Waste Management in Jakarta, Indonesia

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1. Introduction

1.1 Capstone

Indonesia produces about 85,000 tons of trash daily, 25% of which is unhandled and is the second largest contributor to ocean waste. In the capital city of Jakarta, 8,765.5 tons of trash are produced daily. This study analyzes the amount of waste produced by Jakarta compared to the number of trash collection centers within the capital city.

The evaluation will be done by analyzing the locations of trash collection centers and their catchment areas. This will allow us to see whether the current waste management capabilities of Jakarta are sufficient to handle the trash produced daily, and identify if additional facilities would be beneficial.

1.2 Background

Around the world, solid waste is a major problem. Humans throw away paper, plastic, foil, and more as they go about their daily lives, rarely giving a thought to where their trash is going, or what it means for the environment. This waste damages the environment and the ecosystem humans rely upon for their survival, making life harder for everyone and everything. Trash that ends up in the ocean and other water sources harms fish and other sea life, disrupting the food chain, the ecosystem, and the food sources that so many humans rely on for sustenance. One way this happens is via the introduction of microplastics into the food and water that humans eat and drink. This is an issue still under study, as the effects of microplastics on humans are not well known until further research is conducted (Hunjun, 2018).

The Great Pacific Garbage Patch is an excellent example of this issue of oceanic pollution. In terms of general ocean pollution, China is the largest polluter, throwing over 8.8 million metric tons into it annually. Indonesia is second, with over 3.2 million metric tons annually (Hunjun, 2018). Trash that ends up in landfills instead can take an extremely long time to degrade, up to a thousand years for plastics.

One method utilized by Indonesia and other nations to combat their waste problem are waste banks (locally called “bank sampah”), expanded upon in the definitions section. These spatially unconstrained locations have tremendous grassroots support and have helped Indonesia’s waste problem (Wulandari et al., 2017).

1.3 Research Goal

This project looks to analyze the trash problem in Jakarta, and see what insights and suggestions can be produced from the analysis. Unfortunately, the problem is too large for a single project such as this to tackle, and the goal of this paper is not to provide a silver bullet. Instead, the intention is to suggest steps or actions that may help Indonesia continue to overcome this problem. By analyzing the density of trash in the city and where it is being deposited for pickup, a better understanding of the state of garbage in Jakarta can be created.

Once this information is investigated, potential locations for additional waste collection facilities can then be suggested in order to assist in the collection of the waste. Additionally, recommendations can be produced for waste bank locations to help sort and process the trash produced each day so it can be managed more efficiently. This paper will detail the steps of this endeavor while also referencing literature and studies to better explain the process and why this study is being performed in the manner detailed by this report. The end goal is to help improve trash management for Jakarta so that the people living there may have a cleaner environment, and to improve the health of the globe at large.

1.4 Location Background

The focus of this investigation is Indonesia's capital city of Jakarta, located on the island of Java. In general, Indonesia has a major problem with waste generation- some landfills are so large that families live inside them, creating poor conditions for health and raising families (Sattler, n.d.). Looking at Jakarta specifically, it is home to approximately ten and a half million people who generate over 8,750 tons of trash each day. Of this massive amount of trash, around 26% is unhandled (World Bank Report, 2018). This massive production of trash, coupled with little municipal management (Gertman, 2016), has lead to much of the refuse ending up sitting in landfills or polluting rivers and the ocean. In short- tremendous amounts of trash produced, coupled with little management, has led to a major environmental concern for Jakarta.

Bantargebang is a poignant example of this problem, both in terms of plastics and non-reusable waste. The largest landfill in Indonesia, it is spread across 270 acres of land, accumulating over 7,000 tons of trash every day. It is rapidly approaching capacity, after which waste will have to be diverted elsewhere, or be piled even higher onto the mountains of debris found within its boundaries (Jakarta Post, 2018).

This paper will cover the problem presented above, first defining various methods used to analyze the issue of waste management in Jakarta, then moving onto the conceptualization of analyzing the trash produced in the city. After exploring the concept of this issue, the actual implementation will then be discussed, following the steps taken to create an output of catchment area service and new waste bank locations.

2. Definitions & Literature Review

2.1 Waste Management

Waste can be defined as any undesirable or unusable material that is discarded by the user. It is trash in short, but it has many subcategories contained within (solid, liquid, plastic, etc). Overall, waste can be classified into two distinct categories- biodegradable and non-biodegradable. Biodegradable means the materials that can be decomposed by microorganisms, bacteria, and the environment. Non-biodegradable means the materials cannot be decomposed by microorganisms, thus prolonging the time it pollutes the planet as refuse. These non-biodegradable materials will then sit in the environment for years if not properly managed, resulting in the refuse problem many countries face today.

Waste management can thus be defined as the collection, transportation, disposal/recycling, and monitoring of waste, which is handled to avoid its adverse effects on the health of people and the environment (Waste Management Resources, 2009). Trash is a severe problem in Jakarta, and Indonesia in general, as there is little organized management strategies or funding for managing the refuse they produce, especially non-biodegradable (Gertman, 2016).

2.2 Waste Banks

Waste banks are a community-based management system in which people get economic incentives in exchange for recycling trash, and are currently a major part of the Indonesian trash management system (Raharjo et al, 2018). They have seen a huge success in the combating trash problem in Indonesia (Wulandari et al., 2017).

These private ventures operate similar to a bank, hence the name, by allowing people to deposit trash to them, and then pays the depositor an amount based on the trash they gave and the monetary exchange rate for it. Found all over Indonesia, their impact is deeper than a simple trash solution. Waste banks encourage economic activity, community engagement, and neighborhood cleanliness, improving quality of life for the people living near them (Wulandari et al, 2017).

2.3 Central-place Theory

Proposed by Walter Christaller in his book Central Places in Southern Germany (1933), Central-place theory states that a geographic area is populated by a central high-end location (such as a major city) that provides specific services to the smaller locations (towns, villages, etc) within its area of influence, as these smaller locations may only have general services. (Encyclopedia Britannica, 2017). An example might be that smaller towns have generalized grocery stores, while the major city in the middle of the geographic zone containing these towns will have ethnic grocery stores or specialty shops that are not feasible in the smaller towns due to their size.

2.4 Catchment Areas

Catchment Areas are the area or zone of influence around a point of interest, based on the Central-place theory. This project uses catchment areas to analyze the relationship between the trash collection points and the population and trash density within each collection point’s zone of influence. Based on this analysis, overserved and underserved areas can then be identified.

