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MULTI-FACTOR GIS MODELING FOR SOLID WASTE DUMPSITE SELECTION IN BOUMEDFAA, ALGERIA

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Abstract: The integration of the Analytic Hierarchy Process (AHP) with Geographic Information Systems (GIS) presents a powerful framework for improving waste management practices. AHP serves as a structured decision-making tool that enables stakeholders to prioritize and evaluate various alternatives based on multiple criteria, while GIS enhances this process by providing spatial analysis capabilities that allow for the visualization and examination of geographic data. This combination is particularly relevant in the context of waste management, where decisions often involve complex trade-offs among environmental, economic, and social factors. The primary aim of this study is to investigate the synergistic integration of AHP and GIS within the realm of waste management. Specifically, the research focuses on three critical areas: assessing various waste disposal methods, selecting optimal sites for landfills, and optimizing waste collection routes. By leveraging the strengths of both methodologies, the study seeks to enhance decision-making processes in waste management. The methodology involves breaking down complex decision-making scenarios into a hierarchical structure of criteria and sub-criteria. This structured approach allows stakeholders to systematically compare different options based on a range of factors, including environmental impact, cost-effectiveness, community acceptance, and logistical feasibility. GIS complements the AHP framework by providing essential spatial data that reveals patterns and relationships in waste generation and disposal, facilitating a more comprehensive analysis. The integration of AHP and GIS empowers decision-makers to visualize the potential implications of their choices more effectively. For example, GIS can be utilized to map waste generation hotspots, identify suitable locations for waste management facilities, and analyze transportation routes for their efficiency and effectiveness. This visualization aids in understanding the spatial dynamics of waste management and supports more informed decision-making. Overall, the synergy between AHP and GIS significantly enhances the effectiveness of waste management strategies. This integrated approach not only leads to more sustainable waste management practices but also improves resource allocation and fosters better community engagement in waste management initiatives. By supporting informed, data-driven decision-making, the combination of AHP and GIS ultimately contributes to the development of more efficient and environmentally friendly waste management solutions. The findings of this study underscore the importance of utilizing advanced analytical tools in addressing the multifaceted challenges of waste management, paving the way for innovative and sustainable practices in the field.

Keywords: Algeria, AHP, GIS, Boumedfa, environnement, solid waste, complex, sustaianble

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INTRODUCTION

Industrialization and population growth have resulted in unprecedented levels of solid waste production worldwide (Lakhouit, 2025; Abdella et al., 2022; Kogbara et al., 2024; Krishna, 2024; Kurniawan et al., 2022; Zohoori & Ghani, 2017). The swift urbanization occurring in developing nations across Asia and Africa has resulted in a significant rise in the production of municipal solid waste (MSW) (Zhang et al., 2024). The rise in population, urban expansion, and the growth of industrial and economic activities have led to a significant surge in waste production. This presents one of the most pressing challenges globally due to the threats it poses to both human health and the environment (Bouchama & Drias, 2024).

Waste, which is material released from human activities, presents a serious risk to both human health and the environment (Singh, 2019). Solid waste mismanagement and misgovernance in urban areas, mining, and the timber industry, among others, represent global challenges related to environmental pollution, social inclusion, and economic sustainability.

These issues necessitate comprehensive assessments and coordinated strategies for effective resolution (Szpilko et al., 2023; Cacciuttolo & Atencio, 2022; Pheakdey et al., 2022). Geographic Information System (GIS) technology is one of the hottest research tools in the world and is one of the fastest growing high technologies for monitoring (Benferhat & Bouder, 2024). GIS assists decision-makers in planning solid waste collection routes, determining optimal locations for bins, and evaluating environmental health impacts (Shabani et al., 2024). The site selection techniques, assessed the current landfill, and created a multifactor geographic information system (GIS) model (Kalisha & Munthal, 2024).

