Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Journal Home Page: https://e-journal.unair.ac.id/JKL
Vol. 16 No. 2
DOI: 10.20473/jkl.v16i2.2024.153-165
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X

ORIGINAL RESEARCH Open Access

BOOLEAN AND SPATIAL ANALYSIS USING GIS TO DETERMINE LANDFILL WASTE ON BUNAKEN ISLAND WITH AN ENVIRONMENTAL HEALTH APPROACH

Agus Bintara Birawida[1]*, Anwar Daud[1], Anwar Mallongi[1], Steven R Silalahi[2], Nurlia Sila[3], Melisa Todingan[4]

[1]Department of Environmental Health, Faculty of Public Health, Universitas Hasanuddin, Makassar 90245, Indonesia
[2]North Sulawesi Provincial Health Service, Manado 95117, Indonesia
[3]Department of Environmental Health, Faculty of Public Health, Universitas Airlangga, Surabaya 60115, Indonesia
[4]UPTD Geospatial Data and Information Processing BAPELITBANGDA Manado City, Manado 95124, Indonesia

Corresponding Author:
*) agusbirawida@gmail.com

Article Info

Submitted : 13 January 2024
In reviewed : 21 February 2024
Accepted : 23 April 2024
Available Online : 30 April 2024

Keywords : *Boolean, Garbage and landfill, Spatial, Waste*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *Bunaken Island still lacks proper waste management infrastructure, resulting in the accumulation of garbage around residences and along the coastline. This prevalent issue significantly impacts public health and the overall quality of life on the island. The research seeks to evaluate the waste management situation on Bunaken Island and identify suitable locations for waste disposal.* ***Methods:*** *The study employed random sampling techniques to select households within the study area for primary data collection. The research utilized Boolean and spatial analysis methods to pinpoint appropriate waste disposal zones and propose sustainable waste management strategies for Bunaken Island.* ***Results and Discussion:*** *Findings revealed that Bunaken Island spans a land area of 794.12 hectares and is inhabited by a population of 3,843. The analysis identified two recommended locations for final disposal zones, totaling 3.40 and 0.45 hectares, respectively. Moreover, the estimated waste generation over the next decade is approximately 4,277,893 kilograms, necessitating 0.0241 hectares of land for waste accommodation through terracing methods.* ***Conclusion:*** *Addressing this issue requires the identification of two viable disposal zones in distinct locations. Additionally, implementing recycling practices to utilize both organic and inorganic waste from local and marine sources and promoting reuse before landfill disposal are crucial strategies for effective waste management on Bunaken Island.*

INTRODUCTION

Solid waste treatment is one of the main problems in many small islands worldwide, especially in developing countries, due to its impact on the environment and the health of residents (1). In addition to the small geographical size, islands in developing countries have unique special characteristics that are different from their small geographical size. However, it is challenging to implement sustainable waste disposal because of physical and topographical limitations, as well as economic, social, and political conditions (2). Developed countries produce more solid waste than developing countries, but the availability of sufficient technology and costs still make the countries more efficient in their disposal (3-4). A significant obstacle in urban planning in emerging nations is the escalating garbage generation and the exorbitant expenses associated with its treatment (5-6). According to research in Türkiye in 2020, management should pay special attention to preventing waste generation at the source (6).

As a maritime country, Indonesia needs to implement steps to mitigate and prevent waste disposal at sea and on the coast with various programs. The impact will be more pronounced due to the restricted carrying capacity and resources of small islands (7). Furthermore, waste management in this coastal region is still a gray area, as there is no precise regional regulation regarding the duties and responsibilities of coastal waste management (8).

Cite this as :
Birawida AB, Daud A, Mallongi A, Silalahi SR, Sila N, Todingan M. Boolean And Spatial Analysis Using GIS to Determine Landfill Waste on Bunaken Island with an Environmental Health Approach. *Jurnal Kesehatan Lingkungan*. 2024;16(2):153-165. https://doi.org/10.20473/jkl.v16i2.2024.153-165

ScienceMag research indicates a general upward trend in the creation of plastic garbage worldwide between 1950 and 2015. The global trash generation has experienced a significant surge, increasing from 2 million tons per year in 1950 to 381 million tons per year since 2015 (9). According to data provided by the Ministry of Environment and Forestry, 80% of the waste disposed of in the ocean originates from the mainland, with plastic waste accounting for 90% of this amount (10). Indonesia, boasting a population of 187.2 million and an annual plastic waste production of 3.22 million tons, ranks second in terms of the largest plastic waste pollution in the world's oceans. The sea's estimated amount of plastic garbage ranges from 0.48 to 1.29 million tons. Even though the population in Indonesia is almost the same as in India, the level of plastic waste pollution in the Indian sea is only around 0.09-0.24 million tons and ranks 12th. This implies that Indonesia has a poor waste management system (11). The Philippines is an archipelago with over 7,000 islands with a vast coastline. The country faces challenges related to waste management and marine pollution, but initiatives and programs have been in place to address these issues. Efforts such as coastal clean-up drives, waste management programs, and environmental awareness campaigns have been implemented in the Philippines to reduce marine pollution and protect the marine ecosystem (12).

Unfortunately, the problem increases in response to population growth because more waste is generated (13). As a result, a significant rise in solid waste will lead to an unparalleled level of environmental hazards, including diseases, deterioration of ecosystems, contamination of soil and water, global warming, and extreme weather conditions in the eastern part of the Central Anatolia Region. Various methods have been suggested for identifying suitable locations for final disposal sites (TPA) (14–17). In addition, careful planning and site selection for landfills can save construction and planning costs by up to 18% and substantially lower operational expenses, environmental risks, and potential hazards associated with garbage disposal (18), as well as decrease planning and construction costs (19). It is not easy to determine where a TPA should be located; criteria for the island's features and an evaluation method are needed (20). Addressing the environmental, health, aesthetic, economic, and land use issues related to inappropriate garbage disposal for nations, communities, businesses, and individuals globally is the primary goal of the waste management strategy (21).

The utilization of Geographic Information System (GIS) has gained significant popularity as a more accessible and user-friendly tool in the field of landfill selection study. GIS is a computer-based system that manages, analyzes, and presents geographic reference data for decision support (22). The ultimate goal of integrating GIS, Boolean logic, and spatial analysis is to evaluate the appropriateness of the research region for locating the optimal disposal site (23). The boolean value of the desired condition dictates the number of classes. It characterizes the outcome applied to the variables, which are iteratively employed in the two class descriptions, these classes are 0 and 1 (24).

GIS can successfully and efficiently solve the problem of landfill waste disposal. It is considered a valuable tool that facilitates numerous spatial tasks, including inputting, storing, modifying, analyzing, and displaying geographically related data. Data related to spatial modeling (25). The advantages of Boolean analysis are that it is effective in simplifying the spatial analysis process using Boolean operations, efficient because it can save costs and time by utilizing existing data, accurate with tested and optimized results, flexibility in various fields such as ecology and urban planning, feasibility in determining project. The tools combined in this research include Kobotoolbox for determining coordinate points and conducting interviews and Google Earth as a satellite image source for visualizing the actual conditions on the island.

To preserve public health and environmental purity, sustainable forms are required (26). A disagreeable stench that obstructs breathing might result from the improper management of waste accumulation, which can also lead to the spread of illness (27). One of the illnesses brought on by exposure to accumulating trash in the environment is diarrhea (28). According to 2008 data from the World Health Organization (WHO), 15% of the deaths of children under 5 years were caused by diarrhea. The study's findings, determined by the Chi-Square test, yielded a p-value of 0.000 <0.05 and an odds ratio (OR) of 13.00. These results indicate a significant and positive association between the occurrence of diarrhea and possession of a trash can ownership. Children under the age of five were 2,5 times more likely to get diarrhea on islands without landfills than on those with landfills (29).

