IMPACT: International Journal of Research in Humanities, Arts and Literature (IMPACT: IJRHAL)
ISSN (P): 2347–4564; ISSN (E): 2321–8878
Vol. 10, Issue 8, Aug 2022, 41–52

SITE SELECTION ANALYSIS OF WASTE DISPOSAL SITES IN MAOMING CITY, GUANGDONG

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Received: 16 Aug 2022 **Accepted: 19 Aug 2022** **Published: 23 Aug 2022**

ABSTRACT

Due to the increasing amount of domestic waste in urban and rural areas, the scientific location of waste treatment points is becoming more and more important issues when local governments plan environmental sanitation construction plans. According to the actual situation of small cities, this study uses ArcGIS software as a tool to analyze the Euclidean distance of residential areas, water systems and traffic networks in Maoming City. Meanwhile, the slope of the elevation imagery is analysis, the land use type and soil type distributions are reclassified. Then, the raster calculator is used to analyzing spatially superimpose for the factors affecting the site selection of the waste disposal point, and the spatial analysis model is established to obtain the final site selection result. The study shows that: firstly, the current situation of the Waste Disposal Sites (WDS) selection location is mainly distributed in the southwest of Maoming City. Secondly, the existing waste disposal points in the city are in a relatively reasonable condition. Third, according to the analysis of spatial distribution, more consideration can be given to the location in Huazhou City in the future. In conclusion, the method of this study can be used for referencing similar to small cities in China.

KEYWORDS: *Waste Disposal Sites (WDS); Site Selection Analysis; Geographic Information System (GIS); Spatial Analysis; Maoming City*

INTRODUCTION

According to the 2020 Annual Report on the Environmental Prevention and Control of Solid Waste Pollution in Large and Medium-sized Cities Nationwide published by the Ministry of Ecology and Environment, in 2019, 196 large and medium-sized cities generated 235.602 million tons of domestic waste and disposed of 234.872 million tons, with a disposal rate of 99.7%. Among the 196 large and medium-sized cities in China, the largest amount of municipal domestic waste was generated in Shanghai with 10.768 million tons, followed by Beijing, Guangzhou, Chongqing and Shenzhen with 10.112 million tons, 8.088 million tons, 7.381 million tons and 7.124 million tons respectively. The top 10 cities generated a total of 69.871 million tons of Municipal Solid Waste (MSW), accounting for 29.7% of the total amount generated in all cities where information was released. According to the National Bureau of Statistics (NBS) and Organization for Economic Co-operation and Development (OECD) data, China's domestic waste production has maintained a growth of about 5% in recent years, and the annual domestic waste removal volume in China was 242,062,000 tons in 2019. As at the end of 2019, there were 1,183 domestic waste harmless treatment sites (plants) with a daily treatment capacity of 869,900 tons and a harmless treatment volume of 240,128,000 tons in municipal cities nationwide. The harmless treatment rate of domestic waste reached 99.2%. China Business Industry Research Institute (CBIRI) predicts that in 2021, China's domestic waste removal volume and disposal volume can reach 267.075 million tons and 269.134 million tons respectively (MEE, 2020).

In addition, China's Gross Domestic Product (GDP) per capita has been rising with the growth of the country's gross national product, yet China's per capita waste production is only 131kg/person, which is still at a low level compared to most OECD countries. Taking mature developed countries such as the UK, Japan, Germany and France as examples, it has now stabilized at around 500kg/person, with the US and Switzerland even reaching over 700kg/person. A regression analysis of China and 26 OECD countries shows that the coefficient of determination between per capita GDP and per capita waste production is also as high as 0.86. For every US$10,000 increase in per capita GDP, per capita waste production will increase by 99.6kg/person (Li, 2018). It is expected that as China's GDP per capita and the living standards of its residents increase, per capita waste production will further increase.

