Spatial suitability for selecting a site for a plastic recycling facility to enhance bitumen, using remote sensing techniques and geographic information systems: A case study of the visitors' route to Karbala

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Abstract

In light of the increasing challenges posed by climate change and environmental crises, there is an urgent need to develop sustainable strategies that focus on improving the quality of bitumen, the basic component in the asphalt industry. This study aims to explore the use of remote sensing and geographic information systems (GIS) techniques to identify ideal places to set up plastic recycling facilities. Studies indicate that adding materials such as polyethylene terephthalate (PET) to bitumen improves its physical, mechanical, and chemical properties, especially in high-traffic roads such as city entrances and intersections. The exploitation of plastic waste accumulated during religious visits in Karbala in general and the Arba'een pilgrimage in particular for recycling is an example of making use of resources in a sustainable manner, especially in strengthening infrastructure. This study is consistent with Iraq's 2030 vision for sustainable development. Since 2016, the Iraqi government has adopted the 2030 Sustainable Development Goals and has taken serious steps to implement them. Key criteria for site selection include: proximity to sources of plastic waste, availability of basic infrastructure such as roads and public facilities, and compliance with local and national laws and regulations, including labor and raw materials, a deciding factor. The environmental impacts of the facility and the ability to expand to accommodate the increasing demand were also taken into account. The project takes advantage of precise spatial analyzes provided by satellite images and GIS tools, to study the geographical and environmental influences that may affect the effectiveness of recycling operations. Environmental indicators are also used to evaluate the environmental impact of each potential site and determine the economic benefits of each option. This research represents

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Semi-Annual Scientific Journal www.arbnj.com Volume 2, Issue 2, Part 7, Year 2

an important step towards achieving more sustainable use of resources and improving the quality of materials used in infrastructure, which supports efforts to preserve the environment and enhance economic efficiency.

1-Introduction

Geographic Information Systems (GIS) are systems that create, manage, analyze, and map all types of data. GIS links data to a map, combining location data (where things are) with all kinds of descriptive information (what things are there). This provides a basis for mapping and analysis used in science and in almost every industry. GIS helps users understand patterns, relationships, and geographic context. Benefits also include improved communication and efficiency as well as improved management and decision making. In the context of Iraq's pursuit of achieving the sustainable development goals for the year 2030, which the government began adopting since 2016, the importance of this study lies in its being one of the few studies on waste dump sites in the city of Karbala and the first to use Geographic Information Systems (GIS) technology, spatial analysis, and data. Satellites to choose the best locations to create landfills according to health conditions and standards in the city under certain health conditions that serve the environment and citizens alike. Plastic waste constitutes a major burden on urban environments, as the increase in the crowds of millions of people in the city of Karbala, especially the Arba'een visit, which according to statistics reached 21,198,640 million visitors, the expansion of residential areas and their extensions, the rise in living standards, economic growth, the development of industries, and the limited

possibility of tracking waste in terms of... Its size, transportation, and disposal lead to the high volume of waste and the problems associated with it. Waste management is considered one of the biggest challenges facing municipalities in various cities of the world, because poor waste management leads to great dangers to the environment and the population. The city's success in managing this waste is a good indicator of the ability of institutions and organizations to work together to sustain the urban environment. The city of Karbala has recently been suffering from the most dangerous and widespread phenomena. The high prevalence of plastic waste in general has significant impacts on the city and its residents. Therefore, the testing process to choose a healthy and ideal plastic recycling facility location is not an easy process. Finding the best locations requires taking into account an entire geographic area and criteria, excluding unsuitable locations according to specific principles, and identifying the most appropriate locations. This study aims to promote the use of plastic waste in improving bitumen, which is vital for infrastructure and road development. Bitumen, the primary ingredient in asphalt, can be significantly enhanced by the addition of recycled plastic waste, increasing its durability and lifespan. Choosing the best locations to establish plastic recycling facilities requires a comprehensive view of the geographical area and the application of specific criteria that include distance from roads, urban areas, and water sources, and selecting lands with a low slope. This process, based on advanced spatial suitability analyses, aims to determine the optimal places to establish these facilities to achieve environmental sustainability and the required industrial development.