Bunaken Island lacks a disposal facility; organic waste is gathered at a Temporary Disposal Site and subsequently incinerated in an incinerator. The delivery of inorganic waste to the Sumompo landfill is conducted through water transportation, which poses a significant risk in the event of an accident. As an illustration, when inorganic garbage enters the ocean, it will pollute the water and degrade into microplastics or nanoplastics that fish can ingest. If the weather is unfavorable, the accumulation of trash in the TPS might serve as a breeding ground for disease-causing microorganisms. Seeing the condition of the islands like this, there should no longer be any mobilization for transporting waste by sea. Each island should have its own waste processing so that by using Boolean and spatial analysis methods we can find possible waste locations on the island to avoid the mobilization of waste by sea.This study, conducted between September and October 2022, addresses waste issues on Bunaken Island, specifically in Bunaken District, Manado City. It employs Boolean and Spatial Analysis, along with Geographic Information System (GIS), to scientifically analyze environmental and health factors to determine the landfill's location.

METHODS

Study Area

The research site is located on Bunaken Island in Manado. The area is governed by the Bunaken Islands District, which is under the jurisdiction of Manado City. The study region is located between 1º35' and 1º40' North latitude and 124º39' to 124º46' East longitude. The area consists of two sub-districts, Bunaken and Alung Banua, which are further divided into seven and two neighborhoods, respectively. The area's total population is 3,843, with 1,931 males and 1,912 women. Data collection of maps and regional feasibility analysis were carried out using the QGIS application by applying buffers to various elements such as rivers, settlements, roads, and coastlines. The evaluation results were given suitable or unsuitable scores, then area generalization and map overlay assessment were conducted to determine suitable zones for the landfill or Final Disposal Site (TPA). Landfill recommendation points are recorded for field checking including the land capacity of the landfill location. The landfill model used is open dumping, referring to a simple waste disposal method where waste is dumped openly without any protection or separation layer between the waste and the surrounding environment.

Data Collection

The primary data collection involved using random sampling techniques to select households within the study region. Sampling by technique taken subjects from each strata by determining the number of samples based on the number of subjects or populations in 70 regions. The strata referred to in this study are groups or environments in each kelurahan, namely Bunaken village and Alung Banua village. How to sample each unit using the following formula

$$nh = \frac{NH}{N}\, n$$

Information:

- nh = Number of samples per stratum
- NH = Number of populations of each stratum
- N = Number of population
- n = Number of samples

This process took place between September and October 2022, resulting in 178 respondents. The data collection methods include using questionnaires through the Kobotoolbox program, conducting interviews, making field observations, and analyzing documents, specifically in the form of secondary data acquired from relevant agencies. Kobotoolbox is used in this research for collecting research location points. Kobotoolbox is an open-source software platform used for designing surveys, collecting data, and analyzing information (30). Interviews were conducted by distributing questionnaires to respondents with the aim of finding out the condition of waste in the environment as well as the frequency of diseases that can be caused by waste as well as the public's opinion about the existence of a landfill location on Bunaken Island, Manado City. Field observations were conducted to identify research locations and directly observe the environmental conditions and public health at those locations. The secondary data collection involved doing a comprehensive assessment of articles, relevant news sources, and prior research journals on waste management and the identification of disposal sites, specifically focusing on the Indonesian National Standard (SNI) 03-3241-1994. Spatial data in Shape File (SHP) maps, such as geological, hydrogeological, topographical, agricultural land use, disaster-prone, water bodies, protected areas, rainfall, and settlement maps, were obtained from the UPTD, Center for Data and Geospatial Bapelitbangda City of Manado. This research has obtained ethical clearance from FKM Unhas research ethics commission with ethical clearance number: 10989/UN4.14.1/TP.01.02/2022.

Data Analysis

This study employs an observational approach, utilizing a quantitative descriptive methodology. The process of identifying the placement of a landfill is facilitated by the Geographic Information System (GIS) using the Indonesian National Standard (SNI) 03-3241-1994. In addition, the regional feasibility study is conducted by applying a buffer to each parameter and then combining the results with the surrounding area using the Boolean assessment approach, with 0 and 1 indicating "not feasible" and "feasible", respectively.

Map data collection in the form of SHP format maps or basic data in the form of Geology, Hrdrogeology, Topography, Agricultural Land, Flood disasters, Protected areas, rainfall, distance to settlements. Conduct regional feasibility analysis in the QGIS application. Buffering maps of 100m River, 650m Settlement, 50 m Road and 100 m coastline in accordance with regional eligibility criteria based on SNI 03-3241-1994 with adjustments. Doing Unioan or combining buffer and out-of-buffer results with a score of 1 is feasible and 0 is not feasible. Landfill feasible zones, then generalize where it eliminates areas that are not possible such as very small areas or possible areas of development of residential areas. Determining the criteria for allowance according to the characteristics of the island refers to SNI 03-3241-1994 with adjustments. Perform an assessment by overlaying the map on the QGIS application and total all values. Landfill recommendation points that have been determined, recorded coordinate data for then checking (ground check) in the field.

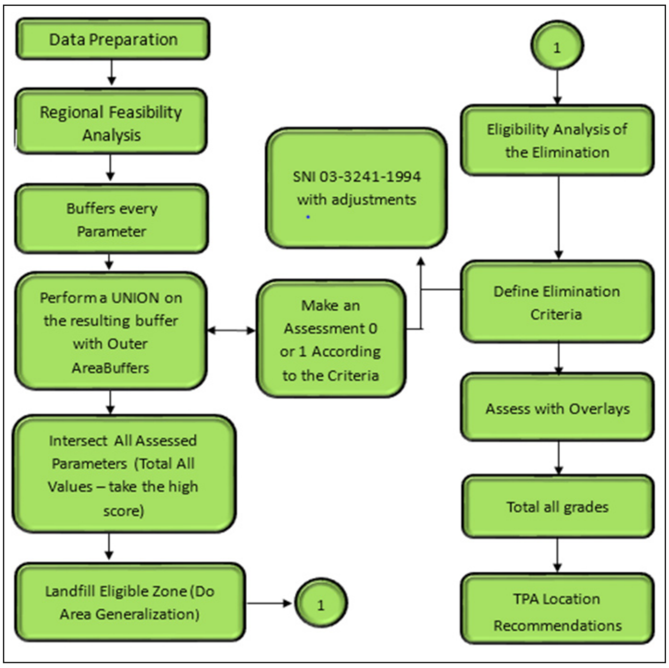


Figure 1. Chart Flow of Data Analysis in GIS Applications

Table 1. SNI 03 3241 1994 Regional Criteria with Adjustments to the Characteristics of Bunaken Island

Parameter	Score
Slope	4
0 – 15	1
> 15 %	0
Geological Conditions	
Not in an active fault zone	1
Located in an active fault zone	0
Distance to Water Bodies (RTRW Manado City 2014 – 2034)	
>300 meters	1
<300 meters	0
Distance to Settlements (RTRW Manado City 2014 – 2034)	
>650 meters	1
< 650 meters	0
Agricultural Cultivation Area	
Outside the area of mixed farming/garden	1
In a mixed agricultural/garden area	0
Protected Area	
Outside the protected area	1
Protected area with adjustments	0
Coastline	
>100 meters	1
<100 meters	0
Flood Prone	
Not prone to flooding	1
Probability of flooding >25 years	0
Traffic	
>50 meters	1
<50 meters	0

The 9 criteria (Table 1) used in this research are Slope, Geological Conditions, Distance to water bodies, Distance to settlements, Agricultural cultivation area, Protected area, Coastline, Flood prone, Traffic. The slope of the land becomes a key factor as it can affect the stability of the landfill and the potential for erosion. In addition, geological conditions such as soil types and rocks also need to be considered to prevent cracking or leaks that could contaminate the environment. The distance between the landfill site and water sources such as rivers and lakes is also an important consideration to protect the quality of groundwater and surface water. Furthermore, the distance between the landfill and residential areas should be taken into account to avoid negative impacts on the health of the community and the surrounding environment. Productive agricultural areas should be avoided as landfill sites to prevent contamination of soil and water used for farming. Additionally, landfill locations should not be in protected areas to conserve nature and maintain ecosystem sustainability. Other factors such as proximity to the coastline, susceptibility to floods, and transportation accessibility should also be considered in the selection of landfill sites.