Shukor et al confirm that methods such as geographic information system (GIS) and multi-criteria decision analysis (MCDA) facilitate decision-making processes. This integration reduces analysis time and costs, improves accuracy, and

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minimizes errors. The analytic hierarchy process (AHP) provides a framework to validate judgments and derive measurable values in decision-making involving theories and concepts (Shukor et al., 2024). The GIS environment was developed by following these steps outlined by (Resende et al., 2025). The use of GIS is more to be demonstrated in several areas, from her point of view, the researcher sees that the integration of modeling software and a geographic information system (GIS) facilitates the creation of a holistic representation of groundwater quality (Megahed et al., 2025). The management of municipal solid waste (MSW) faces a variety of challenges, including health concerns, climate change, and social inequality. Decision-makers are consistently exploring effective and sustainable solutions to address the solid waste management crisis (Sondh et al., 2024). Solid waste management (SWM) has emerged as a critical challenge for the protection and sustainability of ecosystems (Tian et al., 2025).

In his study, the researcher amply proves that GIS is a tool that contributes to the management of spatial data, such as solid waste. The map, as the final result, remains a support for synthesizing several geographic information, which would help managers guide urban development studies. Hence the need for the municipal authority to commit to environmental sanitation for the preservation of humanized and naturalized ecosystems (Tryphon et al., 2025). According to the World Bank, global solid waste generation is expected to increase from 2.01 billion tons in 2016 to 3.40 billion tons by 2050. This increase is driven by urbanisation, economic growth, and changing consumption habits.As a result, sustainable waste management (SWM) within the framework of the circular economy has become a significant issue (Kaza et al., 2018).

MATERIALS AND METHODS

Study area

Boumdfaa is located at coordinates 36°22′13″N and 2°28′35″E, 100 km west of Algiers, 60 km northeast of Ain Defla, 37 km northwest of Midia and 40 km west of Blida. In 2008, the population of the area was 21,509. The population density is 860 people per km². For this study, we selected five criteria to Determining Waste Bins Locations. The average scale method provided the identification of new factors or the use of greater detail of those factors previously used in the large-scale site identification phase. The factors were grouped according to economic or environmental importance and values were assigned to each factor from five to six categories with scores ranging from 0 to 10 (Figure 1).

Figure 1. Location of study Area (Source: Authors)

A "weight" was then assigned to each factor through a hierarchical analysis that creates a scale of priority within the factors. The suitability of the area was then evaluated using a simple weighted summation (SAW, simple additive weighting) system (Figure 2) . This system is widely used to calculate final values in cases using multiple criteria. The mathematical formulation of this system is described by the following equation (Yoon & Hwang, 1995:250).

$$Vi=\sum_{j=1}^{n} Wjvij \qquad (1)$$

Where Vi is the suitability index for area i, Wj is the relative importance of the weight given to criterion j, vij is the priority value of area i concerning criterion j, n is the total number of criteria.

The criteria considered in this study are: • Walking Distance from buildings; • Walking Distance from Facilities; • Walking Distance from Roads; • Walking Distance from Green spaces;

Figure 2. Waste on the Boumedfa road on: 02/28/2025 Boumedfa (Source: Authors)

1. Walking Distance from Buildings: Proximity to buildings is crucial for accessibility and convenience. Areas closer to buildings are likely to be more desirable for residential or commercial development.

2. Walking Distance from Facilities: Access to essential facilities (e.g., schools, hospitals, shopping centers) enhances the livability of an area. This criterion ensures that residents can easily reach necessary services.

3. Walking Distance from Roads: Proximity to roads is important for transportation and connectivity. Areas that are easily accessible by road can facilitate better movement and logistics.

4. Walking Distance from Green Spaces: Access to parks and green spaces contributes to the quality of life. It promotes physical activity and provides recreational opportunities, making areas with nearby green spaces more attractive.

5. Walking Distance from Empty Space: Areas with nearby empty spaces can offer potential for future development or expansion. This criterion allows for the

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The suitability of the area was then evaluated using a simple weighted summation (SAW, simple additive weighting) system. This system is widely used is represented schematically in the diagram below (Figure 3).

