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Socio-economic and Geo-Map analysis of the role of reuse and recycling management in reducing daily waste production

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** Economic growth accompanied by population growth results in various negative externalities, one of which is excessive waste production. Waste conditions that are not handled properly will cause a domino effect on the balance of the ecosystem and environmental health. One of the factors that caused the high rate of waste production is the quality of the population, the existing condition of the community, the population, and environmental management, especially waste. This study looks at the causes of excessive daily waste production from various aspects from the perspective of social, economic, and spatial conditions. Not only that, the management of reduce, reuse, and recycle waste is also taken into account in the decrease in the amount of daily waste production.

**METHODS:** This study identifies spatial distribution through a Geo-Map literature analysis with Vosviewer. The study also examines the influence of social, economic, and spatial factors and the existence of reduce, reuse, and recycle waste management sites with daily waste production using Ordinary Least Square Regression and 2022 cross-section data in 34 provinces in Indonesia.

**FINDINGS:** The results showed that variables with a probability value of  $\alpha < 0.05$  for urban population, Area Size, and Life Expectancy had a significant positive influence on daily waste production. In contrast, the average length of schooling has a significant negative effect. In addition, there are also variables with a probability value of  $\alpha < 0.10$ , namely life expectancy and per capita income, which also have a significant positive effect. However, the existence of Reduce, Reuse, and Recycle Waste Management, shown by a probability value of  $\alpha > 0.10$ , does not show a significant influence on Daily Waste Production. These factors are also reflected in the spatial distribution of the map.

**CONCLUSION:** It is concluded that the achievement of goal 12 in the Sustainable Development Goals program will be successful if the community is committed to raising awareness of environmental responsibility. Not only that, major adjustments are needed, including the role of reducing, reusing, and recycling waste management

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## INTRODUCTION

The global waste issue remains unresolved and could become increasingly worrying due to uncontrolled waste growth (Jadayil *et al.*, 2022; Azzahrah *et al.*, 2023; Ho *et al.*, 2022; Mahendra, 2017). According to a report entitled What a Waste 2.0 published by the World Bank; the world produces about 2.01 billion tons of solid urban waste yearly. Unfortunately, about 33% of the waste is not managed properly and hurts the environment (Edi *et al.*, 2022; Noviyanti, 2019; Saefuddin *et al.*, 2019). In the same report, the World Bank also projects that the amount of global waste will increase by 70% by 2050, reaching 3.40 billion tons per year (Kastolani *et al.*, 2022; Nouri *et al.*, 2021). This is due to rapid urbanization, population growth, and rapid economic development (Kazmi & Chakraborty, 2023). Policies on waste management are also included in the discussion of the United Nations through its sustainable development program, commonly called the 17 (SDGs) (Gricar *et al.*, 2023; Petrova, 2023; Retnowati *et al.*, 2023). Discussions related to waste are included in the 12th goal of the SDGs, namely responsible production and consumption. To achieve economic growth and sustainable development, communities must realize how important it is to reduce their ecological footprint through changes in the way they produce, consume food, and manage other resources, and waste management is no exception (Imran *et al.*, 2024). World Bank data entitled The Atlas of SDGs 2023 states that Indonesia was the 5th largest waste-

producing country in the world in 2020, amounting to 65.2 million tons of waste (Bigwanto *et al.*, 2024). This is one of the urgent needs that must get special attention from the government. The National Waste Management Information System said that the amount of waste generated in Indonesia fluctuates and tends to increase from 2019 to 2023, as shown in Fig. 1.

