# Spatial Suitability of landfill Site in Karbala, Babel and Baghdad Governorates

**Hassan j. Alatta**

University of Baghdad

**Majid A. Albakr**

University of Baghdad

majid.abdalsalam.2021@gmail.com

**Mohammed M. Wadod**

University of Baghdad

**Hussam H.Tizkam**

Karbala centre for studies and research The Husseini Holy Shrine

**Raghda A. Ali**

University of Baghdad

**Enas Kh. Hassan**

University of Baghdad

**Sinan Sameer Mahmood Al-Dabbagh**

University of Baghdad

**Najah abd**

University of Baghdad

## Abstract

Landfill siting is a challenging and intricate process, making it a prominent issue in waste management. The complexity arises from various factors, such as population growth, rapid economic expansion, and improvements in living standards. Unfortunately, in Iraq, landfill siting often neglects environmental regulations, especially in the Karbala, Babel, and Baghdad Governorates, situated in the middle part of Mesopotamia plain. These regions cover areas of 4568.45 km2, 7106.29 km2, and 820.190 km2, with populations of 1,218,732, 2,065,042, and 8,126,755, respectively. Existing landfills in these areas are not selected in accordance with environmental standards. To address this issue, a landfill site was identified through a comprehensive approach that involved spatial overlay analysis using a geographic information system (GIS) to developing a supervised logic decision depends on surface and subsurface geology conditions. Numerous factors were taken into consideration during the siting process, including water resources, building sites, sensitive soil types, and topographic slope. The Weighted Overlay method was employed to assign relative weights to the mentioned criteria. As a result of this thorough process, seven sites were identified as the most suitable landfill locations, covering a total area of approximately 291.057 km.

**Keywords:** Weighted Overlay, Spatial Suitability Analysis, Landfill Site, Supervised logic tree decision, Karbala, Babel and Baghdad Governorates.

## 1. Introduction

The Environment Protection Act of 2009 provides a comprehensive definition of waste, encompassing the discharge of liquids, solids, gases, smoke, dust, radioactive elements, and similar substances that degrade the environment [1]. Solid waste, specifically, refers to discarded materials arising from human and animal activities that are deemed unwanted and useless [2]. The process of Solid Waste Management (SWM) aims to minimize environmental harm and promote reuse of waste materials.

The rapid urbanization in urban centers like Baghdad, Karbala, Babel, and Baghdad, has posed a significant challenge for SWM. The densely populated human activities particularly during the time of Zeyart AL-Arbaeen, along the road linking Baghdad and Babylon to Karbala during this time lead to a substantial increase in waste generation, creating environmental and health hazards. Karbala alone generates around 24 tons of municipal waste daily during Zeyart AL-Arbaeen[3], while Baghdad produces 10,000 tons per day throughout the year [4]. In Babel, the daily waste production reaches 400 tons, causing health and environmental issues for nearby residents due to improper landfilling practices [5]. Unfortunately, less than half of the waste gets collected, and most of the collected waste is disposed of haphazardly [6].

Geographic Information System (GIS) is a digital database management system specifically designed to handle large volumes of spatially distributed data sourced from various origins. It proves to be highly effective for conducting sophisticated site-selection studies, as it efficiently stores, retrieves, analyzes, and presents information based on user-defined specifications. The use of GIS has significantly contributed to streamlining and cost reduction in the process of landfill site selection [7] [8] [9]. Additionally, other site-siting techniques combine Multiple Criteria Analysis (MCA) with GIS to evaluate the suitability of potential sites throughout the study area by employing a suitability index [10] [11] [12] [13] [14]. The weighted overlay technique empowers us to assign weights to various factors and blend them together to form a comprehensive thematic map. By overlaying all causative factors using their respective weights, we can calculate the landfill susceptibility index. This process is facilitated through the use of the overlay tool in ArcGIS.

The combination of rapid and uncontrolled urbanization, lack of public awareness, and poor municipal management has exacerbated environmental problems in towns across Iraq, including unsanitary waste management and disposal [6] . To address this, the present study focuses on improving waste management by identifying suitable areas for landfill sites, particularly in on the road linking Baghdad and Babylon to Karbala. Defining appropriate parameters and criteria will help mitigate the adverse effects of improper SWM. Landfill sites are an essential part of waste management, significantly impacting the physical and socioeconomic aspects of cities.

## 2. Study Area Location

The study area is nestled within the historical and culturally rich Mesopotamian basin, spanning from the bustling city of Baghdad to the ancient sites of Babylon and the holy city of Karbala (figure1). This region offers a diverse landscape and a tapestry of urban and rural settings, making it an intriguing location for conducting a spatial suitability analysis of landfill sites and waste recycling factories. With its unique blend of modern urban centers and historically significant locations, the governorates of Karbala, Babel, and Baghdad present an ideal canvas to explore sustainable waste management solutions and contribute to the preservation of this remarkable heritage.

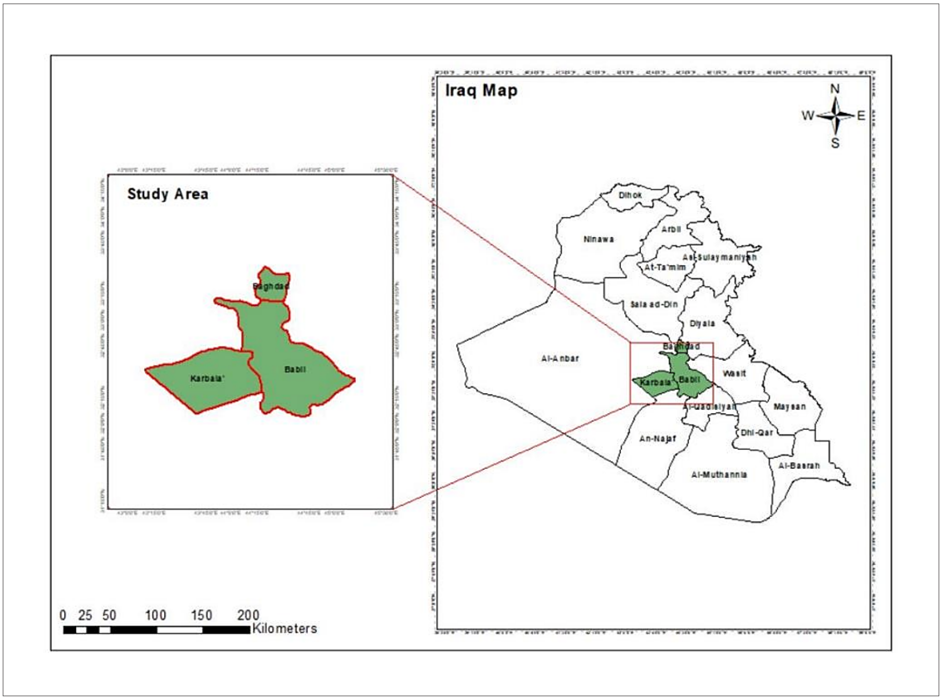


Figure1 location map of study area.

