

HOTSPOT ANALYSIS OF THE SOLID WASTE GENERATION IN THE PROVINCE OF CAVITE, PHILIPPINES

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ABSTRACT

Cavite had the highest population among other provinces in the CALABARZON region with waste generation of 0.385 kg per capita or 1,514.76 tons per day in 2018. This study determined the population and solid waste generation profile of the different cities/municipalities of Cavite and determined the hotspots of solid waste through GIS-based hotspot analysis. Secondary data gathering was performed to collect the data on the population and solid waste generation profiles of the whole province of Cavite while GIS-based hotspot analysis was performed to determine the solid waste generation hotspots. Based on the results, Cavite had the highest population and waste generation among the other provinces in the Region IV-A CALABARZON. Bacoor City, Imus City, and Dasmarinas City were the most populous cities in the province. The province had average generated solid waste per capita of 0.385 kg/day. The hotspots of solid waste generation in Cavite were generally found in the central hilly and low land areas of Cavite (Tanza, Trece Martires City, Naic, Gen. Trias City, Imus City, Dasmarinas City, Bacoor City, Kawit, Gen. Mariano Alvarez, Carmona) while most of the hotspots for solid waste with 95 percent confidence were found in Dasmarinas City, Gen. Trias City, and Bacoor City.

Keywords: *pollution, urbanization, waste management*

INTRODUCTION

Background of the Study

The Philippines was ranked third in the world among all the countries which contributed to plastic waste in the ocean in 2010. The country contributed an average of 0.28-0.75 million metric tons of plastics per year. It is estimated that around eight million metric tons of mismanaged plastic wastes delivered to the ocean annually (Jambeck et al., 2015). Solid waste generated by the different sectors went to the streams and rivers then ending up to the ocean. Watersheds and land-based sources are considered as significant contributors to solid waste pollution to water environment (Rech et al., 2014; Andrary, 2011). Portions of household wastes are the less-

degradable waste like plastics. These plastic wastes further produce secondary plastics through fragmentation process which accumulate in the rivers and find its way to the ocean, posing a bigger threat in our ecosystem (Andrady, 2011). Plastic production and consumption increased over the past decades due to its several properties such as weight, strength and cost. The increase in the number of plastic accumulations in the environment is caused by their inert slow degradation rate and improper disposal (Mohamed Nor & Obbard, 2014). Plastic debris accumulated on the riverbanks can affect tourism and real estate value (Lebreton et al., 2018). In 2016, it was recorded the waste generation of the country climbed from 37,427.46 tons per day in 2012 to 40,087.45 tons per day in 2016 (Senate Economic Planning Office). Cavite has the highest popula-

tion among other provinces in CALABARZON region with waste generation of 0.385 kg per capita or 1,514.76 tons per day in 2018. The province generated waste classification are as follows: biodegradable (44.65%), residual (31.09%) and recyclables (22.6%). The province is projected to generate 1,787.79 tons per day by 2023 (EMB-CALABARZON, 2018). Cavite province is composed of 7 cities and 16 municipalities with a total of 829 barangays (PEMSEA and Provincial Government of Cavite, 2017). Currently, the total population of Cavite is 4,344,829 with an average population growth rate of 4.12 percent which is higher than the national average of 1.90 percent. Municipal solid waste management problem is the most alarming environmental issues encountered in urban areas around the world, specifically in developing countries due to the rapid urbanization and economic growth and development resulting to increase in solid waste generation (Minghua *et al.*, 2009). Since then, solid waste management became a global concern and it was predicted that emerging undeveloped nations will triple their waste generation (Anbarashan & Padmavathy, 2021). Moreover, identifying solid waste hotspot in a specific geographical location is highly relevant to determine the spatial pattern of waste generation. A hotspot can be defined as an area that has higher concentration of events compared to the expected number given a random distribution of events. Hotspot detection evolved from the study of point distributions or spatial arrangements of points in a space (Chakravorty, 1995). Thus, this study explored the population dynamics and the waste generation in the province of Cavite. Moreover, this developed a model to show how the population contributes to the waste generation per barangay and determine the possible hotspots for solid waste in the province.

