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GIS Implementation to Create a Map for Waste Container Sites in Banda Aceh, Indonesia

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Abstract

The capital of Aceh Province, Indonesia, Banda Aceh, has experienced a number of problems with the handling of municipal solid waste due to an increasing urban population. Problems with waste management are also getting worse as a result of inadequate infrastructure and ineffective solutions. Waste containers/bins are the most basic items that can be used to solve issues with waste management. In this study, data from nine subdistricts of Banda Aceh had been gathered for waste dump locations from to analyze the spatial distribution of waste bins. Through the generalization tool in ArcGIS Pro, a spatial variation of distance between the trash cans was discovered. Changing the waste management system requires the application of geospatial approaches on a global scale. In the region of attention, this study evaluated the appropriate distance for waste container placement and the results were used to produce a number of maps showing the various sites where the waste container should be placed for the Banda Aceh government.

Keyword: Geospatial analysis, GIS technology, Municipal solid waste, Waste containers, Waste management.

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1. Introduction

(Describe the situation as it exists today in Banda Aceh and global)

With a population of 257,635 and a 61.36 km2 area, Banda Aceh City saw population growth of 1.56% in 2022. According to data from the Indonesian Central Statistics Agency (BPS) 2022, Banda Aceh City's population growth rate is greater than Indonesia's average population growth rate, which is only 1.49%. The high pace of population increase has an effect on the amount of waste produced everywhere. Waste generation rates are increasing globally. The globe produce 2.24 billion tonnes of solid garbage in 2022. The annual trash generation is anticipated to rise by 73% from 2020 levels to 3.88 billion tonnes in 2050 due to increased urbanization and population growth (The World Bank, 2022). In most nations, solid waste disposal is one of the major and rising potential problems due to the exponential growth of the urban population. Many efforts to reduce and recover waste have been made, but still, land disposal of solid wastes is the most popular one. Managing waste properly is essential for building sustainable and livable cities, but it remains a challenge for many developing countries and cities.

(Waste in Banda Aceh)

Waste is the term used to describe unwanted product residue, which can take the shape of a solid, liquid, or gaseous substance. (Pratiwi, 2018) Everyone wants to live in a green environment and always dreams of living somewhere that doesn't produce any waste. But as the population increases, it is well recognized that waste problems continue to worsen. The effects are so awful, including flash floods, global warming, health issues, and many others. We must take action to improve our environment's cleanliness and sustainability in order to reduce these issues. All stakeholders, including public, commercial, and community sectors (see Table 1) should work together to protect the environment, and citizens should actively participate in maintaining, enhancing, and protecting their local environment.

The overall advantages of the project are that better waste management makes cities cleaner, healthy populations, the environment better and more sustainable. According to data from the National Waste Management Information System (SIPSN), waste output in Banda Aceh has grown during the last three years. The amount of garbage was 87,088 tons in 2019, and it increased to 88,800 tons in 2020. Total trash production increased once more in 2021, reaching 90,765 tons. (Zulkarnaini, 2022). Banda Aceh City's waste management system needs to be

optimized, particularly in terms of waste management, as a result of the rising population and waste generation. Managing waste is still a challenge in all of Indonesia's major cities, therefore the topic is currently being discussed both locally and internationally. One method for preserving the cleanliness and sustainability of Banda Aceh is to use a GIS system to identify the position of waste container sites throughout the city.

(GIS for waste management)

The development of internet technology has presented a Remote sensing and geographic information system (GIS) that can help solve problems encountered related to spatial aspects and their (non-spatial related) properties. GIS and remote sensing are the science and art of interpreting data collected using equipment without direct touch with the object, place, or event being investigated in order to learn more about those things. (Ajadi and Tunde, 2010). The GIS helps to quantify the relationship between the demands and supply of suitable land for waste disposal over time and plays a significant role in decision making for planning and management of solid wastes (Leao et al, 2001). Remote sensing and GIS data have the advantages of having a large coverage area, being able to reach places that are challenging to get terrestrially, and being able to concurrently and accurately record all object appearances. The utilization of GIS is one of the most beneficial methods to evaluate complicated spatial situations (Kallel et al, 2016). The consumption of GIS in location modeling is the well-organized path to ameliorate service coverage and effectuality in the solid waste management system (Aremu et al, 2011). The use of artificial intelligence technology, such as GIS systems, will support in solid waste planning and management, particularly in the process of locating waste containers.

Optimization of the Municipal Solid Waste (MSW) collection system using GIS involves the planning of bins, vehicles and optimal routing that can reduce the effective cost of management and impacts on the environment (Ghose et al, 2006). A significant amount of research is devoted to GIS monitoring of waste accumulation location and condition based on using satellite imagery, which is due to the availability of technology and the high accuracy of the results (Dmytriv & Dudko, 2017). The Spatial Decision Support Tool for waste container site selection is a model that converts input data into an output map using a specific function such as a buffer or overlay (Gao et al.,2004). Jensen and Christenensen (1986) identified potential sites for the storage of wastes in the southeastern United States and then they demonstrated how the

required in situ and remotely sensed data can be placed in a GIS. Zamorano et al. (2009) conducted a study in this Churriana de la Vega (Granada, Spain) about planning scenarios for the application of geographical information systems in municipal waste collection. They concluded that GIS is a useful tool for the optimal siting of landfills as it has the potential to assist planners, decision-makers, and other agents involved in the process of selecting suitable sites for waste containers. Because GIS increases the knowledge about the physical terrain, it facilitates the analysis and implementation of action plans. The use of GIS can facilitate zone exclusion based on a set of screening criteria and effective graphical representation (Sener et al., 2006). GIS can also convert georeferenced data into computerized maps. This technology's development can be used to manage waste and maintain the environmental sustainability. The following section presents the techniques for waste container selection sites with GIS-aided methodologies.

(Purpose of this major paper)

Based on the above issues, waste management projects must be appropriately managed. Planning and implementing an action plan to achieve these goals without the active participation of various stakeholders is a challenging task. All stakeholders, including public, commercial, and community sectors, must work together to help lower the costs associated with waste management. Efforts should be made at all levels to minimize generation of wastes and manage the generated wastes in an environmentally sound manner (Wilson & Tormin, 1998). The environmental problems of cities can be addressed in large part by the interaction of several actors/ stakeholders as presented in Table 1. Therefore, this study's purpose is to find the best locations in Banda Aceh for waste containers utilizing remote sensing and GIS. This information will be beneficial and will help the city and its stakeholders address the problem of environmentally sustainable waste management, and it will also increase the public's awareness of environmental issues as a result.

NO	Stakeholders	Role

1	Public	• Practice source reduction and source segregation • Cooperate with civic bodies in identification of sites for waste management facilities and their operation • Pay for waste management
2	Municipalities	• Keep waste management in priority • Provide infrastructural inputs and services

		• Have a definite organizational setup with trained staff • Implement legislation and punish violators • Compliment public/private participation • Enlist informal sector participation • Maintain an up-to-date database
3	City planners	• Keep waste management in mind while developing city plans • Demarcate space for waste management facilities with ideal buffer zones
4	NGOS/social workers	• Take lead in forming ward committees and community participation • Network with the other similar minded organisations in the area and integrate the efforts rather than duplicating most of the jobs • Use existing contacts with the municipality and other influential bodies to ensure maximum support • Try and involve unemployed youth in the area for various jobs Organize/sponsor ‘Clean City’ campaigns

5	Teachers/academia	• Influence minds on the culture of solid waste management • Inculcate a strict discipline in the children's mind with regard to solid waste • Carry out relevant research and development
6	Senior citizens	Help NGOs/CBOs on organizing cleanliness drives in various parts of the city
7	Unemployed youth	Take up various opportunities of part/full time employment that the 'Clean City' would open for them such as: • Managing collection of garbage
		• Helping the organizers in conducting road shows • Helping the promotion of the operation
8	Children/students	• Segregate garbage • Influence/keep check on parents/domestic servants
9	Vendors/shop owners	• Ensure that the waste/litter is properly put in a nearby garbage bin • Ensure to keep small garbage bin outside the shop • Ensure that your customers do not throw the garbage just outside the shops
10	Hospitals	Follow the requirements of bio-medical rules
11	Politicians	• Lead the 'Clean City' campaign and work in unison towards the interest of a 'Clean' city • Pressurize the municipal corporation to make the 'Clean City' issue a priority • Do not to make the 'Clean City' into a political issue

12	Corporations	• Ensure that all employees understand the gravity of the situation and not only take serious actions on the cleanliness front within the office/factory premises but they also spread the message across the city • Provide dustbins outside the office/company premises so that the passers-by do not throw garbage on the road • Sponsor 'Clean City' programmes

Table 1. Stakeholders for sustainable waste management (Joseph, K. 2006).

2. Methods

The proposed methods for achieving the goals of this study are to use a GIS system to first identify waste container sites throughout Banda Aceh city and then map the city to produce waste container sites map that provides information on which area needs to be analyzed and reviewed to place waste containers. Furthermore, the area of Banda Aceh city would then be divided into nine subdistricts to determine which areas were more vulnerable to waste and required additional installation of waste containers.

2.1. Study Area

The study area for this paper consisted of the entire Banda Aceh City. The city is known for its capital Aceh province in Indonesia. The city, which is located on the island of Sumatra, is 35 meters above sea level (115 feet) which has a land area of 61.36 square kilometers (23.69 square miles). At the time of the 2021 Census, the city's population was 255,029, and by the 2022 Census, it had grown to 257,635. The City's population growth rate is 1.56%, which is higher than Indonesia's average rate of population growth, which is just 1.49%, according to data from the Indonesian Central Statistical Agency (BPS) for 2022.

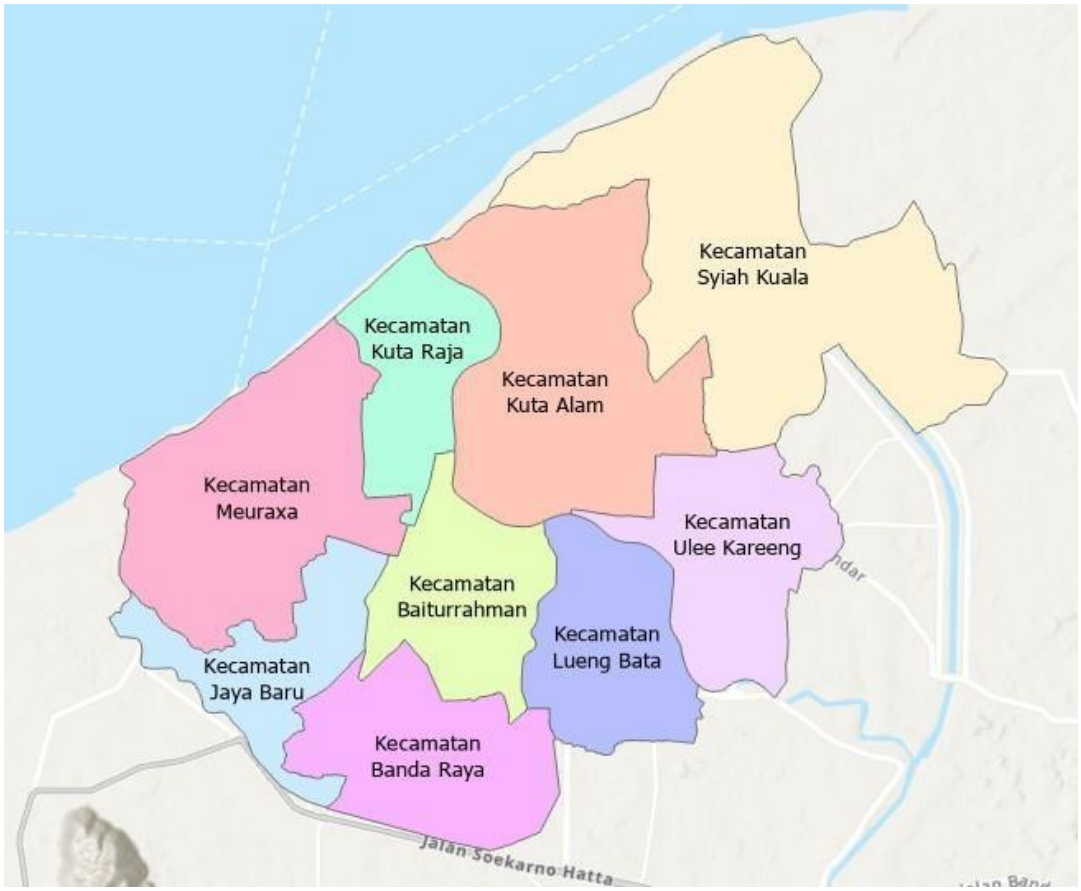

Figure 1: Map of the area of the study showing nine Subdistricts of Banda Aceh.