Semi-Annual Scientific Journal www.arbnj.com March 2025 - Ramadan 1446

2. The use of polyethylene terephthalate cycled and organic bentonite hub to improve the properties of asphalt

The study is about the modified down material, which is characterized by being higher, more durable, resistant, and more endurable.To change in temperature, especially in hot climates, where a rise in air temperatures leads to An increase in the flexibility of asphalt and thus the emergence of many well-known road problems such as rutting Roads are a depression in the road surface in the form of grooves that extend longitudinally and appear in paths

Vehicle tires, and bleeding (bleeding), which is an upward transfer of asphalt binder materials, where they form a layer Sticky on the surface, and thermal fatigue cracks, where when they change. Temperatures in the surface layer produce, due to repeated cycles of temperature change, longitudinal cracks and Transverse, which are known as thermal stress cracks . The additives used in preparation .The study samples determined the cohesion and hardness of the asphalt bond materials by conducting a number of tests .It is used to diagnose the properties of asphalt, such as the penetration test at C25◦ and to examine it Softening point test, ductility test, and testing the sensitivity of asphalt to changes in Temperature susceptibility of bitumen found that the results obtained It indicated a significant improvement in the specifications of the asphalt bond material by adding both plastic materials and Clay together compared to models prepared by adding plastic only.

3-Study area

The city of Karbala is located in the Karbala Governorate in Iraq. It is located at latitude 32.62 and longitude 44.02, and rises above sea level by 32 meters. It is located 88 kilometers southwest of the city of Baghdad, and is connected to it by railway lines. In addition, it is located Near the western bank of the Euphrates River. As for the geographical location of the city of Karbala, it is located in central Iraq. It is approximately one hundred kilometers to the south from the Iraqi capital, Baghdad. It is bordered to the south by Najaf Governorate, to the east and northeast by Anbar Governorate, and to the west and northwest by Babylon Governorate. The city is located next to the Euphrates River. It is famous for its greenery, orchards, and palm trees. The city of Karbala is dominated by a desert climate, where temperatures rise relatively in the summer, sometimes reaching around 45 degrees Celsius at midday. However, in the winter, the temperature drops to zero degrees on some winter nights. As for rain, the city is affected by the desert climate. Because it is exposed to the desert and also to the alluvial plain from the east. The city witnesses religious visits throughout the year, and perhaps one of the most important visits that the city witnesses is the Arabian visit, which is considered one of the religious social and human occasions and rituals that are practiced on the twentieth of the month of Safar of every year according to the Hijri date, and given the religious and emotional characteristics of this million-strong demonstration. It has contributed to igniting thought that encourages volunteer and institutional work to an extent that exceeds all global institutional capabilities in this field. Over thousands of kilometers and from all directions leading to Karbala Governorate, and throughout the days of performing the rituals of the visit, we find old people, young men,

women, men, and even children, in processions, service bodies, government departments and institutions, and thresholds. Holy places, civil society organizations, and the media, who are in a tireless and continuous movement, are making exceptional efforts and spending huge sums of money, free of charge, to be used in the service of all visitors and expatriates from inside and outside Iraq. As shown in the figure (1).