Objectives of the Study

The study generally determined the waste generation dynamics in the province through performing GIS-based hotspot analysis.

Specifically, it determined the population and amount of waste generated of the different cities/

municipalities in the province of Cavite and determined the hotspots of solid waste in Cavite through GIS-based hotspot analysis.

METHODOLOGY

Study Site

The province of Cavite was the location of the study. This (14.2456°N and 120.8786°E) is located in Southern Luzon, Philippines. This was selected since the province has a very high number of population as well as waste generation in Region IV-A.

Secondary Data Gathering

Data mining on the population and waste generation of the province of Cavite was performed. The 2020 population data was obtained from the Philippine Statistics Authority, and the Cavite solid waste generation data in the year 2020 was obtained from the Solid Waste Management consolidated report by the Environment Management Bureau.

Hotspot Analysis of Plastic Waste Generation

Hotspot analysis was conducted to determine the spatial clustering of barangays which have the higher chances to generate high volume of waste. This method involved different processes such as collection of data, mapping of clusters using Getis-Ord G_i^* , and estimation of density using the Kernel Density Tool. All spatial processing were carried out in ArcGIS. The mapping of clusters was examined using the spatial statistic hot spot analysis tool from ArcGIS, which uses the Getis-Ord G_i^* algorithm. According to Environmental Research Science Institute (ESRI) (2020), Getis-Ord local statistic is computed as:

$$G_i^* = \frac{\sum_{j=1}^n W_{i,j} X_j - \bar{X} \sum_{j=1}^n W_{i,j}}{S \sqrt{\frac{[n \sum_{j=1}^n w_{i,j}^2 - (\sum_{j=1}^n W_{i,j})^2]}{n-1}}}$$

Where:
 x_j solid waste production (kg/day) per barangay
 Popn population per barangay
 APG_{PC} average per capita solid waste production

hotspot showing the areas with high and low clusters of waste generation was determined.

RESULTS AND DISCUSSION

The Population and Waste Generation of Cavite

For statistically significant positive Z scores, the higher the Z score, the higher would be the clustering of hot spots (high volume of waste generated). While for statistically significant negative Z scores, the lower the Z score, the higher the clustering of cold spots (low volume of waste generated) (ESRI, 2020).

Based on the data shown in Table 1, the top three most populous cities in the province are Dasmarinas City, contributing 16.2 percent to the total population; followed by Bacoor City, contributing 15.3 percent; and Imus City, contributing 11.4 percent. These three cities contributed a total of 42.9 percent to the total population. On the other hand, the Top 3 least populous municipalities are: General Emilio Aguinaldo, Magallanes, and Ternate. Increasing population and urbanization are big factors that can lead to the increasing waste generation in a specific location (Hoornweg & Bhada-Tata, 2012).

Table 1. Population of Cavite as of 2020

CITY/MUNICIPALITY	POPULATION	PERCENTAGE
Alfonso	59,306	1.4
Amadeo	41,901	1.0
Bacoor City	664,625	15.3
Carmona	106,256	2.4
Cavite City	100,674	2.3
Dasmarinas City	703,141	16.2
General Emilio Aguinaldo	23,973	0.6
General Mariano Alvarez	172,433	4.0
General Trias City	450,583	10.4
Imus City	496,794	11.4
Indang	68,699	1.6
Kawit	107,535	2.5
Magallanes	23,851	0.5
Maragondon	40,687	0.9
Mendez	34,879	0.8
Naic	160,987	3.7
Noveleta	49,452	1.1
Rosario	110,807	2.6
Silang	295,644	6.8
Tagaytay City	85,330	2.0
Tanza	312,116	7.2
Ternate	24,653	0.6
Trece Martires City	210,503	4.8
Total Population	4,344,829	100