The city of Banda Aceh is divided into nine subdistricts (Indonesian: kecamatan), which are shown below with their locations and populations as of the 2010 and 2020 censuses.

NO	Subdistricts	Area in km2	Population at 2010 Census	Population at 2020 Census	Population 2030 Estimate
1	Baiturrahman	4.54	30,377	32,513	34,649
2	Syiah Kuala	14.24	30,850	32,969	35,088
3	Kuta Alam	10.05	42,217	42,505	42,793
4	Kuta Raja	5.21	10,433	15,291	20,149
5	Ulee Kareeng	6.15	22,571	27,257	31,943
6	Meuraxa	7.26	16,484	26,861	37,238
7	Lueng Bata	5.34	23,592	24,336	25,080
8	Jaya Baru	3.78	22,031	25,939	29,847
9	Banda Raya	4.79	20,891	25,228	29,565

Totals	61.36	223,446	252,899	286,352

Table 2. The nine subdistricts in Banda Aceh along with their locations and populations (Badan Pusat Statistik (BPS) Provinsi Aceh, 2022).

2.2. Data

Data used in this project are categorized as secondary data. The data used in this study include geospatial information and population statistics.

2.2.1. Geospatial Data

Data that is related to a specific real-world location is referred to as geospatial data (Shellito, 2012). The ability to assign a location to data is what makes geospatial technology different from other systems. The main benefit of using geospatial technology is to link non-spatial data to a location. The dataset for this study was created using a variety of GIS data from sources like the Indonesian statistical office, Lapak GIS, and The Geoportal Aceh (AcehGIS). The study's primary element consisted of a few layers of datasets that were generated from several shapefiles. The following is a list of the datasets:

- Layer of Banda Aceh
- Shapefile of roads
- Shapefile of schools & university
- Shapefile of Hospitals
- Shapefile of Village offices
- Layer of nine Subdistricts (Baiturrahman, Syiah Kuala, Kuta Alam, Kuta Raja, Ulee Kareeng, Meuraxa, Lueng Bata, Jaya Baru and Banda Raya)

2.2.2. Population Statistics

The population of each subdistrict's residents, lecturers, teachers, and students is also included in this study. this population's data is needed because it will make it simple to calculate the number of waste containers needed for each location. The data on the populations are listed below:

- The total number of students and teachers at each school and university in each subdistrict
- The total population of each village in the subdistricts

1. Data Baiturrahman Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	SD Negeri 3	258	280	538	25	563	261,795	1
2	SD Negeri 40	162	120	282	15	297	138,105	1
3	SD Kartika XIV-2	49	35	84	8	92	42,78	1
4	SD Budi Dharma	36	32	68	8	76	35,34	1
5	SMP Negeri 17	402	416	818	56	874	406,41	1
6	SD Muhammadiyah 2	45	26	71	7	78	36,27	1
7	SD Negeri 12	158	158	316	18	334	155,31	1
8	SD Negeri 29	188	155	343	17	360	167,4	1
9	SD Negeri 22	271	236	507	25	532	247,38	1
10	SD Negeri 33	109	101	210	12	222	103,23	1
11	SD Budi Dharma	53	40	93	12	105	48,825	1
12	SMP Budi Dharma	39	42	81	10	91	42,315	1
13	SMA Budi Dharma	120	134	254	25	279	129,735	1
14	SD Negeri 43	76	64	140	8	148	68,82	1
15	SD Negeri 34	63	56	119	8	127	59,055	1
16	SMA Muhammadiyah	13	16	29	17	46	21,39	1
17	SMK Muhammadiyah	86	43	129	13	142	66,03	1
18	SD Negeri 5	182	152	334	17	351	163,215	1
19	SD Negeri 64	73	57	130	9	139	64,635	1
							Total	19

Table 3. The school's data in Baiturrahman subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Ateuk Pahlawan	1
2	Pustu Ateuk Jawo	1
3	Polindes Ateuk Jawo	1
	Total	3

Table 4. The Hospital's data in Baiturrahman subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg

1	Kampung Baru	2522	1172,73	1
2	Peuniti	6361	2957,865	2
3	Ateuk Pahlawan	4427	2058,555	2
4	Suka Ramai	4429	2059,485	2
5	Neusu Jaya	2590	1204,35	1
6	Ateuk Deah Tanoh	1103	512,895	1
7	Ateuk Munjing	2067	961,155	1
8	Seutui	3348	1556,82	1
9	Neusu Aceh	3872	1800,48	1
10	Ateuk Jawo	2790	1297,35	1
Total				13

Table 5. The Village's data in Baiturrahman subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	19
2	Hospital	3
3	Village Office	13
Total		35

Table 6. The Waste Container's data in Baiturrahman subdistricts

2. Data Syiah Kuala Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	TK Ikal Dolog	28	36	64	8	72	33,48	1
2	SD Negeri 55	108	103	211	10	221	102,765	1
3	STIES	49	35	84	8	92	42,78	1
4	SD Negeri 57	106	85	191	10	201	93.465	1
5	KB Islam Al-Azhar	53	40	93	12	105	48,825	1
6	TK Al-Azhar	45	26	71	7	78	36,27	1
7	SD Al-Azhar	375	357	732	69	801	372,465	1
8	SD Negeri 68	85	77	162	8	170	79,05	1
9	SD Negeri 69	123	109	232	12	244	113,46	1
10	TK Bungong Seuleupok	39	35	74	10	84	39,06	1

11	SMA Lab School	204	247	451	32	483	224,595	1
12	SMAN 5 Banda Aceh	364	365	729	53	782	363,63	1
13	SMP Negeri 13	191	185	376	29	405	188,325	1
14	UIN Ar-Raniry	3095	3090	6185	245	6430	2989,95	2
15	Universitas Syiah Kuala	11290	19118	30408	2020	32428	15079,02	7
16	TK Fkip Unsyiah	78	70	148	14	162	75,33	1
17	TK Miftahul Jannah	26	23	49	5	54	25,11	1
18	STT BCI	182	152	334	17	351	163,215	1
19	Akademi Farmasi Mandiri	13	130	143	10	153	71,145	1
20	STIM	52	32	84	9	93	43,245	1
21	AMIKI	335	332	667	56	723	336,195	1
22	TK Montessori	5	12	17	6	23	10,695	1
							Total	29

Table 7. The school's data in Syiah Kuala subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lamgugob	1
2	Pustu Tibang	1
3	Pustu Deah Raya	1
4	Puskesmas Darussalam	1
5	Puskesmas Lingke	1
6	Polindes Desa Rukoh	1
	Total	6

Table 8. The Hospital's data in Syiah Kuala subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Alue Naga	1270	590,55	1
2	Deah Raya	1361	632,865	1
3	Tibang	1427	663,555	1
4	Rukoh	4547	2114,355	2
5	Jeulingke	5420	2520,3	2
6	Lamgugob	1103	512,895	1
7	Kopelma Darussalam	3976	1848,84	1
8	Pineung	1432	665,88	1

9	Ie Masen Kayee Adang	1263	587,295	1
10	Peurada	1432	665,88	1
Total				12

Table 9. The Village's data in Syiah Kuala subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	29
2	Hospital	6
3	Village Office	12
Total		47

Table 10. The Waste Container's data in Syiah Kuala subdistricts

3. Data Kuta Alam Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	SMP Negeri 4	234	242	476	33	509	236,685	1
2	SMP Negeri 9	192	139	331	25	356	165,54	1
3	SMA Safiatuddin	117	108	225	23	248	115,32	1
4	SD Methodist	138	137	275	18	293	136,245	1
5	SD Negeri 20	224	206	430	22	452	210,18	1
6	TK Gaseh Poma	22	29	51	7	58	26,97	1
7	SMTI Banda Aceh	452	293	745	58	803	373,395	1
8	SMAN 2 Banda Aceh	319	395	714	47	761	353,865	1
9	SD Negeri 27	187	189	376	16	392	182,28	1
10	SMKN 4 Banda Aceh	215	1	216	29	245	113,925	1
11	SMAN 15 Adidarma	53	40	93	12	105	48,825	1
12	SMP Methodist	80	65	145	18	163	75,795	1
13	SMA Methodist	53	64	117	18	135	62,775	1
14	MIN 2 Banda Aceh	296	263	559	25	584	271,56	1
15	SD Negeri 36	85	85	170	9	179	83,235	1

16	MAN 1 Banda Aceh	1280	1281	2561	175	2736	1272,24	1
17	MTsN 1 Banda Aceh	464	715	1179	65	1244	578,46	1
18	MIN 1 Banda Aceh	581	573	1154	54	1208	561,72	1
19	MAS Darul Ulum	166	199	365	53	418	194,37	1
20	MTsS Darul Ulum	191	174	365	35	400	186	1
21	TK AL ABRAR	28	21	49	7	56	26,04	1
22	SD Negeri 28	93	111	204	9	213	99,045	1
23	TK IT Arrahmah	53	50	103	16	119	55,335	1
24	SD Negeri 32	189	148	337	18	355	165,075	1
25	SMAN 3 Banda Aceh	405	601	1006	57	1063	494,295	1
26	SD Kartika XIV-1	98	77	175	12	187	86,995	1
27	TK AB Iskandar Muda	21	24	45	11	56	26,04	1
28	SD Negeri 25	185	145	330	15	345	160,425	1
29	TK Perkib	20	18	38	6	44	20,46	1
30	SMPN 2 Banda Aceh	347	380	727	50	777	361,305	1
31	SD Negeri 35	113	99	212	8	220	102,3	1
32	Poltekes Aceh	4022	1826	5848	231	6076	2826,735	2
33	SD Negeri 41	91	97	188	8	296	137,64	1
34	TK AL-Washliyah	17	14	31	3	34	15,81	1
35	SMAS Inshafuddin	117	108	225	20	245	113,925	1
36	SD Negeri 35	113	99	212	8	220	102,3	1
							Total	37

Table 11. The school's data in Kuta Alam subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lambaro Skep	1
2	Puskesmas Kuta Alam	1
3	Puskesmas Lampulo	1
4	RSU Zainal Abidin	1
5	RS jiwa	1
6	RS Kesdam Iskandar Muda	1
	Total	6

