The Estimation of Waste Generation in Palangka Raya City, Central Kalimantan

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Abstract: The urban development's planning and the rapid population growth require optimal waste service. This study aims to project waste generation in Palangka Raya city for the next 20 years in order to plan sustainable waste management. Estimation of waste generation is made with multiple linear regression models using waste generation, population and real GDRP data in 2014-2018. Based on the analysis result, the waste generation model has an index of determination (R2) of 0.988, which means that the number of inhabitants and the real GDRP influence waste generation up to 98.8%, while the value obtained by F test is 84.96 with Sig. 0.012 which means the regression model is suitable. Based on the estimated model, the handled waste in the Palangka Raya city in 2038 would be 232,379.66 m3/year. The increase in waste generation requires the addition of 31 TPS containers and 13 units of arm roll trucks in 2038 and it also needs performance improvement of garbage transport rites. Furthermore, the local government needs to optimize the performance of 4 units of TPS 3R and 43 waste bank organizations so that organic waste is processed into fertilizer and used for agricultural land around the city. The use of organic waste will provide economic and ecological benefits and reduce the volume of waste transported to landfill.

Keywords: Palangka Raya**;** sustainable waste management; waste generation

1 Introduction

The global population continues to increase. According to UN economic and social data, in 2011 the global population exceeded 7 billion, and is predicted to reach 9 billion by 2045. While at the national level, according to BPS data, the population in Indonesia will continue to increase, from 238.5 million in 2010 to 305.6 million in 2035 (BPS, 2013). Increased population at the global and national levels will have environmental impacts, one of which is an increase in waste production.

One of the cities that faces garbage problems is the Palangka Raya city. Palangka Raya is the Capital of Central Kalimantan Province with a population of 267,757 people in 2017. This number increased from 2016 with a population growth rate of 2.95 percent (BPS, 2018b). Based on data from waste management agencies in the Palangka Raya city, the level of waste service in 2018 is 47.72%. More than half the volume of waste produced is disposed of in a way that is not supposed to and has the potential to reduce the quality of the surrounding environment and endanger the health of the environment. Hence waste management is urgently needed.

There is a previous research study on waste projections titled Analysis of Projected Population Growth and Waste Facilities Needs in Palu City on the year 2015 to 2025. The results of the study projected that in 2025 the population of Palu City would be more compact, with the amount of 433,380 people and waste generation of 1,192 m^3/day. Based on the calculation of projections for the need of waste containers, in 2025 it will be 149 units and based on the calculation of projected needs of garbage truck, in 2025 the need for garbage trucks in Palu City will be 74 units. However, the research was carried out as a whole for the city of Palu and the projection model used was only the exponential projection model (Tampuyak et al., 2016).

In this study, to project the population and real GDRP, 3 mathematical projection models were used. In addition, the estimation of waste generation is calculated by constructing an estimation model with a multiple linear regression. The purpose of this study is to plan a sustainable waste management in Palangka Raya city.

2 Material and method

2.1 Study Area and Data

This research was conducted in the Palangka Raya city, the Capital of Central Kalimantan Province. The Palangka Raya city is administratively made up of 5 sub-districts and 30 villages. However, this study is limited to

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only 3 sub-districts in the city. The selection of the location for this study is considered that these sub-districts are in the center of the city and are important areas for the municipal waste management. The location of the study can be seen in **Fig. 1**. The data used in this study are secondary data, namely waste generation, population and real GDRP per capita data in the year 2014 to 2018.

2.2 Data analysis

2.2.1Waste generation

The estimation of waste generation was calculated by linear regression models, namely by modeling the relationship between waste generation with the population and real GDRP per capita. Linear regression analysis used to estimate the waste generation has been done before [4-5] which is basically a multiple linear regression model as follows:

$$WG = Y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn \quad (1)$$

Making the waste generation estimation model used population, real GDRP (on the basis of constant price) per capita and municipal solid waste generation data in the 2014 to 2018 period. Waste estimation model will be used to estimate the waste generated in Palangka Raya city in 20 years.

2.2.2 Projected population and real GDRP

To obtain data on projections for the n-year population and projections for the n-year of the real GDRP, 3 mathematical methods were used, namely the arithmetic, geometric and exponential models. Index of determination (R^2) was used to choose the model used for calculating population and the real GDRP projection. Determination index is an indicator that indicates the existence of relationship between one or more independent variables and non-independent variables as the target for the final results of the study (Sunarsih & Farikhin, 2016).