## 3. Methodology

The overarching problem statement lies in the accumulation of uncollected wastes, which are found in drainage ditches, roadside spaces, and the vicinity of the city's river. This situation has led to conflicts between waste management authorities and the local communities. Consequently, the pollution caused by these unattended waste sites has resulted in an increase in communicable diseases and various other hardships faced by the local population. Therefore, the weighted overlay procedure (figure 2) has been utilized for this purpose.

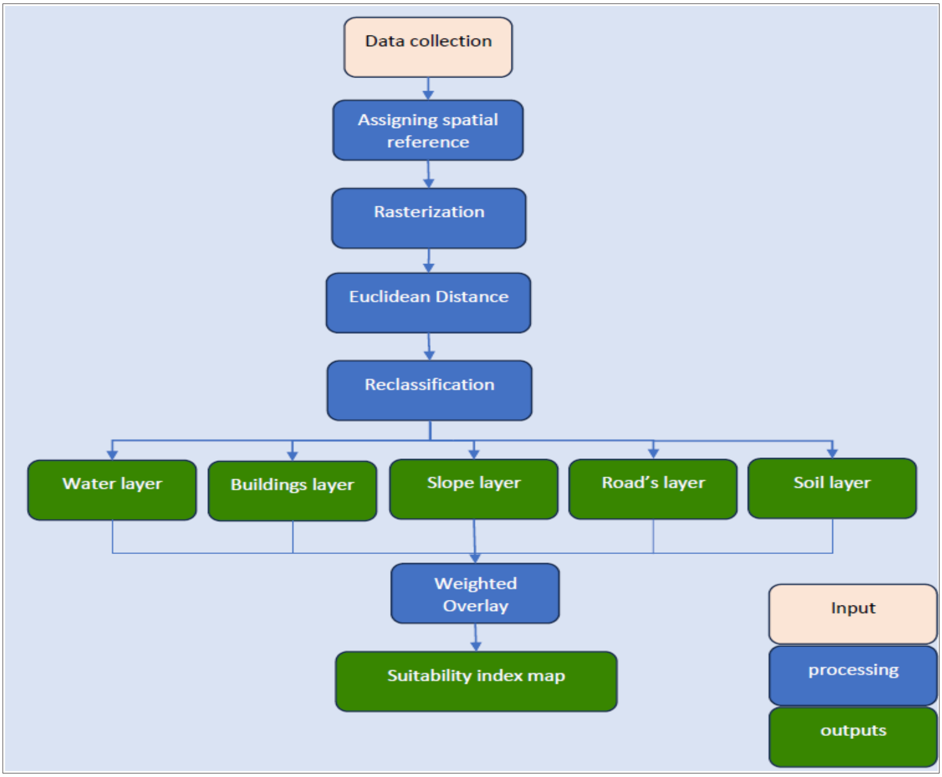


Figure 2 Flowchart utilized in current study.

In this procedure, fixed criteria were applied to each factor that is believed to influence the suitability of the landfill site. The selection of a landfill site involves a thorough evaluation of various factors to ensure that the chosen location is suitable for waste disposal and minimizes environmental impacts. The factors considered for landfill site selection can vary depending on local regulations, environmental conditions, and specific project requirements. However, some common factors [15] (table 1) include: distance from water body, The distance from a water body is an important factor to consider in landfill site selection. Keeping a safe distance between a landfill and water bodies (figure 3) is crucial to protect water quality and prevent contamination. Water bodies include rivers, lakes, streams, ponds, wetlands, and other surface water features, as well as groundwater sources like wells and aquifers. Ideally, landfill sites should be located as far away from water bodies as possible to minimize the risk of pollutants leaching into the water and causing environmental and public health concerns. The distance required between a landfill and water bodies can vary depending on local regulations, the type of landfill, and the characteristics of the water body. The distance from settlement areas is another crucial factor in landfill site selection. Settlement areas (figure 4), which include residential neighborhoods, commercial centers, and other inhabited regions, must be kept at a safe distance from landfills to safeguard public health, minimize nuisances, and prevent potential conflicts between waste disposal activities and human activities. The distance required between a landfill and settlement areas can vary based on local regulations, environmental conditions, establishing buffer zones between landfill sites and settlement areas can provide an additional protective layer, helping to reduce the potential impact of landfill activities on neighboring communities.

**Table 1- Factor criteria for selection of a landfill site [15]**

| Criteria | Ranking (from 1 is unsuitable to 4 is best suitable ) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Distance from water body | <1000m | 1000-1500m | 1500-2000m | >2000m |
| Distance from settlement area | <500 | 500-1000m | 1000-2250m | >2250m |
| Distance from roads networks | >1500 m | 1000-1500m | 500-1000m | <500m |
| Slope and elevations | >20% | 15-20% | 10-15% | 0-10% |
| Soil type | Sandy Soil | Loam Soil | Silt Soil | Clay Soil |

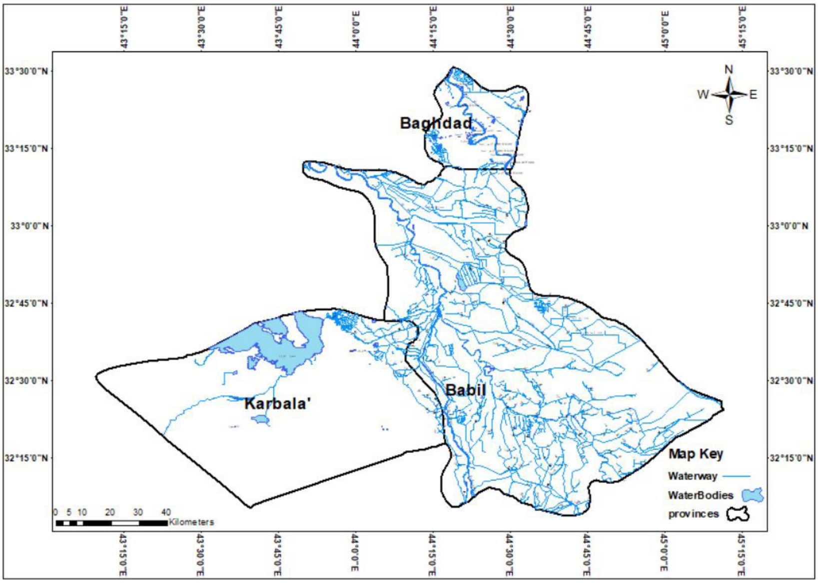


Figure 3 Surface water body in current study.