The amount of waste produced in 2019 reached 16 million tons of waste every year and increased to 19 million tons of waste in 2020, the highest amount in the last five years. In 2021, the amount of waste in Indonesia was successfully reduced to 13 million tons due to the COVID-19 pandemic. This condition caused several industries to be closed so that waste from production activities was significantly reduced (Krisdhianto *et al.*, 2023). However, this did not last long. In 2022, when the COVID-19 pandemic began to subside, waste generation increased to 18 million tons and remained at that number until 2023. These results are also measured through an increase in Daily Waste Production, which is the total amount of waste produced every day for a certain time. Research by Krisdhianto *et al.*, (2023) states that the cause of the increase in daily waste production in Indonesia is social and economic factors. The intended social factor consists of several aspects, including the average length of schooling and life expectancy. In contrast, the intended economic factor is the per capita expenditure of the population of an area. Another case is the results of Elyasa (2019), which

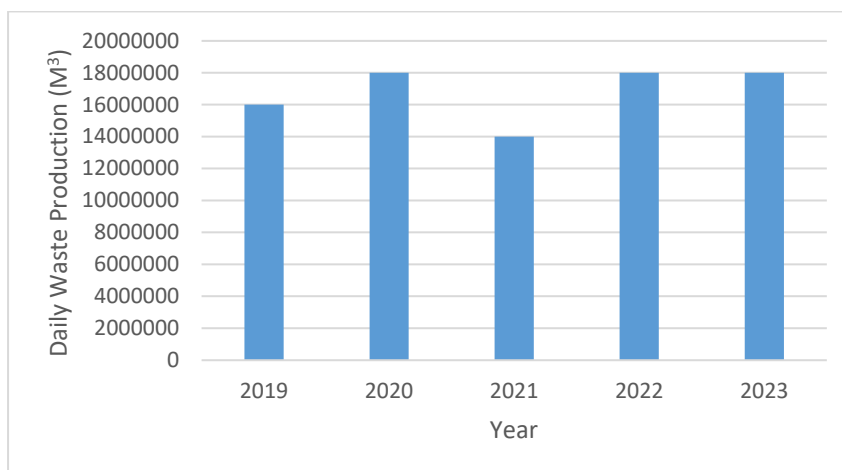


Fig.1: Total waste generation in Indonesia from 2019 to 2023 (Source: Indonesia Waste Management Information System, 2024)