Hotspot Analysis of Waste Generation in Cavite

Based on the results generated from the solid waste generation hotspot analysis map (Figure 1), most of the hotspots were generally found in the central hilly and low land part of Cavite (Tanza, Trece Martires City, Naic, Gen. Trias City, Imus City, Dasmarinas City, Bacoor City, Kawit, Gen. Mariano Alvarez, and Carmona). The identified hotspot municipalities and cities were also the ones with most population of over 100 thousand individuals (Cavite Ecological Profile). Most of the hotspots for solid waste with 95 percent confidence were found in Dasmarinas City, Gen. Trias City, and Bacoor City, which is also the top most populous city in the province with more than 450 thousand individuals. According to World Bank (2022), population growth and urbanization are directly linked to the increase in annual waste generation specifically in the developing nations. Moreover, most of the generated wastes in this regions tend to be disposed off to the bodies of water.

Municipalities and cities classified as hotspot areas were characterized by having more built-up areas and settlement areas which are directly related to the higher population count and waste generation. Moreover, these hotspot areas are the barangays with high positive Z values with the P value of less than 0.01. On the other hand, cold spot municipalities and cities were characterized by having low population count and have less built-up areas and patches of agricultural

land and other types of land-use (Figure 2). The identified cold spot areas also have a high negative Z score with the P value of less than 0.01 in the future if these cities/municipalities will have an increasing population rate and if the province will not impose strict implementation of the solid waste management act. Insignificant values are those that have low positive/negative Z values (Figure 1).

According to the Environment Management Bureau (EMB) Solid Waste Management (SWM) consolidated report of 2018 as shown in Table 2, Cavite ranked first in terms of solid waste per capita among the other provinces in the region IV -A with an average per capita of 0.385 kg/day. In terms of waste classification, the province produced a high amount of biodegradable waste (44.65%) and produced the least amount of special wastes.

According to the solid waste management survey of waste generation in Cavite (PEMSEA and Provincial Government of Cavite, 2017), the top three cities with the highest amount of waste generated in 2012 are Bacoor (260 tons/day), Dasmariñas (250 tons/day), and Imus (130 tons/day). These cities were also identified as solid waste generation hotspots together with other cities/municipalities (Figure 1). The hotspot analysis map shows that the barangays in Imus City have majority of cold spots due to the total number of barangays within the hotspot map and the spatial weight of each barangay within the city.

Table 2. Solid waste generation of Cavite

PROVINCE	BIODEGRADABLE (KG/DAY)		RECYCLABLE (KG/DAY)		RESIDUAL (KG/DAY)		SPECIAL WASTE (KG/DAY)		TOTAL	AVE. PER CAPITA (KG/DAY)
	Total	%	Total	%	Total	%	Total	%		
Cavite	676,340.26	44.65	342,335.72	22.6	470,938.83	31.09	25,145.01	1.66	1,514,759.83	0.385

Mismanaged solid waste could lead to different problems that will eventually pose an alarm to the public as well as to the environment. These generated solid wastes, if not properly collected, managed, and disposed, will end up to the rivers and eventually end up to the oceans (International Union for Conservation of Nature, 2018). In terms of microplastic pollution in the river, the commonly found macroplastics were packaging, bottles, and bags which were observed in Imus River. Moreover, the plastic flux in the said river is affected by urbanization, elevation, tides, winds, flow rate, and river curvature (Rubio et al., 2022).

CONCLUSIONS

In light with the results, the following conclusions were drawn:

Cavite ranks first in terms of population and solid waste generation among the provinces in Region 4-A. The three cities in the province namely: Imus, Bacoor, and Dasmarinas are the most populous. Cavite has an average generated solid waste per capita of 0.385 kg/day which is the highest in Region 4-A.

Most of the hotspots of solid waste generation in the Cavite are identified in the cities/municipalities found in the central hilly and low land areas of Cavite namely: Tanza, Trece Martires City, Naic, Gen. Trias City, Imus City, Dasmarinas City, Bacoor City, Kawit, Gen. Mariano Alvarez, and Carmona.

RECOMMENDATIONS

The following recommendations were made:

Perform the same study using actual data gathered from the field like solid waste generation and characterization per municipality/city to generate more reliable and localized results. Hotspot analysis may also be performed per type of waste;

Generate solid waste generation hotspot map for each municipality/city to clearly determine the areas of concern for the LGU to take actions on

this matter; and same study can be replicated to other provinces in Region IV-A.