Thiessen polygons will be used to generate these catchment areas. This method will allow each collection point to be set as the center of an area defined by the polygon. Any location within each polygon is closer to its associated collection point than to any other collection point (ESRI, 2018). Thiessen polygon areas are created by connecting each point to all the nearest neighbor points surrounding it, then creating boundaries at the middle of these connection lines to generate the boundaries of the polygon.

2.5 Geocoding

Geocoding is the process of taking a written location and spatially locating it to its position on the earth’s surface (ESRI, 2018). Geocoding is extremely valuable as it allows data that is not spatially formatted to become usable by a geospatial program. In this project, an original data layer will be generated by taking the location of the trash collection points in Jakarta and Geocoding the location addresses.

Conceptualization- see appendix A, figure 1

3. Techniques and Methodology

This section will investigate the data obtained to answer the research question, the format of the question and analysis, and finally the steps taken to investigate the obtained data and the methods used to answer the research question. In the appendix, a conceptualization diagram is included to help visualize the starting point of this study, and an implementation diagram to visualize the project steps from beginning to end for the understanding of this research process.

3.1 Data Collection

The key component for any project to become successful is authenticate and accurate data. The data required for this project is the administrative boundaries of Jakarta, the road network, temporary trash collection locations, refuse produced, and population census data. This data is procured from Jakarta Open Data Portal (the official portal from the government of Indonesia), ESRI Open Data, and The World Bank.

3.2 Key Concepts

The two key concepts here are trash catchment areas and optimal waste bank locations. Trash catchment areas are the area of influence around each temporary collection location, indicating their service area. Optimal waste bank locations are the proposed locations to build additional banks, taking into consideration the current collection locations and distance people are willing to walk to deposit their recycling trash.

3.3 Variables

1. Population:

The population is key to this study, as it helps understand the amount of refuse produced per person in a given catchment area. Analyzing the amount of trash produced in each catchment area will then identify the underserved and overserved areas. This data was obtained from ESRI Open Data portal.

2. Trash:

The amount of trash produced each day is one of the key factors in this study. The variable will be used to determine not only the total amount of garbage but also the density of it, which is dependant on the region of Jakarta in which it is being produced. This data was obtained from the World Bank.

3. Collection Points:

Collection points are the locations at which individuals can dispose of their trash before it is then transported to the landfills, similar to dumpsters in other nations like the U.S. For this study the addresses of each point will be geocoded to generate the service area of each collection location. It is a complex method, and if the data is poorly geocoded it can lead to an incorrect understanding of the issue during analysis. Google Geocoding API will be utilized to perform this task. This data was obtained from the Jakarta Open Data portal.

4. Roads:

This data layer contains the road network of the city of Jakarta. It is important to exclude this area while identifying the optimal site for the waste banks, as it would be problematic and dangerous to suggest placing a new waste bank in the middle of a busy street. Data on roads was obtained from the Jakarta Open Data Portal.

3.4 Data Processing

Data processing is one of the most crucial steps in the implementation of this project. Actions such as verify, organize, transform, and extract are performed on the data here, to generate an understandable and actionable output. The following are the series of actions and steps that will be performed on the data for creating this output.

1. Population data:

Using the obtained population data, the population density of Jakarta will be extracted as people per square kilometer according to the different regions. This will then become a reference layer from which other analysis can be performed, such as trash produced per person, and help gauge how many people are living within each collection point's catchment area.

2. Trash Produced data:

This data layer contains information on the total trash produced by the entire city. Combined with the population density of the city, the average trashed produced by individuals in the city can be determined. This average will further be applied to the population of each service area to determine the refuse produced in each service area.

3. Collection Point data:

The collection point data, once geocoded with the code provided in Appendix A figure 10, will visualize the locations of each point in Jakarta. The locations will then be analyzed using Thiessen polygons to generate the service areas of each collection point. The region of Jakarta will then be considered to determine the trash produced within each service area, and then the amount of trash will be analyzed. This will help identify the underserved and overserved areas in the city.

4. Overserved and Underserved Areas:

In addressing the issue of the underserved and, to a lesser extent, overserved areas, the placement of the temporary trash collection locations takes primary importance. The important factors which should be considered for identifying the location of these points are the population it is serving, and the amount of refuse produced in the service area. The application of Central-place theory will help identify the favorable spatial arrangement of the temporary trash collection locations in the study area, while considering population, distance, and refuse produced.

Additional points will be added at the intersections of multiple underserved locations to create a better service network. These revised locations will be used for generating the final catchment areas. Overserved areas will not be altered, as their collection points may be multiple nearby businesses or houses, and thus cannot be compressed or relocated easily. In addition, more collection points that already exist assist in handling the produced trash.

5. Optimal Waste Bank Locations:

Waste banks are an effective method to manage trash and recycling since they are spatially unconstrained, as previously mentioned in the introduction. According to the World Bank, it is recommended to have a bank per 1,000 people (World Bank Report, 2018). Research has shown that people are willing to walk up to 500 to 1000 meters to deposit there recycling trash (Stuguby, 2014 & Bergman, 2017). Using this as a basis, buffers of 500m and 1000m can then be generated in the final catchment areas to help propose optimal locations for the waste banks.

Implementation- see appendix A, figure 2

4. Results, Analysis, and Discussion- (see Appendix A for all output figures and visual aids)

The analysis shows that the current trash situation in Jakarta is extremely varied- the amount of trash produced in the catchment areas ranges from 16 kilograms a day to a quarter million kilograms, and the strain on individual points is also varied, as shown in figure 4, Appendix A. The results of the overall analysis for the basic geocoded collection locations can be seen in figure 6. The starting point of the results and analysis is the original data layer of this study, which is found in Appendix A, figure 3, and generated through the use of the python code in figure 10. These points indicate the physical location of each collection point across the city as logged by the government of Jakarta. From here, the density of the collection points across the districts can be determined (as seen in figure 5 from Appendix A), which assists with a strong visualization of where many collection points are congregated. With these hot spots identified, which are generally located around the central district, cool spots are then also identified. This allows a more quantitative evaluation of where the underserved areas are, and thus where additional facilities should be located.