The determination is made using Boolean criteria, where the necessary information from each input map is converted into binary form, represented explicitly by the numbers 0 and 1, corresponding to True and False. In this case, 9 criteria were used based on sub-variables with a result of 9 feasible and < 7 inappropriate. The geometric method was used to determine and predict the percentage of population growth.

Projected Population Growth

The formula below is used to project the population in order to determine the amount of waste generated in a few years or in the next 10 years (2022 -2023). The area of the landfill sites was determined using the geometric method with the formula:

The formula calculates the percentage of the population (31)

$$r = \left(\frac{pn(\frac{1}{n})}{po} \right) -1 \qquad (1)$$

The formula calculates population growth predictions (31)

$$pt = po\ (1+r)^{t} \qquad (2)$$

Information:

Mrs = Total population in year t
Po = Total population in the base year
t = Time period (difference)
r = Population growth rate

It is necessary to review the required land area in order to determine the location of the new landfill feasible zone. The calculation of the landfill area is carried out using the formula:

Determination of the waste landfill area formula (32)

$$L\ Landfill = \frac{V.sc}{T} \qquad (3)$$

Determination of the buffer land area formula (32)

$$L\ buffer = 25\% \times L\ TPA \qquad (4)$$

Information :

L TPA = Final processing site area (m^2)
L buffer= Landfill buffer zone area and supporting facilities (m^2)
V = Waste volume ($meter^3$)
SC = Soil cover (m^3), 15% of waste volume
Q = Height of landfill and overburden (meters) = In Indonesia landfills between 10 – 15 m

This calculation takes into account:

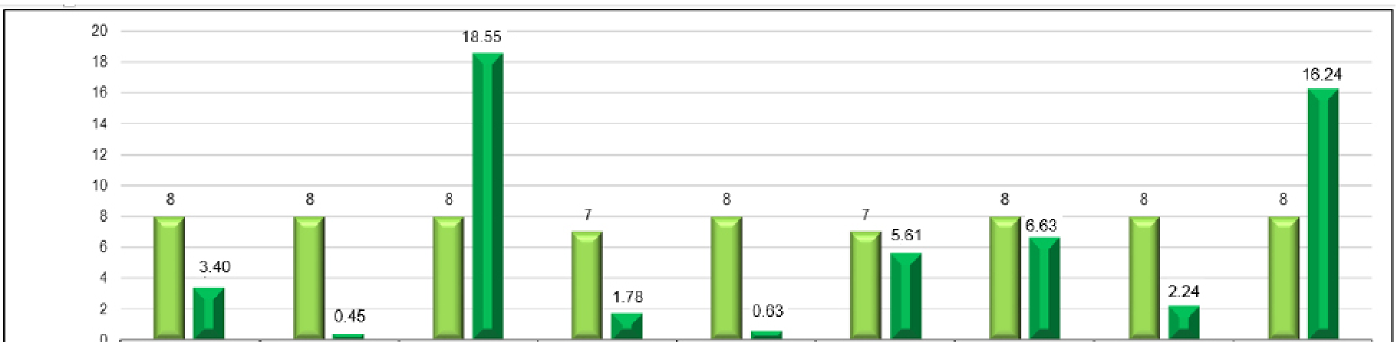
a. The stack shape is modeled in a square shape
b. The waste contained in the dilanfil is carried out with a compaction of 250 kg/m^3. In Indonesia, the density of waste varies from 250 – 500 kg/m^3, with Jakarta having 259 kg/$meter^3$
c. The waste that goes to the landfill is taken by scavengers, especially non-organic components, which make up 25%.
d. The daily garbage height has decreased by 0.002 m/day, and the landfill height ranges from 10 - 15 m (32-33)

Disposal of household waste and diseases were analyzed using a questionnaire with the KoboToolbox and SPSS statistics version 22 applications in percentages through tables and narration (30-34).

RESULTS

Boolean Analysis With Regional Criteria

The results of the analysis are based on the Boolean method and the area of each zone. The landfill worth is shown in Figure 2 From the results of regional criteria using SNI 03-3241-1994 and the GIS application, 9 zone locations were feasible to be used as landfills, as shown in Figure 3 and Figure 4.



	1	2	3	4	5	6	7	8	9
Road	Not the Road Network 1	Not the Road Network 1	Not the Road Network 1	Not the Road Network 0	Not the Road Network 0	Not the Road Network 0	Not the Road Network 1	Not the Road Network 1	Not the Road Network 0
Coastline	Not the Coastline 1	Not the Coastline 1	Not the Coastline 1	Coastline 1	Coastline 1	Coastline 1	Not the Coastline 1	Not the Coastline 1	Coastline 1
Water	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1	Not a Body of Water 1
Flood	Not Prone to Flood 1	Not Prone to Flood 1	Not Prone to Flood 0	Not Prone to Flood 1	Not Prone to Flood 1	Not Prone to Flood 1	Not Prone to Flood 1	Not Prone to Flood 1	Not Prone to Flood 1
Gardens	Not Mixed Gardens 1	Not Mixed Gardens 1	Mixed Garden 1	Not Mixed Gardens 1	Not Mixed Gardens 1	Not Mixed Gardens 1	Not Mixed Gardens 1	Not Mixed Gardens 1	Not Mixed Gardens 1
Area status	Protected area 0	Protected area 0	Protected area 1	Protected area 0	Cultivation Area 1	Protected area 0	Protected area 0	Protected area 0	Protected area 1
Settlement	Settlement 1	Settlement 1	Not Settlements 1	Settlement 1	Not Settlements 1	Settlement 1	Settlement 1	Settlement 1	Not Settlements 1
Geology	Qv : Young volcanic rocks 1	Qv : Young volcanic rocks 1	Qal : Alluvium 1	Qv : Young volcanic rocks 1	Qv : Young volcanic rocks 1	Qv : Young volcanic rocks 1	Qv : Young volcanic rocks 1	Ql : Unnamed Limestone 1	Ql : Unnamed Limestone 1
Slope	0-8%	0-8%	0-8%	0-8%	0-8%	0-8%	0-8%	0-8%	0-8%
Total	8	8	8	7	8	7	8	8	8
Area (Ha)	3.40	0.45	18.55	1.78	0.63	5.61	6.63	2.24	16.24

Figure 2. Boolean Analysis Results of Regional Criteria based on SNI 03 3241 1994 with Adjustments to the Characteristics of Bunaken Island