Table 12. The Hospital's data in Kuta Alam subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Lambaro Skep	1522	707,73	1
2	Lampulo	5443	2530,995	2
3	Lamdingin	3155	1467,075	1
4	Kota Baru	1432	665,88	1
5	Bandar Baru	6640	3087,6	2
6	Mulia	1103	512,895	1
7	Peunayong	2258	1049,97	1
8	Beurawe	3348	1556,82	1
9	Keuramat	3872	1800,48	1
10	Laksana	2790	1297,35	1
11	Kuta Alam	4489	2087,385	2
Total				14

Table 13. The Village's data in Kuta Alam subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	37
2	Hospital	6
3	Village Office	14
Total		57

Table 14. The Waste Container's data in Kuta Alam subdistricts

4. Data Kuta Raja Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	SD Negeri 17	105	91	196	8	204	94,86	1
2	TK AL Hidayah	23	24	47	9	56	26,04	1
3	TK AL Akhyar	23	29	52	5	57	26,505	1
4	SMAN 13 Banda Aceh	30	25	55	23	78	36,27	1
5	SD Negeri 70	184	178	362	16	378	175,77	1
6	SMP 12	56	64	120	15	135	62,775	1
							Total	6

Table 15. The school's data in Kuta Raja subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Kampung Pande	1
2	Puskesmas Lampaseh	1
Total		2

Table 16. The Hospital's data in Kuta Raja subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Gampong Pande	1552	721,68	1
2	Gampong Jawa	1341	623,565	1
3	Peulanggahan	2421	1125,765	1
4	Keudah	2388	1110,42	1
5	Merduati	2753	1280,145	1
6	Lampaseh Kota	1213	564,045	1
Total				6

Table 17. The Village's data in Kuta Raja subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	6
2	Hospital	2
3	Village Office	6
Total		14

Table 18. The Waste Container's data in Kuta Raja subdistricts

5. Data Ulee Kareeng Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			

1	SD Negeri 56	187	174	361	16	378	175,77	1
2	MIN 9 Banda Aceh	318	308	626	40	666	309,69	1
3	TK IT Mon Kuta	86	87	173	12	185	86,025	1
4	TK Poteumeureuhom	33	37	70	6	76	35,34	1
5	SMP Negeri 10	207	166	373	39	412	191,58	1
6	SD Negeri 66	155	112	267	15	282	131,13	1
7	SD Negeri 3	257	278	316	25	535	248,775	1
8	SD Negeri 11	88	116	204	9	213	99,045	1
9	TK AL Munawarrah	21	15	36	4	40	18,6	1
10	Paud AL Munawarrah	11	9	20	1	21	9,765	1
							Total	10

Table 19. The school's data in Ulee Kareeng subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lambhuk	1
2	Pustu Pango Raya	1
3	Puskesmas Ulee Kareng	1
4	Polindes Pango Deah	1
5	Polindes Lambhuk	1
Total		5

Table 20. The Hospital's data in Ulee Kareeng subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Doy	2660	1236,9	1
2	Lambhuk	5312	2470,08	2
3	Ie Masen	1427	663,555	1
4	Ceurih	3714	1727,01	1
5	Lam Glumpang	1672	777,48	1
6	Lamteh	1120	520,8	1
7	Ilie	2047	899,775	1
8	Pango Raya	1935	1556,82	1
9	Pango Deah	1857	863,505	1
Total				10

Table 21. The Village's data in Ulee Kareeng subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	10
2	Hospital	5
3	Village Office	10
Total		25

Table 22. The Waste Container's data in Ulee Kareeng subdistricts

6. Data Meuraxa Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	SMP Negeri 1	433	445	878	51	929	431,985	1
2	SMA Negeri 1	341	462	803	44	874	406,41	1
3	SMA Al-Misbah	84	44	128	13	141	65,565	1
4	SD Negeri 2	299	283	582	24	606	281,79	1
5	TK Nusa Indah	64	68	132	6	138	64,17	1
6	SD Negeri 38	107	90	197	9	206	95,79	1
7	SMP Negeri 11	118	108	126	21	147	68,355	1
8	SMA Negeri 6	175	151	326	34	360	167,4	1
9	SD Negeri 49	86	96	182	8	190	88,35	1
10	TK. Pembina	19	11	30	4	34	15,81	1
11	SMP Negeri 5	107	120	227	17	244	113,46	1
12	SD Negeri 5	182	154	336	17	353	164,145	1
13	SD Negeri 31	142	129	271	11	282	131,13	1
14	SD Negeri 7	76	64	140	8	148	68,82	1
15	SD Negeri 48	101	99	200	9	209	97,185	1
16	SD Negeri 13	198	98	206	11	217	100,905	1
17	SD Negeri 23	139	117	256	11	267	124,155	1
							Total	17

Table 23. The school's data in Meuraxa subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lamjabat	1
2	Puskesmas Meuraxa	1
3	RS Ibu dan Anak	1
Total		3

Table 24. The Hospital's data in Meuraxa subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Lampaseh	1522	707,73	1
2	Deah Baro	2361	1097,865	1
3	Alue Deah Teungoh	2427	1128,555	1
4	Ulee Lheue	1429	664,485	1
5	Deah Glumpang	2090	97,185	1
6	Blang Oi	1983	922,095	1
7	Punge Jurong	2037	947,205	1
8	Punge Ujong	1348	626,82	1
9	Cot Langkuweuh	2872	1335,48	1
10	Gampong Baro	2990	1290,35	1
11	Gampong Blang	1653	768,645	1
12	Lamjabat	1562	726,33	1
13	Asoe Nanggroe	1782	828,63	1
14	Surien	1676	779.34	1
15	Lambung	2412	1121,58	1
Total				15

Table 25. The Village's data in Meuraxa subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	17
2	Hospital	3
3	Village Office	15
Total		35

Table 26. The Waste Container's data in Meuraxa subdistricts

7. Data Lueng Bata Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	MIN 3 Kota Banda Aceh	209	259	468	25	493	229,245	1
2	TK AL JANNAH	38	34	72	6	88	40,92	1
3	SMP Negeri 13	191	185	376	31	407	189,255	1
4	SD Negeri 62	220	231	451	23	474	220,41	1
5	SMA Negeri 11	307	309	616	43	659	306,435	1
6	Universitas Muhamadiyah	1835	1825	3660	132	3792	1763,28	1
7	TK Aisyiyah	30	25	55	4	59	27,435	1
8	SD Negeri 60	87	77	164	8	172	79,98	1
							Total	8

Table 27. The school's data in Lueng Bata subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lueng Bata	1
2	Puskesmas Batoh	1
3	Polindes Lam Dom	1
4	Polindes Cot Mesjid	1
5	Polindes Blang Cut	1
Total		5

Table 28. The Hospital's data in Lueng Bata subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Lamseupeung	2899	1348,035	1
2	Suka Damai	2345	1090,425	1
3	Panteriek	2429	1129,485	1
4	Blang Cut	1823	847,695	1
5	Lueng Bata	2590	1204,35	1
6	Lampaloh	2104	978,36	1
7	Batoh	2327	1082,055	1
8	Cot Mesjid	2138	994,17	1

9	Lamdom	1822	847,23	1
Total				9

Table 29. The Village's data in Lueng Bata subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	8
2	Hospital	5
3	Village Office	9
Total		22

Table 30. The Waste Container's data in Lueng Bata subdistricts

8. Data Jaya Baru Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	TK Aisyiah Bustanul A	53	55	108	9	117	54,405	1
2	TK Permata Bunda	23	29	52	4	56	26,04	1
3	SD Negeri 18	199	184	383	18	401	186,465	1
4	TK IT Subussalam	20	15	35	4	39	18,135	1
5	UT UPB-JJ-UT Aceh	402	416	818	56	874	406,41	1
6	Akademi Kebidanan M	-	2682	2682	102	2784	1294,56	1
7	SD Negeri 26	99	110	209	9	218	101,37	1
8	SD Negeri 37	99	75	174	9	183	85,095	1
9	SD Kemala Bhayangkari	153	127	280	14	294	136,71	1
10	MIN 7 Kota Banda Aceh	588	691	1279	73	1352	628,68	1
11	MAN 2 Banda Aceh	119	164	283	42	325	151,125	1
12	TK Kemala Bhayangkari	82	52	134	11	145	67,425	1
13	TK Anak saleh	8	10	18	2	20	9,3	1
14	SMP Bhayangkari	24	15	39	3	42	19,53	1
15	SMP Negeri 15	122	89	211	18	229	106,485	1
16	SD Negeri 51	131	124	255	13	268	124,62	1
17	SMA T. Nyak Arief	0	108	108	5	113	52,545	1
18	TK Meunara Pancasila	10	12	22	2	24	11,16	1
19	TK Permata Bunda	14	16	30	4	34	15,81	1

Total	19

Table 31. The school's data in Jaya Baru subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Ateuk Pahlawan	1
2	Pustu Ateuk Jawo	1
3	Polindes Ateuk Jawo	1
Total		3

Table 32. The Hospital's data in Jaya Baru subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Punge Blang Cut	5256	2444,04	1
2	Bitai	1057	491,505	1
3	Lamteumen Timur	2427	1128,555	1
4	Lampoh Daya	1429	664,485	1
5	Lamteumen Barat	1590	739,35	1
6	Geuceu Meunara	2103	977,895	1
Total				6

Table 33. The Village's data in Jaya Baru subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	19
2	Hospital	3
3	Village Office	6
Total		28

Table 34. The Waste Container's data in Jaya Baru subdistricts

9. Data Banda Raya Subdistrict

a. School Data

NO	Name	Student			Teacher	Total Person	Waste 0.465 kg/person x total person	Waste Container 2000 kg
		Male	Female	Total Student	Male & female			
1	SD Negeri 50	387	369	756	35	791	367,815	1

2	TK Pertiwi	141	107	248	24	272	126,48	1
3	TK Bhakti Pertiwi	14	16	30	2	32	14,88	1
4	SMP Negeri 7	375	314	689	43	732	340,38	1
5	SMA Negeri 7	411	468	879	62	941	437,565	1
6	AKBID Saleha	0	1134	1134	79	1213	564,045	1
7	SD Negeri 6	102	91	193	9	202	93,93	1
8	TK Ananda	7	13	20	2	22	10,23	1
9	Paud Harapan Bunda	8	8	16	5	21	9,765	1
10	SMKN 1 Lhong Raya	332	463	795	67	862	400,83	1
11	SMKN 2 Lhong Raya	997	35	1032	94	1126	523,59	1
12	SMKN 3 Lhong Raya	25	821	846	86	932	433,38	1
13	MIN 8 Kota Banda Aceh	484	485	969	35	1004	466,86	1
14	TK Aisyiah Bustanul A	30	25	55	3	58	26,97	1
15	SD Negeri 71	91	77	168	8	176	59,055	1
16	SMPS Madinatul Fata	19	6	25	5	30	13,95	1
17	TK Al Ikhlas	14	6	20	3	23	10,695	1
18	Akbid Fisioterapi H	0	801	801	33	834	387,81	1
19	SMA Teuku Nyak Arief	73	57	130	9	139	64,635	1
							Total	19

