	951.774	59.288	47.288	515.413	206.165	21,67	(63.455)
2022	953.654	62.783	50.075	565.488	226.195	23,77	(83.485)
2023	955.538	66.483	53.027	618.514	247.406	26,00	(104.696)
2024	957.425	70.402	56.152	674.667	269.867	28,37	(127.157)
2025	959.317	74.552	59.463	734.129	293.652	30,87	(150.942)
2026	961.212	78.947	62.968	797.097	318.839	33,51	(176.129)
2027	963.111	83.601	66.679	863.776	345.511	36,32	(202.801)
2028	965.013	88.529	70.610	934.386	373.755	39,28	(231.045)
2029	966.920	93.747	74.772	1.009.158	403.663	42,43	(260.953)
2030	968.830	99.273	79.180	1.088.338	435.335	45,76	(292.625)
2031	970.744	105.125	83.847	1.172.185	468.874	49,28	(326.164)

3.7. The Bulusan Landfill Needs Analysis

To find out the land needs for replacing the Bulusan landfill we calculate for 15 years planning capacity. It has been know that the population served for the next 15 years in 2031 is 970,744 people, The rate of landfill (R) is 0.70 kg/person/day, Operating Period is 15 years, Assumption of garbage density (D) is 250 kg/m^3, percentage of volume reduction after solidification (P) is 60%, High solid garbage and overburden which planned is 16 m. So the calculations is

$R = 0.70 \times 365 = 256$
$P = 60\%$
$D = 250\ kg / m^3$
$V = 1.25\ x\ (256/250)\ x\ (1 - ((60\%) / 100)$
$= 0.51 m^2 / person / year$
Land area (A):
$= ((0.51\ x\ 970{,}744)) / 16 = 31{,}003\ m^2 / year$
$= (31{,}003 m^2 / year) / 10{,}000 = 3.10\ ha$
New landfill needs:
$= 3.10\ x\ 15 = 46.50\ ha$
$= 46.50\ x\ 10{,}000 = 465{,}047\ m^2$
So the demand for Bulusan landfill is planned at 46.50 ha or 465,047 m^2.

Based on the results of [6], the determination of the location of candidates for the replacement of the Bulusan landfill based on the Geographic Information System is located at 114 ° 21'45.0 "- 114 ° 22'13.2" BT and 8 ° 06'14.5 "-8 ° 06 ' 36.3 "LS in Ketapang Village, Kalipuro District, Banyuwangi Regency, with area is 0.4641 Km^2 or 46.41 Ha. the amount of land needed from the selection results of the Geographic Information System is in line with the projected landfill needs for the next 15 years.

4. CONCLUSION

From the projection it has been declared that the Bulusan landfill capacity in 2018 is overloaded with the height of the embankment is 16.03 m, and has been unable to accommodate trash of 9.810 m. in the next 15 year projections from 2017 to 2031, the Bulusan landfill will be overloaded 326.164 m^3 of garbage with embankment height is 49.28 m. for the next 15 years the area needed is 46.50 ha or 465,047 m^2. A financial and technical feasibility study is needed for potential replacements for the Bulusan Landfill so that it can be immediately realized as a pilot project as a replacement for the Bulusan landfill.

5. ACKNOWLEDGEMENT

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