This quantitative analysis reveals the outer boundaries of Jakarta to be significantly underserved, compared to the inner regions of the city. This is reflected in Appendix A, figure 6, as the largest catchment areas, and thus highest amounts of trash produced, are located around the outer edges of Jakarta, and most of the smallest trash produced values are found around the inner catchment areas. The class breaks for the trash produced values were generated using natural breaks, due to their effective capture of the range of values. Other classifications, such as geometric, grouped the values for the highest class from about 90,000 to 255,504 kgs, which made the problematic areas of trash production and strain appear more widespread than they really were. Natural breaks group the values more effectively, better representing the spread of results across the city. Overall, it appears that the inner portions of Jakarta are served well by the trash collection sites placed throughout the city. By having many points near each other, it allows individuals to easily access a means of getting rid of their trash in a controlled manner, which then prevents it from littering the ground and polluting the waterways.

Figure 7 then takes these observations of density and trash produced and acts on them. Using the density information from figure 5 and the catchment area calculations from figure 6 in Appendix A, suggestions for new collection points can be positioned in an effort to improve the trash management across the entire city. These suggestions are informed by the Central-place theory to better judge optimal placement locations of the collection points. In total, based on the results of this study, 14 points were added around the outer boundaries of the Jakarta to better handle the trash produced in the catchment areas. After rerunning the analysis with the original points and added suggestion points, the results shown in figure 8 in Appendix A were produced using the same class breaks as figure 6.

Figure 8 demonstrates just how effective adding only 14 points to Jakarta can be at creating a more effective trash management system. In figure 6, the highest trash produced value was found in the northwest corner of West Jakarta, with 255,504 kgs of trash being produced within the area each day. After adding additional collection points nearby, and thus splitting the catchment area into smaller sections, the highest trash production value fell by nearly fifty thousand kilograms, down to 206,444 kgs/day. This new high is located in the southeast of East Jakarta, across the entire city from the original highest value. In figure 6, seven catchment areas are classified in the highest class range, which then falls to three in the highest class range after analyzing the impact of the suggested points. By adding these points, the amount of highly underserved areas are cut in half. Overall, the high values, representing underserved, high trash production areas, are reduced and spread out, showing that the suggested points are indeed having an impact on the trash problem, making it easier for the trash to be disposed of properly.

Finally, a parallel analysis was run to display what locations would be effective for waste banks to be located at, with roads removed for more effective placement suggestions. These results can be seen in Appendix A, figure 9. The buffer zones around each collection point indicate walkable distance for individuals to move trash, and especially recycle, from collection points to the waste banks for proper disposal. The buffer of 500m indicates the optimal zone, and the 1000m buffer being acceptable, but not as ideal. This analysis was run only to produce the general suggestion zones and was not as in-depth as the collection location analysis.

One interesting point to note is the similarities and discrepancies between the density of the population and the density of the points, as addressed in figures 3 and 4. The population is most dense in the western and central districts, but the average number of people serviced by an individual collection location is highest in the eastern and northern districts. In fact, the strain on each point, or the number of people serviced by them, in the eastern district is roughly double that of the northern district. Overall, the locations are generally allocated adequately at the district level, as the more densely populated districts have lower population to collection point ratios. However, there are not nearly enough points to adequately service the entire city, as evidenced by the highest strain value being over quadruple the lowest strain value.

This research was not without its hurdles and problems. One major issue is that the suggestions had little quantitative value. Central-place theory is a relatively qualitative idea, and the points were placed according to it, at the intersections of numerous catchment areas with high trash production values. Since these locations were suggested with qualitative, human judgement, there is an implicit level of human error related to them.

A second problem is that the geocoded points only account for those inside the city. There was no information analyzed for possible collection locations outside the district boundaries, which would impact the density analysis and Thiessen creation if points exist outside the city limits.

5. Conclusions & Future Research

From these results and analysis, it can be determined that increasing the number of trash collection points lowers the strain on each CA, as an increase in points divides the catchment areas into smaller and more manageable units, servicing a smaller amount of individuals. Adding merely fourteen collection points across the entire city reduced the highest trash production value by nearly fifty thousand kilograms. This study shows that adding collection locations to underserved areas, particularly around the outer boundaries of the city, will dramatically reduce the overall strain on the waste management capabilities of Jakarta.

Further research can suggest locations of trash collection points based on more quantitative methods, which may have a greater impact on the result. Smaller CA can enhance people’s ability to properly manage trash produced in a catchment area by making it easier for them to access the points, and giving them more options for waste disposal.

Waste banks are one of the sophisticated ways to manage trash, as they are spatially unconstrained, they provide monetary incentives, and are also well accepted by the people of Indonesia, as noted previously. At least 1 waste bank per 1000 people, within walking distance of 500m to 1000m, will significantly reduce landfill inflow and environmental pollution. Future research could identify the exact locations for additional waste banks which would impact the maximum number of people and waste, similar to what this study accomplished for collection points. Running the above analysis, or a similar style, for waste bank locations instead of trash collection locations would accomplish this goal and expand upon the findings of this study and suggested solutions to Jakarta’s waste management issues.

Finally, the data could be analyzed at a finer resolution, such as the neighbourhood or block level, instead of administrative boundaries would generate more detailed results to narrow down what locations are underserved in terms of refuse collection and management.

