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MAP, PEOPLE, AND POLLUTANTS: LINKING SOCIOLEGAL-SPATIAL SCIENCE TO UNDERSTANDING WASTE MANAGEMENT IN SLEMAN REGENCY, INDONESIA

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Abstract: Indonesia's waste management strategy promotes sustainable management and effective use of natural resources, as do many others. Due to a shortage of final processing sites (FPSs), ineffective solid waste management, and low environmental awareness, delivering information on ecologically friendly waste management has been difficult. Therefore, this research aims to locate typical landfills in highly populated metropolitan regions, explore solid waste management difficulties, and suggest feasible solutions. Sleman Regency, Province of the Special Region of Yogyakarta, was our focus while choosing an FPS location and assessing socioeconomic factors. We filter and classify quantitative and qualitative data from maps, observations, interviews, and document searches before using them in our mixed-methods approach. This study used sociolegal-spatial methods to improve waste management. The results show that geographical accuracy and comprehensiveness may be achieved within legal and institutional contexts. Trash reduction can be achieved if provincial, district/city, sub-district, and village administrations are compelled to adopt waste management policies and plans. These findings show that the government cannot accomplish its 2030 waste elimination goal without systematic and long-term public infrastructure and village home socialisation.

Keywords: Alternative landfill location, landfill, waste management.

Introduction

Concerns about public health, global warming, poverty alleviation, food and resource security, and environmentally responsible consumerism all tie into waste management. It is affected by several variables, including but not limited to population density and distribution, socioeconomic status, the nature of the physical environment, and local norms and customs (Deville *et al*., 2021). Since industrialisation and urbanisation are such driving forces, waste generation is an inescapable byproduct of these processes. The disparity between the volume of garbage that needs to be disposed of and the available transportation options, waste management personnel, and land will affect various facets of society. Growth in urbanisation means an increase in urban activities and lifestyles, both correlated with increased consumer spending (Turok & McGranahan, 2013). As a side effect, this wasteful habit might have if not addressed.

At the global level, at least 7–9 billion tons per year of waste are generated, consisting of 44% in the form of food waste, 15% organic waste, and 41% inorganic waste such as plastic (Wagner, 2017; Wilson & Velis, 2015). When burned openly, waste has been shown to emit large amounts of harmful pollutants, such as 3–4% of greenhouse gas emissions. Then, when waste is stockpiled, it pollutes the environment (groundwater around it due to leachate waste) (Chen *et al*., 2020; Hoang & Fogarassy, 2020). Like the waste management crisis that hit Beirut, Lebanon (Ghadban *et al*., 2017). Around 22,000 tons of waste littered the streets of Beirut and sparked widespread protests in 2015 after the city's overburdened Naameh FPS was forced to close. At long last, the municipality has adopted a significant waste management strategy with the establishment of two new FPSs (Akkar & Masnaa). New Delhi, India, has also been impacted by the garbage problem, with around 15,000 tons of trash piling up on the streets for the past ten days (Reddy, 2021). Twelve thousand janitors went on strike because of unpaid pay. Ultimately, the waste dump released 1.5 million litres of toxins into the Yamuna River. Lastly, garbage issues in Metro Manila, Philippines, and West Java, Indonesia, tend to accumulate at the Patayas FPS and the Leuwigajah FPS. Hundreds of people died as the trash pile gave way (Muliawaty, 2020; Coracero *et al*., 2021).

Since the city's garbage problems have far-reaching ramifications for the surrounding society and environment, immediate action is necessary to reduce their susceptibility and implement novel waste management (Ferronato & Torretta, 2019). Economic, social, and environmental considerations in waste management have been demonstrated to benefit the Sustainable Development Goals (SDGs). 12.3 (halve global food waste in retail and consumer sectors) and 14 (prevent the spread, indiscriminate use, and disposal of plastic waste that leads to marine litter and microplastic-related issues) are two examples of SDGs that rely on accomplishing sustainable management waste targets. Improper waste collection and disposal seriously affect human health and the environment (SDGs 6 and 13). Effective waste management methods are much more cost-efficient in the long run than dealing with their unintended effects. Even inadequate access to FPS and other critical utilities may be linked to the twelve SDGs (Rodić & Wilson, 2017).

In this study, we emphasise the need to raise public awareness of waste concerns to generate economic, social, and environmental sustainability and the relevance of selecting a standardised and relevant landfill site with the area's physical features. As a barometer of government effectiveness and an instrument for winning over sceptical citizens, efficient and effective waste management is crucial for every nation or city, including Indonesia. Public health and environmental sustainability suffer when waste management is inadequate. There is a shortage of FPS space in Indonesia, with 2020 projections calling for 1,610 m2 of FPS space (Kahfi *et al*., 2019; Ministry of Environment and Forestry, 2021).