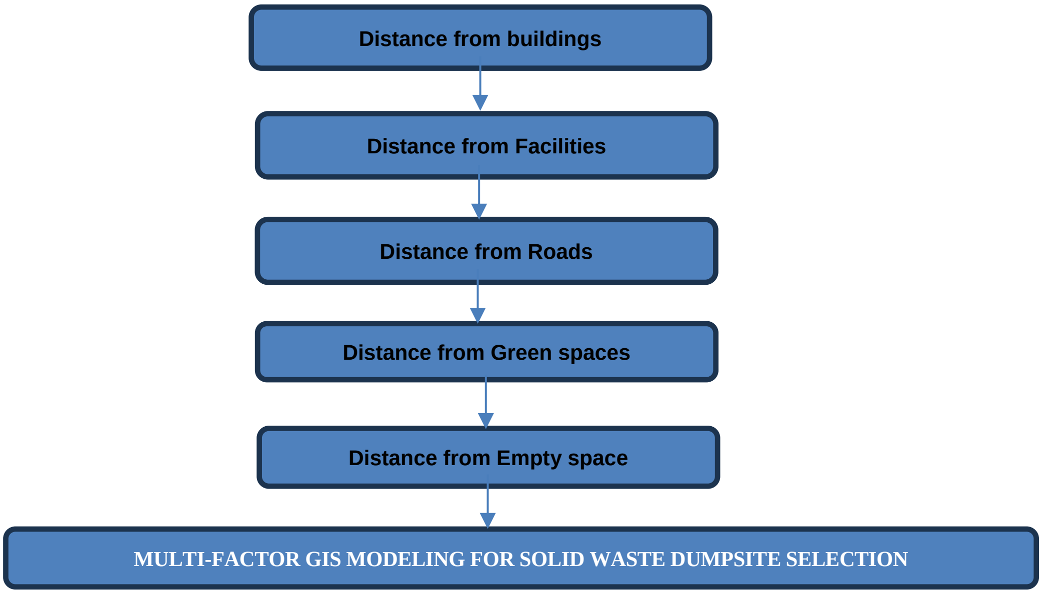

Figure 3. Method modeling for solid waste dumpsite selection

RESULTS AND DISCUSSION

A model was created to perform the spatial analysis tasks by model builder tools, and in it, the working environment was set. Within the model, all operations were performed until the Determining Waste Bins Locations was obtained: Firstly: the datasets were derived based on the previously mentioned criteria as follows:

Building

The Building a raster layer. The distance was derived from buildings by the Euclidean distance tool located in the distance toolset in the spatial analyst tools toolbox, the result is a raster layer. in this raster layer the hue is from Green and light green to red color (changed from the properties to clarify), as, where the preference, according to the criteria followed, returns to the classes with the Green color, followed by the light green color, yellow, orange and the red color respectively (Figure 4).