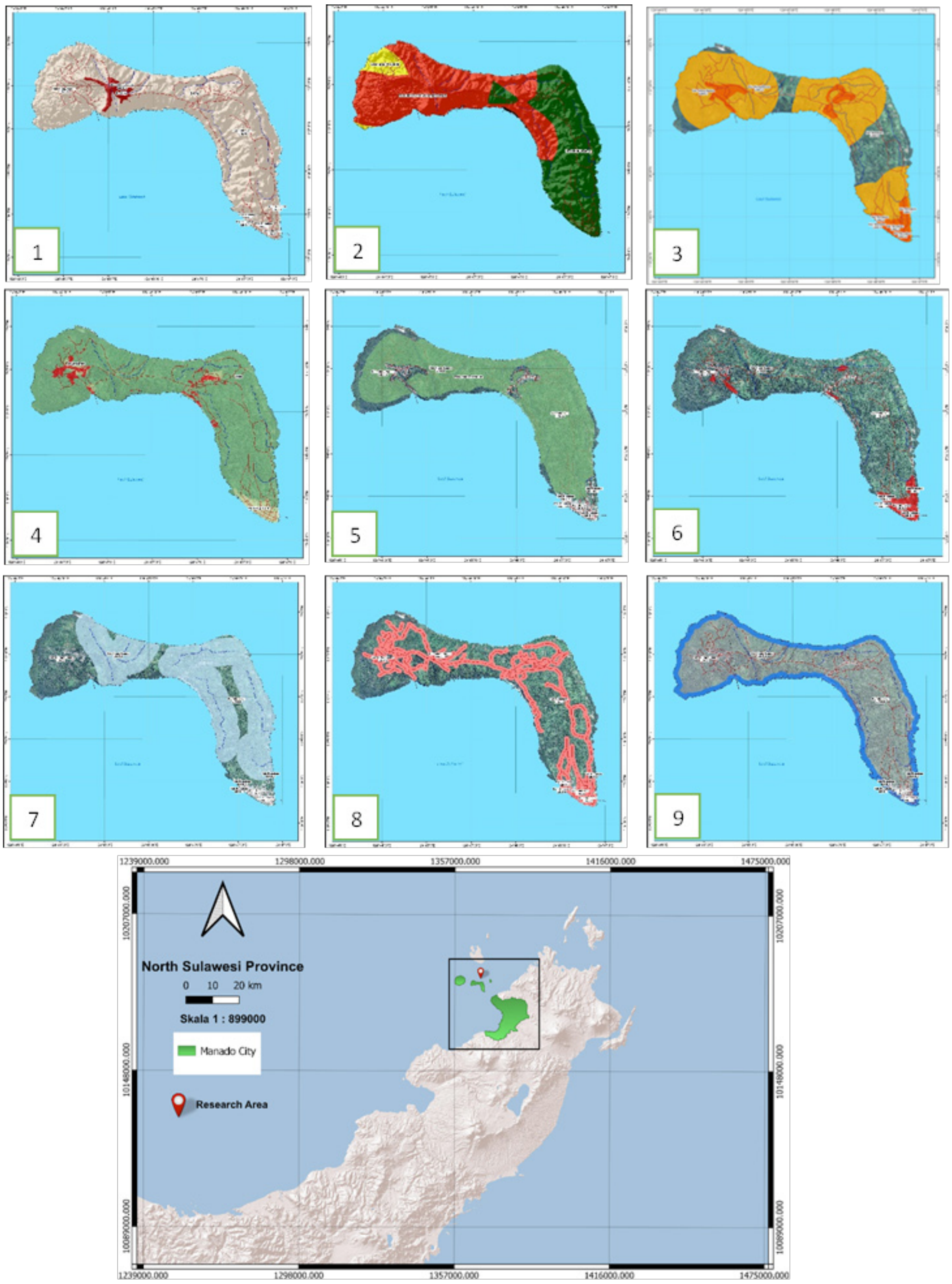


Figure 3. Union Results and Buffer Results on the Map of Bunaken Island (1) Slope Class Map, (2) Geological Types, (3) Residential Areas, (4) Protected Areas, (5) Agricultural Area Map, (6) Floods, (7) Rivers, (8) Roads, and (9) Lines Beach

Figure 4. Eligible Zone for TPA Bunaken Island

The results of the review of the 9 locations were generalized to eliminate small areas that are not feasible or allow the development of residential areas and plantations, as shown in Figure 5.

From the results of the map analysis, the slope is not more than 15%, with 769.57 Ha and 22.81 Ha of flat and sloping lands, respectively. In nine locations, the landfill is not in an area with a slope above 15%, hence, it gets a value of 1 for 9 TPA feasible zone locations. This is consistent with the result of Irawan and Ade that the slope is closely related to the ease of construction and operational work of the landfill (35).

Based on research analysis using application tools QGIS with basic map data in SHP format (Shape

File) Administrative boundaries, geology, hydrogeology, road networks, protected areas, agricultural areas, slopes, settlements and average rainfall. The next step is to carry out a buffer analysis in the SHP format of 300 meter rivers, 650 meter settlements, 50 meter roads and 100 meter coastline. After buffering, the next stage is union analysis or combining two or more maps to produce a new map where all the features and their attributes will be included in it by making a Boolean assessment, changing the map data into a binary model of 0 and 1 according to the SNI-03-3241-criteria. 1994 with adjustments to Bunaken Island which can be seen in table 1, after that intersect or combine two sets of spatial data that intersect each other (overlay method) with the aim of creating coverage new data (total all values and take the highest score) the results are analyzed into a map of waste landfill feasible zones with 9 locations.

The 100 m coastal line at this regional stage commensurate with the coast is urgently needed to establish landfills, especially on small islands. This aims to protect coastal areas from pollution and has important benefits for maintaining the preservation of coastal functions and as a land fortress from the negative influence of ocean dynamics (36). From the nine landfill feasible zones, 4 locations were in the coastal area, namely, 4 (1.78 Ha), 5 (0.63 Ha), 6 (6.61 Ha), and 9 (16.24) were rated 0, and others were rated 1. The results of generalization showed that two recommended locations for feasible landfill zones on Bunaken Island were 1 and 2, with an area of 3.40 Ha and 0.45 Ha, respectively. The generalization aims to eliminate places that are close to settlements or have the potential to become settlements, areas close to the beach, and residents' plantations which can be disturbing in the future, as shown in Figure 5. Based on semi-permanent observations, 50.56% of Bunaken Island's landfills are holes in the yard, 49.44% are semi-permanent landfills, 53.37% of waste is burned, and 46.63% is collected and disposed of in temporary landfills.

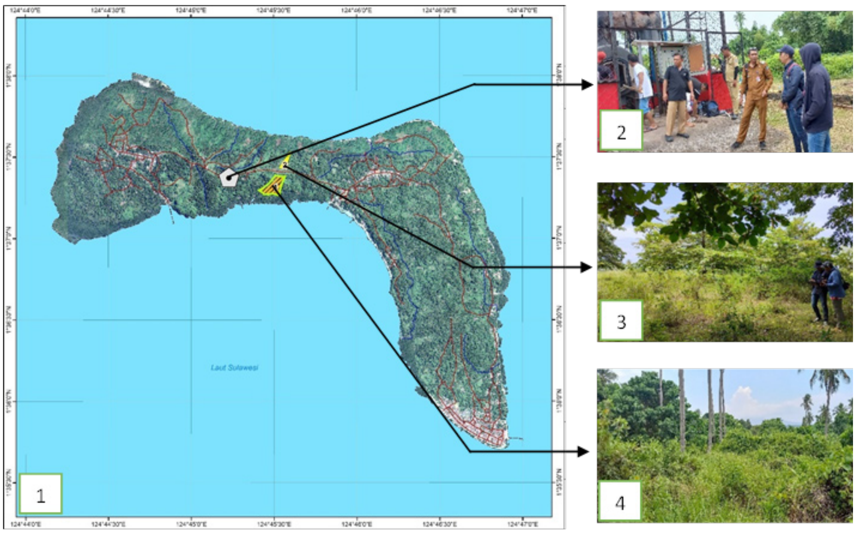


Figure 5. Recommended Zone for TPA Bunaken Island (1), TPS Bunaken Island (2), Ground Check Location 2 (3), Ground Check Location 1 (4)