Appendix A

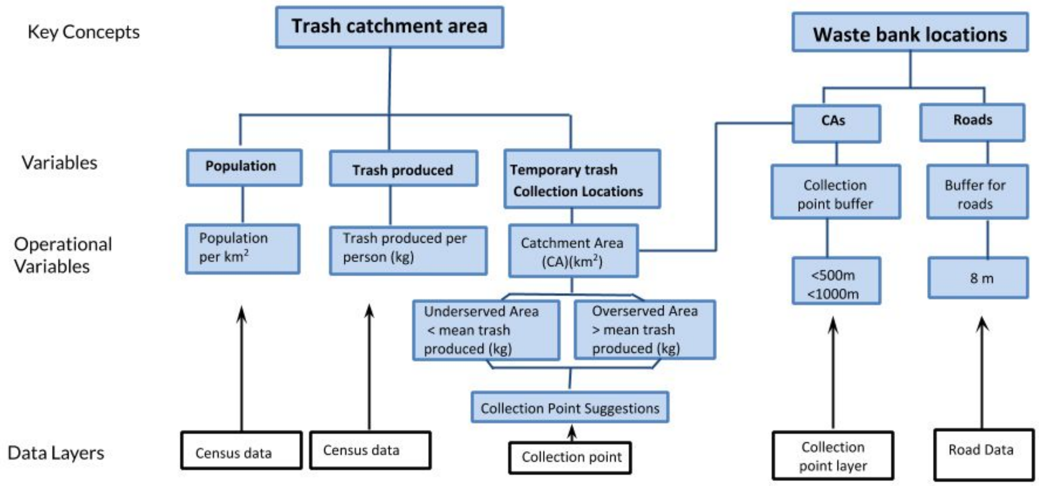

Figure 1- Conceptualization

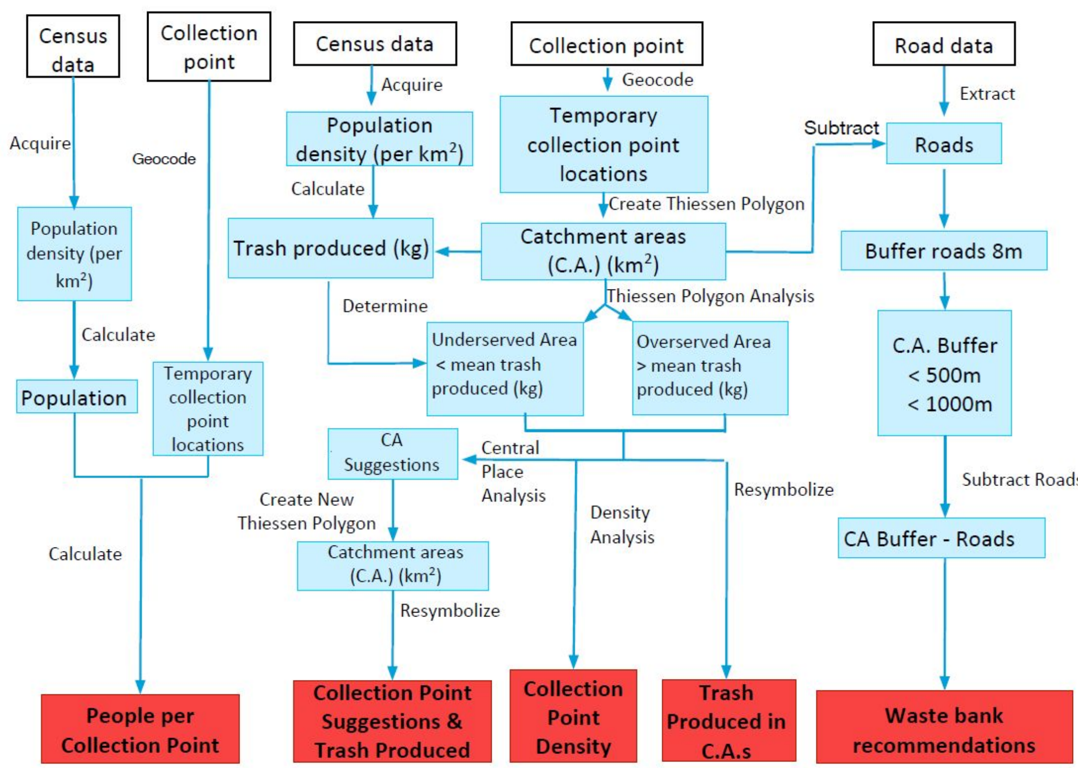

Figure 2- Implementation

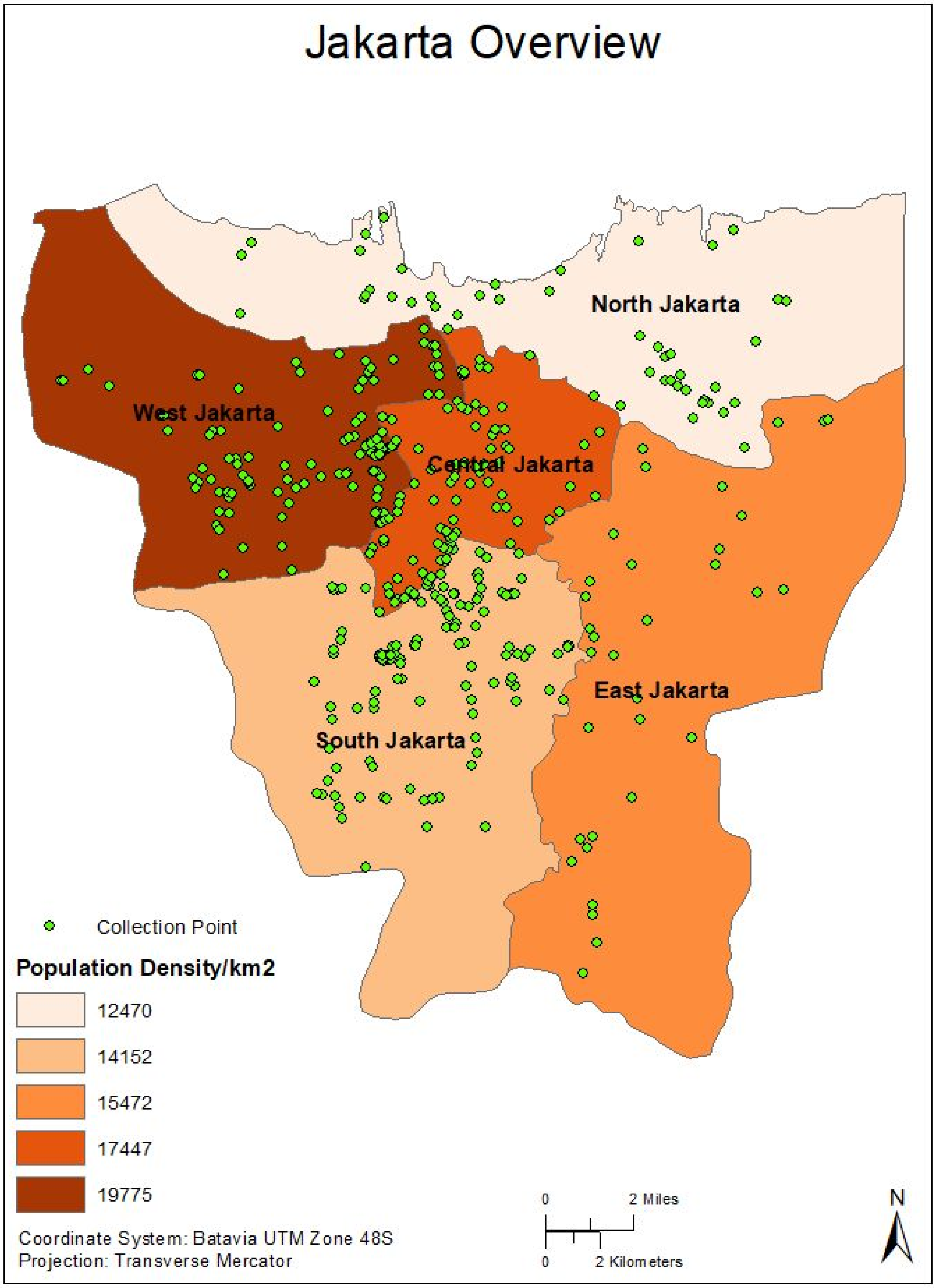

Figure 3- Jakarta Overview And Original Data Layer

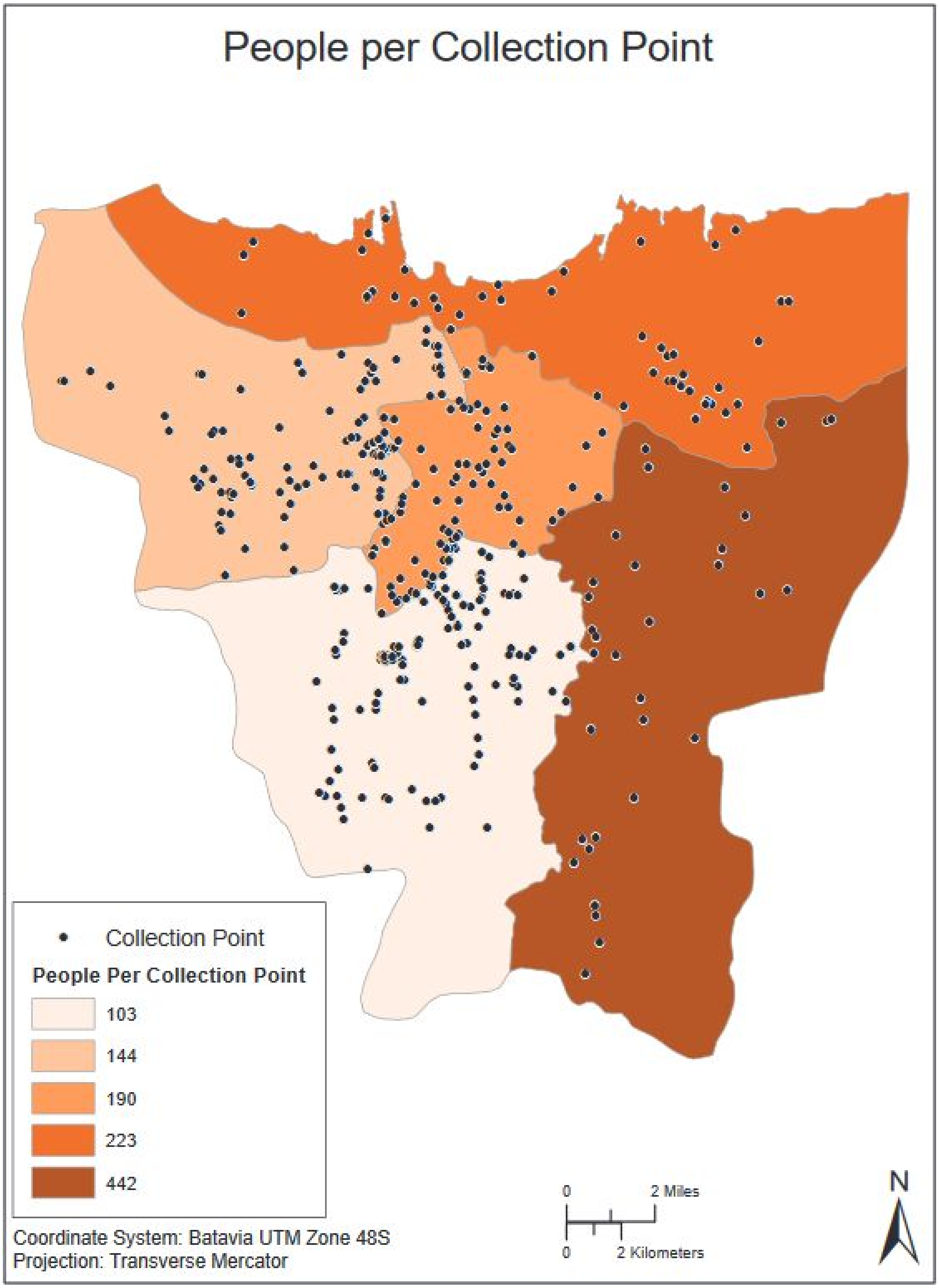

Figure 4- People Per Collection Point

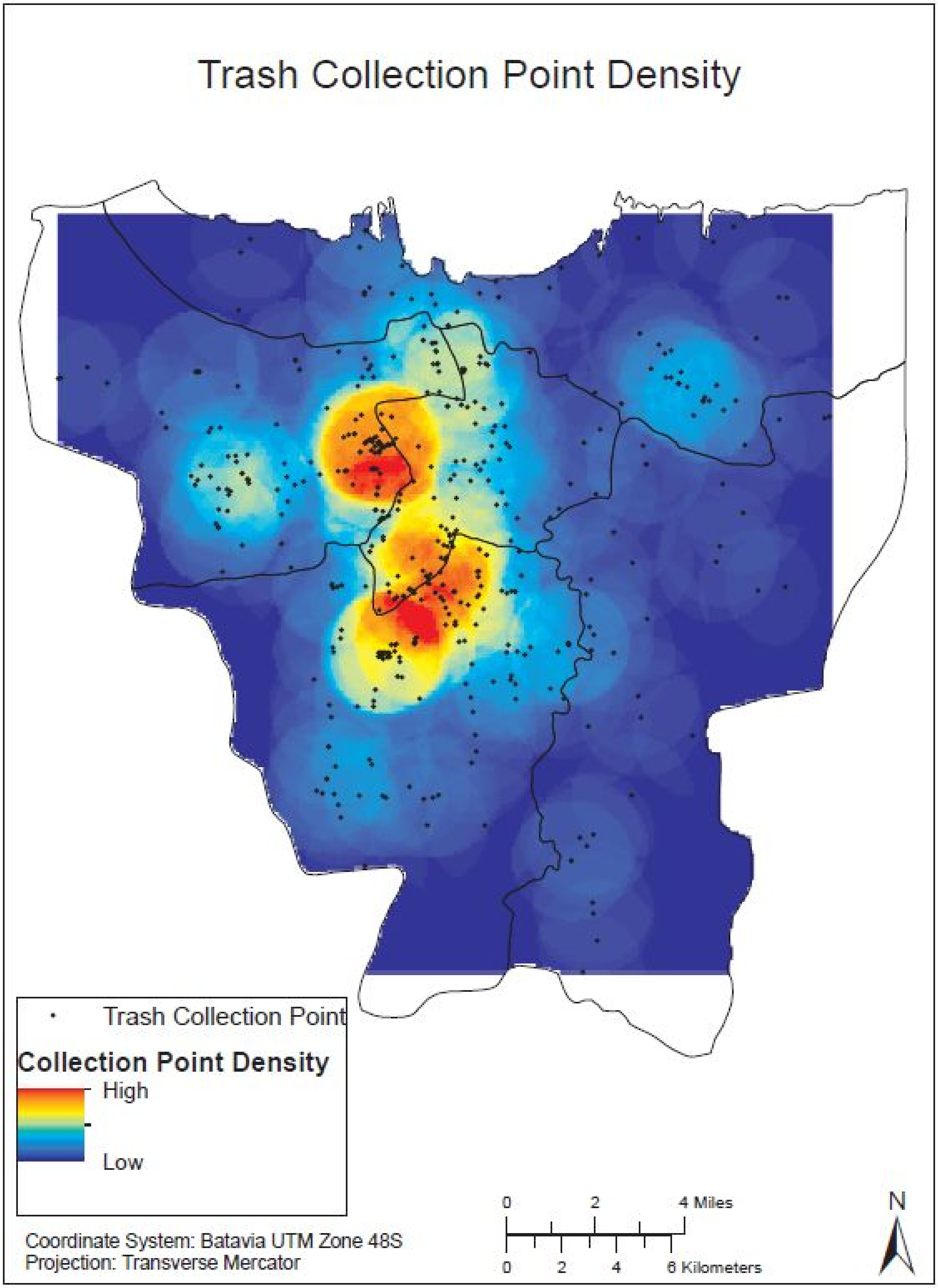