The problem of choosing a landfill site based on regional characteristics and land suitability can be solved effectively using several geospatial techniques (Singh, 2019). Over the previous decades, researchers have extensively used Geographic Information Systems (GIS) to solve waste management problems worldwide (Hannan *et al*., 2015; Adlin, 2021). These techniques are very helpful in preliminary studies to determine the right location for waste disposal because of their ability to handle large amounts of spatial data (Kinobe *et al*., 2015; Majid *et al*., 2021). GIS can easily manage and simulate the necessary technical, social, economic and environmental constraints because many of these attributes involve spatial representation (Zhu *et al*., 2021). On the other hand, community activities fulfilling their needs and common interests cannot be separated from using space. Therefore, good planning for using space by involving the community needs to be done to achieve the goal of a clean and sustainable environment (Indartik *et al*., 2018; Junarto & Salim, 2022). In addition, it is also necessary to pay attention to the values that influence human behaviour that is already rooted in the community while still paying attention to the public interest and mutual benefits (Hsu & Feng, 2019; Cai *et al*., 2020; Katt & Meixner, 2020).

Some of the studies described are very interesting and can explain how to choose a landfill site and solve waste problems by cooperating with the community. However, this study still contains gaps, for example, it does not discuss how the standard landfill location is relevant to the physical characteristics of the area, in this case Sleman Regency, and how to create economic, social and environmental sustainability. The previous study did not show the strategy of community participation and enthusiasm in managing waste in their environment. The area's constantly developing physical condition will limit the choice of desired locations such as landfill sites (Kamdar *et al*., 2019; Rahimi *et al*., 2020). The social conditions of local communities greatly influence the business processes of conducting waste management (Hein *et al*., 2020; Petrović *et al*., 2020). Waste problems require coordinated and integrated responses from all stakeholders (local government, private sector, NGOs, and citizens as a group of individuals). The need to expedite waste management starting from the household/community unit/village requires integrated understanding and planning by all stakeholders.

By referring to the difficulties in trash collection and disposal in Sleman Regency, Yogyakarta Special Region Province (Ariyani *et al*., 2019; Aryantie & Hidayat, 2019; Krismantoro & Oktavany, 2020; Ministry of Public Works and Public Housing of Republic of Indonesia, 2021; Lodan *et al*., 2022), we want to illustrate, how can the government of Sleman 'push' its citizens to practice ecologically responsible waste management? How can we choose a suitable and uniform FPS region that considers regional specifics? Finding a straightforward and inexpensive approach to waste management by integrating physical, social, and regional knowledge is a major contribution of our research. Our research has the additional benefit of being transferable to similar regions in Indonesia and cities in other developing nations.

Materials and Methods

The object of this research is located in the Sleman Regency area which consists of 17 sub-districts/districts and 86 sub-districts/villages with an area of 574.82 km^2 or 18.34% of the total area of Yogyakarta Province. Sleman Regency is part of the fast-growing Yogyakarta Province in Java with a population growth of 1.02%/year and a population density of 1,958 people/km^2 (Giyarsih & Marfai, 2018; Sari *et al*., 2018; Devi *et al*., 2020; Rahajeng *et al*., 2022; Wibisono & Sulistya, 2022). Based on the centre of growth and the level of community mobility between sub-districts, this area is divided into three major areas, which are the agglomeration areas (Depok, Gamping, Mlati, Ngaglik), sub-urban areas (Godean, Sleman), and buffer areas (Tempel, Pakem, Prambanan). This indicates that the population is not evenly distributed, with almost 90% living in 80 'urban' villages. The research location can be seen in Figure 1 in full. On the left is the position of Sleman Regency, which is on the island of Java with a dense