Population Growth Projection and Prediction

The results of backward calculations using the Geomatic Projection formula/ratio of population growth for the Bunaken Village in 2022 – 2031 is 0.011734973%.

$$r = \left(\left(\frac{3133}{2788}\right)^{1/10}\right) - 1$$

$$r = ((1.1237446198)^{0.1}) - 1$$

$$r = 0.011734973\%$$

The result of backward calculations using the Geomatic Projection formula/population growth ratio for Alung Banua Village from 2022 – 2031 is -0.010994934%.

$$r = \left(\left(\frac{710}{793}\right)^{1/10}\right) - 1$$

$$r = ((0.895334174)^{0.1}) - 1$$

$$r = -0.010994934\%$$

The population growth prediction for the Bunaken Sub-District in 2022 is 3,097 people

$$Pt = 2.788\,(1+0{,}011734973)^{9}$$

$$Pt = 3.096{,}660777814$$

$$Pt = 3.097$$

The prediction of population growth for Alung Banua Village in 2022 is 718 people

$$Pt = 793\ (1+(-0{,}010994934))^9$$

$$Pt = 717.8931891599$$

$$Pt = 718$$

The predicted population of the Bunaken and Alung Banua sub-districts for 2022 is 3,815, as shown in Table 2.

Table 2. Prediction of the Amount of Waste and Waste Generation in Bunaken Village and Alung Banua Year 2022 – 2031

Year	n	Standard SNI 19-3964-1994 for Medium and Small Cities	Garbage Weight Per Day	Garbage Weight Per Month	Garbage Weight Per Year
		0.3 kg/ person/day	Kg/ Person/ Day	30 Days/ Kg	12 Months/ year
2022	3,815	0.3	1,444	34,331	411,972
2023	3,792	0.3	1,138	34,129	409,553
2024	4,026	0.3	1,208	36,230	434,755
2025	4,026	0.3	1,208	36,230	434,755
2026	3,873	0.3	1,162	34,853	418,234
2027	3,855	0.3	1,157	34,698	416,381
2028	3,963	0.3	1,189	35,665	427,976
2029	3,963	0.3	1,189	35,665	427,976
2030	4,176	0.3	1,253	37,587	451,050
2031	4,123	0.3	1,237	37,103	445,242
					4,277,893

In landfill planning for the next 10 years, it is necessary to determine the projections and predictions of population growth using the geometric method and backward calculations. The population data is calculated for the last 10 years (2012 – 2021) and the result showed 0.011734973% and -0.010994934% for Bunaken Village and Alung Banua sub-district, respectively.

Population projection predictions are calculated by calculating population growth with formula (2). Then the results of population growth for the Bunaken and Alung Banua sub-districts in 2022 amounted to 3,097 and 718, respectively, totaling 3,815. The next year's calculation and the amount of waste generated for the next 10 years using SNI Standard 19-3964-1994 are shown in Table 3.

Table 3. Distribution of Household Waste Ownership and Management by Respondents, Existence of TPA Garbage According to Respondents on Bunaken Island, and Distribution of Respondents, the number of Diarrheal Diseases in the Last 6 Months

Ownership of Trash and Waste Management		n	%
Types of Household Garbage Disposal Sites	Semi Permanent	90	50.56
	Hole in the page	88	49.44
	Amount	178	100
How to manage household waste	burned	95	53.37
	Others (Waste disposed of in TPS/ sacks and then transported by the kelurahan government)	83	46.63
	Amount	178	100
Landfill (TPA Garbage)		n	%
How to manage household waste	1. Agree	93	52.25
	2. Disagree	85	47.75
	Amount	178	100
Disease Incidence in the Last 6 months		n	%
Cases of Diarrhea	Yes	15	8.43
	Not	163	91.57
	Amount	178	100

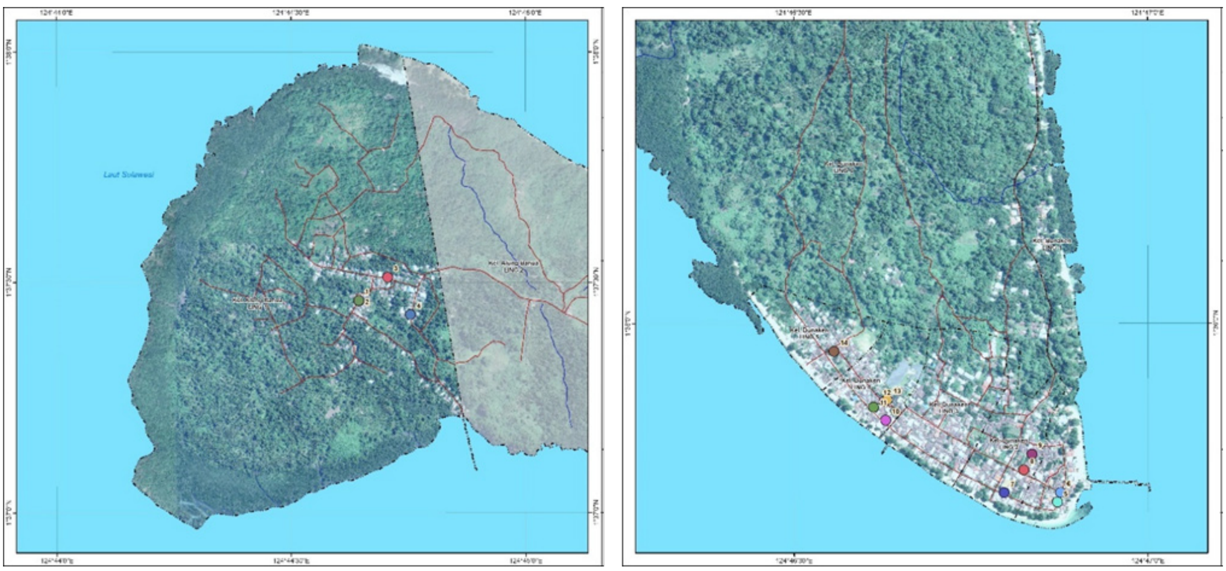


Figure. 6: Distribution of Diarrhea Disease in Bunaken and Alung Banua Villages

Determination of Land Area for Landfill Operations

Based on the calculations above, the total amount of waste generated in 2022 – 2031 is 4,277,893 kg. The specific gravity of waste is needed to determine its volume by considering some assumptions.

Since the specific gravity is 250 kg/m³, the waste volume can be calculated as follows:

$$Volume_{total} = 4{,}277{,}893 \text{ kg} : 250 \text{ kg/m}^3 = 17{,}111.572 \text{ m}^3$$

Based on these assumptions, the volume of waste that goes to the landfill is reduced by 25% due to scavenger activities, such that the total volume of waste becomes:

$$Volume = 17{,}111.572 \text{ m}^3 - (17{,}111.572 \text{ m}^3 \times 25\%) = 12{,}833{,}679 \text{ m}^3$$

Landfill area using formula (3) =

$$L\ Landfill = \frac{12.833{,}679 \text{ m}^3 \times 15\%}{10 \text{ (m)}}$$

$$L\ Landfill = 0.0193 \text{ Ha}$$

Buffer land area using formula (4) =

$$L\ Buffer = 25\% \times 192{,}505 \text{ m}$$

$$L\ Buffer = 0.0048 \text{ Ha}$$

The total quantity of rubbish is utilized to ascertain the necessary landfill space. The required landfill area was determined using formulas (3) and (4). The core zone has an area of 0.0193 Ha, and the buffer zone has an area of 0.0048 Ha. Therefore, the total required land area is 0.0241 Ha. In addition, according to Regulation No. 19 of 2012 issued by the Minister of Public Works, the area within a 500-meter radius of the waste final processing site is classified as a buffer zone. The function of the buffer sub-zone is to reduce the negative impact caused by the final disposal of waste on the surrounding environment. This buffer area can be in the form of green belts or hedges around the TPA, with the following provisions. Tall plants are combined with shrubs that are easy to grow and dense (37).