Table 35. The school's data in Banda Raya subdistricts

b. Hospital Data

NO	Name	Waste Container 2000 kg
1	Pustu Lamlagang	1
2	Puskesmas Mibo	1
3	Polindes Geucu Komplek	1
4	Polindes Geucu Inem	1
5	Polindes Geucu Kayee Jatho	1
6	Polindes Lam Ara	1
7	Polindes Lhong Raya	1
Total		7

Table 36. The Hospital's data in Banda Raya subdistricts

c. Village Data

NO	Name	Number of villagers	Waste 0.465 kg/person x total person	Waste Container 2000 kg
1	Lamlagang	4760	2213,4	2
2	Geuceu Kayee Jato	1450	674,25	1
3	Geuceu Komplek	3307	1537,755	1

4	Peunyerat	2164	1006,26	1
5	Lhong Raya	2910	1353,15	1
6	Geuceu Inem	5000	2325	2
7	Lhong Cut	1900	883,5	1
8	Lam Ara	3218	1496,37	1
9	Mibo	2872	1335,48	1
10	Lampeuot	1790	832,35	1
Total				12

Table 37. The Village's data in Banda Raya subdistricts

d. Waste Container Data

NO	Name	Total of Waste Container
1	School	19
2	Hospital	7
3	Village Office	12
Total		38

Table 38. The Waste Container's data in Banda Raya subdistricts

10. Waste Container Data Banda Aceh City requires to be placed

NO	Name	School	Hospital	Village Office	Total of Waste Container
1	Baiturrahman	19	3	13	35
2	Syiah Kuala	29	6	12	47
3	Kuta Alam	37	6	14	57
4	Kuta Raja	6	2	6	14
5	Ulee Kareeng	10	5	10	25
6	Meuraxa	17	3	15	35
7	Lueng Bata	8	5	9	22
8	Jaya Baru	19	3	6	28
9	Banda Raya	19	7	12	38
TOTAL		164	40	97	301

Table 39. The waste container data requires to be placed in Banda Aceh City

2.2.3. Data processing procedures

This project was processed using the Tool in ArcGIS Pro. These are the methods used in order to complete this project:

1. From the Banda Aceh city layer, select the Subdistrict.

Figure 2 : Model builder to select area

2. All layers were clipped to the study area in the Subdistrict.

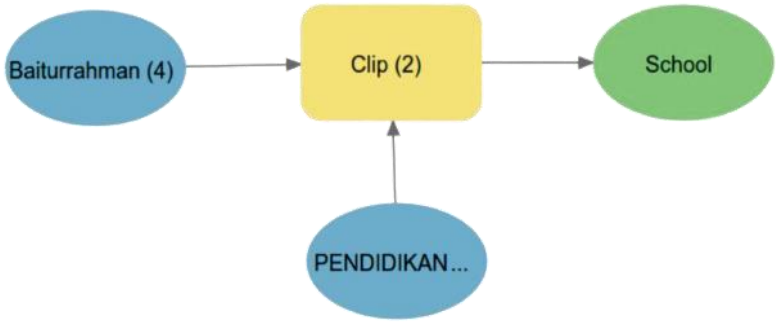

Figure 3 : Model builder to clip area

3. Update the school shapefile with information on the overall student and teacher numbers at each school and university.

School							
NO	Name	Student			Teacher	Total	Waste Container
		Male	Female	Total Student	Male & female		
1	SD Negeri 3	258	280	538	25	563	2
2	SD Negeri 40	162	120	282	15	297	2
3	SD Kartika XIV-2	49	35	84	8	92	1
4	SD BUDI DHARMA	36	32	68	8	76	1
5	SMP Negeri 17	402	416	818	56	874	2
6	SD MUHAMMADIYAH 2	45	26	71	7	78	1
7	SD Negeri 12	158	158	316	18	334	2
8	SD Negeri 29	188	155	343	17	360	2
9	SD Negeri 22	271	236	507	25	532	2
10	SD Negeri 33	109	101	210	12	222	2
11	SD BUDI DHARMA	53	40	93	12	105	1
12	SMP BUDI DHARMA	39	42	81	10	91	1
13	SMA BUDI DHARMA	120	134	254	25	279	2
14	SD Negeri 43	76	64	140	8	148	1
15	SD Negeri 34	63	56	119	8	127	1
16	SMA MUHAMMADIYAH	13	16	29	17	46	1
17	SMK MUHAMMADIYAH	86	43	129	13	142	1
18	SD Negeri 5	182	152	334	17	351	2
19	SD Negeri 64	73	57	130	9	139	1

Figure 4 : Update the shapefile

4. Update the village Office shapefile with information on the total population of each village.
5. Determine how many waste containers are needed for each total population of each school and village

Based on the Paper on the production and composition of domestic waste in Surabaya's Rungkut District, authored by Ratya et al. and published in the *ITS Teknik Journal* Vol. 6, No. 2 (2017). The average quantity of garbage produced by the community each day is 0.465 kg/person. and one 2 m3 waste container has a capacity of 2000 liters, which is equal to 2000 kilograms.

Therefore, using the following information may be used to determine how many waste containers are required for each school and village:

$$\frac{\text{The number of persons x Waste produced by a person (0.465 kg)}}{\text{container size volume (2000 kg)}} = \text{Waste Container waste}$$

Only one container is necessary at a location where rubbish production averages less than 2000 kg per day. Furthermore, more containers are needed if a location generates more than 2000 kg of waste each day.

6. Create a new shapefile including the locations of the waste containers across the school and village based on the calculations made earlier.

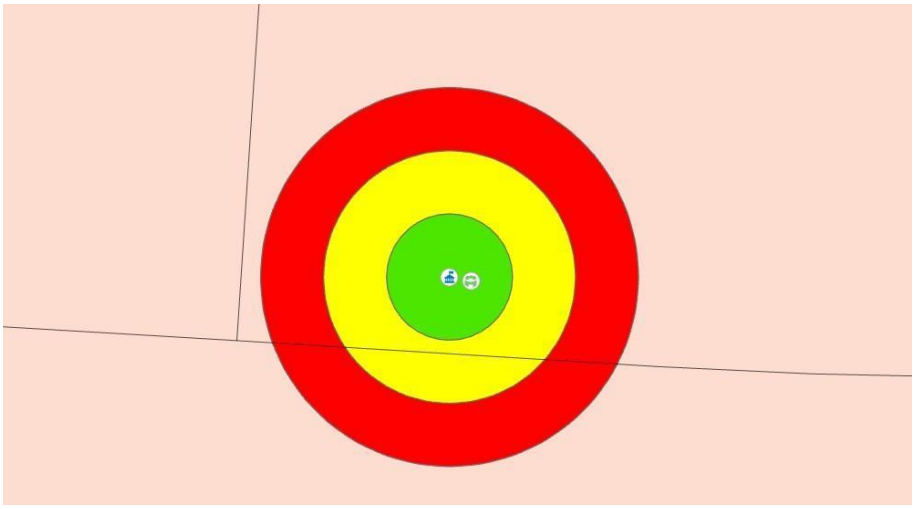

Figure 5 : New shapefile including the locations of the waste containers

7. For each site of a waste container, create three buffer zones at a distance of about 20 meters, using the colors green, yellow, and red.
   - The area within 20 meters of the waste container is shown by the color green, and this is the ideal place to install the waste container.
   - The area within 40 meters of the waste container is indicated in yellow, and this area is the second-best place to install waste containers.
   - The area within 60 meters of the waste container is indicated in red, and this area is the third-best place to install the waste container.

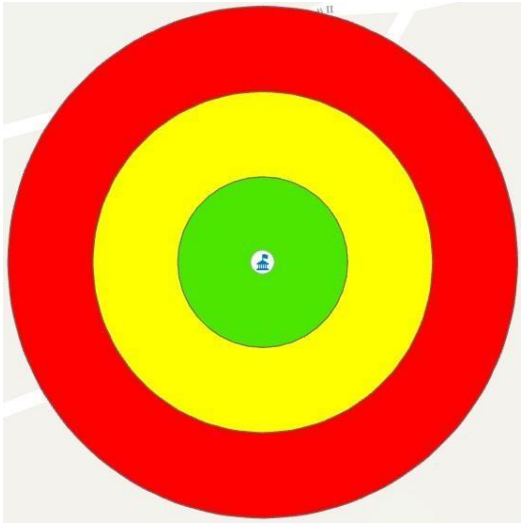

Figure 6 : Green, yellow, and red are used in three zones with a radius of about 20 meters apart.

8. Make a map with the following elements: a title, map frames, legend, scale bar, and a north arrow.

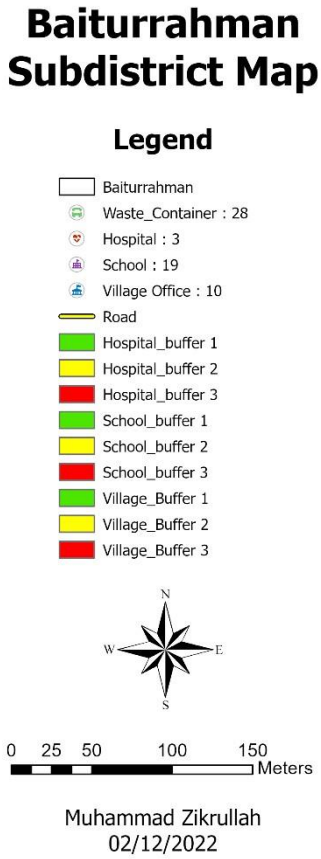

Figure 7. Element's map: a title, map frames, legend, scale bar, and a north arrow.

9. Once the map has been exported into a document, the final map indicating the ideal spot to install a waste container is available.

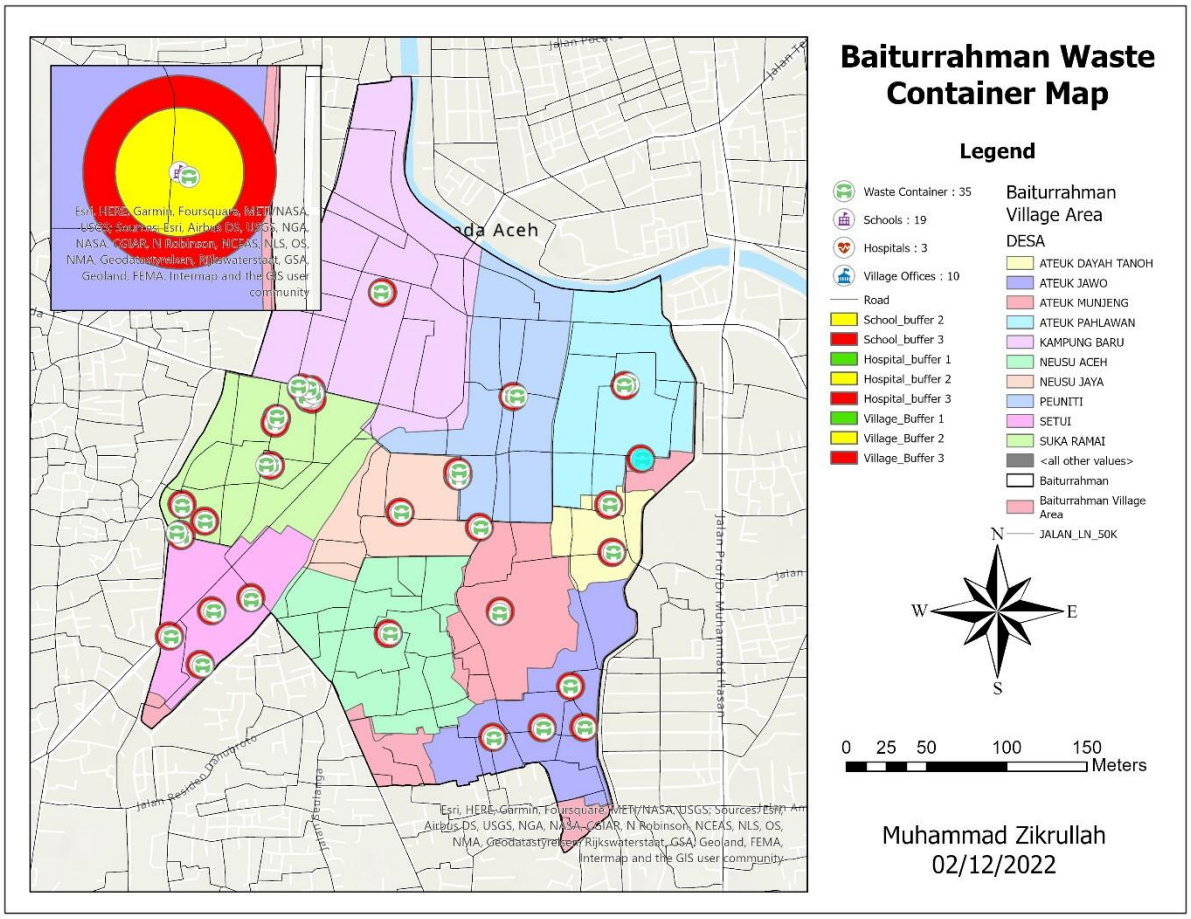

Figure 8. the final map indicating the ideal spot to install a waste container.