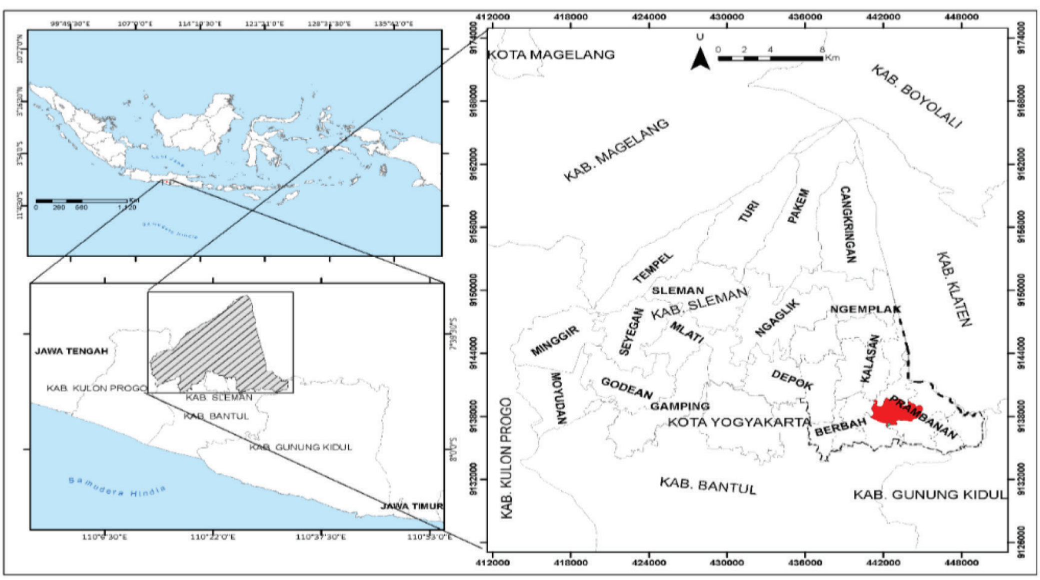

Figure 1: Research Locations. Source: Ina Geoportal (2022)

population concentration, while the red area on the right is an appropriate and standardised area based on regional characteristics, namely in Madu Rejo Village, Prambanan District, and Sleman Regency.

This research uses mixed methods combined between the two research methods, which are qualitative and quantitative, so that the data obtained is complete, correct, reliable, and neutral (Tashakkori & Creswell, 2007; Stern *et al*., 2020). Therefore, the initial screening of potential sites and assessment of their land suitability are two key steps in selecting a landfill site.

In practice, this research initially screened criteria based on Indonesian National Standard (SNI) Number 03-3241-1994 regarding the requirements for the location of landfill and Regulation of the Minister of Public Works No.20/PRT/M.2007 concerning technical guidelines for physical and environmental, economic and socio-cultural analysis in the preparation of Spatial Planning (hereinafter referred to as Indonesian National Standard and Land Capability Unit). These criteria are: (1) The area is in a flat/sloping location with a slope of < 8% and an altitude of < 1000 m. This prevents landslides from occurring at the landfill; (2) The type of soil in the waste disposal area is soil types that are not sensitive to erosion, such as Alluvial and Latosol; (3) Indonesian National Standard explains that regions with lower rainfall are considered good. Alternative locations are in areas with low rainfall, namely < 1000 mm/year; (4) The location is far from the river to avoid polluting the water flow. According to the Indonesian National Standard, the criteria for a landfill are that the distance from the river is greater than 100 m; (5) The location should not be too close to residential areas so as not to cause disease and disturb residents' activities. Distance to settlements greater than 1 km; (6) The landfill location is not too close to the main road and will hinder traffic. The minimum distance from public roads is 500 meters; (7) It is located on land use in the form of shrubs, fields, and grass or bare land; and (8) Administrative boundaries are used to determine sub-district and village locations for new landfill specifications.

The next step, apart from collecting qualitative data regarding the waste management process (activity), waste management actors (actors) and regional characteristics in Sleman (place), also collect quantitative data in a vector-number format related to 8 filtered criteria. These data were collected through interviews, field observations, document studies, and reports from official agencies and reputable journals. It is important to find and choose a suitable and sustainable alternative location for landfill development in Sleman Regency. The complete research flowchart is shown in Figure 2. Based on Figure 2, from the land use data, a selection is made for the bush, moor, and bare land (grass) areas to get a layer containing the three land-use types. From the land use data, re-select residential features, then buffer with a radius of 1 km. From the 1 km buffer results, there is not the slightest space in Sleman district except at the top of Mount Merapi, considering that the settlements in Sleman are quite dense. Therefore, the buffer distance is adjusted by lowering the radius to 250 m. Then, from the results of selecting shrubs, moors, and barren land (grass), an erase is performed with the resulting buffer radius of 250 m from the settlement to get a location area of at least 250 m. This step is to fulfil criteria (5) and (7).

Then, from the landform data, a selection is made to obtain areas with alluvial soil types with characteristics that are not sensitive to erosion. This step is to fulfil criteria (2). According to SNI, areas with lower rainfall are better. Therefore, from the rainfall data, select areas with 1000 mm/year rainfall. However, areas with rainfall of 1000 mm/year are not in alluvial soil types, so rainfall is adjusted to the conditions of Sleman Regency to 1000–1500 mm/year. This step is to fulfil criterion (3). Then, from the contour data, a classification is made based on height. Classification is done after the TIN contour data is created in raster form, followed by reclassification at 1000m and

> 1000 m, and then the reclassification results are converted into vector (polygon) format. From the vector data, we select an area with a height of 1000 m. From the contour data, the stage of making a slope map is also carried out, as done in the previous practicum. From the reclassification results, we then select areas with a slope of 0-8%. These two steps are to fulfil criterion (1).