Table 5. Comparison between Boolean and Spatial Methods using GIS on Bunaken Island with other Studies

Country/City	Method	Results	Reference
Indonesia/Manado (Bunaken Island)	Boolean and Spatial using GIS in landfill determination	This study has found two suitable places for landfill development, each with an area of 3.40 hectares and 0.45 hectares, respectively. The cumulative amount of solid waste for 10 years (2022-2031) was 4,277,893 kilograms with a required land area of 0.0241 Ha.	Current study
Iranian Kurdistan/ Sulaimanyah	Spatial Analytical Hierarchy Process (AHP) is integrated with GIS	area of candidate location 1 (15,050,000 m²), candidate location 2 (3,900,000 m²), candidate location 3 (2,580,000 m²), and candidate location 4 (730,000 m²). area required from the landfill site to include the cumulative amount of solid waste in 2035 is 53.7488 m²	(47)
India/Durgapur	Using Geographic Information Systems and Multicriteria Evaluation Techniques	This study identified three potential lands for urban waste disposal covering an area of 13.83854 Ha, 33.80678 Ha, and 27.20085 Ha, respectively, in the city of Durgapur	(48)
Bangladesh/ Metropolitan Rajshahi	Integration of Geographic Information Systems (GIS) and Fuzzy Analytical Hierarchy Process (F-AHP)	This study identified the most suitable TPA location with an area of 21.84 m²	(49)
Thailand/Songkhala	Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) are two methodologies.	The study indicated a highly suitable area of 560.59 hectares for TPA, a highly suitable area of 993.19 hectares, and a moderately suitable area of 180.72 hectares.	(22)
Iranian Kurdistan/ Saqqez	Boolean, Analytic Hierarchy Process (AHP), and Weighted Linear Combination (WLC) techniques applied with Geographic Information Systems (GIS)	The study results for the use of landfills with a cumulative 15-20 years are very good for a landfill site with an area of 74 Ha	(50)

DISCUSSION

The advantage of Boolean analysis in reducing waste on an island through the provision of a landfill that is most suitable for the characteristics of the small island is that it allows for the determination of permit criteria according to the island's characteristics referring to SNI 03-3241-1994 with adjustments. There are 9 criteria used in this research, namely Slope, Geological Conditiosns, Distance to water bodies, Distance to settlements, Agricultural cultivation area, Protected area, Coastline, Flood prone, and Traffic. This can serve as a reference in determining landfill locations both in Indonesia and internationally. This research uses multi-criteria variables, where quantitative data is primary data obtained from respondent interviews to assess environmental conditions and health impacts. Qualitative data in the form of spatial data in SHP format (geological maps, hydrogeological maps, topographic maps, agricultural land use maps, disaster-prone maps, water body maps, protected area maps, rainfall maps, and settlement maps) were obtained from the Data and Geospatial Center of the Manado City Regional Development Planning Agency.

The steeper an area, the more difficult it will be in construction and operation activities/work. Most of the study areas are suitable because of their relative slopes (35). Slope instability in landfills can result in environmental disasters, pose environmental and health risks, as well as affect leachate levels and pressure gas produced by the landfill (38). The analysis result showed that the map of protected areas for cultivation is 26.58 Ha and protected with adjustments of 759.32 Ha. Furthermore, the protected area maps are needed at the regional stage to ensure that they do not become alternative landfill areas. Protected forest areas have unique characteristics that enable them to protect the surrounding area and are innate as regulators of water management, prevention of flooding and erosion, as well as maintenance of soil fertility (39). This study gave a score of 1 from the nine landfill feasible zone locations because they are in a protected location with adjustments.

The results of the map analysis for public facilities/settlements must be 650 m from the settlement according to the Manado City Spatial Plan 2014 – 2034, with a residential area of 82.40 Ha. A map of the distance to settlements is needed to ensure that the landfill site is not in the vicinity of settlements such that it cannot pollute the environment. Therefore, a settlement buffer technique of 650 m was carried out, and the result showed that locations 1, 2, 4, 6, 7, and 8 with areas of 3.40 Ha, 0.45 Ha, 1.78 Ha, 5.61 Ha, 6.63 Ha, 2.24 Ha, respectively, are in the 650 m settlement buffer. Therefore, a value of 0 was assigned to denote the spatial distribution of Boolean logic findings, which delineate areas unsuitable for establishing landfill sites and are deemed as prohibited zones. Locations 3 and 4, with an area of 18.55 Ha and 1.78 Ha2 on Bunaken Island. These two locations are too low so there are concerns that they are prone to disease transmission. This is in line with conditions in Nasiriyah, Iraq, showing that being too close or too far results in lower evaluations. This is because when a landfill is too close it can transmit disease or cause unpleasant odors in the temporary environment.

The examination of the road network map for Bunaken Island obtained a length of 34.98 Km, and the nine possible zones for landfill were outside the road network. Consequently, a value of 1 was given. Based on a 2021 study conducted in northern Iraq, highways play a crucial role in selecting a landfill site for waste disposal. This is because the transportation of garbage from its source to a suitable landfill site is a key aspect of the project. This scenario underscores the significance of road infrastructure while also necessitating consideration of the nearby landfill due to the potential adverse effects of unpleasant odors on the tourism industry (1).

Waste is regarded as a nuisance with numerous adverse health and aesthetic repercussions, hence its management by segregating organic and inorganic waste is vital. According to a study conducted on Bunaken Island, 52.25% of respondents agree with the existence of a landfill, whereas 47.75% disagree. According to a study conducted in the Klaten area of the Yogyakarta Region, the majority of participants responded favorably to the presence of a landfill, hoping it would lead to improved waste management (40). The consequence of garbage transportation by ships is that in the event of an accident, the surrounding area will become contaminated by the presence of a cargo load of waste. Plastic debris entering the ocean can undergo fragmentation, resulting in microplastics forming between 0.3 to 5 millimeters in size (41). The preservation of the ocean is crucial, particularly in regard to waste management, specifically plastic waste. Plastic waste has the potential to break down into microplastics, which fish can readily ingest. Subsequently, fishermen capture these fish, and humans consume them. This poses a significant worry for pregnant women, as the ingestion of microplastics might result in developmental impairments in subsequent generations (42).

The 2021 Napid study showed that burning waste is generally carried out openly, and the emissions containing CO and CH4 gases have the potential to pollute the environment and have a negative impact on health (43).

Decomposing waste (organic and solid) generally emits gases such as methane (CH_4) and carbon dioxide (CO_2) as well as other compounds. Globally, these gases are one of the causes of declining environmental quality (air) because they have a greenhouse effect (green house effect) which causes an increase in temperature, and causes acid rain (44). Large amounts of rotten garbage will result in the spread of unpleasant odors that make nausea and dizziness because they contain gases resulting from the decay process including methane H_2S, NH_3 etc. Waste disposed of in the landfill is still at risk because if the landfill is closed or landfilled, especially with buildings, it will cause methane gas to not be able to escape into the air which can cause an explosion. In addition, if the garbage is burned, it will produce smoke that interferes with breathing and vision which will cause the effects of shortness of breath and sore eyes and the results of burning plastic in the form of dioxin gas are very dangerous because they include carcinogens that can cause cancer (45).