China's industry chain of domestic waste treatment is divided into the middle, upper reaches and the lower reaches, of which the middle and upper reaches mainly include the supply of equipment for domestic waste treatment and collection, classification and transfer. The domestic waste treatment industry is in the downstream of the industry chain, which mainly includes waste incineration disposal, sanitary landfill treatment and other treatment technologies as well as resource recovery (Zhang and Li, 2018). At present, there are three main methods of sanitary landfill, incineration and composting for the environmentally sound disposal of domestic and foreign domestic waste. Among them, sanitary landfills and incineration are the two most important disposal methods. Compared with the incineration method, sanitary landfill is the most important means of domestic waste disposal in China at this stage. In 2019, the amount of urban domestic waste disposed of harmlessly in China was 240,128,000 tons, of which 109,480,000 tons were disposed of in sanitary landfill, accounting for 45.59% of the total amount of all waste disposed of harmlessly, and 121,742,000 tons were disposed of by incineration, accounting for 50.70%. In recent years, the number of sanitary landfills for urban domestic waste and their treatment capacity in China has increased year by year. By the end of 2019, 652 municipal domestic waste landfills had been constructed across the country, with a landfill treatment capacity of 367,000 tons per day.

The way of green, low-carbon, circular development has become the global consensus, is now the era of science and technology revolution and industrial reform direction, and is also the current adjustment of economic structure, the sustainable development of the inevitable choice. The China government attaches great importance to the harmless use of urban household waste and the recycling of resources, and has formulated a series of laws and regulations to encourage and support policies, which promote the rapid development of landfill treatment industry. For example, the 13th Five-Year Plan for the Construction of Harmless Treatment Facilities for Urban Household Garbage, the 13th Five-Year Plan for the development of biomass energy, the Renewable Energy Law, and the Management Measures for the Purchase of fully Guaranteed Renewable energy Power Generation, etc.(Ma et al., 2016).

Against this background, the study of the analysis on selecting WDS is thus very important to improve the solid domestic waste disposal chain in China and is a necessary guarantee for the healthy development of the waste disposal industry.

STUDY AREA

Maoming is located between 110-114°41'E and 21°22'30"N - 22°42'30"N (shown as Figure 1). It is bordered by the South China Sea in the south and Guangxi in the north, and is situated in the tropical to subtropical transition zone. It has a warm climate, abundant rainfall and relatively obvious resource advantages (Yang et al., 2004). The city has 92 towns, 2 pilot development zones and 17 street offices. The city's land area is 1,426 square kilometers and the built-up area of the city is 37.10 square kilometers.

After more than 40 years of construction, the present urban area of Maoming has formed an industrial city with obvious functional zoning. The west of the city is the Hexi industrial zone, with petrochemical, thermoelectric, building materials, leather fertilizer and other industries. The east of the city is Hedong commercial and residential area, which is the place for Party and government organs and commercial residence. The northeast of the city is the official cultural and educational area, which is a relatively concentrated place for large and technical secondary schools. To the south of the city is Maonan Development Zone, which mainly develops commercial and residential areas and light pollution industries. Hexi mixed area is located between the east commercial and residential areas and Hexi industrial areas (Huang, 2014).

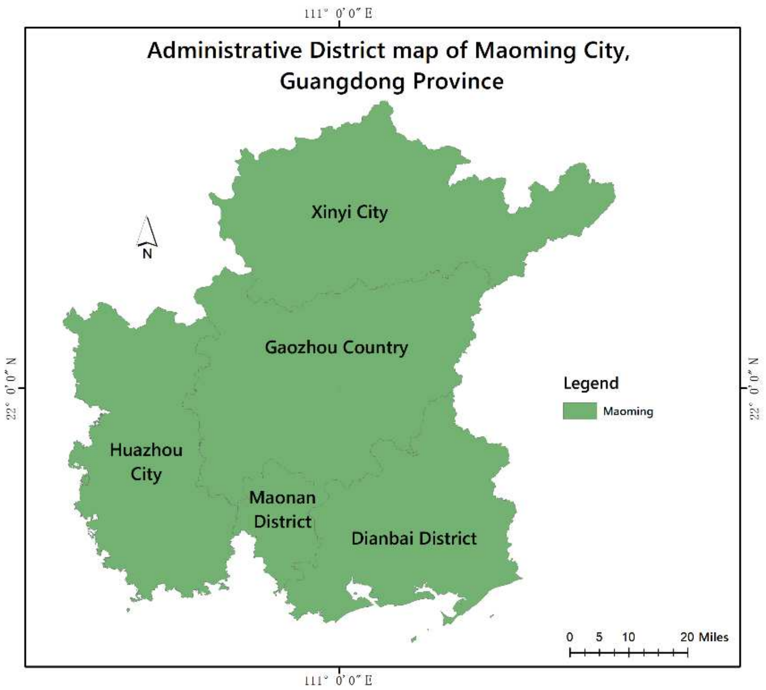

Figure 1: The Map of Administrative District of Maoming City, Guangdong.