10. Based on the findings of this study, we may suggest that the Banda Aceh municipal government place waste containers near certain locations using this map.

2.2.4 Reflect the entirety of the project

The research data were gathered in Aceh in 2021 while conducting the studies there. The data was gathered from surveys conducted at several sites within the Banda Aceh subdistrict, and

also from a variety of websites, including those for the government, schools, hospitals, villages, and other sources.

NO	Activities	2021	2022	2023
1	Data collection	√	√	
2	Data process		√	√
3	Data results			√
4	Data Evaluation			√

Table 40. Timetable of data collection and evaluation

This is the period of time that the researcher works with step-by-step from the table above.

1. Data collection: the researcher spent the first three months of 2021, from October to December, observing the area and gathering data. In order to organize all of the content into one folder, the researcher spent three months in 2022, from January to March, gathering information from several sources.
2. Data processing: The researcher spent 6 months in 2022, from April to September, processing the data, and another 6 months in 2023, from October to March consulting the data with the advisors.
3. Data results: The researcher spent 3 months in 2023, from January to March, to obtain the research paper's findings.
4. Data Evaluation: The researcher spent two weeks in 2023, completing the evaluation of the research's findings in this step.

3. Results

This section presents the result of the analyses and provides some discussions for each one of them. It is organized to address the major objectives of the study. This section is organized to address the results of each subdistrict individually and Banda Aceh City overall.

3.1. Baiturrahman Subdistrict

Based on GIS analysis, this study might result in 35 waste containers. There were three areas where the garbage containers should be located. The schools are the first location.

Due to the quantity of schools and children in this district, there should be 19 waste containers surrounding schools. The second area is the Villages. 13 garbage containers should be generated in the area. Villages typically install the second most waste containers due to their large population and volume of waste production. The final is the hospital, which should have 3 waste containers installed because it is not a large facility and there is not a lot of garbage produced there.

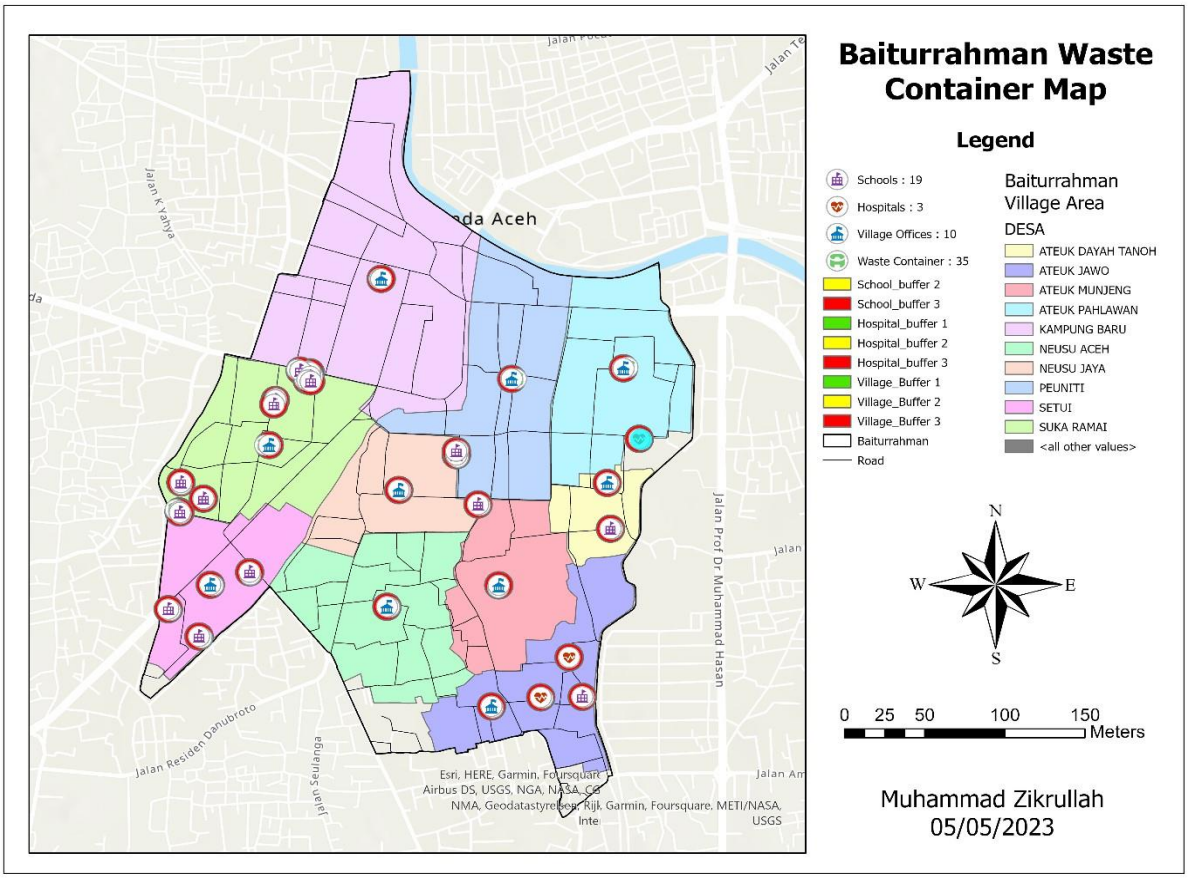

Figure 9: Baiturrahman subdistrict Waste Container Map

3.2. Syiah Kuala Subdistrict

This study may result in 47 waste containers, according to GIS analysis. Waste containers have to be placed in among the three locations. The first location is a school. There should be 29 waste containers placed around schools because of the number of schools and students in this district. The Villages are the second location. There have to be 12 waste containers produced nearby. Due to their high population and rate of waste production, villages normally install the second highest number of trash cans. The

hospital is the last, and as it is a small building with little waste generated there, 6 waste containers should be installed there.

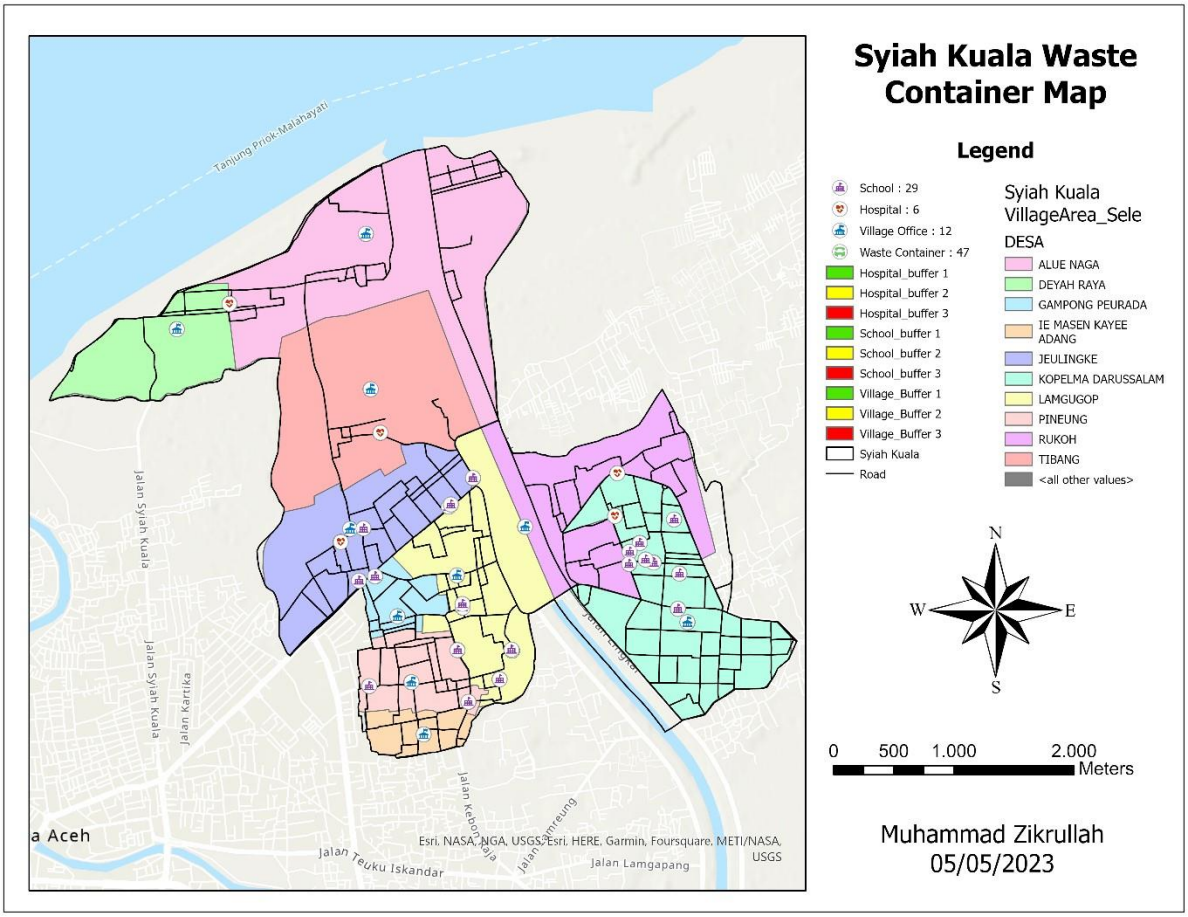

Figure 10: Syiah Kuala subdistrict Waste Container Map

3.3. Kuta Alam Subdistrict

GIS analysis shows that this study might generate 57 waste containers. These waste containers were supposed to be placed in three different locations. The first place is the schools. 37 waste containers should be placed close to schools due to the number of schools and students in this district. The Villages make up the second area. There should be 14 waste containers produced in the surrounding area. Due to their big population and high levels of trash generation, villages normally install the second most waste bins. The hospital is the last, and since it is a small building and generates little garbage, it should have 6 waste containers installed.