One of the diseases caused by waste is diarrheal, and in the age category of Toddler, as many as 7 respondents are affected. Based on study in the Coastal Communities in Piru Village 2019, a total of 108 respondents, accounting for 63.9%, suffered from diarrhea caused by trash cans, use of latrines, and disposal of wastewater that did not meet health requirements. It also includes the conditions of sanitation facilities that did not meet healthy conditions. Therefore it is very conducive to the development of disease (46).

ACKNOWLEDGMENTS

The authors acknowledge their gratitude to the Department of Environmental Health Lecturers, Faculty of Public Health, University of Hasanuddin. The authors thank the Manado City government, particularly the Bunaken Islands District government, UPTD Data Processing, and Geospatial Bapelitbangda Manado City, for facilitating the study.

CONCLUSION

The results of the regional feasibility analysis using the QGIS application show the existence of 9 zones suitable for Landfill Sites (TPA) with varying land areas. After generalization, 2 recommended locations were identified as suitable landfill zones: location 1 covering 3.40 hectares and location 2 covering 0.45 hectares. This decision ensures that the selected locations are most appropriate for the landfill, taking into account environmental impact and community welfare.

REFERENCES

1. Mahmood KW, Khzr BO, Othman RM, Rasul A, Ali SA, Ibrahim GRF. Optimal Site Selection for Landfill Using the Boolean-Analytical Hierarchy Process. *Environ Earth Sci*. 2021;80(5):1–13. https://doi.org/10.1007/s12665-021-09501-0
2. Weekes JG, Wasil JCM, Llamas KM, Agrinzoni CM. Solid Waste Management System for Small Island Developing States. *Glob J Environ Sci Manag*. 2021;7(2):259–272. https://doi.org/10.22034/gjesm.2021.02.08
3. Teshome YM, Habtu NG, Molla MB, Ulsido MD. Municipal Solid Wastes Quantification and Model Forecasting. *Glob J Environ Sci Manag*. 2023;9(2):1–14. https://doi.org/10.22034/GJESM.2023.02.04
4. Muliarta IN, Sudita IDN, Situmeang YP. The Effect of Eco-Enzyme Spraying on Suwung Landfill Waste, Denpasar, on Changes in Leachate Characteristics. *J Environ Health*. 2023;15(1):56-66. https://doi.org/10.20473/jkl.v15i1.2023.56-66
5. Chabok M, Asakereh A, Bahrami H, Jaafarzadeh NO. Selection of MSW Landfill Site by Fuzzy-AHP Approach Combined with GIS: Case Study in Ahvaz, Iran. *Environ Monit Assess*. 2020;192(7):433. https://doi.org/10.1007/s10661-020-08395-y
6. Şener E, Şener Ş. Landfill Site Selection Using Integrated Fuzzy Logic and Analytic Hierarchy Process (AHP) in Lake Basins. *Arab J Geosci*. 2020;13(21):1130. https://doi.org/10.1007/s12517-020-06087-y
7. Cahyadi FD, Widiyanto K, Prakoso K. Edukasi Gerakan Bersih Pantai dan Laut di Pulau Tunda. *Abdimas Unwahas*. 2021;6(1):46–49. https://publikasiilmiah.unwahas.ac.id/index.php/ABD/article/view/4432
8. Darwati S. Pengelolaan Sampah Kawasan Pantai. *Artik Pemakalah Paralel* p-ISSN 2527-533X. 2019;(18):417–426. https://proceedings.ums.ac.id/index.php/snpbs/article/view/868/851
9. Widyaningrum GL. Studi Terbaru: Masalah Sampah Plastik di Bumi Sudah di Luar Kendali. Jakarta: National Geographic Indonesia; 2020 https://nationalgeographic.grid.id/read/132346281/studi-terbaru-masalah-sampah-plastik-di-bumi-sudah-di-luar-kendali
10. Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, et al. Plastic Waste Inputs From Land Into Teh Ocean. *Mar Pollut*. 2015;347(6223):768–771. https://doi.org/10.1126/science.1260352
11. Das S, Jha P, Chatterjee A. Assessing Marine Plastic Pollution in India. Delhi: Institute Of Economic Growth, University Enclave, University of Delhi; 2020.
12. Wernstedt FL. The Philippine Island World. Californa: University of California Press; 1967.

13. Ganivet E. Growth in Human Population and Consumption Both Need To Be Addressed To Reach An Ecologically Sustainable Future. *Environ Dev Sustain*. 2020;22(6):4979–4998. https://dx.doi.org/10.1007/s10668-019-00446-w
14. Karakuş CB, Demiroğlu D, Çoban A, Ulutaş A. Evaluation of GIS-based Multi-Criteria Decision-Making Methods for Sanitary Landfill Site Selection: The Case of Sivas City, Turkey. *J Mater Cycles Waste Manag*. 2020;22(1):254–272. http://doi.org/10.1007/s10163-019-00935-0
15. Chakraborty S, Kumar RN. Assessment of Groundwater Quality at a MSW Landfill Site Using Standard and AHP Based Water Quality Index: A Case Study from Ranchi, Jharkhand, India. *Environ Monit Assess*. 2016;188(6):335. https://link.springer.com/article/10.1007/s10661-016-5336-x
16. Ratnawati B, Yani M, Suprihatin S, Hardjomidjojo H. Waste Processing Techniques at The Landfill Site Using The Material Flow Analysis Method. *Glob J Environ Sci Manag*. 2023;9(1):73–86. https://doi.org/10.22034/gjesm.2023.01.06
17. Wang G, Qin L, Li G, Chen L. Landfill Site Selection Using Spatial Information Technologies and AHP: A Case Study in Beijing, China. *J Environ Manage*. 2009;90(8):2414–2421. https://doi.org/10.1016/j.jenvman.2008.12.008
18. Asefi H, Zhang Y, Lim S, Maghrebi M. An integrated Approach to Suitability Assessment of Municipal Solid Waste Landfills in New South Wales, Australia. *Australas J Environ Manag*. 2020;27(1):63–83. https://doi.org/10.1080/14486563.2020.1719438
19. Abad PMS, Pazira E, Abadi MHM, Abdinezhad P. Application AHP-PROMETHEE Technic for Landfill Site Selection on Based Assessment of Aquifers Vulnerability to Pollution. *Iran J Sci Technol - Trans Civ Eng*. 2021;45(2):1011–1030. https://doi.org/10.1007/s40996-020-00560-0
20. Bouroumine Y, Bahi L, Ouadif L, Elhachmi D, Errouhi AA. Sitting MSW Landfill Combining GIS and Analytic Hierarchy Process (AHP), Case Study: Ajdir, Morocco. *Int J Adv Res Eng Technol*. 2020;11(5):318–328. https://ssrn.com/abstract=3628393
21. Muiruri J, Wahome R, Karatu K. Assessment of Methods Practiced in The Disposal of Solid Waste in Eastleigh Nairobi County, Kenya. *AIMS Environ Sci*. 2020;7(5):434–448. https://doi.org/10.3934/environsci.2020028
22. Kamdar I, Ali S, Bennui A, Techato K, Jutidamrongphan W. Municipal Solid Waste Landfill Siting Using An Integrated GIS-AHP Approach: A Case Study from Songkhla, Thailand. *Resour Conserv Recycl*. 2019;149(1):220–235. https://doi.org/10.1016/j.resconrec.2019.05.027
23. Mousavi SM, Darvishi G, Dinan NM, Naghibi SA. Optimal Landfill Site Selection for Solid Waste of Three Municipalities Based On Boolean and Fuzzy Methods: A Case Study in Kermanshah Province, Iran. *Land*. 2022;11(10):1779. https://doi.org/10.3390/land11101779
24. Chang V, Bhavani VR, Xu AQ, Hossain MA. An Artificial Intelligence Model for Heart Disease Detection Using Machine Learning Algorithms. *Healthc Anal*. 2022;2(1):100016. https://doi.org/10.1016/j.health.2022.100016
25. Kraak MJ, Ormeling F. Cartography: Visualization of Geospatial Data. Netherlands: CRC Press; 2020. https://doi.org/10.1201/9780429464195
26. Tosepu R, Yunita EW, Ratnawati L, Insan N, Sugiarti A. House Conditions Based on Public Knowledge of Healthy Homes in the Coastal Area of Wawonii Barat District, Konawe Islands Regency In 2022. *KnE Soc Sci*. 2023;487–493. https://doi.org/10.18502/kss.v8i9.13362
27. Ayilara MS, Olanrewaju OS, Babalola OO, Odeyemi O. Waste Management Through Composting: Challenges and Potentials. *Sustainability*. 2020;12(11):4456. https://doi.org/10.3390/su12114456
28. Cruvinel VRN, Zolnikov TR, Obara MT, de Oliveira VTL, Vianna EN, do Santos FSG, et al. Vector-Borne Diseases in Waste Pickers in Brasilia, Brazil. *Waste Manag*. 2020;105(1):223–232. https://doi.org/10.1016/j.wasman.2020.02.001
29. Goyal V, Dharwal M. The Puzzle of Garbage Disposal in India. *Mater Today Proc*. 2022;60(2):926–929. https://doi.org/10.1016/j.matpr.2021.10.465
30. Das AS. KoboToolbox. In: Open Electronic Data Capture Tools for Medical and Biomedical Research and Medical Allied Professionals. *Elsevier*. 2024;4(1):241–329. https://doi.org/10.1016/B978-0-443-15665-6.00004-X
31. Ananda S, Tri Y. Analisis Perencanaan dan Penyediaan Sumber Air Bersih di Kecamatan Bangkala Barat Kabupaten Jeneponto. Pengayakan. 2020;37(1):1–4.
32. Manurung DW, Santoso EB. Penentuan Lokasi Tempat Pemrosesan Akhir (TPA) Sampah yang Ramah Lingkungan di Kabupaten Bekasi. *J Tek ITS*. 2020;8(2):123-130. https://doi.org/10.12962/j23373539.v8i2.48801
33. Wibisana SNG, Endarwati MC, W WHS. Penentuan Lokasi Tempat Pemrosesan Akhir (TPA) Regional Sampah pada Wilayah Sarbagita (Denpasar, Badung, Gianyar, Tabanan) Provinsi Bali. *Skripsi.* Malang: Institut Teknologi Nasional Malang; 2018 https://eprints.itn.ac.id/126/
34. Allen P, Bennett K, Heritage B. SPSS Statistics Version 22: A Practical Guide. Australia: Cengage Learning Australia; 2014. https://researchportal.murdoch.edu.au/esploro/outputs/991005543019207891
35. Irawan AB, Yudono ARA. Studi Kelayakan Penentuan Tempat Pemrosesan Akhir Sampah (TPA) di Pulau Bintan Propinsi Kepulauan Riau. *Jurnal Ilmu Lingkungan*. 2014;12(1):1-11. https://doi.org/10.14710/jil.12.1.1-11