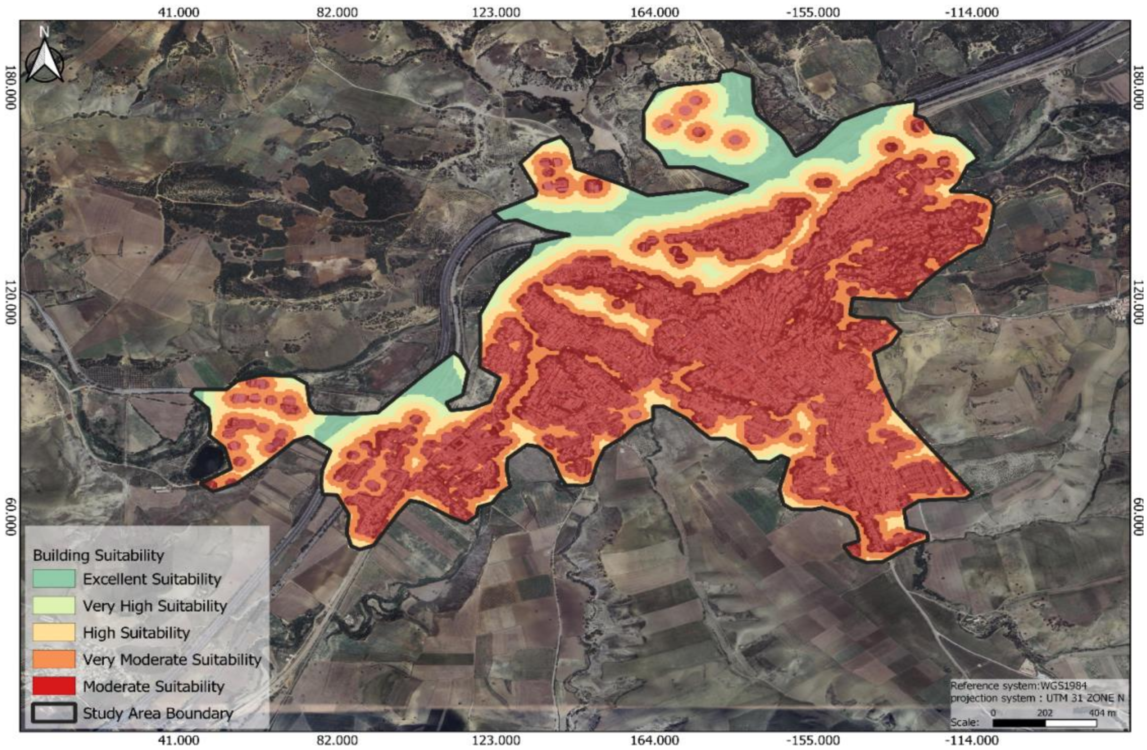

Figure 4. Building criteria map (Source: Authors, 2025)

2. Facilities

The distance was derived from Facilities by the Euclidean distance tool, the result is a raster layer. In this raster layer, the hue is from pink to crepe color (changed from the properties to clarify), as, where the preference, according to the criteria followed, returns to the classes with the pink color, followed by the fuchsia color, purple and the crepe color respectively (Figure 5).