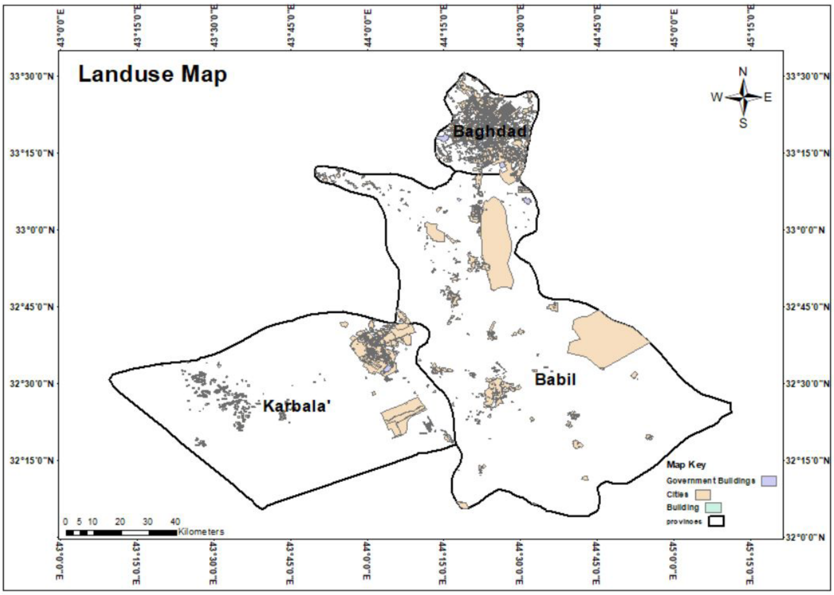


Figure 4 Settlement area in current study.

**Distance from roads networks**, the road networks (figure 5) is an essential consideration in landfill site selection. Proximity to road networks can significantly impact the efficiency and cost-effectiveness of waste transportation to the landfill site. It also affects traffic management, public safety, and potential nuisances caused by waste transportation. The site model takes into account that a location too close to a road is highly unsuitable, as sludge may affect both the road's integrity and the safety of passersby. However, the chosen location should still be easily accessible by road for efficient waste disposal.

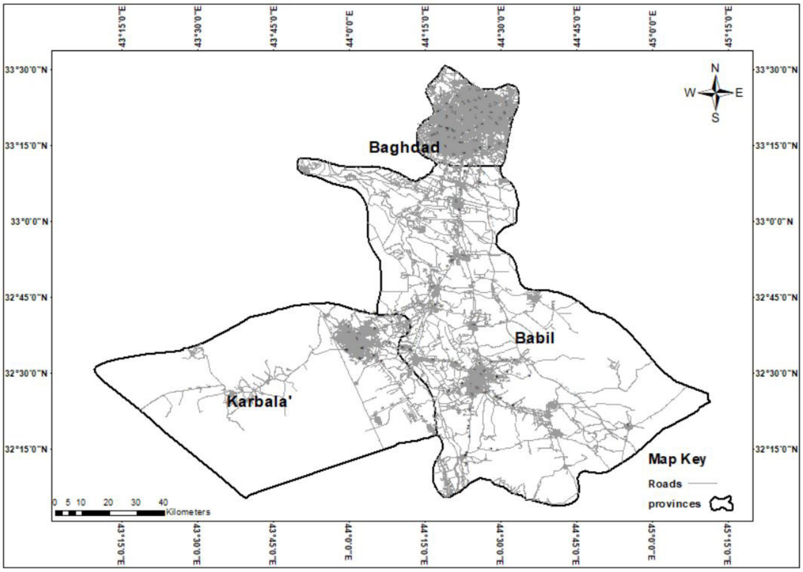


**Figure 5 Road networks in current study.**

**Slope,** is important topographical factors to consider in landfill site selection. The slope calculation is need to prepare DIM model (figure 6). The topography of the site can significantly impact the landfill's stability, drainage, and construction costs [16]. Landfills should ideally be located on flat or gently sloping terrain. Steep slopes can create engineering challenges during landfill construction and management. They may also increase the risk of erosion and potential instability of the landfill structure. Flat or gently sloping areas allow for more straightforward landfill design and waste placement. The stability of the landfill is critical to ensure long-term containment of waste and to prevent landslides or slope failures. Sites with stable soil and rock conditions are preferred to reduce the risk of potential instability issues. Proper drainage is essential to manage rainwater and leachate within the landfill. Excessive slopes can lead to poor drainage and increased runoff, which can transport pollutants into surrounding areas and water bodies. Adequate slope design and engineered drainage systems help mitigate these risks. Steeper slopes are more prone to erosion, which can lead to soil and waste material runoff. Controlling erosion is vital to prevent sediment pollution and protect water bodies.

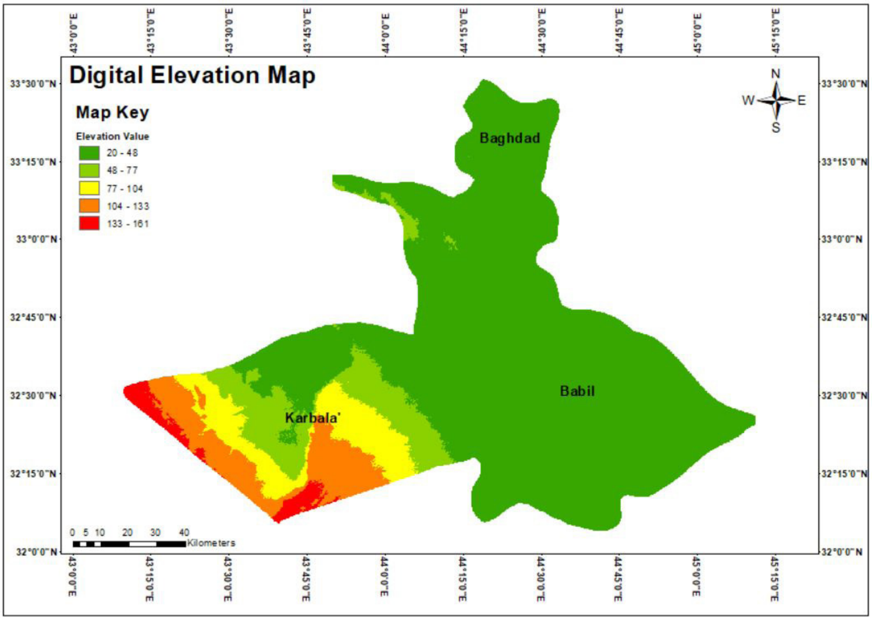


Figure -6 Digital elevation map (DEM) in current study

**Soil type**, the best soil type for a landfill site is one that exhibits low permeability and high stability [17]. A low-permeability soil layer acts as a barrier, preventing leachate (liquid that comes in contact with the waste) from seeping into the surrounding environment and contaminating groundwater and surface water. A stable soil type ensures that the landfill structure remains intact and does not experience settlement or instability over time. Clay soils have low permeability due to small particle sizes and tightly packed structures, which greatly restrict the movement of water and other liquids. This property helps contain leachate within the landfill, reducing the risk of groundwater contamination. Clay soils can be effectively compacted during landfill construction, leading to a more stable and structurally sound waste containment area. While clay soils are preferred, the availability of suitable clayey soils may be limited in some regions. In such cases, engineered liners, such as high-density polyethylene (HDPE) or geomembrane liners, can be used to create an impermeable barrier between the waste and the surrounding environment. These liners, when properly installed, can provide an effective alternative to natural clay soils.