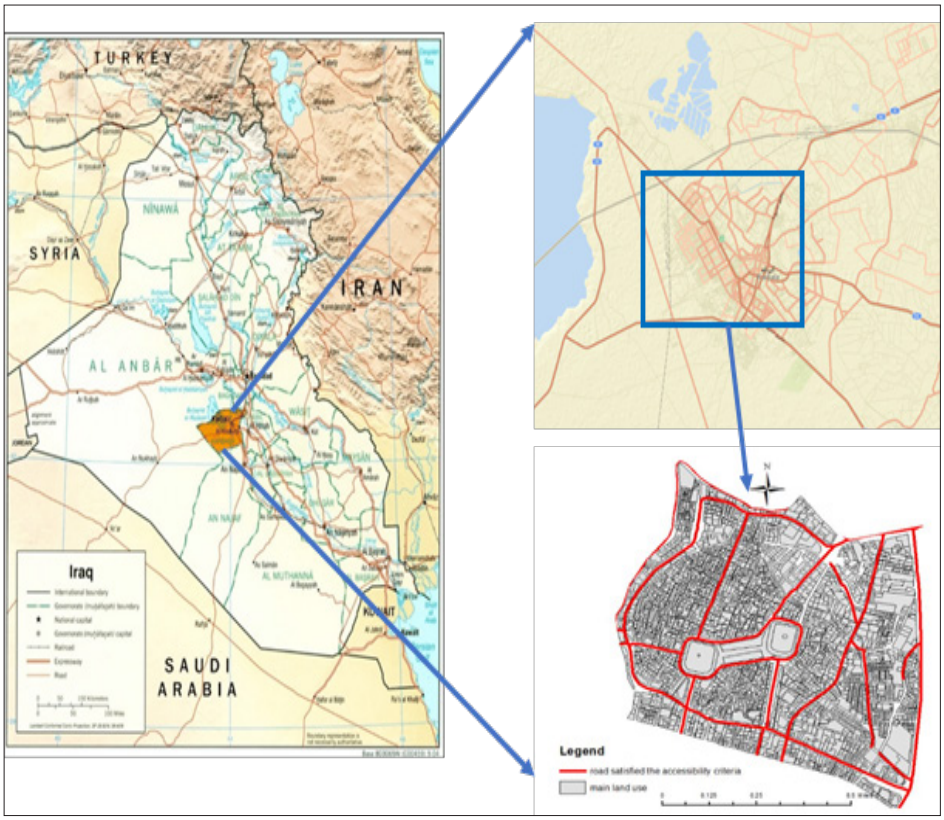


Figure (1): The geographical location of the Holy Karbala and the routes taken by visitors during the Arba'een visit: (Source: Researcher's work and General Authority for Geological Survey).

4- Data used

To conduct research on the spatial suitability of a plastics recycling facility site for bitumen reinforcement using remote sensing and GIS techniques, we needed to collect a variety of geographic and environmental data which included:

1. Satellite data: satellite image in 2023 were used during the spring season on March 23 (acquisition time: CCT 9:38 AM) from USGS-certified Sentinel satellite program to determine the areas Urbanism, bare lands, and vegetation coverage. This data is useful for identifying areas that meet environmental and planning standards.

2. Climatic data: Giovanni data was used to obtain climatic data for the study area. It is a web platform of NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) and Distributed Active Archive Center (DAAC) developed by Goddard Earth Sciences Data and Information Services Center. (GES DISC) which provides a simple and intuitive way to visualize, analyze and access vast amounts of geoscience remote sensing data.

3. Topographic data: to identify areas with appropriate slope and avoid areas prone to flooding or with high elevations. It included the use of a radar image from the Japanese Aster satellite.

4. Infrastructure data: such as road locations, water and sewage networks, which will affect construction and operating costs. Which was used from the annual statistical bulletins of the Arba'een visit

5. This data will allow us to conduct an accurate spatial suitability analysis to determine the best locations for the recycling facility

based on a variety of criteria through the use of GIS programs to collect and analyze the data. The inputs represent the inputs of the proposed analysis and their relative weight in choosing the appropriate location, according to Table 1.

Table (1):Criteria that represent the inputs to the spatial analysis of the proposal and their relative weight

Standard	Scale	Relative weight
Distance between the city and major highways	A distance of no less than 500 meters	3
Local real estate regulation and land use	Barren lands and saline areas are considered excellent locations, while lands with dense agriculture and greenery are considered bad locations	3
Far from residential areas	It is located 500 meters away from existing residential projects or under mitigation	21

Water sources and wells	The distance between the site and the nearest water well should be 25 km	7
Slope and soil type	5% after perfect regression	5
temperature	It prefers higher temperature areas, which results in increased evaporation rates for the black sap	2
Relative humidity	It prefers less humid areas, which results in increased evaporation rates for the black sap	2