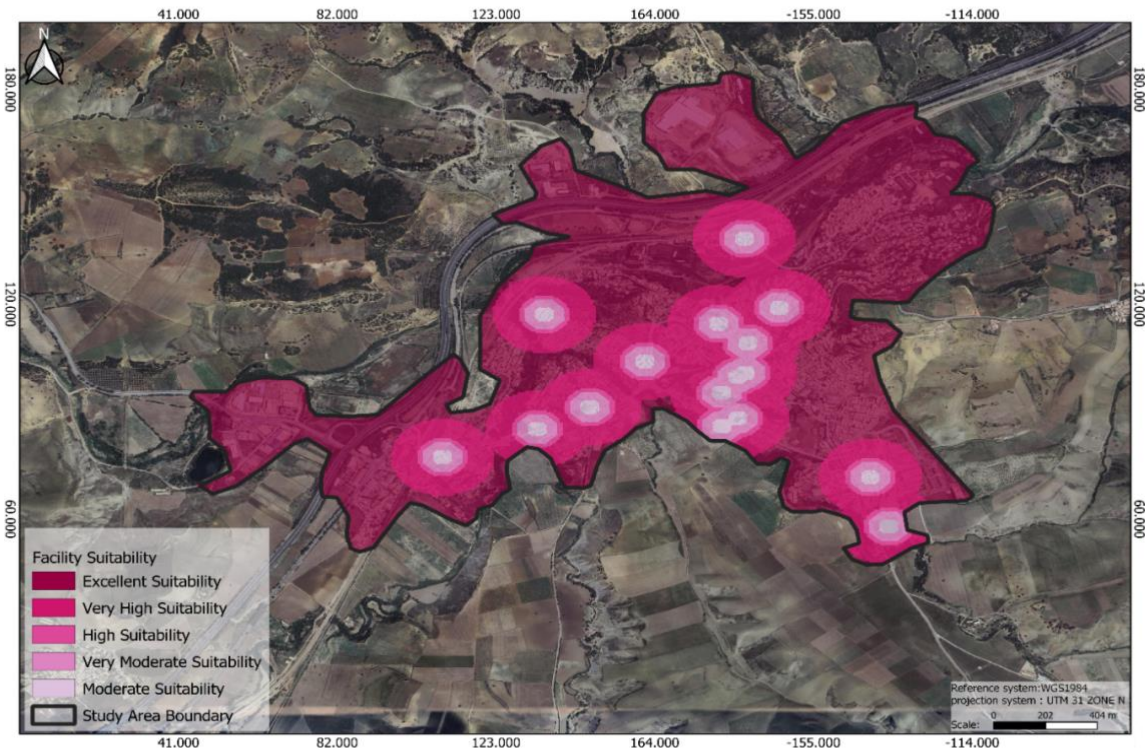

Figure 5. Facilities criteria Map (Source: Benferhat, 2025)

3. Green space sustainability

To evaluate this criterion, we established five buffer zones around all the Green space areas, spaced 150 meters apart. These zones were then converted into a grid map with 20x20-meter cells. A distance-based scoring system was applied, assigning higher scores to areas farther from the rivers. The distance was derived from the Green space areas by the Euclidean distance tool, the result is a raster layer. In this raster layer, the hue is from tawny to yellow color (changed from the properties to clarify),, where the preference, according to the criteria followed, returns to the classes with the tawny color, followed by the copper colour, deep saffron, orange and the yellow color respectively (Figure 6).

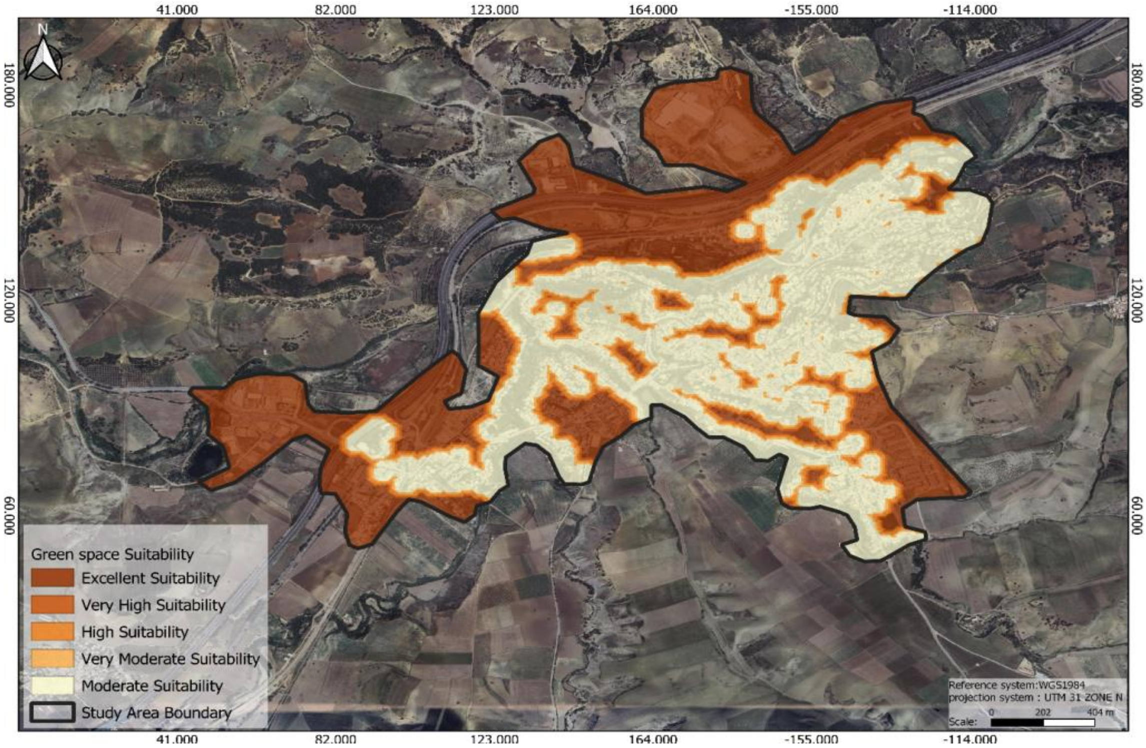

Figure 6. Green space criteria map (Source: Benferhat, 2025)