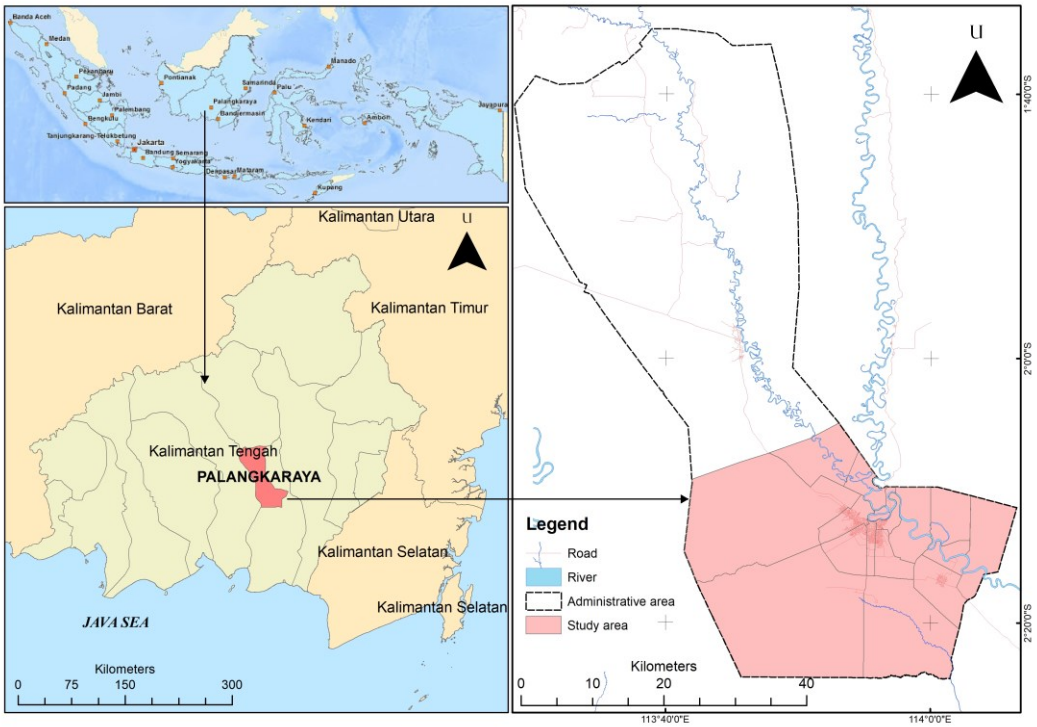

Figure 1. Study Area

2.2.3 Waste Management Facility Needs

Based on the calculation of the waste generation projection, it can be seen that the waste management facility needs to be in the form of TPS (2) and the transport fleet (3). The calculation for the need of TPS and transport fleets were taken from SNI 3242:2008 on Settlement Waste Management with the following modifications:

$$Nc = (Wg - TPS\ Capacity)\ x\ Container\ capacity^{-1}\ x\ Fp^{-1} \quad (2)$$

$$Fleet\ transport = (Wg - fleet\ capacity)\ x\ Capacity\ fleet^{-1}\ x\ Fp^{-1}\ x\ recitation^{-1} \quad (3)$$

where : Nc (number of container required); Wg (waste generation per days); Fp (compaction factor = 1.2)

3 Result and discussion

3.1 Population Projection

Based on data from BPS, the population growth rate of Palangka Raya City in 2015-2017 is 3.08%, 3.04% and 2.95% respectively, so the average population growth rate for 3 years is 3.02%. The initial population used is the population in 2017 in the three sub-districts that were chosen as the study areas, which are 258,153 people (BPS, 2018a).

Based on the analysis result of the population projections using arithmetic, geometric and exponential models, the index of determination (R^2) obtained in a row are 1.000; 0.994; and 0.994. It can be seen that the arithmetic model is considered as the most suitable model for projecting the population of Palangka Raya city. Total population projection in the city of Palangkaraya within the next 20 years is shown in **Table 1**.

3.2 Real GDRP Projection

According to data from BPS, the percentage of real GDRP growth per capita of the 2010 ADKH Palangka Raya city in 2015-2017 was 3.99%, 3.77% and 3.90%, respectively. So the average of the percentage of the growth rate of the real GDRP per capita in Palangka Raya city is 3.89%. While the initial data used for real GDRP is 2017 data which is 34,376.60 thousand rupiah/capita/year (BPS, 2018a).

Based on the analysis of the projected real GDRP using the arithmetic, geometric and exponential model, the index of determination (R^2) obtained in a row is 1.000; 0.991; and 0.990. So based on the index value of determination, the arithmetic projection model is the chosen model that will be used in the projection of real GDRP in Palangka Raya city. Real GDRP projection in the city of Palangkaraya within the next 20 years is shown in **Table 1**.