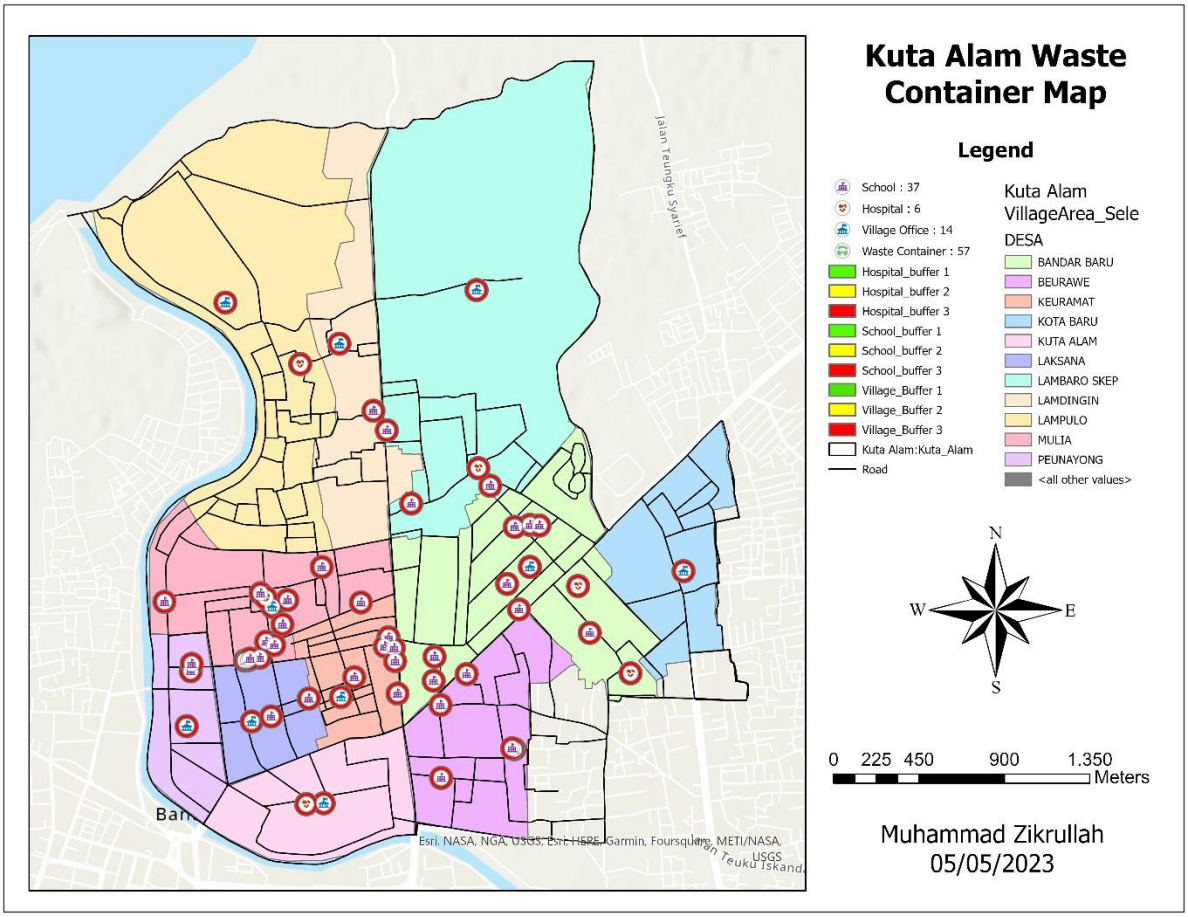

Figure 11: Kuta Alam subdistrict Waste Container Map

3.4. Kuta Raja Subdistrict

14 waste containers could be the result of this study, according to GIS analysis. The waste containers were supposed to be placed in three different locations. The first place is the schools. 6 waste containers should be placed close to schools due to the number of schools and students in this district. The Villages make up the second area. There should be 6 waste containers produced in the neighborhood. Due to their big population and high levels of trash generation, villages normally install the second most waste bins. The hospital is the last, and since it is a small building and generates little garbage, it should have 2 containers of waste installed.

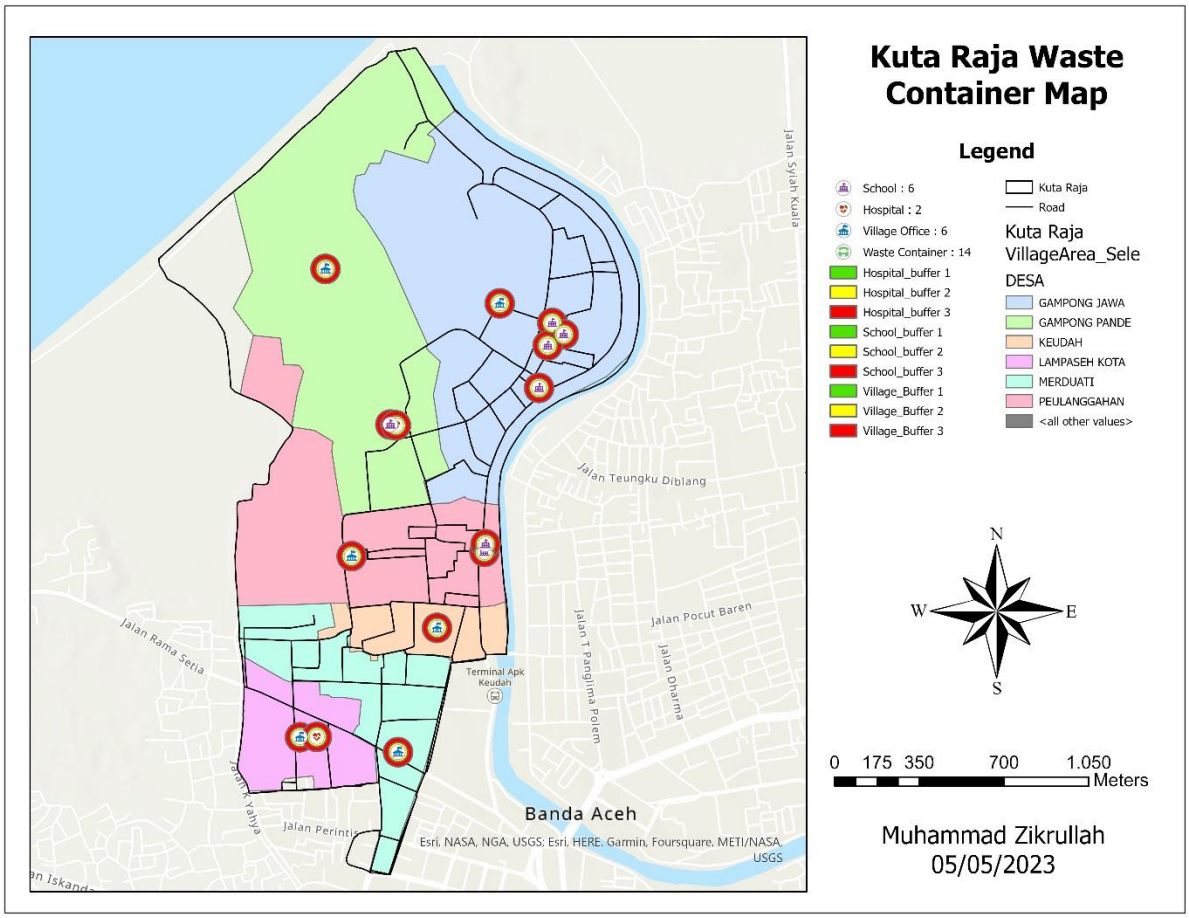

Figure 12: Kuta Raja subdistrict Waste Container Map

3.5. Ulee Kareeng Subdistrict

This study might result in the process of creation of 25 garbage containers, according to GIS analysis. The locations of containers for waste should be in three different places. As a starting point, consider the schools. There have to be 10 waste containers close to schools, given the number of schools and students in this district. The Villages constitute the second region. In the vicinity, 10 waste containers should be produced. Villages often install the second-highest number of trash cans due to their high population and rate of garbage production. The hospital is the last, and as it is a small facility with little waste production, it should have 5 waste containers installed.

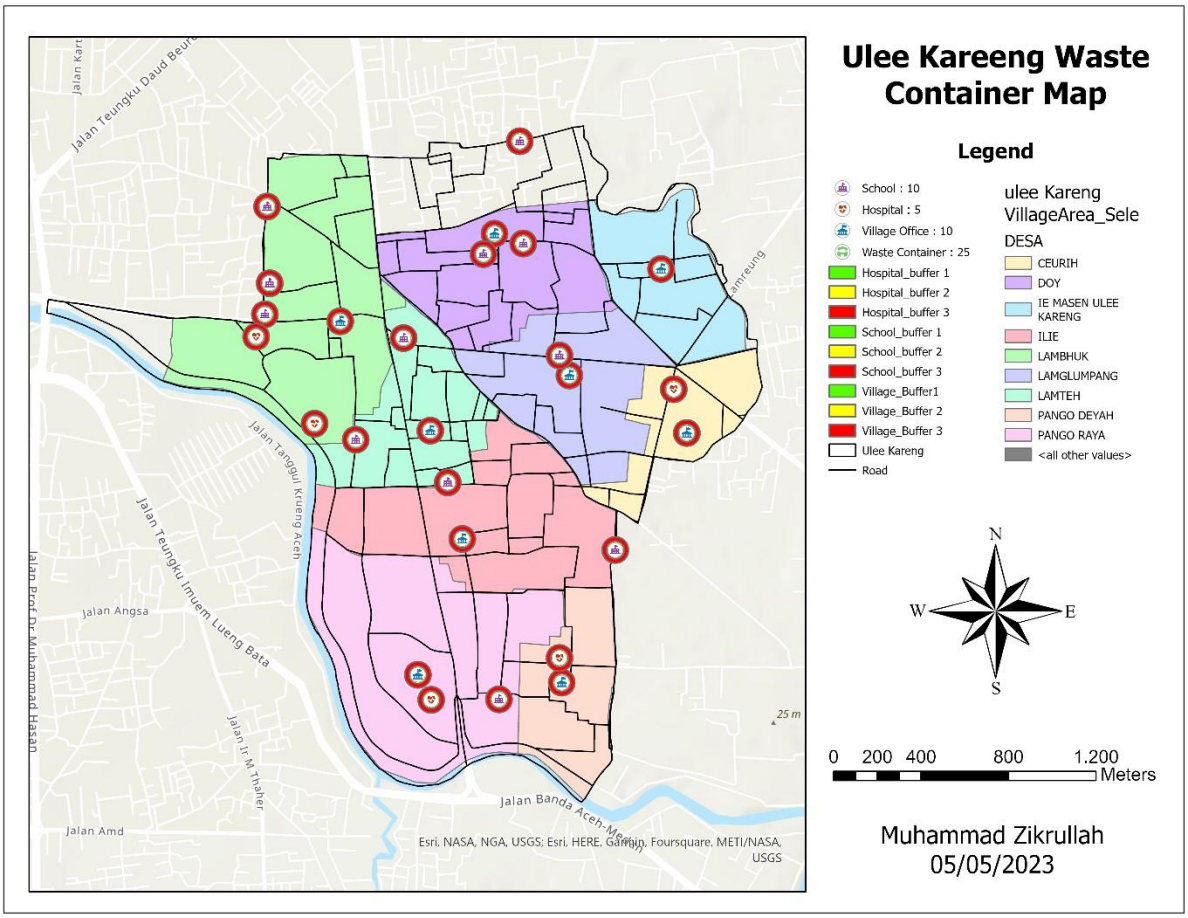

Figure 13: Ulee Kareeng subdistrict Waste Container Map

3.6. Meuraxa Subdistrict

35 waste containers could be the result of this study, according to GIS analysis. The waste containers were supposed to be placed in three different locations. The first place is the schools. There should be 17 waste containers placed close to schools due to the number of schools and students in this area. The Villages make up the second area. There should be 15 waste containers produced nearby. Due to their big population and high levels of trash generation, villages normally install the second most waste bins. The hospital is the last, and since it is a small building and generates little garbage, it should have 3 waste containers installed.