The weighted overlay method involves integrating various inputs by applying a standardized scale of measurement. In this approach, the decision maker assigns weights to each input using analytical techniques and subjective judgments. In the study, a weighted analysis was applied to each input layer based on its sensitivity to determine the appropriate location for solid waste disposal in Karbala, Babel, and Baghdad Governorates. Here we developed a new type of Ranking Methods procedure utilizing supervised logic tree (figure 7) to make a final decision without use any traditional multi criteria decision algorithm analysis e.g., Rating Methods. Pairwise Comparison Method. Trade-off Analysis Method.

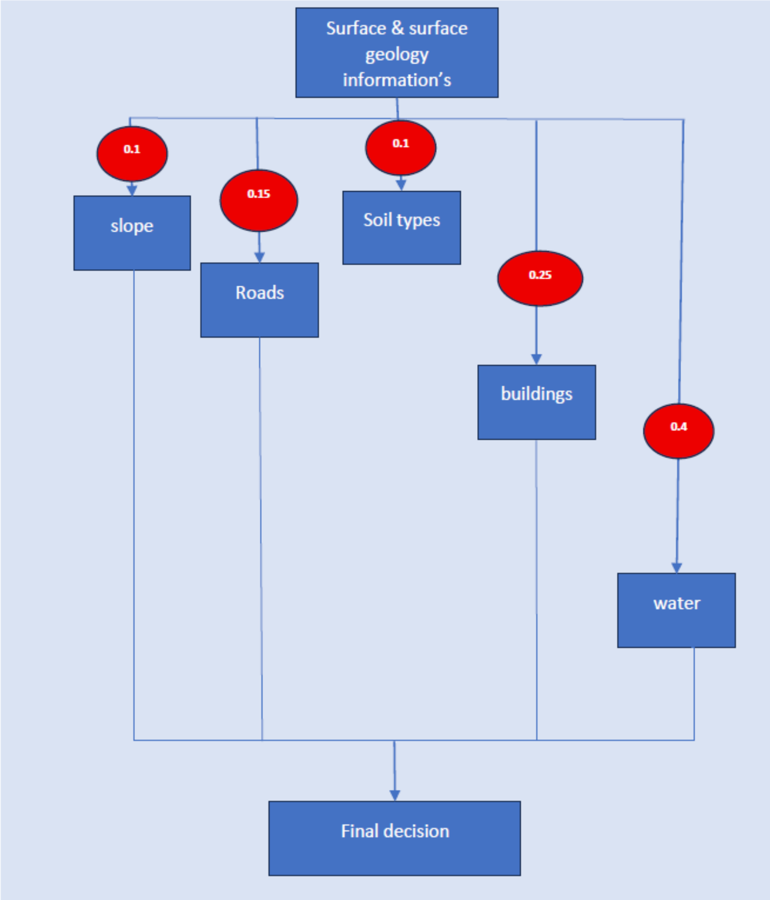


Figure -7 Supervised logic tree utilized in current study.

Generally, one drawback of this method, such as the ranking method, is the absence of a solid theoretical foundation. Additionally, justifying the assigned weights could prove to be challenging. Therefore, it must give a logical justification for weighted of some important factors, such as surface and subsurface geology factors (water, soil types and slope). for ground water there are three most important aquifers are Dibdbba, Dammam and Euphrates located within study area [18]. In the western area of Karbala city, there is a noticeable hydraulic connection between the aquifers, resulting in similar resistivity values for both the Dammam and Umm Er Radhuma layers [19]. Moreover, the region contains many water bodies such as the Tigris and Euphrates rivers and Al-Razzara lake, in addition to other secondary rivers for this reason the water takes a high weighted value. The Mesopotamia basin exhibits a relatively flat topography, while the Iraqi Desert shows a gradual decrease in elevation from West to East, with some exceptions. It is considered an extension of the Northern part of the regional plateau of the Arabian Peninsula [20]. The region showcases a combination of positive and depressed topographic features. Notably, Jabel Anah represents the positive features in the North, Jabel Aneiza in the West, Karbala – Najaf Plateau in the East, Jabal Sanam in the South, along with some mesas and buttes [21]. This made the weighted value is low for this factor. The Mesopotamia basin are generally considered to be of Quaternary age. The Quaternary period is the most recent geological time period, spanning from approximately 2.58 million years ago to the present [22]. It is characterized by significant climate fluctuations, including multiple ice ages and interglacial periods and this very considerable to the soils in the study area are similar in terms of texture composition, so the weighted was 0.1.

After overlaid all the results obtained from reclassification, the assigned equal weights to all factors by:

$$s = \sum_{i}^{5} = 1\, w_i c_i \,, \qquad (1)$$

Where s is suitability, wi is weighted for all factors and ci is criteria. To perform the suitability map, we used the following equation:

$$s = \sum_{i}^{5} = 1 w_i \, c_i \Pi_j^3 = 1 r_j \,, \qquad (2)$$

Where s suitability of waste disposal site, wi is weighted for factor, ci is criteria for suitability and rj is restriction.

## 4. Results and Interpretations

The results of soil classification (figure 8) in the provinces show that the soils in Baghdad and Babylon are and clay soil and loamy mixtures (silt and clay). While the northern part of Karbala Governorate, it represents clay soil, whilst the western and southwestern part towards the desert is sandy soil.

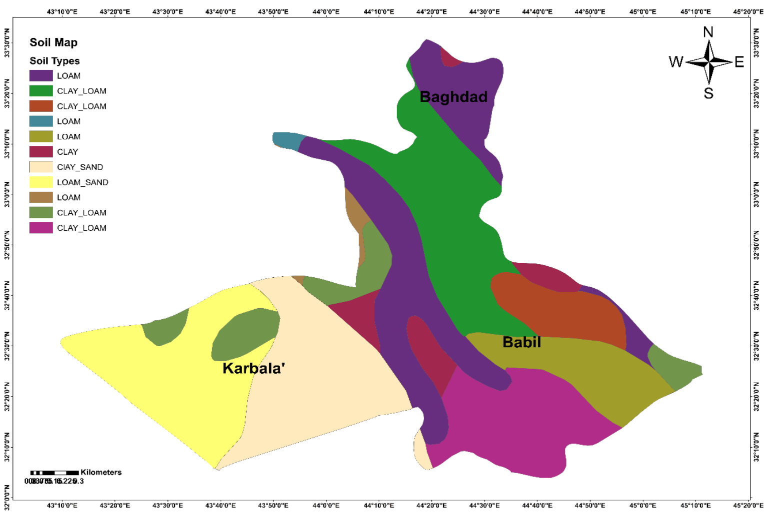


Figure -8 Soil types in study area.