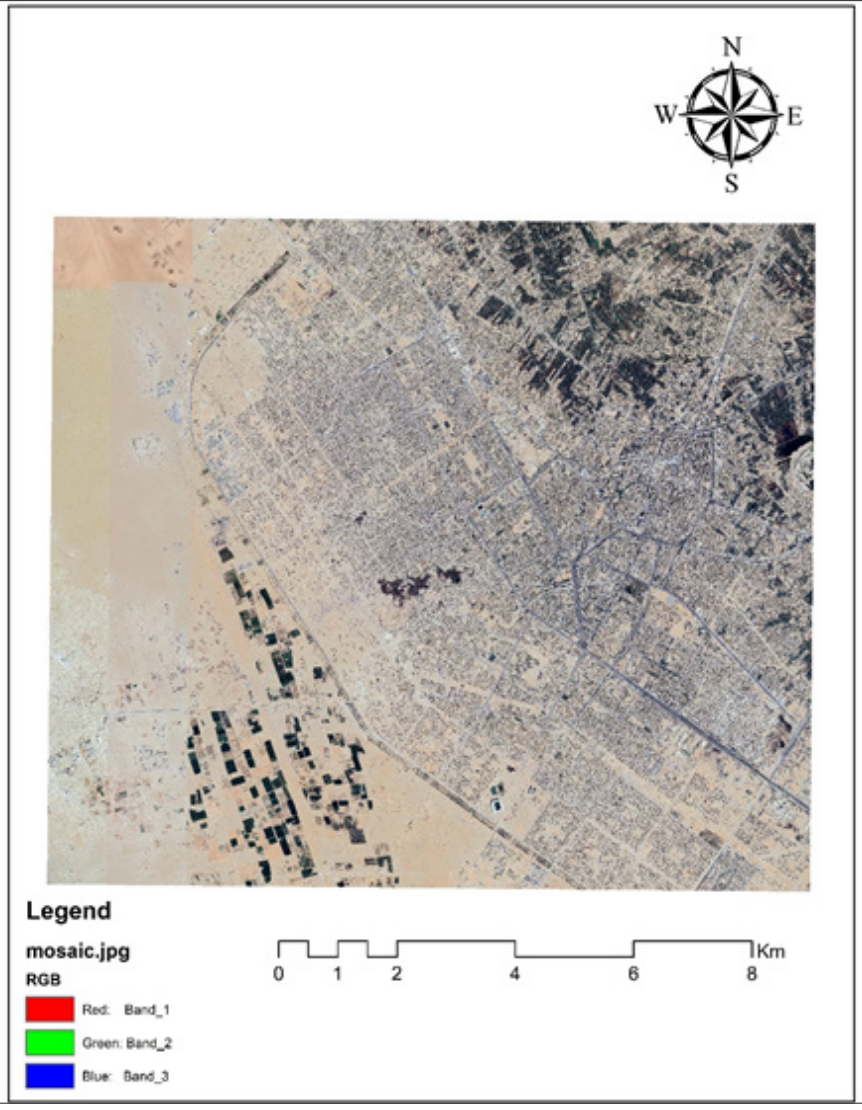
5-Methodology and Procedure

5-1 Digital image processing and classification:

After obtaining the images, some processing was performed using GIS 10.6, as the images contain geometric and radiometric errors. Therefore, a geometric correction of the captured image was performed using corrected satellite images in order to convert it to images with known geographical coordinates according to the UTM system for Iraq, and then it was Performing radiation correction to convert data into known radiation units or reflection units with logical values that represent the true reflection of ground features. Many bands were combined to produce a new image (RGB), where the spectral bands (MID IR, NER-

IR, GREEN) were combined to show differences in land cover more clearly than in grayscale images. After merging the spectral bands and making the corrections required by the satellite image, we analyze Image data through directed classification and selection of training samples, as these analyzes include the process of classifying the land cover of the city of Karbala to determine patterns of changes in urban areas, bare lands, and vegetation land by dividing image units into groups or classes based on the spectral parameters of the digital numbers of these units. If the image unit achieves specific spectral criteria or specific conditions, it is attributed to the class or group that is characterized by these spectral criteria, as it is considered the most important step in digital processing operations as it is the primary goal of these operations as the image is transformed into a thematic map about the phenomena in the studied area. And the figure (2) shows an image of the study area from the Sentinel satellite in false color and represents the final product of the correction and normalization process required for the data which will involve conducting and implementing all necessary analyses in the process of selecting the best location for establishing the plastic recycling facility.

Figure (2): false-color image (FCC) with bands (MID IR, NER-IR, GREEN) of the study area taken from the Sentinel-2 satellite, representing the final product of the radiometric correction and calibration process necessary for the data. This process will include implementing and conducting the necessary analyzes to choose the best location to establish a plastic recycling



5-2 Geological features and digital elevation models

A digital elevation model is a raster representation of a continuous surface that usually refers to the Earth's surface. The accuracy of this data is determined primarily by the resolution (distance between sample points). Other factors that affect accuracy are the type of data (integer or floating point), and the actual sampling of the surface when creating the original digital elevation model. The digital elevation model is one of the important methods and modern applications within the geographic information systems program, which provides a three-dimensional view of the terrain, which provides tremendous application potential in many sciences and fields, including its use as a tool for the geographic researcher, especially in the field of determining spatial suitability for choosing the location of the plastic recycling facility. The digital elevation model, which is based on satellite and aerial images, the Global Signature System, digital maps, and even corrected topographic maps, provides accurate measurements, analysis, and results when the digital elevation model is extracted from them, as it is possible to know the slopes, determine the locations of possible landslides, and direct, that is, know the effect of wind, rain, and solar radiation, and then determine The extent of the development of the soil and land erosion process. Good soil prevents odors from emitting from the facility and reduces erosion and wind scattering of buried waste. Suitable sites for establishing a landfill are those whose soils have slow permeability and weak pores, such as clay and calcareous soils, which reduces the leakage of landfill leachate fluids or leaching into groundwater and the spread of gases into adjacent areas. As for the slope, the waste cube area must slope slightly, which does not impede the natural drainage procedures for rainwater, does not pose a difficulty in construction and operation operations, or

cause waste seepage to leak into the groundwater formations that feed the area. Therefore, lands with a slope exceeding 25% can be excluded, and a slope of less than 5% is considered appropriate for creating a sustainable facility.