Waste disposal is mainly carried out by landfill or incineration after harmless treatment, and waste classification, collection, transport and recycling are carried out within a certain range. In 2020, the city's urban area generated 1.2106 million tons of domestic waste, which will be disposed of by incineration for power generation, with a harmless treatment rate of 100% (Shen and Zhong, 1997). There is one domestic waste incineration power plant (located in Maonan District) and four biochemical pond landfills (located in Dianbai District, Xinyi City, Gaozhou City and Huazhou respectively) in the city of Maoming. At the same time, 110 towns (streets) in the city of Maoming have basically built domestic waste transfer (compression) stations, and 21,113 waste collection points have been built in the city's villages.

According to the environmental hygiene survey of roads, villages, pueblos and waters in various areas of Maoming City from 27 November to 1 December 2017 by the Maoming City Urban and Rural Cleanliness Project's Inspection Team, the appearance of urban and rural areas is generally tidy with the existing domestic rubbish disposal sites in Maoming City becoming increasingly saturated with capacity. Generally, the city is clean, but there is still the phenomenon of rubbish remaining in non-urban township areas for a long time. Meanwhile, due to the long cleaning cycle of many township waste sites, villagers choose to burn their own waste, resulting in more serious air pollution problems. As of 2021, there are three main types of treatment plants (sites) for urban and rural domestic waste in Maoming, including the Green Energy Environmental Protection Power Generation Project (waste incineration and power generation project), the Household Waste Harmless Landfill and the Kitchen Waste Treatment Centre (Hou & Chen, 2018).

PRINCIPLES OF WDS SELECTION

According to the “Domestic Waste Landfill Pollution Control Standards” (GB16889-2008) for landfill site selection requirements, landfill site selection should meet the following rules and principles:

- The site selection of household waste landfill site should be combined with the local actual situation, conform to the requirements of local urban planning, local environmental protection planning, and local environmental sanitation facilities planning, and the landfill site selection should be made according to local conditions.
- Domestic waste landfill site selection should be fully considered the distance must far away from the area in need of protection such as the industrial park, agricultural natural reserves, ecological conservation, historic sites and scenic spots, the drinking water source reserves, mineral development, military reserve, state secrets areas etc.and commonly should not be building domestic waste landfill sites in these areas.
- The site selection of household waste landfill should consider the occurrence of natural disasters, especially the flood disaster caused by heavy rain, and the site selection standard should be able to resist the flood disaster once in 50 years. From the long-term perspective of site selection, the landfill site should be far away from artificial water storage areas such as reservoirs and canals and the planning protection scope, and also consider the distance from the mountain to avoid the occurrence of disasters such as mountain floods and landslides, try to reduce the probability of various natural disasters, and appropriately improve the standard of site selection.
- Domestic waste landfill site should fully consider the characteristics of the local geology, away from the danger zone geological features, away from the active sand dune area, mountain river estuary, mineral waste subsidence, collapse of the earth's crust sag area, frequent seismic activity area, the karst development area, regional geological activities, such as the tsunami prone to instability.
- The location of MSW landfill should consider the distance from urban and rural settlements, and analyze the relationship between MSW landfill location and population from the perspective of environmental impact assessment. Urban and rural residential areas are the main source of household waste production, so the site selection should not be too far away from the source of waste production, meanwhile because the landfill site is easy to produce pollution (e.g. leachate, odor gas) and easy to breed mosquitoes, the site selection should be a certain distance from the source of waste production. It is generally stipulated that the distance between the landfill site and the urban and rural residential areas is 500m. Such a distance can ensure that the landfill site has

the least impact on the surrounding environment, the production and life of residents, and can effectively guarantee the people's health.

- The site selection of domestic waste landfill treatment site should also consider the distance relationship with the airport, traffic (highways, railways, urban trunk roads) and so on. The site selection of landfill sites is planned scientifically from the perspective of environmental impact assessment (Xu, 2018).

METHODS AND ANALYSIS

Spatial Analysis Model

Spatial analysis is one of the most core functions of GIS, and its ultimate goal is to solve various practical problems in geographic space. Through various tools such as mathematical statistics methods, geometric logic operations and algebraic operations, the geospatial database is studied and analyzed (Lu, 2017). There are two main methods of spatial analysis: vector data spatial analysis and raster data spatial analysis. The spatial analysis methods of vector data mainly include buffer analysis, overlay analysis and so on, while the spatial analysis methods of raster data mainly include distance analysis, reclassification analysis and raster calculation analysis. The spatial analysis tools such as distance analysis, reclassification analysis and raster calculation are used to study the geographical problems, which is called geospatial analysis model. In this paper, the spatial analysis method of raster data is used in the site selection of WDS.