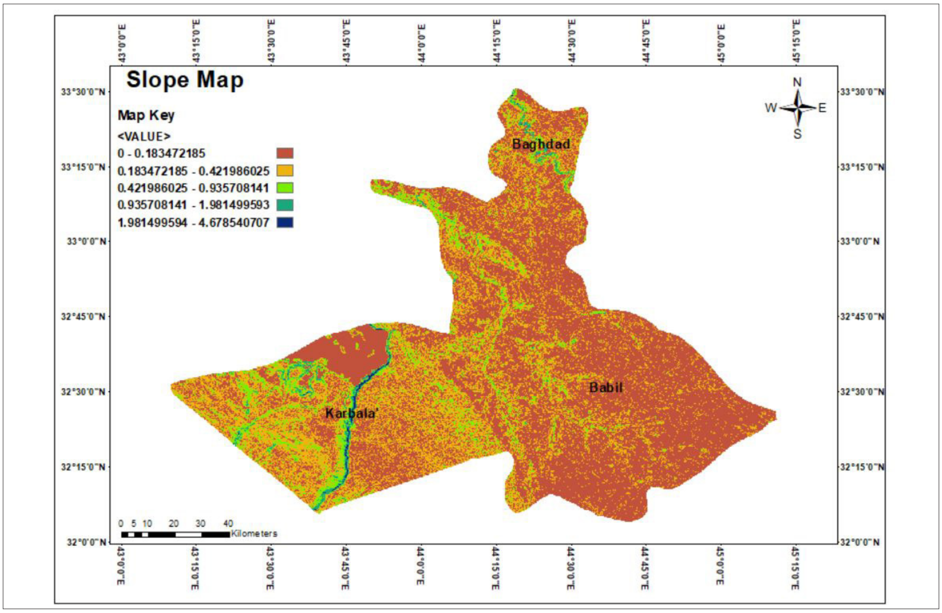


Figure -9 Slope values in study area.

In the Spatial Suitability Analysis of landfill site selection for Karbala, Babel, and Baghdad Governorates in Iraq, slope values (figure 9), hold significant importance as they impact the potential suitability of different areas. Karbala Governorate, with its diverse terrain, exhibits varying slope values. The north and northeast regions of Karbala are relatively flat, offering favorable conditions for landfill site placement. However, towards the western and southwestern parts, closer to the desert, the landscape becomes more elevated and exhibits topographic features (Karbala-Najaf plateau), requiring careful consideration to avoid stability issues and ensure effective waste management. In contrast, both Baghdad and Babel governorates relatively flat areas, providing suitable conditions for landfill site placement, which can optimize waste disposal and ease access for waste collection and transportation. To preserve the environmental integrity of these water sources, a minimum buffer zone of 2000 meters should be established using a straight-line calculation.

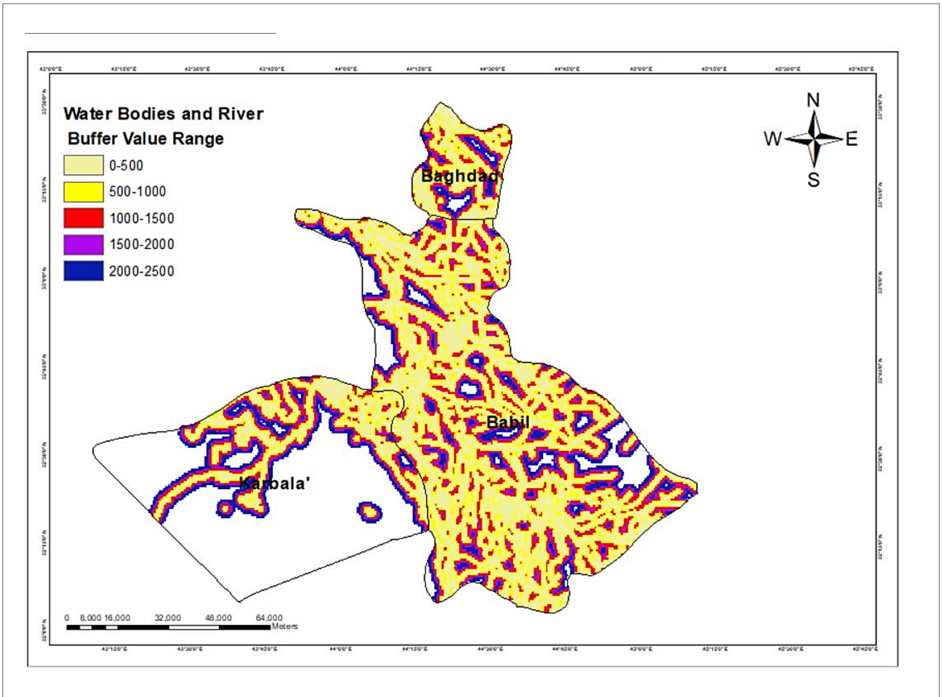


Figure -10 Distance from water body in study area.

In the process of landfill site selection for Karbala, Babel, and Baghdad Governorates in Iraq, evaluating the suitability of surface water bodies and groundwater is of paramount importance. Karbala Governorate, while having some flat regions, also features water bodies, the map showed (figure 10) an extended strip area in the

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northern part of the governorate, far from groundwater aquifers as well as from water bodies. Concerning the province of Babil, there are many suitable places in the center, south and north of the province. For Baghdad Governorate, the presence of the Tigris River and its tributaries requires a thorough analysis to avoid adverse effects on this vital waterway. The map shows (figure 10) three suitable buffer ranges, in north part and west also small area in the southern part.