5-3 Spatial analysis of climatic characteristics

Protecting populated areas from any undesirable effects of a landfill is the goal sought by planners and those responsible for selecting and designing landfill sites. Scientific research has proven that a group of gases harmful to human health are often emitted from a landfill site, and that exposure to these pollutants at concentrations higher than the permissible levels and for long or short periods of time may increase the chances of contracting dangerous diseases. Therefore, it is necessary to choose a location for burying the waste, provided that it is placed in the direction opposite to the wind blowing relative to populated areas, thus forming a global standard and a public demand that must be taken into account and taken into account in order to accept the establishment of a sustainable facility for the waste landfill. In addition to temperatures and precipitation. In urban environments, air temperatures can rise dramatically due to urban heat islands, where materials used in construction and the dense buildup of industrial structures cause heat to be stored, affecting surface temperatures. Humidity affects the air's ability to conduct and store heat. Humid air retains heat more than dry air, which affects surface temperatures in particular. Evaporation from water surfaces and transpiration from plants also play a role in cooling the surface. According to international standards EN 1525, ideal air temperatures usually range between 29°C to 33°C during the winter and between 35°C to 40°C during the summer. These ranges

Semi-Annual Scientific Journal www.arbnj.com March 2025 - Ramadan 1446

may vary slightly depending on the environments in which the project is implemented. Regarding humidity, the relative humidity within the environments should be between 30% and 60%. Humidity that is too high or too low can lead to discomfort and health problems for workers. The IDW method is commonly used in creating maps of different variables due to its accuracy and efficiency in processing spatial data, provided by ArcGIS 10.6 software to produce maps of the spatial distribution of climate data.

6- Results and discussion

6-1 Evaluation of environmental standards

When conducting the supervised classification process, five classes were identified located within the study area, representing three types of land cover (water, plants, and soil), and the plants were classified in turn into (dense plants and sparse plants), noting that land plants were not included in this study; Because it is spread outside the boundaries of the studied area, while the soil was classified into (dark soil and dry soil), this classification was applied by using the non-wave classification process, as well as through visual interpretation of satellite images, as the differences between the types are clear and distinguishable, in addition to Field information available in the annual statistical bulletins of the Arba'een visit and adapted by the General Secretariat of the Hussein Shrine. Note that the method used to implement the directed classification process is Parallelepiped. Using the capabilities provided by ArcGIS 10.6.

Bare lands, fallow lands, and saline lands that are not suitable for agriculture are considered the most suitable for establishing a Plastic

Recycling Facility, while agricultural lands are considered inappropriate and urban areas must be removed from the possibility of establishing the facility on them. The area has been classified into three main uses: urban and agricultural use, and abandoned lands (saline and decertified fallow). According to Table 2, which shows the percentages of land uses for the study area.

Table (2): Areas and percentages of LULC based on the supervised classification

Land use	Area (Km2)	Percentage %
Built up area	17.9	25.6
Agriculture land	11.5	19.1
Bare land	33.7	55.3