Distance analysis is the distance from the raster element to all other raster points according to the needs of the object of study distance for analysis. The Euclidean distance function in ArcGIS software is often used to calculate the Euclidean distance between each raster and the object raster to be processed, and then the Euclidean distance of each object raster to be processed can be graded according to the distance. In this study, this method is used for hierarchical processing.

As GIS stores data with the attributes of the original data, it is generally necessary to use reclassification analysis methods to reclassify and organize the original data collected before processing the data. For this reason, land use types as well as soil types were reclassified during the site selection process for this study.

Raster computing is widely used in mathematical modelling, and is one of the most commonly used data processing components and analysis methods in spatial data analysis. The raster calculator uses function operators and function formulas to perform mathematical model calculations. In this study, the raster calculator is used to spatially overlay the factors affecting the selection of WDS to obtain the final selection results.

Establishment of Basic Information and Multivariate Analysis

According to the "Domestic Waste Landfill Pollution Control Standards" (GB16889-2008) and relevant literature, the following six conditions for the site selection of WDS are obtained.

Condition 1

The waste disposal point should be more than 500m and less than 1000m away from the residential point (shown as Figure 2). Urban and rural residential areas are the main source of household waste production, so the site selection should not be too far away from the source of waste production, and because the landfill site is easy to produce pollution (e.g. leachate, odor gas) and easy to breed mosquitoes (Berisa & Birhanu, 2015; Xu, 2018; Zhang et al., 2020), thus the site selection should be keeping a certain distance from the source of waste production.

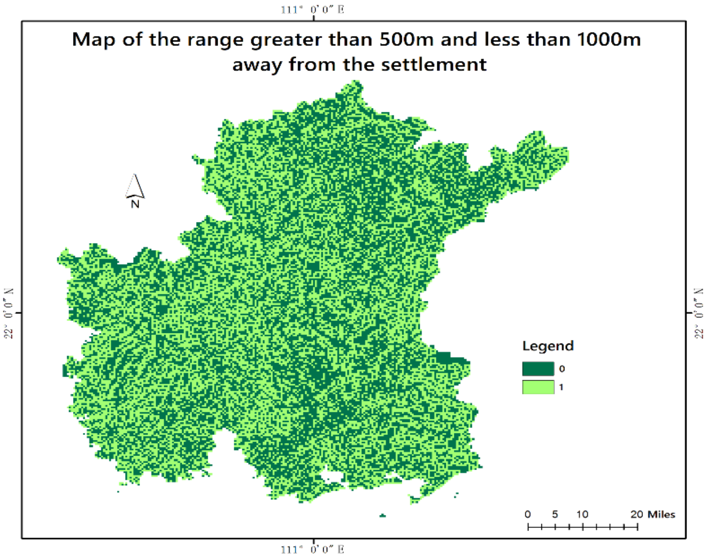

Figure 2: Map of the Range Greater Than 500m and Less Than 1000m Away from the Settlement (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend).

Condition 2

The slope of the waste disposal point should be less than 20° (shown as Figure 3). Terrain slope refers to the degree to which surface elements are steeper and slower. Slopes affect the rate of pollutant infiltration into soil and groundwater, as well as the rate of surface runoff. The larger the slope, the faster the pollutant migration, and the greater the potential harm to water-soil (Al-Hanbali et al., 2011; Xu Hui, 2020; Zhang, 2020).