The results of steps 1 to 4 are then intersected to obtain areas with location criteria: land use in the form of shrubs, moorlands, and barren land; being outside a radius of 250 m from settlements; alluvial type soil; low rainfall of 1000–1500 mm/year; and being located in a flat area of 1000 m with a slope of 8%. From the river data, a 100 m buffer is used to obtain a 100 m radius area from the river. The stream buffer results are merged and erased with the previous intersect results (number 5). Thus, we obtained an area at least 100 meters from the river. This step is to fulfil criteria (4). From the data of primary roads (main roads) and secondary roads (collector roads and local roads), a 500 m buffer is performed to obtain a 500 m radius area from the two roads. The result of the two buffers is the merge path, which is erased with the results of the previous erase (number 4). Thus, an area at least 500 m from the main road (primary and secondary roads) is obtained. This step is to fulfil criteria (6). To find out which village is the alternative location, a selection by location was carried out in the previous results.

This research requires sociolegal-spatial analysis techniques to process quantitative data and qualitative data. Spatial analysis is useful for processing quantitative data from eight important criteria based on the spatial distribution of geographic objects. Some of the techniques chosen are overlays in the form of select by location, erase, intersect, buffer and reclassification, and conversion to prepare map layers for alternative landfill locations (vector-based) and their table attributes (numbers). Furthermore, using sociolegal-spatial analysis, qualitative data (observations, interviews, and document searches) are connected to explore the uniqueness and uniqueness (local wisdom) at the research location. In other words, this sociolegal-spatial analysis is useful in narrating the relationship between humans who use land resources, such as spatially referenced landforms, soils, topography, climate, rivers and roads. As a whole, sociolegal-spatial analysis is used to understand regional resilience's environmental and biophysical conditions related to landfill placement at the local scale (Hein *et al*., 2020; Petrović *et al*., 2020). This will help decision-makers to get solutions to the research problems that have been described. Policymakers can design and build a sustainable solid waste management system in Sleman Regency.

Results and Discussion

It is time for the local government of Sleman Regency to think about and provide an environmentally friendly and sustainable landfill as a public space in line with the rapid development of urban areas. The existence of metropolitan regions previously influenced the formation of new urban centres because they were supported by a healthy social environment, a comfortable physical environment, affordable living costs, and easy accessibility. The reality on the ground shows that the area directly adjacent to the City of Yogyakarta is filled with residents as an alternative settlement such as in the Districts of Mlati, Pakem, Depok, Gamping and Godean. This provides an understanding that the increase in population, settlements, economic activities, and social society always puts pressure on the environment (land-carrying capacity) because it goes hand in hand with waste production. Various impacts of waste if not handled, will eventually cause problems for the environment and humans, both tangible and intangible.

This research obtained a suitable and standardised alternative landfill location based on regional characteristics. The overlay technique, conducted by overlapping related maps based on parameters on the Indonesian National Standard and Land Capability Unit, is good enough to