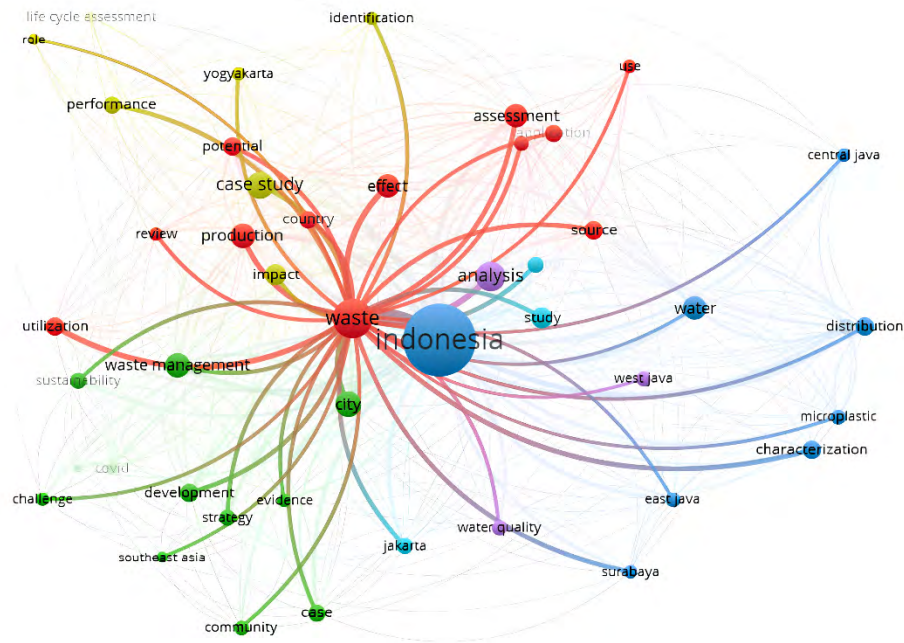


Fig.2: Research and waste generation

state that the number of urban residents is a dominant contributor to the amount of total waste produced. Not only that, but the area also contributes to the amount of daily waste generation. This condition causes the government, through stakeholders and non-governmental organizations, to launch solutions to reduce the amount of waste in Indonesia with the implementation of the Reduce-Reuse-Recycle Waste Management (3RWM) (Saputra et al., 2024). 3RWM is a strategy used to manage waste at the communal or regional level, involving active participation from the government and community, with a focus on community empowerment. The program aims to reduce the amount of waste generated to achieve environmental improvement through responsible production and consumption following the 12th goal of SDGs (Stanković et al., 2024). The study by Lawa et al., (2021) states that 3RWM has not been able to reduce the waste generated due to limited resources and the existence of 3RWM, which is not evenly distributed in each region. This fact is reinforced by data from the Ministry of Environment and Forestry in 2023, namely that the majority of 3RWM is at

the sub-district level and not all sub-districts have it (Mustikasari, 2021).

Research on waste generation has been carried out in the last five years, namely, 2019–2024. The majority of research is carried out in major cities in Indonesia, such as Jakarta, Surabaya, Yogyakarta, and cities in Central Java Province, as shown in Fig. 2. However, research related to waste generation and waste management, specifically 3RWM, human development index, and spatial analysis through geographic information, has not been widely carried out, especially in the period 2019-2024, as shown in Fig. 3.

Therefore, this study aims to analyze the influence of social factors, namely average length of schooling and life expectancy, economic factors shown by per capita expenditure, spatial factors in the form of area and number of urban population, and the existence of the number of 3RWM on the amount of daily waste production in 34 provinces in Indonesia (Azzahrah et al., 2023). The method used is a mixed method with ordinary least square regression analysis and mapping geographic information using the Geo-Map



Fig.3: Research on waste generation related to social, economic, and spatial factors.

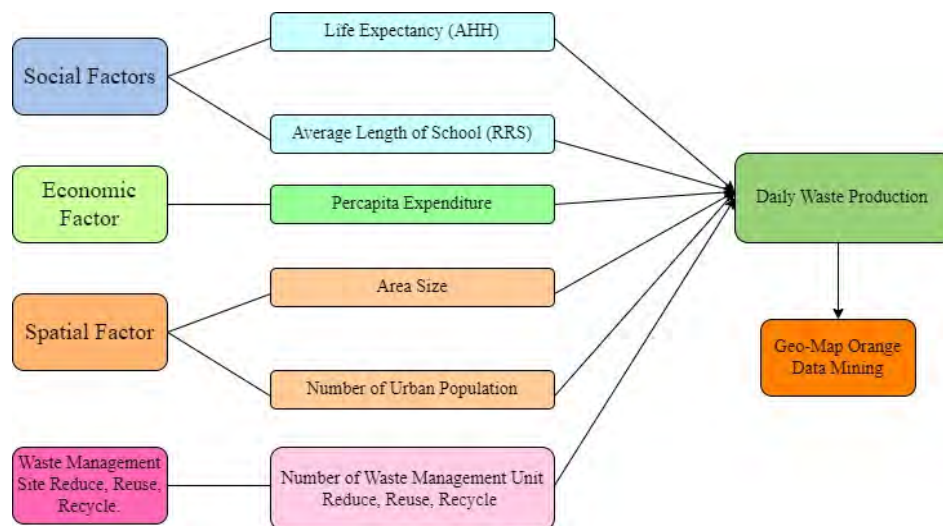


Fig. 4: Research concept

orange data mining tool, which can be seen in the frame of mind in Fig. 4 (Udin, 2024). This study is aimed at determining the influence of social factors, economic factors, spatial factors, and the existence of 3RWM on daily waste production in 34 provinces in Indonesia with the last most complete data available, namely in 2022.