3.3 Estimated Waste Generation

Based on the multiple linear regression analysis of the data population, the real GDRP and waste generation in the city of Palangkaraya from 2014 to 2018 obtained an index of determination (R^2) of 0.988, which means that the number of inhabitants and the real GDRP influence waste generation up to 98.8%. While based on the F test the value is 84.964 and Sig. 0.012. With Sig. <α = 0.05, it means that the regression model is built accordingly and can be used to predict waste generation. The regression model of the population and real GDRP on the waste generation in Palangka Raya city can be elaborated as follows :

$$WG = Y = 144267{,}323 - 0{,}790*x1 + 6{,}743*x2 \quad (4)$$

with WG is waste generation, x1 is the population and x2 is real GDRP. Based on the projected population data and real GDRP, it can be estimated that the waste generation in Palangka Raya city in the next 20 years using the model (4) as shown in **Table 1**.

Table 1: Projection of Total Population, Real GDRP and Estimated Waste Generation in Palangka Raya City

No.	Year	Total population (people)	Real GDRP (thousand / capita / yr)	Waste generation (m^3 / yr)
1	2023	304,930	42,405.03	189,309.74
2	2028	343,911	49,099.20	203,653.54
3	2033	382,893	55,795.31	218.009,63
4	2038	421,884	62,493.37	232,379.66

3.4 Facility Requirements

Based on data from Dinas Perumahan Rakyat dan Kawasan Permukiman (Public Housing and Settlement Area Office), the facilities and infrastructure for waste management in Palangka Raya City are as shown in **Table 2**.

Table 2: Condition of Facilities and Infrastructure

No.	Infrastructure	Total	Capacity	Information
1	Dump Truck	13	7 m^3/unit	273 m^3/day *
2	Arm Roll	5	6 m^3/unit	90 m^3/day *
3	Conventional TPS	122	3 m^3/unit/day	366 m^3/day
4	Container TPS	8	6 m^3/unit/day	48 m^3/day
5	Depo transfer	3	64 m^3/unit/day	192 m^3/day
6	Mini depo transfer	3	16 m^3/unit/day	48 m^3/day
7	Landfill	1	10 hectares	14 Km from the city center
8	WC Trailer	1	-	
9	Bulldozer	1	-	
10	Excavator	1	-	

Source: Disperkim of Palangka Raya city, 2019; *: optimal rites = 3 times a day

Based on the waste generation data and the condition of existing facilities and infrastructure, the need for additional TPS and transport to optimize solid waste services can be calculated. In this study, it is assumed that the type of TPS that will be developed in the future is the container type TPS, considering that conventional TPS made out of bricks is not quite efficient. Then the fleet planned to be added is arm roll truck, considering that this garbage transportation system is more practical in operation, so that the need for additional container TPS and arm roll truck has been calculated as presented in **Table 3**.

Table 3: Need for Container TPS and Arm Roll

No.	Year	Additional Container TPS (6 m^3 capasity)	Additional Arm Roll (6 m^3 capasity)
1	2023	15	7
2	2028	20	9
3	2033	25	11
4	2038	31	13

The transport fleet in the table above is calculated using optimal rites, which is 3 times a day. Based on research, the actual garbage transportation rites in Palangka Raya City is 2 times a day (Triani, 2017). So as to improve the performance of solid waste services, the management agencies need to optimize transportation rites, increase the number of containers, and increase the number of transportation.

While the placement of additional container TPS needs to consider the level of population density and locations that have difficult access to solid waste facilities, especially densely populated areas on the edge of the kahayan river and sub-urban areas that have difficult access to garbage facilities.

3.5 Utilization of Organic Waste

The types of garbage in Palangka Raya City is dominated by organic waste, which is 55.61% of the total volume of waste produced (Triani, 2017) so that it has the potential to be used as organic fertilizer. The use of fertilizer made by organic waste will reduce the amount of garbage carried to landfill, which will save the transportation budget since the dominant type of waste is organic waste. Based on the results of the estimated volume of waste in 2023, which is 189,309.74 m^3, then approximately 105,275.15 m^3 is organic waste has the potential to be composted into fertilizer. The reduction volume of organic waste transported to landfill will reduce the burden of landfill in terms of managing leachate and gas generation (Bandara et al., 2007). Composting organic waste can be carried out in 4 units of TPS 3R that have been owned by the local government. In addition, composting activities can involve 43 waste bank organizational units that already exist in Palangka Raya city.