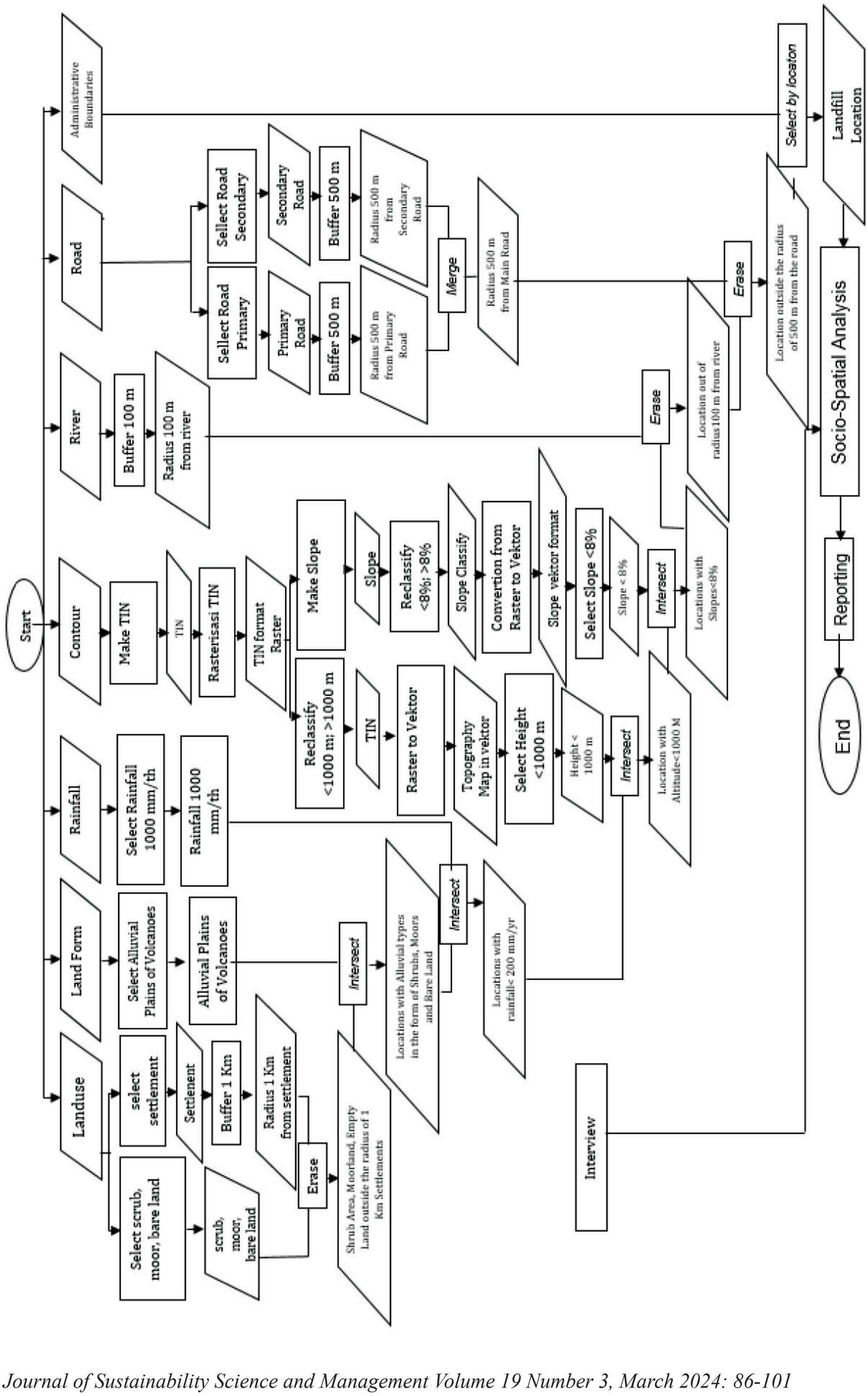

Figure 2: Flowchart of research

obtain an alternative location for the landfill in Sleman Regency. Based on the spatial analysis, a flat landform with an alluvial soil type not sensitive to erosion has been obtained. Then the variable height with a height < 1000 m and a slope with a slope of 0-9% of the contour reclassification can be fulfilled. In addition, from the map of the river and the map of the primary road (main road) and secondary road (collector, local road) after buffering the three criteria of 100 m and 500 m, it was also possible to obtain a representative area. However, there are two adjustments to the two criteria, which are rainfall < 1000 mm/year (criterion three) and a location with a radius of 1 km from settlements (criterion four), because the characteristics of the area in Sleman Regency are not possible. As it is known, Sleman Regency is one of the fast-growing and densely populated districts, so the location required in the Indonesian National Standard is not found except at the peak of Mount Merapi. One of the indicators is that buildings/houses in residential areas are quite dense. Therefore, adjustments were made to the two criteria: rainfall to 1000-1,500 mm/year and distance to settlements to 250 m.

So that the validity of the geospatial data that comes from the analysis can be proven and is in line with national standards, the data used as a starting point for analysis must also meet the requirements set by norms, standards, procedures, and criteria. One map that is often used as a basis for data analysis and compiling information is a topographic map. A topographic map is a map that displays some of the natural and artificial elements throughout the territory of the unitary state of the Republic of Indonesia. The elements can be grouped into seven themes, namely: land cover, which includes land cover areas such as forests, rice fields, settlements, and others; hydrographic elements, which include water elements such as rivers; hypsography elements, which have elevation data such as high points and contours; building elements, including buildings, houses; transportation and utility elements, including road; elements of administrative boundaries; and elements of toponymy, which include geographical names such as the names of islands, straits, and others. Topographic maps have various scales, including 1:250,000, 1:50,000, 1:25,000, and 1:10,000.

Topographic maps can be accessed via the Indonesian portal and cover almost all of Indonesia by Presidential Regulation Number 23 of 2021 on Accelerating Implementation of the One Map Policy. Considering that this research is in an area with topographic maps, we took basic geospatial data from the official government agency geoportal site with a scale of 1:25,000. Furthermore, the geospatial data was only used as a basic map. The result of the author's original research is the thematic map of alternative landfill locations that are suitable and standardised. The author believes that it is impossible for a base map to be built by the author and that the base map should refer to official legal and formal Indonesian government documents, such as (http://tanahair.indonesia.go.id/) and (http://gis.jogjaprov.go.id/). This argument is also based on research by Sarkodie & Owusu (2021).

Based on Figure 3, the widest location is the most appropriate requirement to accommodate waste production, which increases yearly. This area not only supports storing waste in the active zone but can also maintain the continuity of waste-handling activities such as sorting, collecting, moving, recycling, composting, and backfilling (passive zone). Then, it is still possible to create a buffer zone with that area. The buffer zone functions as a barrier preventing and protecting the landfill area from the activities of the surrounding community. Infrastructure such as leachate processing areas and access roads must also be considered. Overall, in addition to the area for landfilling, the landfill operation also requires an area of around 20-30% for supporting facilities and infrastructure. Suppose the assumed height of the compressed waste pile is 18 meters. In that case, an analysis of the landfill's capacity with a net area of 32,800 m^2 (after deducting 20% of the total area for supporting infrastructure) can be obtained as 590,400 m^3. In addition, to extend the service life of landfills, it is necessary