Figure 5- Trash Collection Point Density

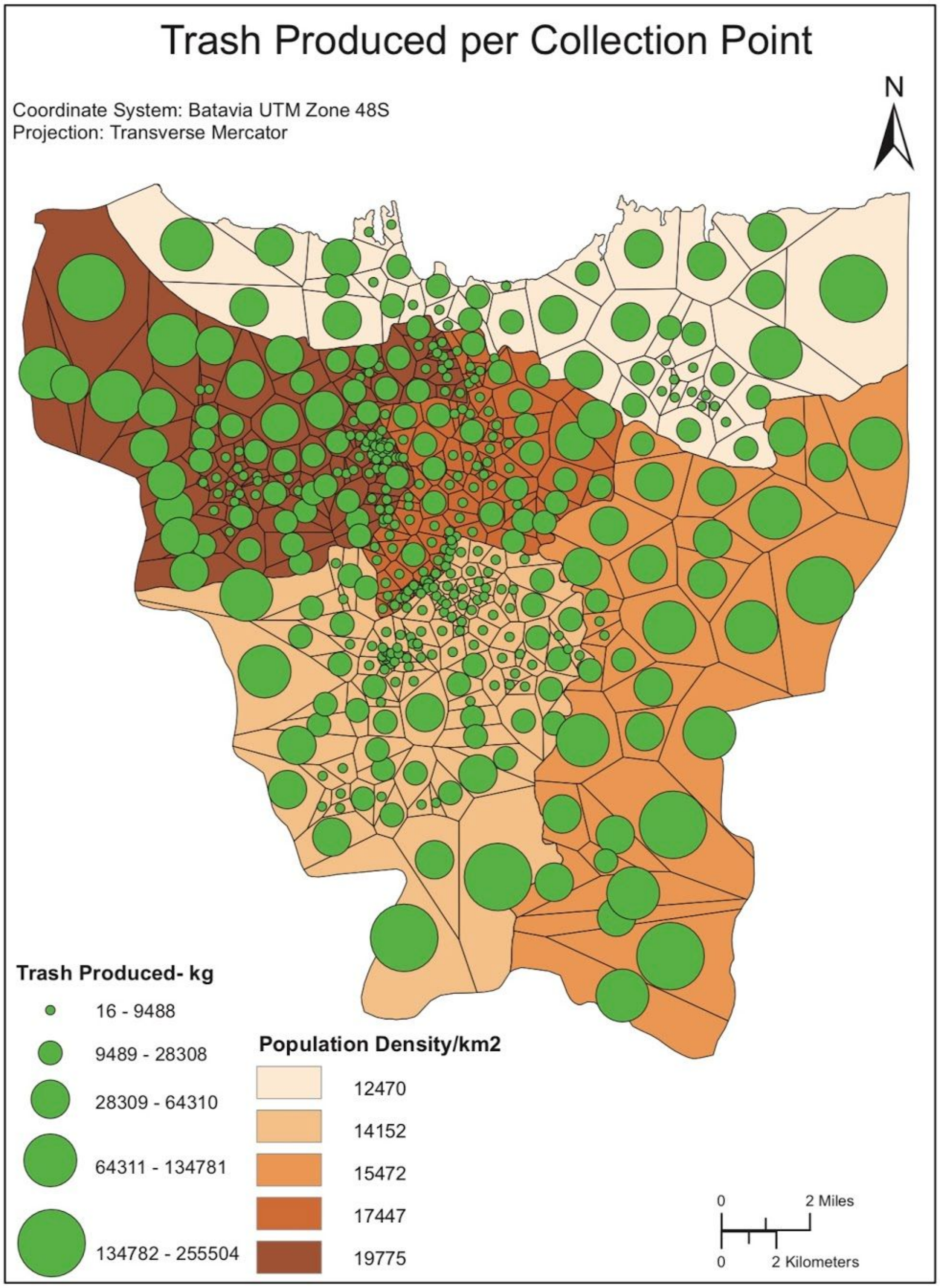

Figure 6- Trash Produced per Collection Point

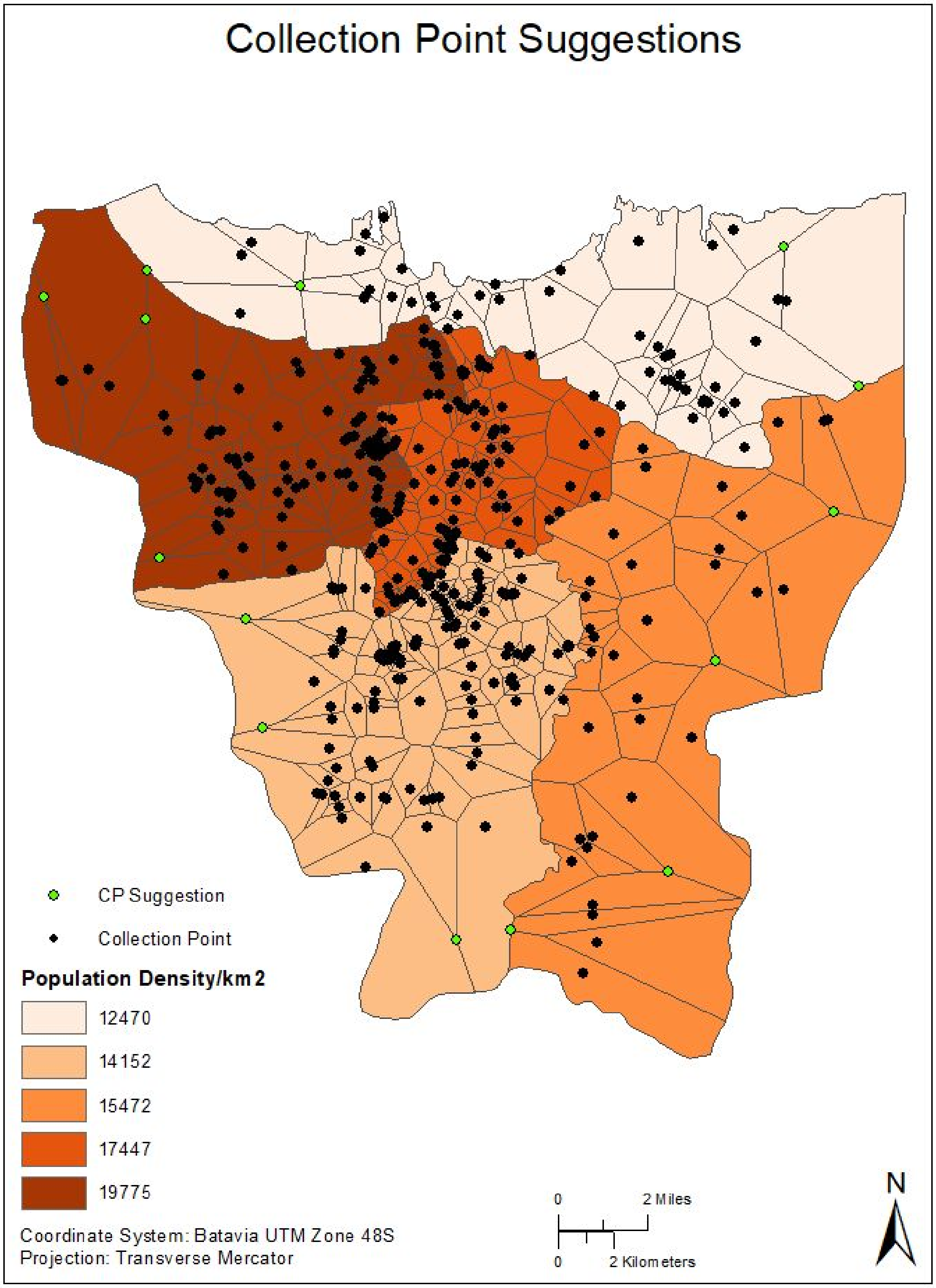

Figure 7- Collection Point Suggestions

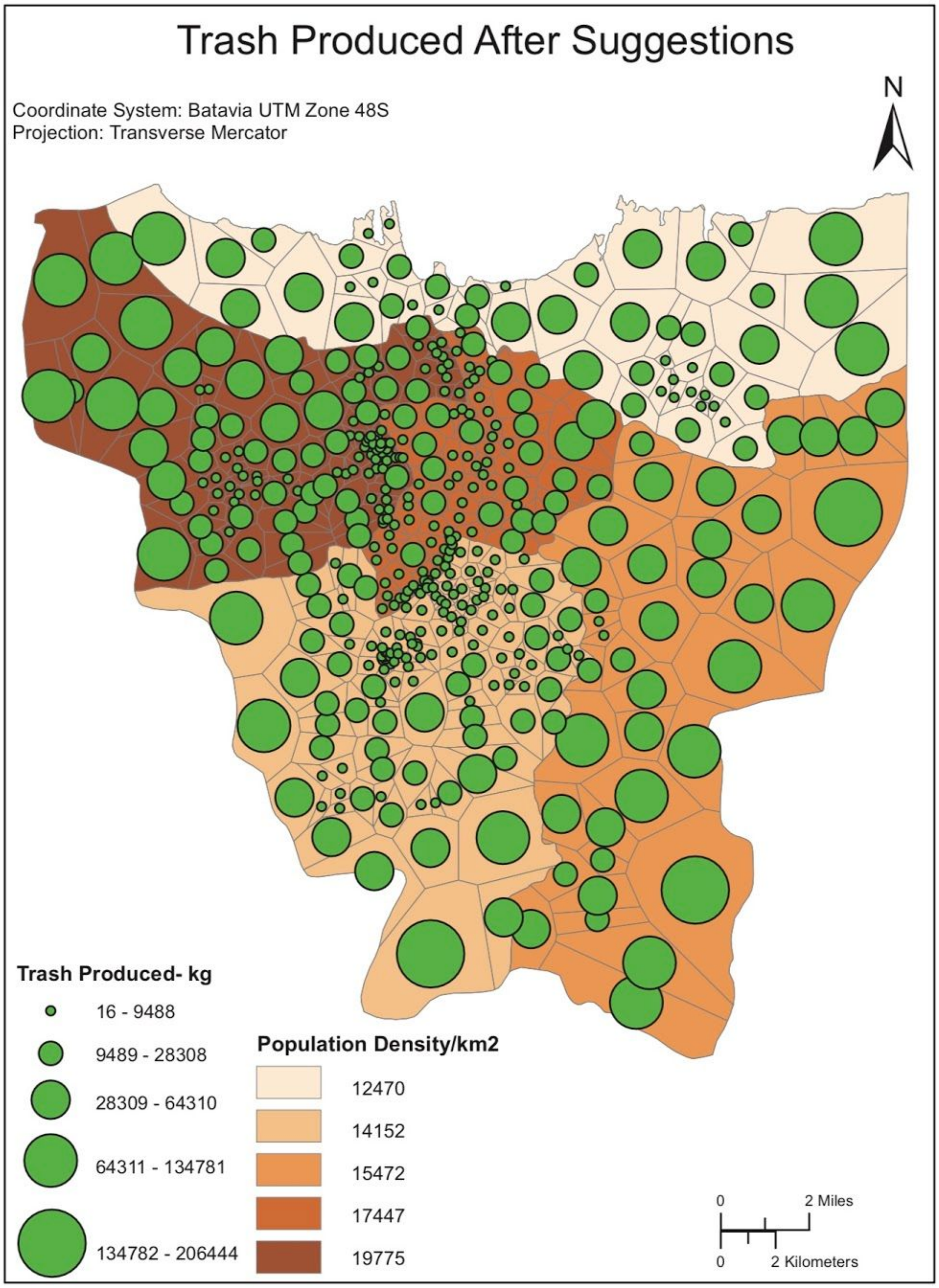

Figure 8- Trash Produced After Suggestions

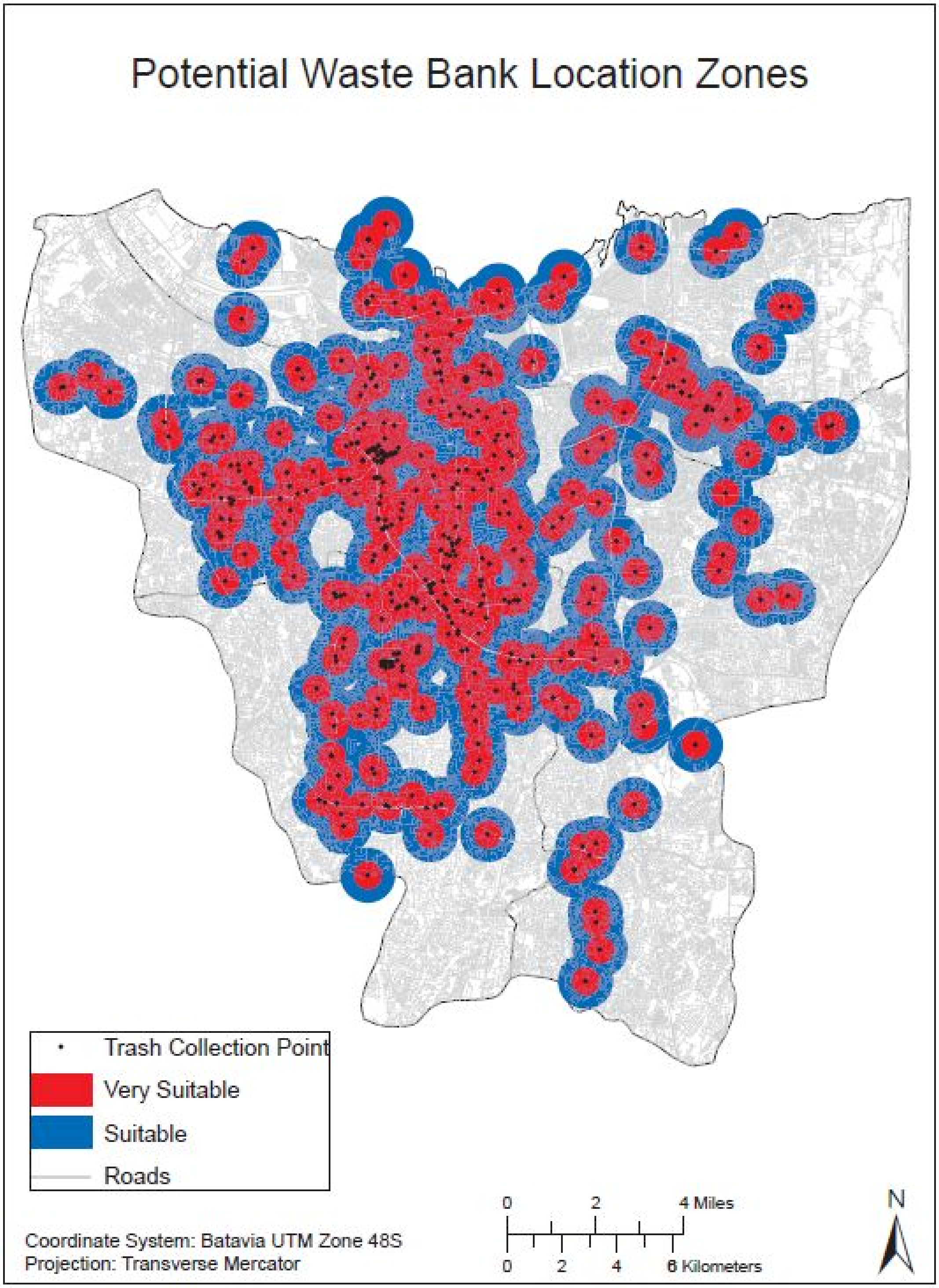

Figure 9- Potential Waste Bank Location Zones

```
import googlemaps
from datetime import datetime
import pandas as pd

#setting key
gmaps=googlemaps.Client(key="AIzaSyCIlI7qyVP9kSdrk0kzshT4wzkbCX2kdYI")

BACKOFF_TIME = 30
# Set your output file name here.
output_filename = 'output2019.csv'
# Set your input file here
input_filename = "Book2.csv"
# Specify the column name in your input data that contains addresses here
address_column_name = "Address"
# Return Full Google Results? If True, full JSON results from Google are included in output
RETURN_FULL_RESULTS = False

# Read the data to a Pandas Dataframe
data = pd.read_csv(input_filename, encoding='utf8')
addresses = data[address_column_name].tolist()

addresses = (data[address_column_name] + ',Indonesia').tolist()
for address in addresses:
    #print address
    geocode_result=gmaps.geocode(address)

    print
geocode_result[0]['geometry']['location']['lat'],geocode_result[0]['geometry']['location']['lng']
```

Figure 10- Python Geocoding Script

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