Fertilizer produced from composted organic waste can be supplied to the agricultural village center around the town of Palangka Raya such as Kalampangan, Tumbang Tahai, Bukit Batu village and surrounding areas. Thus, with good waste management planning, a sustainable development goal can be achieved where the city's duty in managing waste, especially in transporting waste to landfill, will decrease, and also it will benefit the area around the city by utilizing organic fertilizer for agricultural land.

The use of organic fertilizers on agricultural land around the city would also provide economic and ecological benefits. From the economic aspect, it will reduce the production costs from the use of chemical fertilizers, while from the ecological aspect, the use of organic fertilizers will improve the physical, chemical and biological properties of the soil as well as will maintain and increase soil fertility and later reduce farmers dependence on chemical fertilizers (Yong-Hwan Lee, Sang-Min Lee, 2004).

4 Conclusion

The population of the Palangka Raya city is estimated to reach on 304,930 people in 2023 and will increase to 421,884 people by 2038. As well as the waste generation is estimated to reach on 189,309.74 m^3/year in 2023 and will increase to 232,379.66 m^3/year in 2038. The waste management facilities required in the form of increasing the number of adding 15 units of containers TPS in 2023, then increased to 31 units in 2038 from the current condition. While for the addition of a transport fleet in the form of arm roll trucks, an additional 7 units will be needed in 2023 which will require an additional 13 fleet units in 2038 from the current conditions.

In addition for planning the management facilities, the local government needs to optimize the performance of 4 units of TPS 3R and empower 43 units of waste banks that have been formed. Waste management through the formation of communities process organic waste into organic fertilizer, while non-organic waste is recycled into handicraft items that possess economic value. In addition to reduce waste generation, empowering waste banks provides additional income for the poor in urban areas (Asteria & Heruman, 2016; Suryani, 2014). Turning organic waste into organic fertilizer would make a great advantage, since the composition of waste in Palangka Raya city is dominated by organic waste, which is 55.61% so it would provide both economic and ecological benefits for the regions around Palangka Raya city and the Palangka Raya city itself.

References

Asteria, D., & Heruman, H. (2016). bank sampah sebagai alternatif strategi pengelolaan sampah berbasis masyarakat di Tasikmalaya. *Jurnal Manusia dan Lingkungan*, *23*(1), 136–141.

Bandara, N. J. G. J., Hettiaratchi, J. P. A., Wirasinghe, S. C., & Pilapiiya, S. (2007). Relation of waste generation and composition to socio-economic factors: A case study. *Environmental Monitoring and Assessment*, *135*(1–3), 31–39. doi:10.1007/s10661-007-9705-3.

BPS. (2013). *Proyeksi penduduk Indonesia*. Badan Pusat Statistik.

BPS. (2018a). *Produk domestik regional bruto Kota Palangka Raya Menurut lapangan usaha*. Badan Pusat Statistik Kota Palangka Raya.

BPS. (2018b). *Statistik daerah Kota Palangka Raya 2018*. Badan Pusat Statistik Kota Palangka Raya.

Ghinea, C., Drăgoi, E. N., Comăniţă, E. D., Gavrilescu, M., Câmpean, T., Curteanu, S., & Gavrilescu, M. (2016). Forecasting municipal solid waste generation using prognostic tools and regression analysis. *Journal of Environmental Management*, *182*, 80–93. doi:10.1016/j.jenvman.2016.07.026.

Khajuria, A., Yamamoto, Y., & Morioka, T. (2010). Estimation of municipal solid waste generation and landfill area in Asian developing countries. *Journal of Environmental Biology*, *31*(5), 649–654.

Sunarsih, & Farikhin. (2016). *Buku diktat statistik lingkungan*. Program Magister Ilmu Lingkungan Universitas Diponegoro.

Suryani, A. S. (2014). Peran bank sampah dalam efektivitas pengelolaan sampah (Studi Kasus Bank Sampah Malang). *Aspirasi*, *5*(1), 71–84.

Tampuyak, S., Anwar, C., & Sangadji, M. N. (2016). Analisis proyeksi pertumbuhan penduduk dan kebutuhan fasilitas persampahan di Kota Palu 2015-2025. *Jurnal Katalogis*, *4*(4), 94–104.

Triani, E. (2017). *Optimalisasi kinerja pengelolaan sampah di Kota Palangka Raya*. Institut Teknologi Sepuluh Nopember.

Yong-Hwan Lee, Sang-Min Lee, Y.-J. L. and D.-H. C. (2004). Rice cultivation using organic farming system with organic input materials in Korea. *4th International Crop Science Congress*.