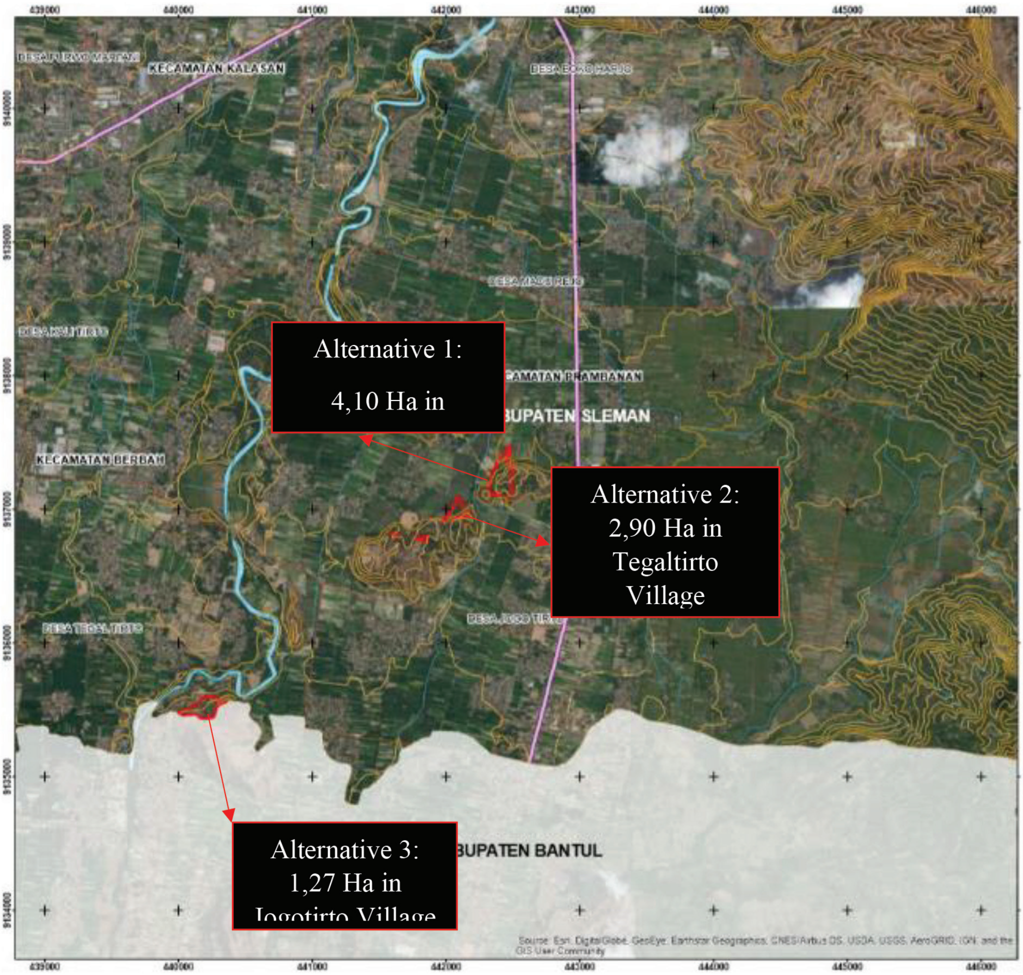

Figure 3: Alternative landfill location

to strengthen waste reduction (waste bank and 3R landfill) and waste handling (sorting, collecting, processing and transporting) in the coming years. For waste that ends up in the landfill to be handled properly, it is necessary to apply technology and management of sanitary landfills (SL) in these locations. SL is a method of disposing and piling waste into a concave field and then compacting it with a layer of soil until it is full. The compaction process uses a bulldozer to form layers of solid waste (60 cm) up to a height of 2. 4 m (1 cell) which is topped with a layer of soil (15-60 cm). In each storage cell, ventilation facilities and drainage channels are placed connected to oxidation ponds to remove gas and wastewater that can contaminate groundwater.

Besides focusing on final disposal solutions at the landfill, waste infrastructure planning must also cover all stages, from its reduction to managing the landfill facility after it is closed. At the abatement stage, the Sleman local government can promote recycling, reuse, and composting/recovery to minimise disposal costs to landfills while receiving revenue from the sale of recycled materials. For the waste management process to be successful, the Sleman government must also pay attention to economic and social sustainability aspects, such as sustainable development (Sakai *et al*., 1996;

Yaqi *et al*., 2023). The principle of sustainable waste management in terms of the economic aspect is implementing a circular economy (CE) and turning waste into an alternative energy source. CE means that in addition to protecting the environment, it is also followed by creating a natural regeneration system, namely by leaving disposable goods and packaging, composting organic waste, and reusing goods/packaging. Alternative energy sources can be carried out by processing waste into fuel (refuse-derived fuel/RDF), electrical energy (waste to electricity) or heat energy (waste to heat). On the other hand, the principle of sustainable waste management on the social side can be carried out by involving all components of society based on their needs and desires so that it can run effectively. One of the first steps is integrating all stakeholder interests, starting from the family, Neighbourhood Unit/Community Unit, and village level (bottom-up planning).