## MATERIALS AND METHODS

### Research type and design

This research uses a mixed method, namely quantitative methods through Ordinary Least Square (OLS) regression, and qualitative elaboration methods,

namely mapping using Geo-Map orange data mining. OLS regression is a statistical method used to model the relationship between the dependent variable, which is the variable you want to predict, and one or more independent variables, which are used to predict the dependent variable. The approach is commonly used in statistical analysis (Ariska et al., 2023). OLS regression in this study was used to help analyze the relationship between the dependent variable and the independent variable. The data used is cross-section data from as many as 34 provinces in Indonesia in 2022. The year was chosen based on the latest complete data justification held by the

Indonesian Central Bureau of Statistics before the provinces in Indonesia were divided into 38 provinces. This study used six independent variables, namely per capita expenditure, life expectancy, average length of schooling, number of urban populations, area, and number of 3RWM. At the same time, the dependent variable used is the amount of daily waste production.

#### Model and Specification

The regression model used in this study is as follows:

$$\ln psh = \alpha + \beta_1 \ln pk_1 + \beta_2 \ln ah_2 + \beta_3 \ln rrls_3 + \beta_4 \ln jppk_4 + \beta_5 \ln wl_5 + \beta_6 TPS3R_6 + \varepsilon \quad (1)$$

Where =

$\ln psh$  = Daily Waste Production (M<sup>3</sup>)

$\ln pk$  = per capita expenditure (million rupiah)

$\ln rrls$  = Average Length of School (years)

$\ln ah$  = Life expectancy (years)

$\ln jppk$  = total urban population (million)

$\ln wl$  = area per province (m<sup>2</sup>)

$TPS3R$  = Number of Waste Management Sites Reduce, Reuse, Recycle (Units)

#### Spatial analysis: Geo-Map Orange data mining

Spatial analysis is the process of describing and

analyzing data that has a geographical position reference (Wyszkowski *et al.*, 2023). This study uses the Geo-Map Orange data Mining tool by analyzing latitude and provincial longitude references with criteria according to the variables used (Mahmoudzadeh *et al.*, 2024). This is included in the analysis of Geographic Information Systems (GIS), which is a technology that is useful for collecting, storing, managing, analyzing, and visualizing data that has spatial elements.

#### RESULTS AND DISCUSSION

The amount of daily waste production in Indonesia in 34 provinces in 2022 tends to decrease compared to the previous year. However, the amount of production is not evenly distributed in each province. This can be seen from the results of the mapping analysis using Geo-Map Orange data Mining, which is shown in Fig. 5.

Fig. 5 shows that the majority of areas with high daily waste production in Indonesia are provinces located on the islands of Java, Kalimantan, and Sumatra. The highest amount is in Central Java Province, with total daily waste production reaching 5600.88 m<sup>3</sup> of waste. The area is marked with a yellow dot, while the bright blue dot is an area with total daily waste production reaching 1000-2000 m<sup>3</sup>. These areas are South Sumatra, East Java, West Kalimantan,



Fig.5: Map of daily waste production in Indonesia

Central Kalimantan, and South Sulawesi. The majority of waste produced is household waste and waste from the industrial sector. Factors causing the increase in daily waste production also vary, including Socio-economic Factors, Spatial Factors, and the existence of related institutions such as Waste Management Sites, Reduce, Reuse, and Recycle (Almagharb, 2024). Testing variables that affect daily waste production in Indonesia were tested using cross-section data consisting of 34 provinces in Indonesia in 2022 with six independent variables. The data were then tested using OLS regression, with the results shown in Table 1.

The regression results obtained are displayed in the equation as follows:

$$\ln psh = 12.33 + 0.575 \ln pk_1 + 10.740 \ln ah_2 - 5.199 \ln rrls_3 + 0.688 \ln jppk_4 + 0.420 \ln wl_5 - 0.002 TPS3R_6 + \varepsilon \quad (2)$$