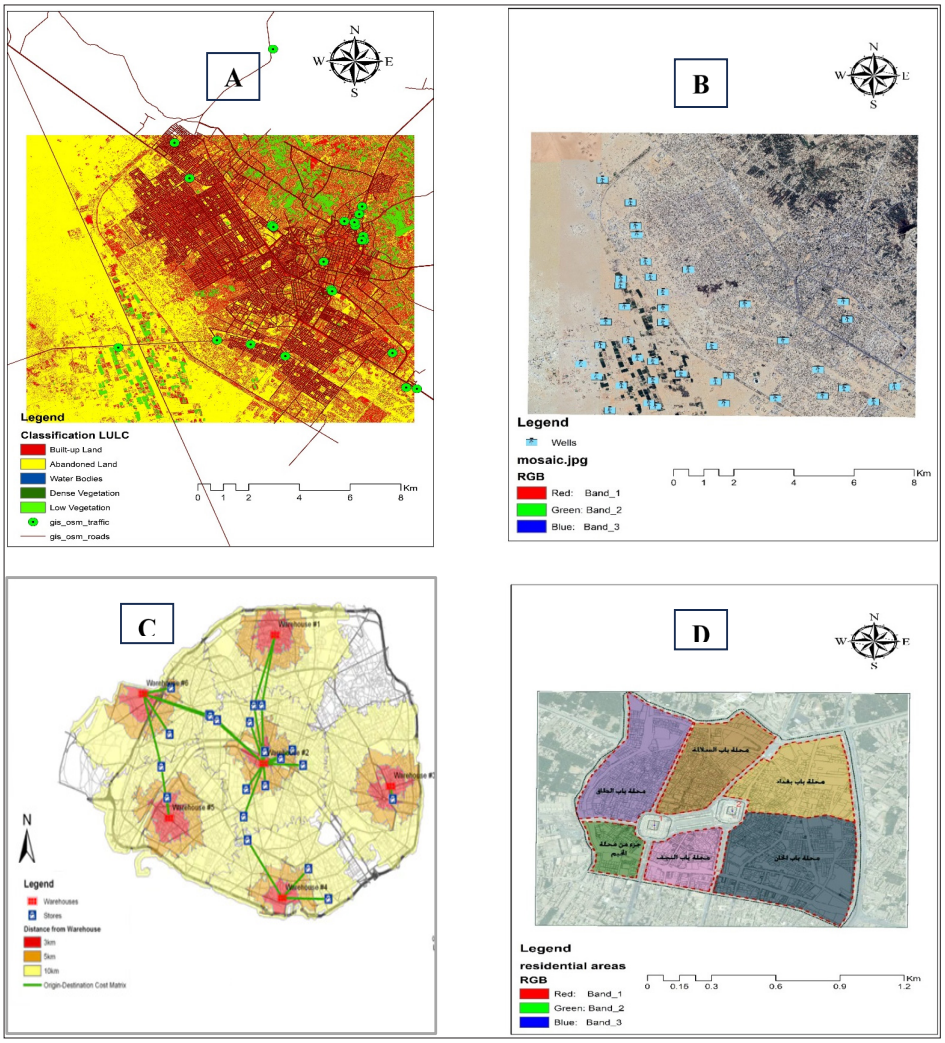
When planning a plastic recycling facility, it must be far from the main roads in order to reduce the health and visual effects and the annoying odors and fumes that cause inconvenience to vehicles passing on the road. Therefore, it is recommended to take a spatial scope around the main roads' of 1000 meters, which reduces the health and visual effects while maintaining the distance. Standardization. Also, away from rivers and wells, in order to avoid environmental risks that could occur if pollutants leak into river water or the well that residents depend on for drinking, agriculture, and various daily activities. Therefore, it is preferable for the landfill to be far from a river, and it is recommended to exclude any site located within 5 km of it. Rivers and wells in all directions, and areas located at a distance greater than 5 km are considered the most suitable for establishing a Plastic Recycling Facility.

The distance from side roads must be determined when planning

Plastic Recycling Facility. Therefore, a spatial radius around the side roads is recommended to be 250 meters to reduce the cost of transporting waste from its generation centers to the site. When planning Plastic

Recycling Facility, a separation distance from residential areas must be determined in order to protect residents from health and visual effects and the possibility of odors and fumes being transmitted to them, which causes the spread of diseases. It is recommended that a distance of 1,500 meters from residential areas be represented as a circle surrounding them. Figure 3 shows the final output of the environmental assessment processes, which included the distance between the city and major highways, Local real estate regulation and land use, far from residential areas and water sources and wells.

Figure (3): (A) map showing the classification of land uses and land cover of the study area and the most important traffic intersections in addition to the main transportation network within the region. (B) A map showing the spatial distribution of wells and drinking water sources. (C) A map showing the spatial and weight analysis of the transportation network within the city. (D) A map showing the important residential and neighborhood areas within the city