Analysis of the content of waste that is specific, community-based and fruitful over time can also help the Sleman Regional Government identify opportunities to recycle certain types of materials in their area. Local governments can set goals and design policies that are adapted to local characteristics so that handling waste through content analysis has the potential to create new businesses and jobs. Reducing waste means changing the paradigm of waste management by providing pressure points for the 6R activities upstream: reduce (reducing waste accumulation at the source), reuse, recycle, repair, refuse, and rethink. The 6R activities provide various opportunities to create value and work from further waste material handling. One example is recovering valuable or rare materials for a zero-waste and waste-to-profit movement. However, the negative or positive impacts of the waste handling process need to be considered, such as the adequacy of funds or providing incentives for environmentally conscious activities (such as waste reduction and recycling) and disincentives for polluting activities (such as littering). In addition, increasing the number and size of recycling sites can be used as an additional approach. Sustainable waste management needs to change the focus from minimising waste to maximising the value of waste materials/sources. Increasing awareness and sincerity is the key to success in alleviating the waste problem from the lowest level. Concrete steps that can be taken are communication, information, and awareness-raising or education. The waste problem should be solved upstream (home, school, office) by separating waste into organic and inorganic waste. Therefore, it is necessary to act with emphasis and togetherness in waste reduction and management. These actions must be organised to promote better environmental conditions and create sustainable development. In summary, sustainable landfill development, starting from the home/family/office/school to the village level, can be carried out with a strategy as shown in Table 1.

Even though waste management regulations vary, at a practical level, the government should emphasise every citizen at the lowest level, namely the family, to change consumption patterns and wasteful lifestyles, increase awareness to protect the environment by disposing of waste in its place, cleaning the surrounding environment, cleaning sewers/rivers to reduce waste piles, promote clean and healthy living socialisation. Based on statistical data, of the 1,125,804 residents of Sleman Regency, around 30.33% are millennials (age 20-39) and 21.63% are Generation Z (age 5-19) (Indonesian Statistics, 2021). This is the potential of human resources that can be maximised to drive waste management in the future. The younger generation can interact and is highly committed to sustainable waste management. In addition, they have strong ideals, a high level of mobility (dynamic), a greater sense of social concern/friendship, being innovative-creative, courage and openness. In general, Generation X (age 40-55) is becoming leaders in various organisations/companies, Millennials have become middle managers and Generation Z has become the young workforce. As a decisive generation, Generation Z can act in waste management and environmental preservation and work together to turn environmental problems into business opportunities, such as making technological

Table 1: Sustainable waste management at the local level

Strategy	Family house/ School Office	Neighbourhood Unit/ Community Unit	Village
Preventive (prevention before the accumulation of waste occurs)	Cleaner production (commitment to waste segregation); provide a minimum of 2 bins (organic and inorganic)	Providing a place for incineration of waste; provide a fleet of garbage bins	Providing waste banks and landfill-6R; setting up a waste management depot; organic waste chopper machine
Persuasive (approach through understanding awareness and ethics)	Cleaning picket schedule; Self-management of waste processing into compost	Formation of healthy environmental cadres (scheduled garbage pick-up officers), socialisation of waste sorting (organic and non-organic) to residents through mosques	Organise environmental discussion forums, education training, digital campaigns, brochures, leaflets, forming cooperatives
Curative (environmental improvement)	Make waste as compost/ green manure by planting in the yard/rice field/moor/garden yard	Cooperation to clean up the environment; Neighbourhood Unit cleaning competition; creating environmental awareness groups, procuring Neighbourhood Unit/Community Unit halls	clean times program; clean tourism village program (eco-tourism); Proactive NGOs in empowering communities; provision of waste collection facilities
Repressive (acts of suppression with threats)	Reward and punishment actions for members	Social sanctions; Fund sanction; reprimand	Revocation of temporary/ permanent licenses, product boycotts, digital news

Source: Field observations and conversations with waste bank administrators, 2022

innovations in implementing concepts with a high level of mobility (dynamic), a greater sense of social concern/friendship, being innovative-creative, courage and openness. Currently, Generation X (age 40-55) is becoming leaders in various organisations/companies, millennials are becoming middle managers, and Generation Z is becoming the young workforce. As the decisive generation, Generation Z can act in waste management and environmental preservation and work together to turn environmental problems into business opportunities. For example, making technological innovations in applying the concept of economic circulation, implementing a minimal waste lifestyle (rejecting and reducing the use of plastic bags, sorting waste from home, and always finishing food and composting leftovers), playing an active role in open discussions and campaigning for a clean environment through social media; social supervision; create and disseminate positive and constructive content or opinions on social media; as well as participating in the development of waste management innovations. It is very good when one generation becomes a pioneer in waste management concerns. Therefore, the older generation needs support and attention to keep this generation on an idealistic path, equipping it with in-depth knowledge and facilitating it with technology-based systems.