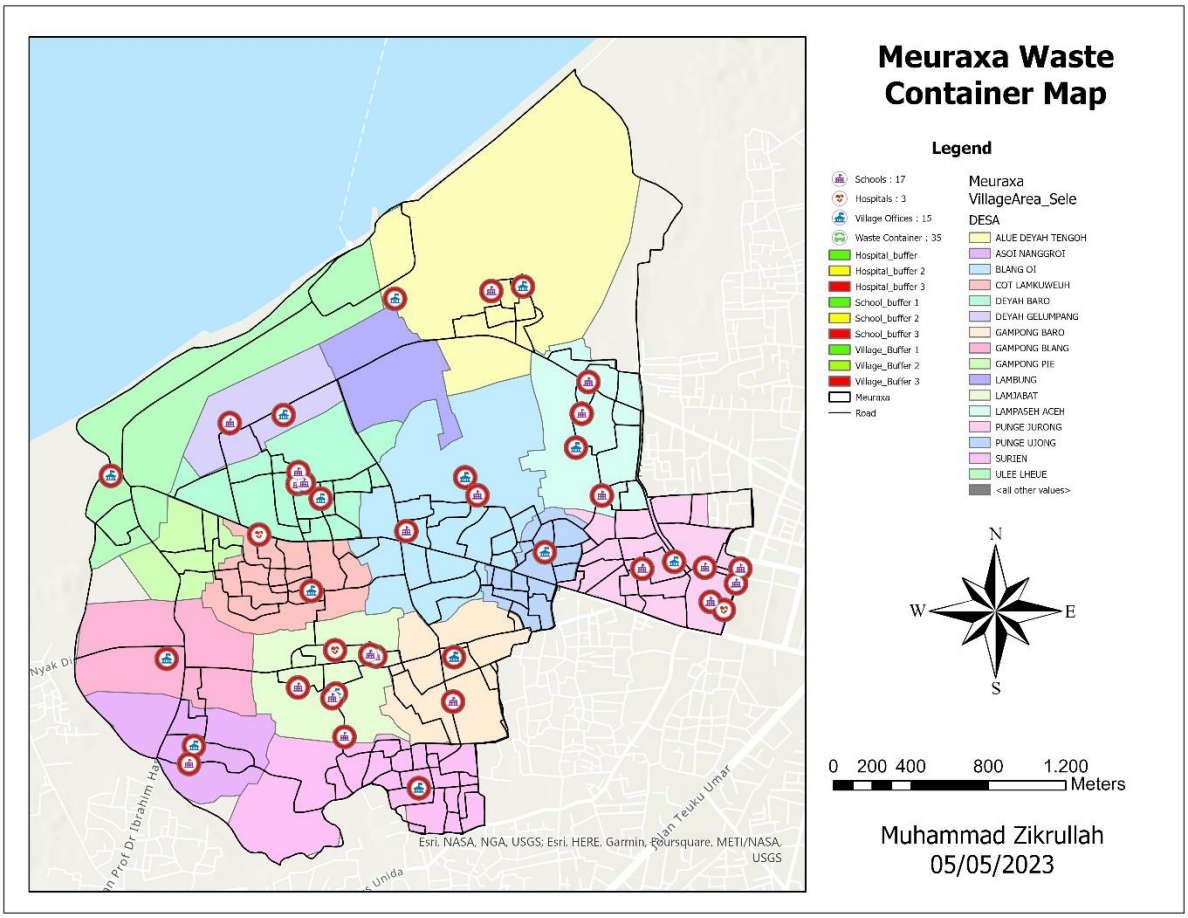

Figure 14: Meuraxa subdistrict Waste Container Map

3.7. Lueng Bata Subdistrict

This study might generate 22 waste containers, according to GIS analysis. Waste containers have to be placed in one of three locations. The first location is a school. There should be 8 waste containers placed close to schools due to the number of schools and students in this district. The Villages are the second location. There has to be 9 waste containers produced nearby. Due to their high population and rate of waste production, villages normally install the second highest number of trash cans. The hospital is the last, and because it is a small facility with little garbage produced there, it should have 5 waste containers installed.

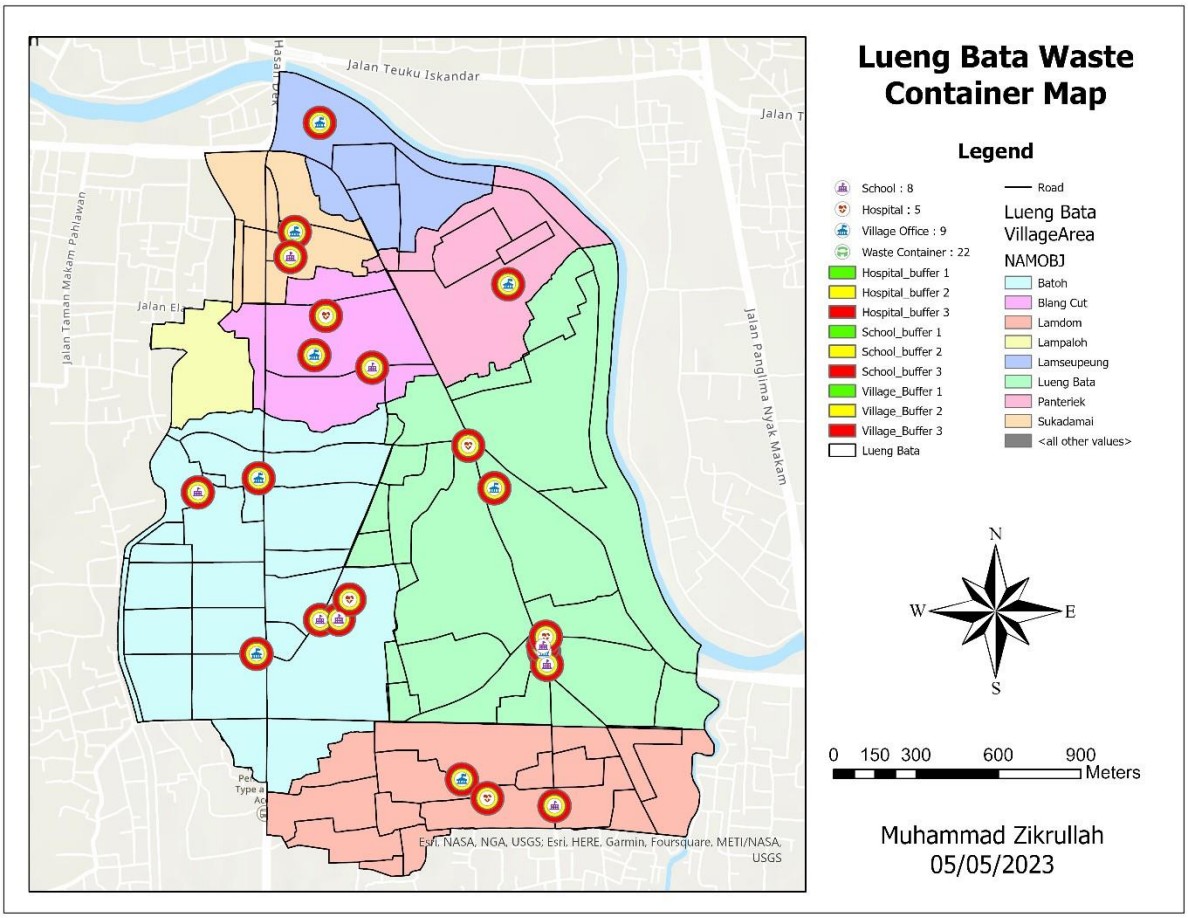

Figure 15: Lueng Bata subdistrict Waste Container Map

3.8. Jaya Baru Subdistrict

This study might result in 28 waste containers, according to GIS analysis. Waste containers have to be placed in one of three locations. The first location is a school. There should be 19 waste containers placed close to schools according to the number of schools and students in this district. The Villages are the second location. The region should produce 6 waste containers. Due to their high population and rate of waste production, villages normally install the second highest number of trash cans. Last but not least, the hospital, which should have 3 waste containers built because it is not a large facility and does not produce a lot of waste.

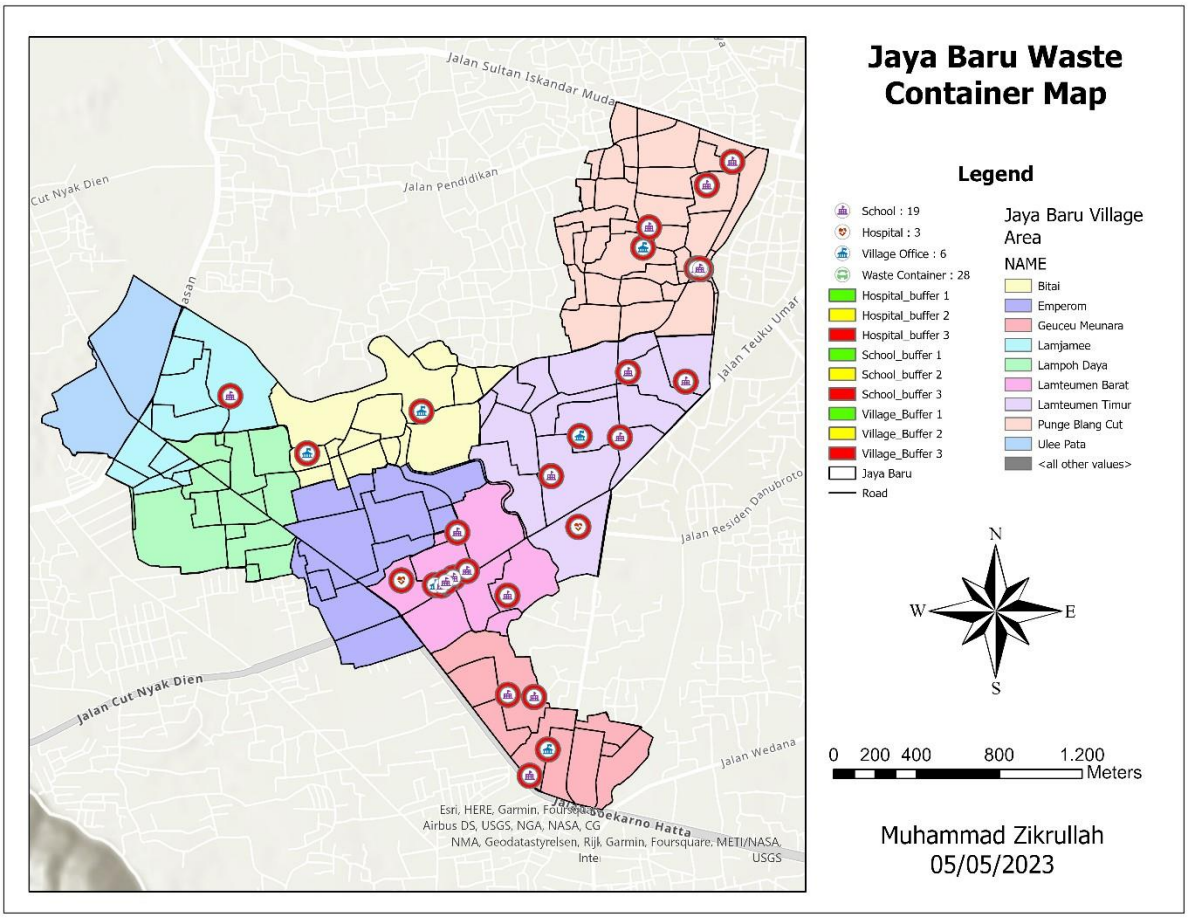

Figure 16: Jaya Baru subdistrict Waste Container Map

3.9. Banda Raya Subdistrict

Based on GIS analysis, this study might result in 38 waste containers. There were three areas where the garbage containers should be located. The schools are the first location. Due to the quantity of schools and children in this district, there should be 19 waste containers surrounding schools. The second area is the Villages. 12 garbage containers should be generated in the area. Villages typically install the second most waste containers due to their large population and volume of waste production. The final is the hospital, which should have 7 waste containers installed because it is not a large facility and there is not a lot of garbage produced there.