Table 1 explains that daily waste production in 34 provinces in Indonesia is influenced by several factors: Life Expectancy, Average Length of School, Per Capita Expenditure, Area, and Number of Urban Population. This can be seen from the probability value of each variable, which is not greater than 5% and 10%. However, in the 3RWM variable, it can be seen that the probability value of more than 5% shows the result that 3RWM has no effect, especially for daily waste production in Indonesia. The value of the life expectancy variable coefficient of 10.74 shows that if the life expectancy of the community increases by 1%, the daily waste production will increase by 10.7%. Life expectancy is one of the components used to calculate the human development index (Hasanah, 2021). This indicates that life expectancy has a significant positive effect on daily waste production (Janah et al., 2019). High life expectancy will affect individual productivity. Every individual who can still carry out activities will produce a higher amount of

waste. This assumption is supported by research by Purwita et al., (2022), which states that a person's age influences productivity. If someone has a long life supported by a strong body and soul, it will increase the value of productivity. Every activity carried out by humans will cause residues or negative externalities, namely in the form of waste (Koeshendrajana et al., 2017). This fact is also reinforced by mapping analysis through Geo-Map Orange data Mining that can be seen in Fig. 6, which shows that areas with yellow dots have a high life expectancy. Most of these areas are on the island of Java, one of which is the Central Java Province, which also produces daily waste.

The next influential variable is the average length of schooling. Every increase in the average length of schooling in an area will reduce daily waste production by 5.2%. The average length of schooling refers to the number of years spent by individuals completing their formal education. This life expectancy is calculated based on residents aged 25 years and over, assuming that by the age of 25, the education process has been completed (Syabrina & Mustika, 2021). The higher the average length of schooling in a region, the higher the level of literacy related to environmental concerns (Lagis & Matthew, 2023). So, the community will be more concerned and wise in managing waste. The negative correlation between the average length of schooling and daily waste production is supported by spatial analysis, which can be seen in Fig. 5 and Fig. 7. The latter shows that areas with younger dot colors signify that they have a higher average level of the length of schooling. As seen in the Yogyakarta Special Region Province, which has an average school rate of 11 years, and Central Java Province, with an average school length of 9 years, in the Yogyakarta Special Region Province, the amount of daily waste production is lower than in Central Java Province.

The third variable that affects daily waste production in Indonesia is per capita expenditure.

Table 1: OLS regression result

Variable	Coefficient	Probability
LnAHH	10.740	0.0869*
LnRRLS	-5.199	0.0128
LnPK	0.575	0.0653*
LnWL	0.420	0.0304
LnJPPK	0.688	0.0040
3RWM	-0.002	0.5526
Adj R-Squared	0.543	





Fig. 6: Map of life expectancy in Indonesia



Fig. 7: Map of the average length of schools in Indonesia

The value of the variable coefficient is 0.57, indicating that if per capita expenditure increases by 1%, it will increase daily waste production by 0.57%. Per capita expenditure is one aspect that can be used as an indicator of a region's economy. Areas with high per capita expenditure will generally have a high level of population productivity. The intended productivity is the productivity of human resources both in the industrial and industrial sectors. It also has an impact on the surrounding ecosystem, namely negative externalities in the form of daily waste production (Hasanah, 2021). The spatial analysis used in this study also supports the results of OLS regression, which can be seen in Fig. 5 and Fig. 8.

The next factor that affects daily waste production in Indonesia is the spatial factor, namely the area. Area and population, especially urban residents, are closely related to the amount of daily waste production. Urban residents are considered to play a more crucial role as producers of daily waste because the majority of households and industries are in urban areas. This can be seen from the value of the area coefficient of 0.42 and the population coefficient of 0.69. This Figure

shows that if an area is 1% larger than the area of other areas, the amount of daily waste production will increase by 0.42%.

In comparison, if the population in the area increases by 1%, it will cause an increase in daily waste production by 0.69%. This fact is following research conducted by Mustikasari (2021), which says that the population and area affect population density, so the resulting side effect is that the denser the population, the higher the waste production. Areas with a large area will have the opportunity to become industrial and residential land (Krisdhianto et al., 2023). The analysis then continues with the substantiation of spatial data in the form of mapping, as shown in Fig. 9 and Fig. 10.