In addition, village/sub-district governments and community leaders continue to spread community awareness and include financing in recycling and environmental improvement activities. It should also be explained that wrong waste management will impact local, regional and global levels. Organic waste such as vegetables and leaves (easily decomposed) and inorganic waste such as paper, plastic, iron, glass, and zinc (not easily destroyed). The ultimate goal of organic waste is to be used as compost or fertiliser, while inorganic waste is to be recycled. Recyclable organic and inorganic waste can be sold at the nearest waste bank. Waste banks can be made available to receive and process into fertiliser or compost, which can then be resold. So, this sorting has already reduced the volume of waste at the initial level, and the waste that goes into transportation is only waste that cannot be recycled. An important waste management concept is educating the public to reduce waste and manage waste starting from the environment and starting from the source. So, with a good understanding, each individual can become a leader by doing what is appropriate and leaving what is inappropriate. In addition, the rules implied in religion and government can direct the actions of every citizen to do things that are good, proper and proper. Having some shame can also be cultivated to control littering behaviour. Lastly, cooperation, sharing, and mutual help can be continuously fostered to create a harmonious and conducive environment.

Technology in the form of computers and the Internet is one possible answer to the garbage problem (Javaid *et al*., 2022). In addition, the increased efficiency, decreased operational expenses, and reduced labour needs of automation data collection have replaced. Problems upstream (home, school, office, industry, market) can provide two types of smart waste bins (Budiarti *et al*., 2018; Chaudhari *et al*., 2019; Syaifudin *et al*., 2019). The concept is a tool for storing waste equipped with sensors and automatic imaging that provides daily information on condition, weight and volume. Sensors are devices that sense and measure the waste's physical quantity or chemical properties and convert it into a signal that other devices can directly observe. Meanwhile, imaging is an activity of sensing, capturing, storing, manipulating and displaying digital images by synthesising images from sensors (digital processing). Sensors are scattered and installed in cell phones, radios, schools, cars and other applications, while imaging is obtained via video surveillance, cameras or scanners. Then, the problems of transporting and scheduling to landfills can be solved with Internet, mobile, and social media-based applications. In principle, the application manages computerised data and can present that information. Applications such as transport, mountain trash, octopus, plastic pay, and e-recycle offer waste alleviation services. The passion is to educate and invite people from within the family circle to exchange waste for money/points/goods and manage waste from an early age. Even the solution to handling waste is by providing a landfill. The adoption and application of modern technology are expected to increase the efficiency of materials and waste management services, accelerate the integration of waste management operations, facilitate data collection, and offer opportunities for stakeholder participation. At the operational level, there are also potential opportunities to engage citizens and stakeholders to achieve the goals of efficient data collection and diversion of waste from landfills. For example, a smart trash program is a web-based waste management application that promotes waste reduction in landfills and provides data on the volume of waste piles at the community or neighbourhood level.

Conclusion

The Regional Government of Sleman Regency must provide an environmentally friendly and sustainable final processing site (landfill) in line with the rapid development of urban areas. This research found that alternative landfill locations were suitable and standardised based on regional characteristics. Sleman Regency needs the widest location to accommodate waste production and maintain the continuity of waste-handling activities. Apart from that, 20–30% of land is also required for supporting facilities and infrastructure to extend the service life of the landfill as well as to handle waste properly.

The local government of Sleman should promote recycling, reuse, and composting/recovery to minimise disposal costs to landfills while receiving revenue from the sale of recycled materials. The principle of sustainable waste management in terms of the economic aspect makes waste an alternative energy source. Increasing awareness and sincerity is the key to alleviating the waste problem at the lowest level. The Sleman Regional Government must emphasise to every citizen at the lowest level, namely the family, to change consumption patterns and wasteful lifestyles, increase awareness to protect the environment by disposing of trash in its place, cleaning the surrounding environment, cleaning gutters and rivers to reduce piles of garbage and promote socialisation for a clean and healthy life.

This study has limitations, namely that all activities following the discovery of a landfill location must be followed up with stages of land acquisition following legal corridors. This is important for anticipating and overcoming various problems, especially when there is a budget allocation and a project winner. In addition, our research does not address in detail political issues that can arise at any time due to technical errors, such as the readiness of the local government to build a landfill. We suggest to the Regional Government of Sleman that they immediately follow up on the findings of the landfill locations by implementing efficiency and transparency so that everything is open to the general public. This study suggests that future research be carried out related to strengthening human resources in implementing waste management at all levels. This is important so that all devices and officers can work properly.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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