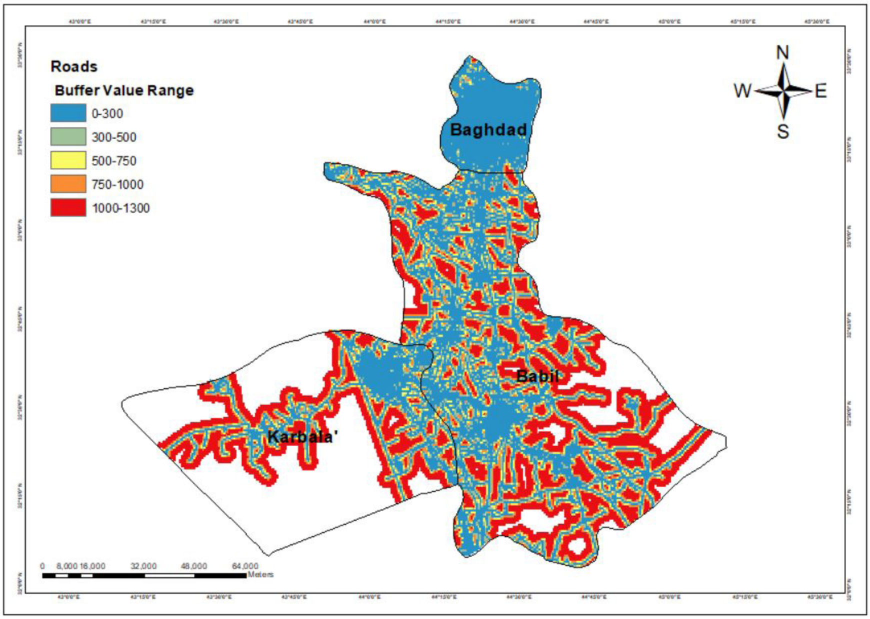


Figure -11 Distance from roads networks in study area.

As a fundamental principle, landfills should not be situated within 100 meters of major highways, city streets, or other transportation routes. It is essential to choose a suitable distance from the road network to ensure efficient waste transportation and reduce associated costs. Based on various sources, the study recommended a buffer zone of 500 meters from main roads. Distances ranging from 1000 to 1500 meters were considered moderately suitable, while the highly suitable range fell between 300 to 500 meters. The findings revealed that 31.3% of the total buffered distance is highly suitable for solid waste dumping sites (figure 11).

The study determined safe distances from settlements (figure 12), setting them at 2500 meters for urban centers and 1500 meters for rural villages. The settlement areas were then classified based on their suitability. the map reclassified as unsuitable (0-500 m), less suitable (500-1000 m), moderate suitable (1000-1500 m), and most suitable (1500-2000 m). Among the levels of suitability, the study area had the highest proportion of unsuitable land, covering 45% of the total area. The appropriateness of the buildings in relation to the Baghdad governorate was confined to the administrative borders of the governorate, as well as the southern part. for Babil, the best area was distributed to the northern and eastern part and a small part to the south of the province. While in Karbala Governorate, the best area was in the northern and northeastern part.

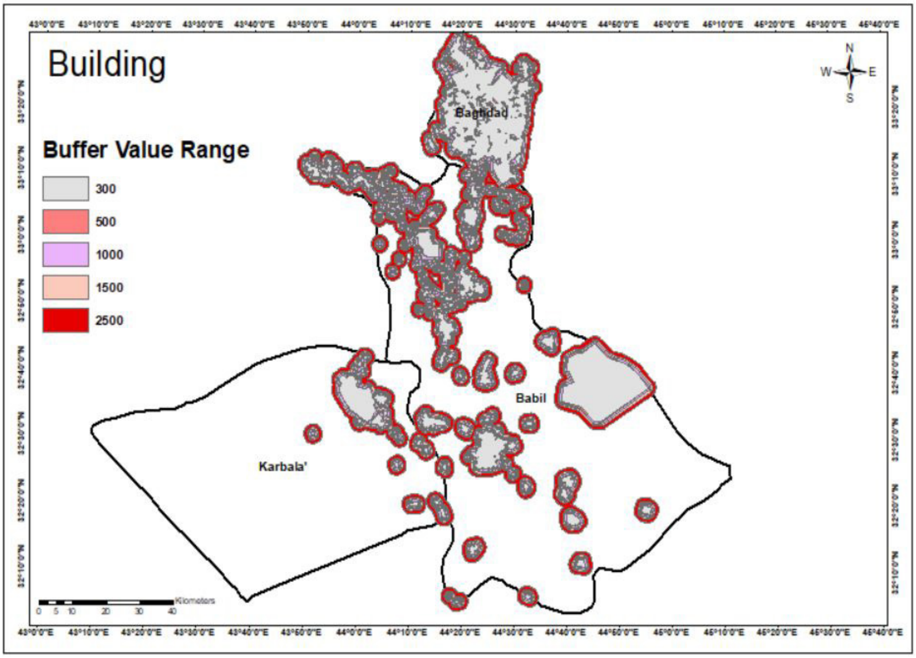


Figure -12 Distance from settlement area.

The process of selecting a solid waste disposal site involves a comprehensive assessment of various options, considering geological, environmental, social, and economic impacts. By analyzing these factors, the final map of the suitability index (figure 13) has been computed, enabling a well-informed comparison of different potential locations for the dumping site. The map has been classified into four class (best, moderate, low, very low).

For Baghdad province, the largest part was very low class, while the moderate class were distributed in the northeastern and southeastern parts, for the best class (figure 14) there are four sites, one in the north, second in the south, and the last two one in the west part, all these sites on the administrative borders of the governorate.

For Babylon, there are many sites suitable (figure 14) for landfilling waste (35 sites) distributed in the north, center and south parts of the province, for the moderate class (figure 13), they were distributed largely in the western part. While for the unsuitable sites, they were generally concentrated in the center and west of the province.

In Karbala Governorate, the best parts were in the northern and northeastern part (about 7 sites) (figure 14), and the unsuitable parts (figure 13) in Karbala Governorate are also located in the northern part, which is close to Al-Razzara Lake.

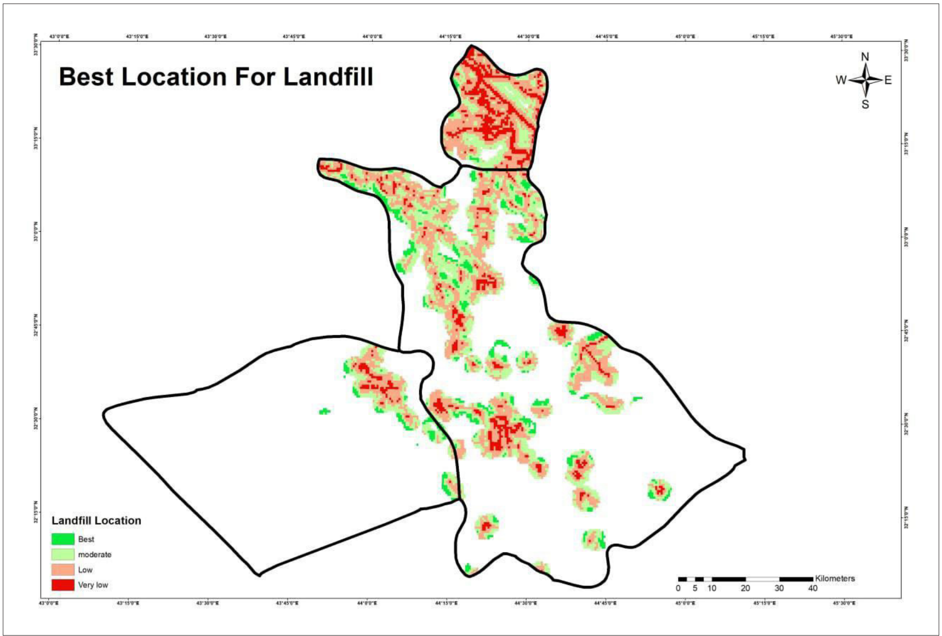


Figure -13 Final map of suitable location of landfill site in study area.