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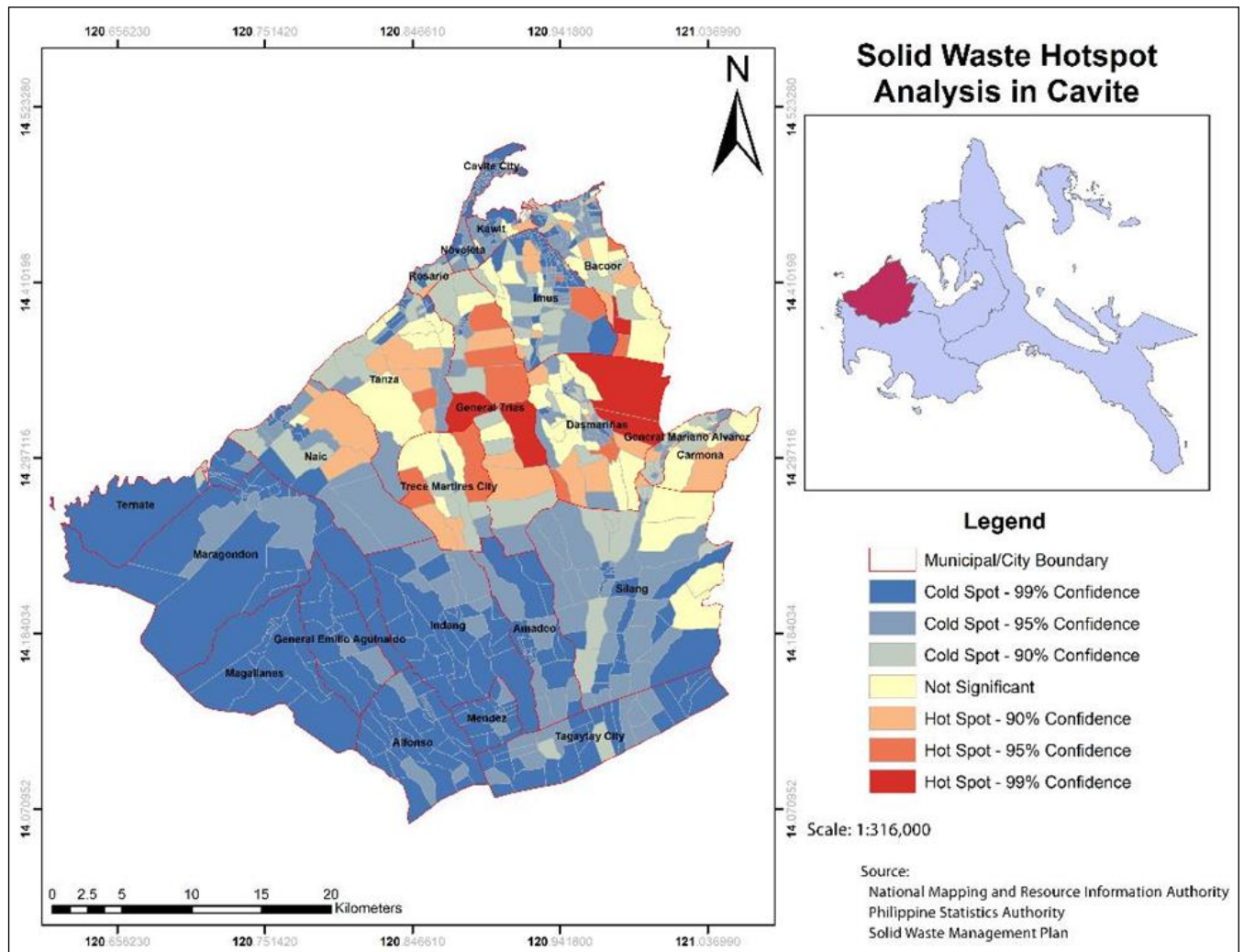