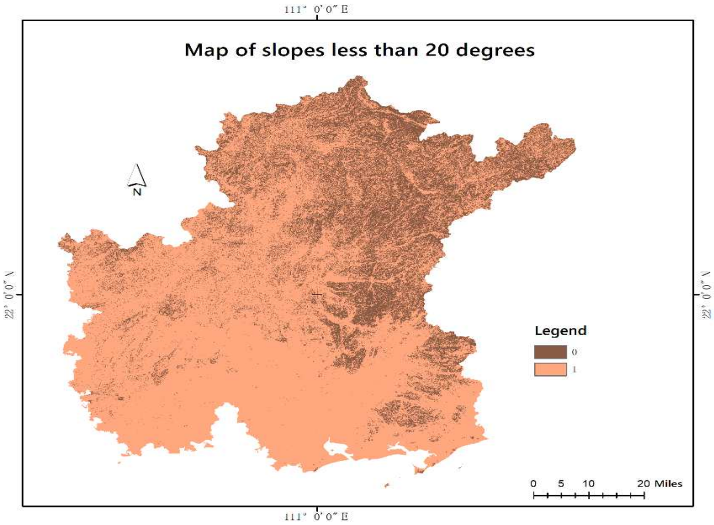

Figure 3: Map of Slopes Less Than 20 Degrees (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend).

Condition 3

The waste disposal point should be more than 50m away from the water system and less than 3000m away (shown as Figure 4). WDS should be far away from water sources to avoid pollution of water resources, such as waste generated during disposal. At the same time, they should not be too far away from water sources to prevent insufficient water supply (Sener et al, 2010; Zhang, 2020).

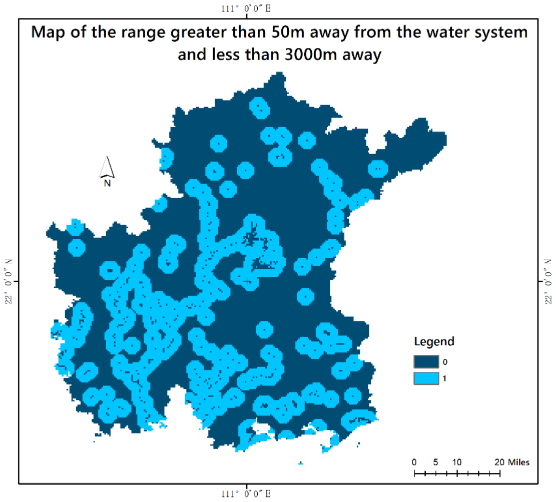

Figure 4: Map of the Range Greater Than 50m Away from the Water System and Less Than 3000m Away (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend; Data Derived from Research Production for this Paper).

Condition 4

The waste disposal point should be more than 60m away from the traffic network and less than 2000m away (shown as Figure 5). Considering the efficiency of waste disposal and investment cost, the transportation distance of the selected site should not be too far. However, in order to prevent the construction of the site from affecting traffic, the distance of the selected site from the traffic network should not be too close (Isard, 1956;Zhang, 2020).

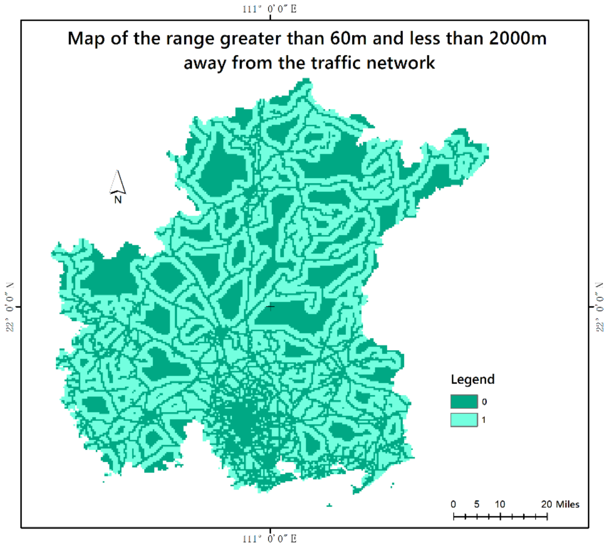

Figure 5: Map of the Range Greater Than 60m and Less Than 2000m Away from the Traffic Network (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend; Data Derived from Research Production for this Paper).

Condition 5

Land use type refers to the land resource unit with the same land use mode, which is divided according to the regional difference of land use, and is the basic regional unit reflecting the land use, nature and distribution law. It is also a variety of land use categories with different utilization directions and characteristics formed by human beings in the process of land production and construction. Therefore, according to the artificial surface, grassland, forest, wetland, cultivated land, water area and sea area, the values of 7, 6, 5, 4, 3, 2 and 1 are assigned respectively (shown as Figure 6) (Zhang, 2020; Sisay et al., 2021).