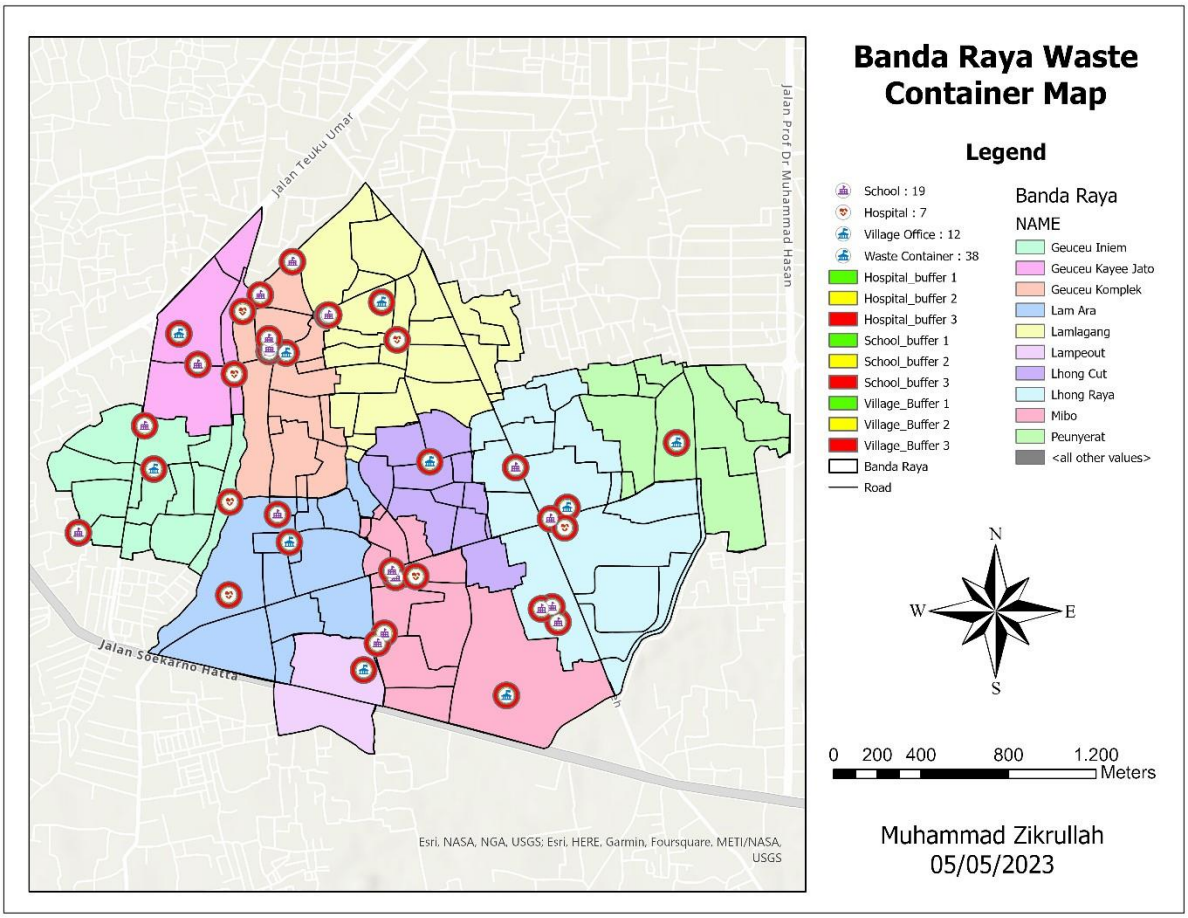

Figure 17: Banda Raya subdistrict Waste Container Map

3.10. Banda Aceh City

This research project may result in 301 waste containers, according to GIS analysis. The waste containers should be placed in each of those three regions. The first location is in the schools. Due to the number of schools and students in this city, 164 waste containers should be placed around them. The Villages are the second section. In the area, 97 waste containers should be produced. Due to their enormous population and volume of trash generation, villages often have the second highest number of waste containers installed. The hospital, which is not a large facility with a lot of garbage, should have 40 waste containers installed.

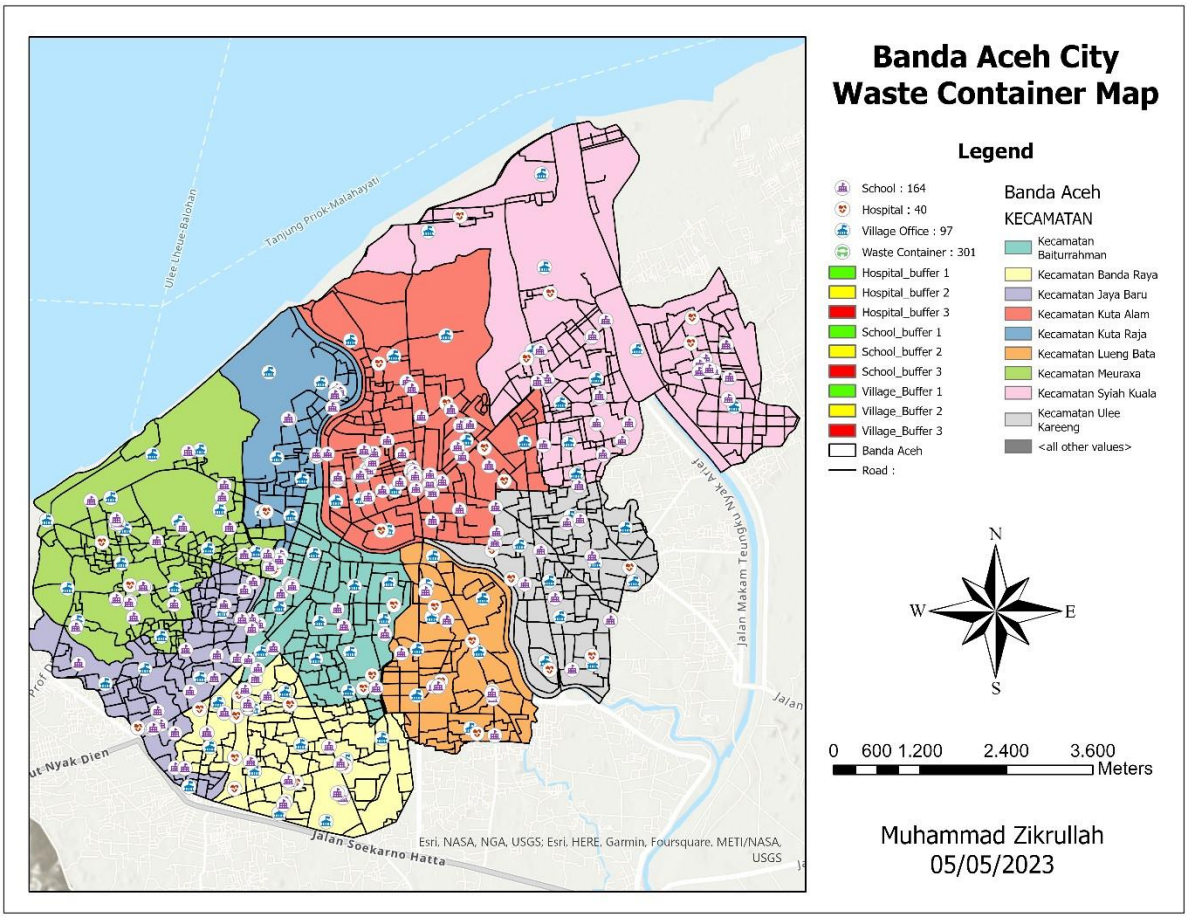

Figure 18: Banda Aceh City Waste Container Map

4. Conclusions

In 2022, Banda Aceh City's population increased by 1.56% to 257,635. The rapid rate of population growth has an impact on the waste products production rate. Globally, the rates of waste generation are rising. In 2022, the world generated 2.24 billion tons of solid waste. Due to growing urbanization and population expansion, it is predicted that the yearly waste creation will increase by 73% from 2020 levels to 3.88 billion tons in 2050 (The World Bank, 2022). Due to the rapid increase in urban population, solid waste management is one of the important and growing potential issues in most countries. Even though there have been several efforts to reduce and recycle waste, solid waste remains the most common issue. The paper analyzed Banda Aceh City's waste container sites and suggested solutions to make them better. For the purpose of achieving this objective, a methodology based on a wide variety of variables, such as population density and waste generation, was developed using GIS technology.

It is concluded that the large number of open dumping sites in Banda Aceh City, which are caused by the improper placement or lack of waste containers in various areas, cause a severe problem for the present solid waste management system. Waste containers are the key components for managing the solid waste problem in a city since a lack of waste container and inappropriate placement encourage individuals to dump their waste in open areas, parking sites, roadside, and dumping in streams. By improving waste management, we improve human health and environmental sustainability in highly populated areas in order to manage the solid waste problem in an urban area.

The application of GIS and remote sensing for mapping Waste containers in Banda Aceh city is well documented. With the use of this GIS application, practically everyone can easily determine the location of the waste container site in Banda Aceh city. The result of the waste container mapping site can be visualized through GIS application, and provide information for decision making. In order to reduce overall transportation costs and save money for the management of Banda Aceh City, it is advised that future research for include a waste container bus track area with waste container reference points distributed appropriately across the map. Additional locations would also give proper information to create and track the most effective Bus route for waste containers.

With the completion of this study, we can now clearly see the next challenge: turning this project into a freely accessible internet resource that can be accessed by anyone and anywhere. The results of this study play an important role because they will help the researcher and the community become more environmentally conscious, and they may also increase our concern for protecting the environment and participating in waste management. As a result, every waste management policy and regulation that is implemented in the future will be in line with the expectations of all parties, including the government and the general public.

The final results of these tools are expected to provide information and resources for local governments, scientists, and average citizens to help enhance the cleanliness and beauty of cities or villages while delivering public services for every level of society everywhere in the world. This is a tool that anybody, wherever in the entire world, may use to contribute to their

own city, subdistrict, town, etc. to help address the rising issue of waste management and promote improved environmental sustainability and human health.

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