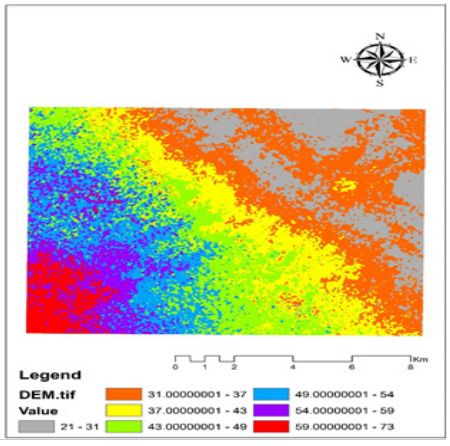


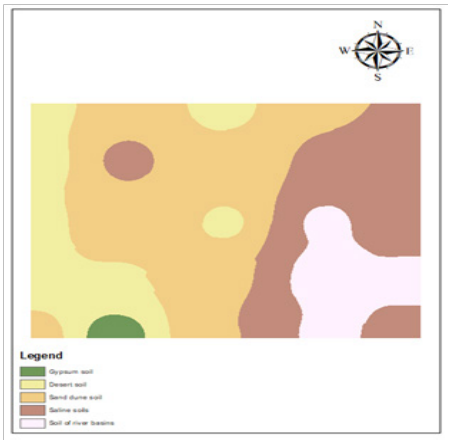
Semi-Annual Scientific Journal www.arbnj.com March 2025 - Ramadan 1446

6-2 Geological criteria

The slope of the land surface represents an important element when planning to establish any project because of its direct impact on the appropriate location and the cost of preparing the site. This applies to a plastic recycling facility that needs flat or gently sloping land, and accordingly the slope was determined from. - 5% is ideal and the appropriate slope is less than 20%, but greater than 20% is an inappropriate slope. Soil is one of the important factors in determining suitable locations for establishing a plastic recycling facility because it is associated with soil types that have low permeability to prevent the seepage of pollutants into the ground. Low permeability represents high-density soils and rocky soils, and in the last stage comes sandy soils, which are characterized by their high permeability. And Figure (4) represents the digital elevation model of the study area to determine the slope ratio in addition to the spatial analysis of soil types in the study area

Figure (4): (A) radar map representing the digital elevation model (DEM) of the study area to determine the slope rate. (B) the spatial analysis of soil types in the study area



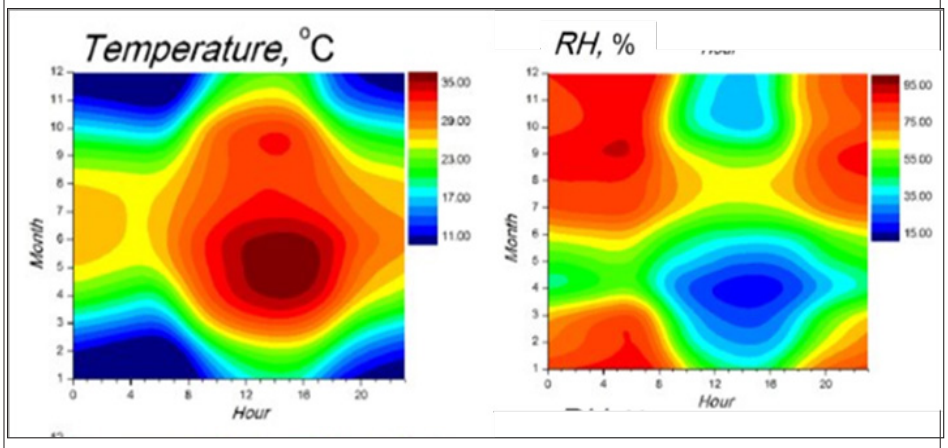


6-3 Climatic standards

Study of climatic parameters such as temperature and relative humidity is very important to determine the suitable location for a plastic recycling facility. These factors can affect the efficiency of operations within the facility and the sustainability of the materials used. Plastic can be affected by high temperatures, which may lead to damage or a change in its properties such as softness and strength. The temperature in the area must be determined because it has an impact on the evaporation speed of the leachate present on the site, which reduces the possibility of this leachate leaking and harming the surrounding environment. In environments with high humidity, plastic may absorb moisture, resulting in changes in its weight and physical properties. It usually ranges between 29°C to 33°C during the winter and between 35°C to 40°C during the summer. These ranges may vary slightly depending on the environments in which the project is implemented. Regarding humidity, the relative humidity within the environments should be between 30% and 60%. Humidity that is too high or too low can lead to discomfort and health problems for workers. Avoid extreme temperature increases as they may damage the plastic or change its properties, such as strength and flexibility. Humidity that is too low can also lead to static electricity problems, which may affect operations and worker safety. Figure (5) shows the spatial analysis of the monthly average temperatures and relative humidity in the study area.

Semi-Annual Scientific Journal www.arbnj.com Volume 2, Issue 2, Part 7, Year 2

Figure (5): (A) Spatial analysis of monthly average for temperatures. (B) Spatial analysis of monthly average for relative humidity in the study area.