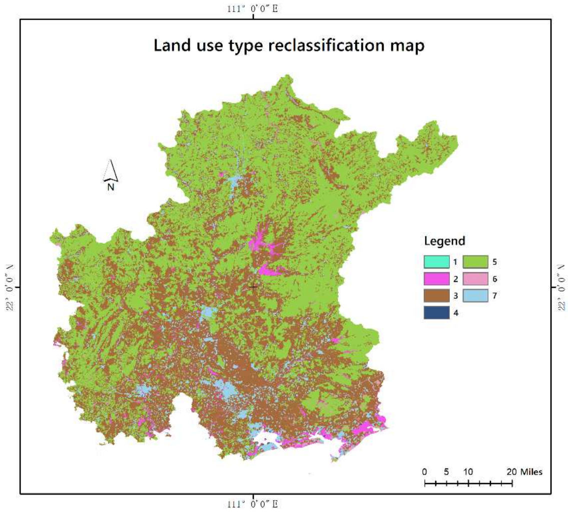

Figure 6: The Reclassification Map of Land Use Type.

Condition 6

Soil type influences the vertical transport of pollutants into vadose zones and the purification of pollutants by soil. Generally, when the soil particles are fine, the amount of infiltration and the rate of pollutants will be reduced, so that the aquifer is not easily polluted (Kapilan & Elangovan, 2018; Xu, 2020). Thus, this study according to the different kind of soils, such as Mollic Greyzems, Gleyic Greyzems, Folic Histosols, Urbic Anthrosols, Luvic Kastanozems, Umbric Leptosols, Glossic Chernozems, Eutric Cambisols, Ferralic Cambisols, Calcaric Arenosols, Cambic Arenosols, Ferric Luvisols, Acrisols, Ferric Acrisols, tHaplic Gypsisols, Gelic Cambisols, Gelic Leptosols, assigning the classify value as 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 respectively (shown as Figure 7).

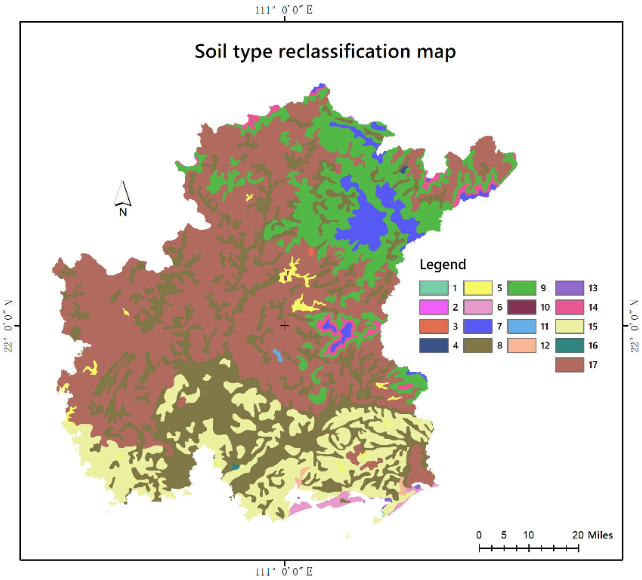

Figure 7: The Reclassification Map of Soil Type.

A raster calculator was used to spatially overlay the above six factors affecting the selection of WDS to obtain the final selection results. The specific GIS spatial overlay calculation formula is as follows. Locate (final site result) = "jiaotongluwang602000" (2000m>waste disposal site >60m from transport road network) & "cunzi1000500" (1000m>waste disposal site >500m from residential site) & "podu20" (20°>slope of the location of the waste disposal site) & "shuixi503000" (3000m>waste disposal site >50m from water system) & "turangleixingchong" (soil type reclassification) & "tudiliyongchong" (land use reclassification). The final map of the distribution of sites for WDS was generated (shown as Figure 8), and it can be seen from the map that the areas where the sites were found are basically located in the south-western part of Maoming City.