36. Syahfitri CN. Implementasi Kebijakan Pengembangan Ruang Terbuka Hijau Sempadan Pantai di Kota Cirebon Provinsi Jawa Barat. *Jurnak Kebijak Pemerintah*. 2020;3(2):62–74. https://doi.org/10.33701/jkp.v3i2.1306
37. Shu S, Li Y, Sun Z, Shi J. Effect of Gas Pressure on Municipal Solid Waste Landfill Slope Stability. *Waste Manag Res*. 2022;40(3):323–330. https://doi.org/10.1177/0734242X211001414
38. Kosakoy MNM, Wallah SE, Riogilang H. Analisis Pemilihan Lokasi Tempat Pemrosesan Akhir Sampah Berbasis Sistem Informasi Geografis (SIG) di Kabupaten Minahasa Tenggara. *J Tek Sipil Univ Warmadewa*. 2022;11(2):57–72. https://doi.org/10.22225/pd.11.1.4194.57-72
40. Irman J. Persyaratan Teknis Penyediaan TPA Sampah. 2013.
41. Wulan INA. Tanggapan Masyarakat Terhadap Dampak Sosial Ekonomi Tempat Pembuangan Akhir (TPA) Sampah di Dusun Biru Desa Candirejo Kecamatan Ngawen Kabupaten Klaten. *Univ Negeri Yogya*. 2018;3(3):503-514. https://journal.student.uny.ac.id/index.php/social-studies/article/view/8984
42. Munir IE IM. Pengaruh Good Corporate Governance dan Corporate Social Responsibility Terhadap Kinerja Keuangan di Perusahaan LQ45 yang Terdaftar di Bursa Efek Indonesia Periode 2018-2021. *Skripsi*. Yogyakarta: Universitas Islam Indonesia; 2023. http://dspace.uii.ac.id/123456789/45452
43. Gallo F, Fossi C, Weber R, Santillo D, Sousa J, Ingram I, et al. Marine Litter Plastics and Microplastics and Their Toxic Chemicals Components: The Need For Urgent Preventive Measures. In: Analysis of Nanoplastics and Microplastics in Food. Florida: CRC Press; 2020 https://doi.org/10.1201/9780429469596
44. Napid S, Budi RS, Susanto E. Pembakaran Sampah Anorganik Menimbulkan Dampak Positif dengan Perolehan Asap Cair Bagi Masyarakat Lingkungan IX Kecamatan Amplas. *J Pengabdi Mitra Masy*. 2021;1(1):30–36. https://jurnal.uisu.ac.id/index.php/JURPAMMAS/article/view/4192
45. Chahal P. Global Warming and Greenhouse Effect. Conserv Sustain Environ Justice India. Lanham: Lexington Books; 2020.
46. Shree P, Kumar M, Singh IK, Singh DK. Dioxin–Exposure Routes, Pathways, and Human Health Implications. In: Dioxin. New York: CRC Press; 2020.
47. Huliselan J, Selomo M, Ane RL. Kondisi Sanitasi Rumah, Perilaku Kesehatan dan Kejadian Diare Masyarakat Pesisir di Desa Piru. *J Kesehat Ilmu Kesehat*. 2019;1(3):45–53. http://journal.unhas.ac.id/index.php/jnik/article/view/6122.
48. Manguri SBH, Hamza AA. Sanitary Landfill Site Selection Using Spatial-AHP for Pshdar Area, Sulaymaniyah, Kurdistan Region/Iraq. *Iran J Sci Technol - Trans Civ Eng*. 2022;46(2):1345–1358. https://link.springer.com/article/10.1007/s40996-021-00605-y.
49. Sk MM, Ali SA, Ahmad A. Optimal Sanitary Landfill Site Selection for Solid Waste Disposal in Durgapur City Using Geographic Information System and Multi-criteria Evaluation Technique. *KN - J Cartogr Geogr Inf*. 2020;70(4):163–180. https://link.springer.com/article/10.1007/s42489-020-00052-1
50. Islam M, Kashem S, Morshed S. Integrating Spatial Information Technologies and Fuzzy Analytic Hierarchy Process (F-AHP) Approach for Landfill Siting. *City Environ Interact*. 2020;7(1):1-15. https://www.sciencedirect.com/science/article/pii/S259025202030026X
51. Shahabi H, Keihanfard S, Ahmad BB, Amiri MJT. Evaluating Boolean, AHP and WLC Methods for The Selection of Waste Landfill Sites Using GIS and Satellite Images. *Environ Earth Sci*. 2014;71(9):4221–4233 https://link.springer.com/article/10.1007/s12665-013-2816-y