Figure 1. Map of the waste generation hotspots in Cavite generated using hotspot analysis tool in ArcMap (EMB SWM Consolidated Report, 2018)

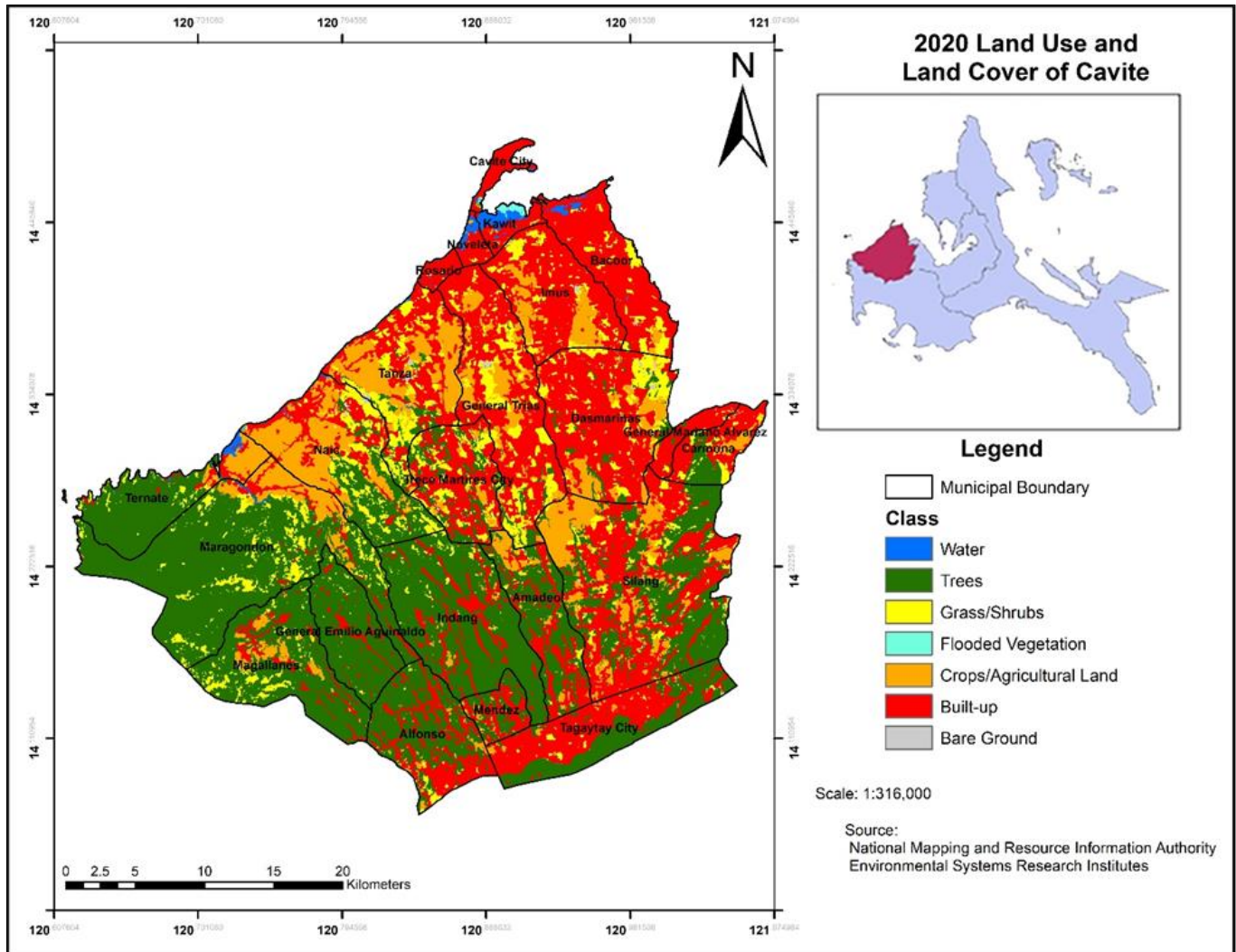


Figure 2. Land use and land cover of Cavite in the year 2020 from ESRI