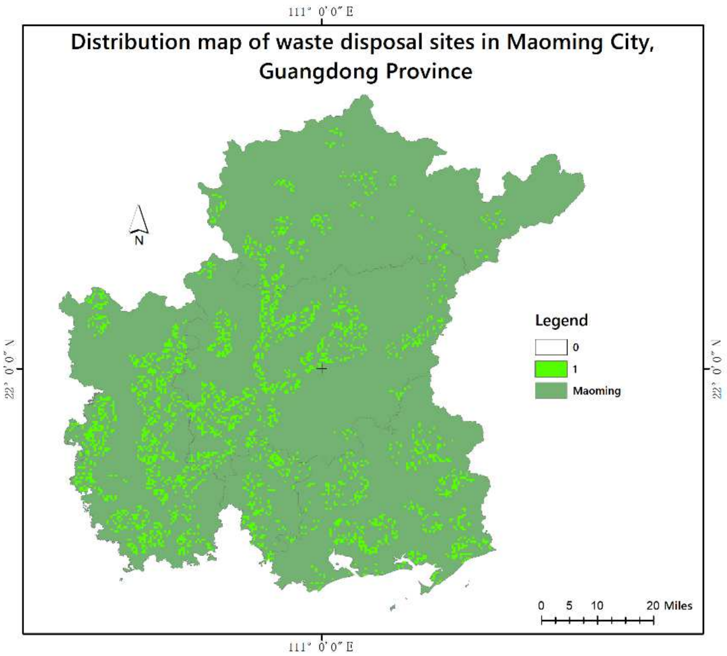

Figure 8: Distribution Map of WDS in Maoming City (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend, that is, the Range of 1 is the Range of the site Selection of the Waste Disposal Point in Maoming City).

Through a subsequent network survey, the names of existing WDS in Maoming (e.g. Genzi Yuanba Food Waste Harmless Treatment Station, Xinyi City Urban Living Waste Landfill, Maoming Binhai New Area Living WDS, Maoming Jintang WDS, Maoming Dianbai District County Living Waste Comprehensive Treatment Plant, Maoming City Landscape Affairs Centre Xinpo Green WDS), its locations and coordinates were counted, using software export them as dBase files, and then subsequently import them into ArcGIS (shown as Figure 9). From Figure 9, it seen that the existing WDS locations in Maoming City match with the site selection area found in this study, and according to the condition model established in this study, it shows that its existing WDS locations are in a more reasonable condition state. In addition, it was found that there are many eligible sites in Huazhou City, but of the five administrative planning regions in Maoming City, Huazhou is the only one that has not yet built a WDS.

Figure 9: Distribution Map of Existing WDS in Maoming City (0 is the Range of Non-Compliance and 1 is the Range of Compliance in the Legend, that is, the Range of 1 is the Range of the Site Selection of the Waste Disposal Point in Maoming City).

CONCLUSION AND DISCUSS

This study establishes six principles based on "Domestic Waste Landfill Pollution Control Standards" (GB16889-2008), and uses the GIS spatial calculator for overlay analysis to extract feasible landfill sites. Based on this, the following conclusions were obtained through the data collection and analysis of this study, which are summarized below.

- The area where the WDS are located is basically in the south-western part of Maoming City.
- The location of existing WDS in Maoming is in a more reasonable condition.
- In terms of the site selection, according to the analysis of spatial distribution, more consideration can be given to build in Huazhou City in the future.

While the research in this paper is a fundamental and important part of the selection of WDS in Maoming, there are many other important details and aspects of WDS construction that need to be discussed. The results of the sitting area calculations show that Huazhou City, one of the five administrative regions of Maoming City, has more sitting areas than any other city, but in reality it is the only city that without built a WDS, whether the actual situation is not suitable for the establishment of a WDS is open to question. As population density is the most intuitive measure of whether a WDS should be built, the sixth census was collected to calculate the population density of each administrative district, as shown in Table 1.

Table 1: Number and Population Density of the Sixth Census in the Five Administrative Regions of Maoming (Data Derive from the National Bureau of Statistics)

Area	Number of People in the 6th Census (Persons)	Population Density (Persons/m^2)
Maonan District	820821	0.00156
Dianbai District	1218716	0.00063
Xinyi City	913708	0.00030
Huazhou City	1178809	0.00049
Gaozhou Country	1288665	0.00038

According to Table 1, the Huazhou city's population density is the third highest in the city, which means that it has a certain population density, it also has a certain amount of domestic waste. Future research on this issue will then need to consider and analyze other factors in more depth (e.g. wind speed, wind direction, rainfall, rock formations, groundwater distribution, normalized vegetation index, willingness of residents, etc.). In addition, the factors selected in this paper are based on factors that can be quantified by GIS, while some of them are not available and can only be eliminated or replaced. These situations can therefore be optimized in future studies in order to provide a more rational basis for the selection of WDS in Maoming.

ACKNOWLEDGEMENTS

The author is grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment (No.2019rc098), Peoples R China under Grant No.702-519208, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

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