Fig. 9 shows that the majority of provinces with a large area are on the island of Kalimantan, namely West Kalimantan and Central Kalimantan. Both provinces produce fairly high amounts of daily waste, as shown in Fig. 5. Still, when viewed from the number of urban residents in Fig. 10, the two provinces are not provinces with high urban populations. According to Ziaulhaq (2022), the majority of waste in the region is not waste from households but comes from industry and



Fig. 8: Map of per capita expenditure in Indonesia





Fig. 9: Map of area size in Indonesia



Fig. 10: Map of urban population in Indonesia



Fig. 11: Map of the number of 3RWM in Indonesia

plantations, namely oil palm. Another thing is in Fig. 10, which shows that the provinces of West Java, DKI Jakarta, Central Java, and East Java have a high urban population. This amount results in high daily waste production due to community activities. The majority of these provinces are centers of education, offices, and trade, so the population density is high (Mardiansjah, 2018). The government has implemented various solutions to solve the problem of waste generation in Indonesia. One of them is through the 3RWM Site program. 3RWM is a location that receives waste from WPS as well as from households and industries (Clasissa Aulia et al., 2021; Nopriani et al., 2022; Norken & Harmayani, 2019). The waste is processed to reduce the amount or improve its properties so that only the remnants of waste are then disposed of in the Landfill. The program is a government initiation program that is upstream to downstream and has a joint commitment with the community to realize balance as a form of environmental responsibility (Aziz et al., 2021). However, the implementation of 3RWM in reducing waste produced by the community is

considered not effective enough. This argument is strengthened by the results of OLS regression in this study; namely, the probability value in the 3RWM variable is more than 10%. Research conducted by (Kurniawan et al., 2020) showed that the role of 3RWM has not been effective in reducing waste, especially waste produced by households. Several things cause this condition; namely, there has been no synergy between the community and the government, and facilities are in the form of tools and places that are less crowded. A similar study conducted by Purwita et al., (2022) in Kulon Progo, Special Region of Yogyakarta, also said that 3RWM could not be implemented optimally because the comparison of the calculation of TPS 3R land area with waste management area did not follow the criteria of Minister of Public Works No. 03 of 2013. Another thing with Herningrum (Herningrum et al., 2022) is that there is a slight difference between 3RWM managed by the government and non-government. The difference lies in the uneven aspects of education related to waste management and the lack of adequate facilities. In addition to infrastructure and human resources, the number



of 3RWM in Indonesia is also not evenly distributed in each province in Indonesia, as shown in Fig. 11.

The majority of areas that have a high number of 3RWM are in Java. This is by areas that have a high amount of waste production. However, in some areas, a high amount of daily waste production is not comparable to the number of 3RWM units provided. Thus, the uneven amount of 3RWM is also one of the causes of unhandled daily waste production.

## CONCLUSION

The existence of 3RWM sites in Indonesia is considered unable to reduce the amount of daily waste production. This is due to the lack of synergy between Human Resources (HR) related to the government, facilities that have not been met, and the uneven distribution of 3RWM units in Indonesia. In addition, the amount of daily waste production in Indonesia has a significant positive effect on social factors, namely life expectancy, economic factors represented by per capita expenditure, and spatial factors consisting of area and population. Other social factors, namely the average length of schooling, have a significant negative effect on daily waste production. Therefore, ongoing training and mentoring are needed for the community to be able to make good use of waste at each 3RWM. This aims to improve the management, productivity, and marketing of existing 3RWM production products. Assistance is needed to develop human resources and maintain equipment facilities. The government should also facilitate the socialization of the implementation of community-based waste management, including the provision of facilities, infrastructure, and comparative study opportunities to areas that have succeeded in waste management.

## AUTHOR CONTRIBUTIONS

A. Ratnadewati performed data processing and interpretation. E. Gravitanian performed in writing and searching literature. N. Widiastuti performed data interpretation and proofreading.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have witnessed ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and submission, and complete redundancy.

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## ABBREVIATIONS (NOMENCLATURE)

M <sup>3</sup>	Cubic meters
M <sup>2</sup>	Square Meters
GIS	Geographic Information Systems
HR	Human Resources
OLS	Ordinary Least Square
3RWM	Reduce-Reuse-Recycle Waste Management
SDGs	Sustainable Development Goals
WPS	Waste Processing Sites

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