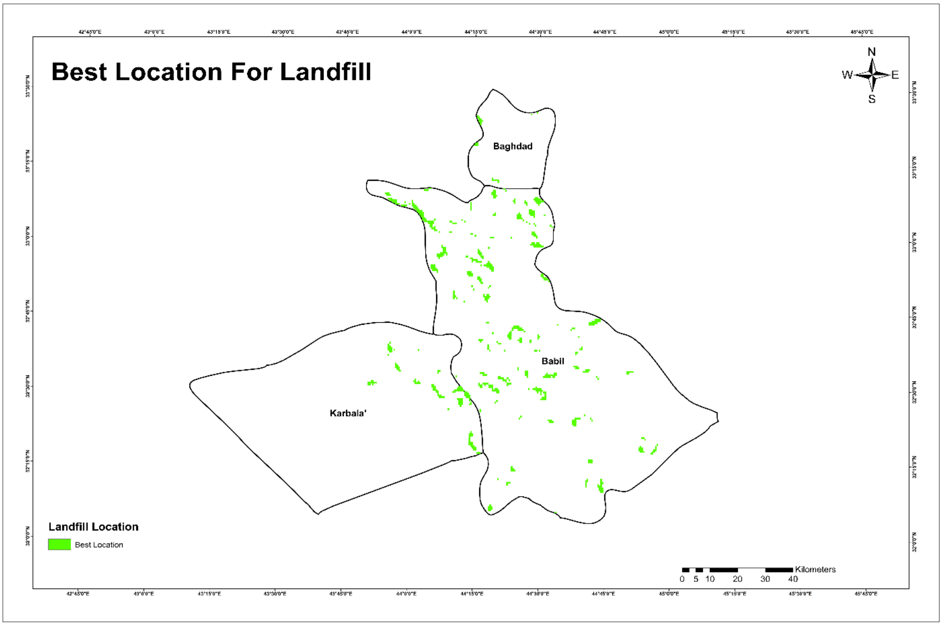


Figure -14 The restricted area for best landfill site in study area.

## 5. The Modern Practical Vision of Establishing a Landfill, and How to Disseminating the Culture of the Waste Recycling

The double liner system (figure 15) is a design concept used in the construction of landfill sites to help prevent the contamination of soil and groundwater by the waste materials placed in the landfill. Landfills are designed to safely contain and manage waste, and the double liner system is one approach to minimize the potential for environmental harm. The double liner system consists of two layers of impermeable materials that are installed within the landfill to create a barrier between the waste and the surrounding environment. The layers typically consist of:

**Primary Liner:** The primary liner is the innermost layer of the double liner system and is in direct contact with the waste materials. It is typically made of a high-density polyethylene (HDPE) geomembrane, which is a synthetic material that is impermeable to liquids. This liner helps prevent the leachate, which is the liquid that forms as water interacts with waste, from seeping into the surrounding soil and groundwater.

**Secondary Liner:** The secondary liner is installed outside the primary liner and serves as an additional barrier to further prevent the migration of leachate into the environment. It is typically made of a compacted clay liner or another impermeable material. The secondary liner provides an extra layer of protection in case the primary liner becomes damaged or compromised.

In addition to the primary and secondary liners, the double liner system may also include various drainage systems, leachate collection systems, and monitoring equipment to detect and manage any potential leaks or environmental concerns.

The goal of the double liner system is to create a controlled environment within the landfill that minimizes the impact of waste on the surrounding ecosystem. It helps to contain potential pollutants and prevent them from seeping into the soil and groundwater, reducing the risk of contamination. However, it's important to note that the effectiveness of the double liner system depends on proper design, construction, and maintenance of the landfill facility.

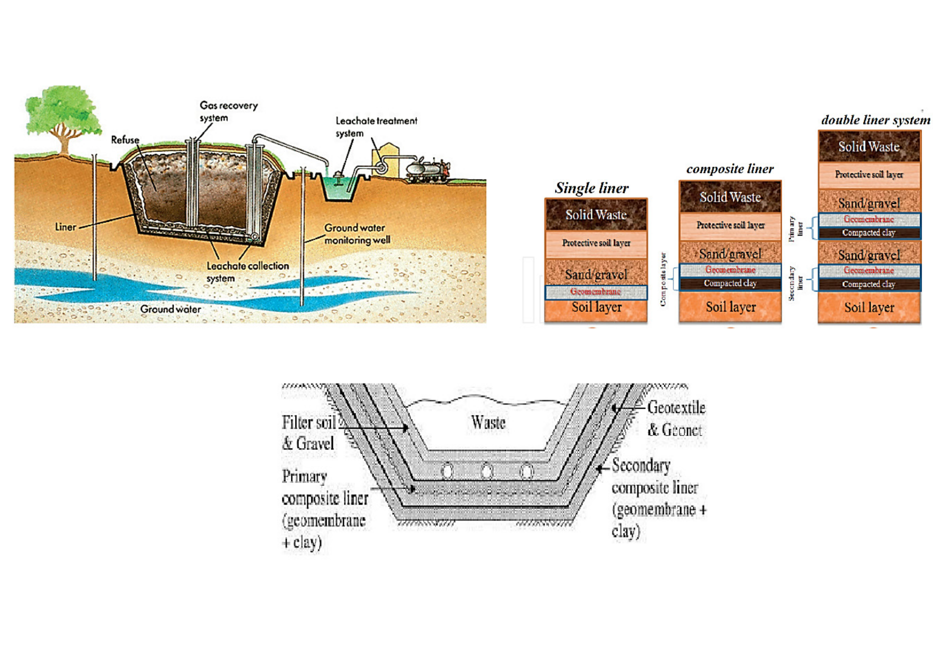


Figure -15 Schematic of modern landfill process (modify from: www.oocities.org).

The choice of the best type of geomembrane depends on various factors, including the specific application, site conditions, environmental regulations, and project budget. Geomembranes are synthetic materials used in various engineering and environmental applications to control fluid migration (such as liquids and gases). When selecting a geomembrane type, considerations include the material's physical properties, chemical resistance, durability, installation requirements, and long-term performance. There are several types of geomembranes commonly used, each with its own advantages and disadvantages. Some of the most common geomembrane materials include:

**High-Density Polyethylene (HDPE):** HDPE geomembranes are popular due to their excellent chemical resistance, durability, and UV stability. They are commonly used in landfill liners, mining applications, and water containment projects. HDPE geomembranes are known for their strength, flexibility, and ability to withstand a wide range of environmental conditions.