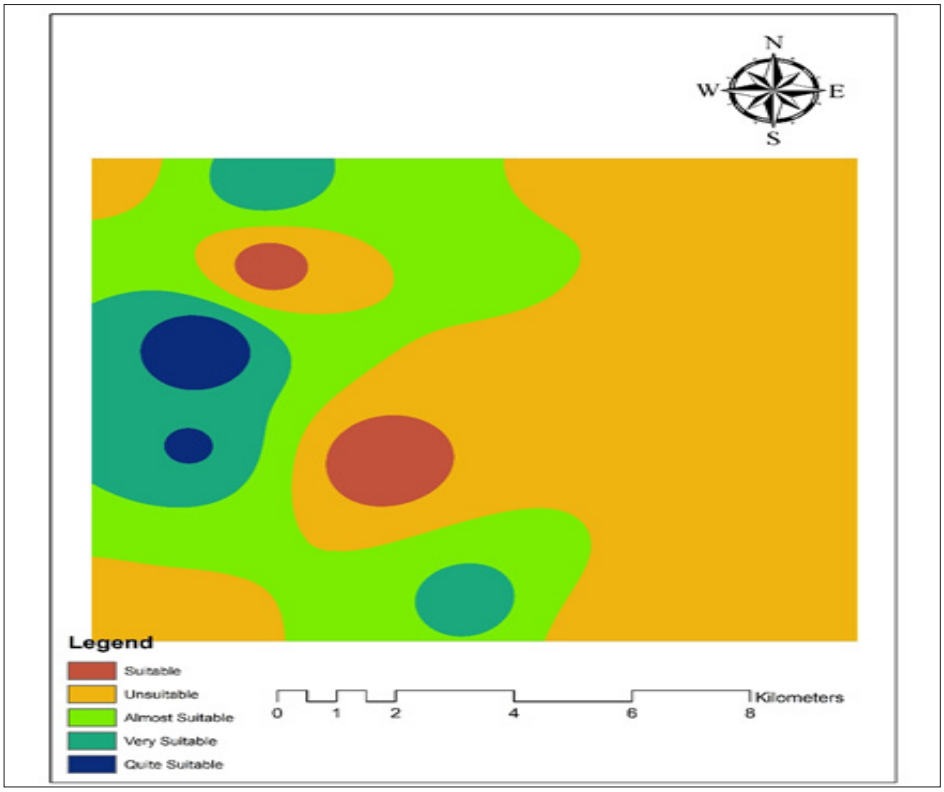


Based on careful integration of spatial data and specific criteria for selecting suitable locations for a plastic recycling facility in Karbala, three potential locations were identified as the best options, and these locations are shown in the final map in Figure (6), which summarizes the results of the study. Each of these locations has unique features that make it ideal for establishing a facility, consistent with the environmental, logistical, and regulatory considerations necessary to ensure efficient and sustainable operation of a plastic recycling facility.

Each site was evaluated based on several key criteria including: proximity to sources of plastic waste, ease of access to major road networks to facilitate transportation and distribution operations, level of environmental protection provided to surrounding areas, and environmental preservation. Also, the visual and health impact of the facility on local residents was taken into account, with an emphasis on minimizing the negative impact of activities associated with the facility on the local environment.

Detailed studies were also conducted to evaluate the land in terms of soil type, slope, and groundwater and river sources to ensure that the selected lands were suitable for the infrastructure and construction requirements of the recycling facility. The results reached enhance the facility's efficiency in achieving sustainable development goals and reducing the environmental footprint of recycling operations

Figure (6): Map showing the proposed locations of the plastic recycling facility based on careful integration of spatial data and specified criteria



7- Conclusion

The purpose of this study was to determine the optimal locations for establishing a plastic recycling facility, in support of sustainable development within the framework of Iraq's Vision 2030, and to reduce environmental pollution resulting from plastic waste accumulated during religious visits to Karbala in general and the Arba'een visit in particular. To achieve this purpose, seven basic criteria were relied upon, on the basis of which geographically optimal locations were determined according to latitude and longitude, taking into account the balance of these criteria based on their priorities.

In this study, for the first time, geographic information systems were used to develop new standards based on the distance between cities and major highways, local real estate regulation, land use, distance from residential areas and water sources, in addition to taking into account the percentage of slope and the type of soil required, As well as climatic parameters such as temperature and relative humidity.

The study presents the possibility of benefiting several government agencies, such as municipalities, municipal waste departments, environmental organizations, and private recycling companies, by exploiting the research results to establish sorting centres in the identified optimal locations. This allows improved transportation management and optimal route planning according to the proposed model. By using various constraints in the model, more realistic conditions can be created to achieve accurate and useful future results.

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