**Low-Density Polyethylene (LDPE):** LDPE geomembranes are similar to HDPE geomembranes but have lower tensile strength and are typically used in less demanding applications.

**Polyvinyl Chloride (PVC):** PVC geomembranes offer good chemical resistance and are often used in applications such as decorative ponds, water containment, and wastewater treatment facilities. They are also available in various formulations to suit specific needs.

**Ethylene Propylene Diene Monomer (EPDM):** EPDM geomembranes are commonly used in applications requiring high flexibility and elongation properties. They are often used in water containment systems and decorative ponds.

**Polypropylene (PP):** PP geomembranes offer good chemical resistance and are used in applications similar to HDPE geomembranes. They are known for their resistance to heat and some organic solvents.

**Chlorosulfonated Polyethylene (CSPE)**: CSPE geomembranes are known for their excellent chemical resistance to a wide range of substances, making them suitable for applications involving aggressive chemical environments.

**Reinforced Geomembranes:** These geomembranes combine a geomembrane with a reinforcement layer (typically a geotextile) to provide additional strength and durability. They are often used in applications where high mechanical stress or puncture resistance is required. Geotextiles are permeable fabrics, made from either polypropylene or polyester. When used in several different applications, mainly associated with soil, geotextiles have the ability to separate, filter, reinforce, protect, or drain. Geotextile fabrics come in three basic forms: non- woven geotextiles, woven geotextiles (needle punched), or heat bonded geotextiles (structural woven).

Minimum buffer strip between composting facility boundary and landfill site also adjacent property shall be min 350 -500m.

Promoting waste segregation precedes the phase of waste recycling. The dissemination of this culture may take from one to three years, accompanied by monitoring, follow-up, and corrective measures to rectify improper practices. However, this step will yield both cultural and financial benefits for the entities involved. We can initiate by organizing awareness campaigns for visitors, then extend our efforts to all institutions, eventually encompassing all establishments in Karbala. Cultivating waste segregation begins with the very first institution in building any society—the family—followed by schools. It is essential to create a general culture among young individuals that disposing of waste should be in designated locations. There should be separate receptacles for plastic waste, glass waste, food scraps, and so forth. This practice should extend to state institutions and public facilities where regulations can be enforced. There are three main aspects that need clarification in this context:

- **Utilizing media, publicity, and advertisements to disseminate the culture of waste separation:** Raising awareness about waste separation can be achieved through strategic media campaigns, public relations efforts, and targeted advertisements. These initiatives should focus on educating the public about the importance of segregating different types of waste for proper disposal and recycling. By effectively utilizing various media platforms, such as television, radio, social media, and billboards, we can reach a wide audience and encourage them to adopt responsible waste management practices. This approach will contribute to building a more environmentally conscious society and pave the way for successful waste recycling endeavors. It is possible to use educational institutions such as universities and institutes to achieve this subject.

- **Waste Containers Waste separation is facilitated by utilizing five distinct colored containers:** a. Paper Waste Container: Designed to accommodate the significant amount of paper waste generated within educational institutions. b. Plastic Waste Container: Intended for collecting plastic water bottles and other plastic materials. c. Metal Waste Container: Reserved for the collection of metal cans from carbonated beverages and other products. d. Glass Waste Container: Allocated for the disposal of juice and other glass container remnants. e. Food Waste Container: Dedicated to the disposal of food leftovers, vegetable waste, and similar organic materials. By implementing this container system, the efficient sorting and appropriate disposal of various waste types can be achieved, contributing to an environmentally conscious waste management strategy.

- **Waste Recycle bins** (figure 16) It is preferable to have five colored bags to facilitate waste separation. In case these colors or labels are unavailable, the contents inside the bag should indicate their category.
- A vehicle equipped to securely transport these sealed bags to a storage facility for waste bags.
- Compacting the separated waste, each type individually, into cubic meter-sized units.
- Paper waste is thermally treated and recycled to manufacture cardboard for food and other products. Plastic waste is thermally treated and recycled to produce reusable plastic products. Metal waste is cut and recycled according to requirements. Glass waste is melted and recycled as needed Food waste is recycled into fertilizers.

**Figure -16 Recycle bins**

- To minimize the operational costs of this project, the following mechanisms are recommended:

- A clause in contracts with procession owners ("Al-Mawakib") stipulating that the second party bears the cost of five colored containers placed near their premises.
- Municipalities of Karbala, Babylon, and Baghdad enforce the provision of containers of various types for Husseiniyahs procession owners.
- Manufacturing compactors can be initiated as graduation projects for engineering students, particularly in the engineering colleges of Karbala, according to the type of compressed materials.
- Utilizing publishing houses to create labels for different containers.
- In the future, the Ministry of Industry or private plastic factories could be involved in producing colored bags.

Promoting the culture of waste separation will not only benefit institutions and municipalities, but it will also instill a new mindset among students, employees, and professors, transforming the city into a more environmentally friendly and cherished place for its residents. Let's start taking action from this moment forward!

## 6. Conclusions

The analysis provided valuable insights into suitable locations for landfill sites and waste recycling factories in the three governorates, considering various geological environmental and socioeconomic factors. The information derived from this study can guide decision-makers in implementing effective waste management strategies and selecting appropriate sites to minimize environmental impact and optimize waste disposal practices. The Spatial Suitability Analysis of landfill site and waste recycling factories in Karbala, Babel, and Baghdad Governorates yielded the following main conclusions:

1. Suitability Index Map: The comprehensive assessment of geological, environmental, social, and economic factors led to the development of the Suitability Index Map, which classifies potential locations for the dumping site into four classes - best, moderate, low, and very low.
2. Baghdad Governorate: The majority of Baghdad province was categorized as very low suitability for landfill sites, indicating limited viable options. Moderate suitability areas were dispersed in the northeastern and southeastern parts. However, only four sites were identified as the best class, located in the north, south, and west regions, near the administrative borders of the governorate.
3. Babel Governorate: Babel displayed a higher number of suitable landfill sites (35 sites) distributed across the north, center, and south regions. The moderate suitability class was mainly concentrated in the western part, while unsuitable sites were generally found in the center and west of the province.
4. Karbala Governorate: The best areas for landfill sites (around 7 sites) were located in the northern and northeastern parts, offering potential options for waste disposal. However, the unsuitable areas were concentrated in the northern region, particularly near Al-Razzara Lake.
5. Area of Best Class: The total area of the best class in each governorate was approximately 8 km in Baghdad, 236.82 km in Babylon, and 45.9 km in Karbala, suggesting the availability of

limited space with higher suitability for landfill sites.

6. The research presented a practical implementation vision for promoting a culture of waste recycling, starting from home(family), and extending to the stage of execution.

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