Figure 7. Roadscriteria Map (Source: Benferhat,2025)

4. Roads

The selection of Waste Bins Locations should consider the criteria of road distance or proximity, as it determines the site's accessibility. Ideally, Waste Bins should be reachable via alternative routes. However, they should not be located too far from existing road networks to minimize the cost of constructing connecting roads. Additionally, waste transportation should not disrupt regular traffic flow. To assess this factor, we established five buffer zones around major roads (highways, main roads, secondary, and urban roads), each spaced 500 meters apart. These zones were then converted into a 20x20 meter grid map. A scoring system was applied based on road proximity to the Waste Bin, with the highest scores assigned to locations closest to existing roads The distance was derived from roads by the Euclidean distance tool, the result is a raster layer. In this raster layer, the hue is from black to yellow color (changed from the properties to clarify), as, where the preference, according to the criteria followed, returns to the classes with the black color, followed by the purple color, pink, orange and the yellow color respectively (Figure 7).

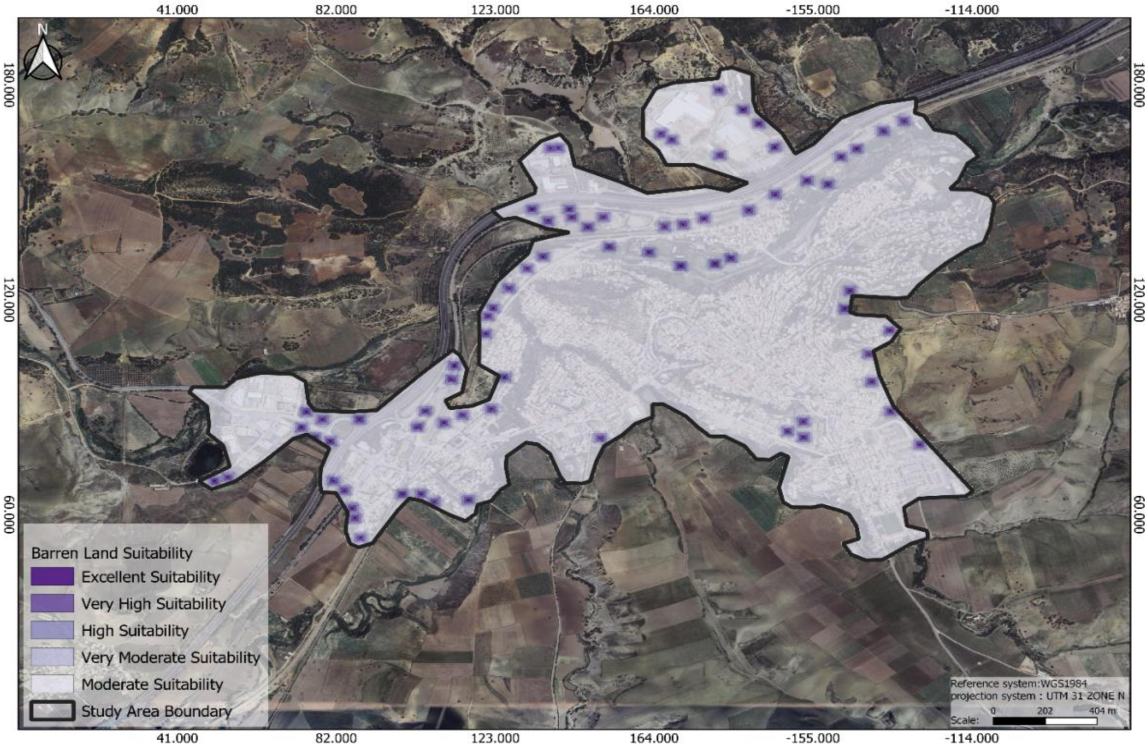

Figure 8. BARREN LAND criteria map (Source: Benferhat, 2025)

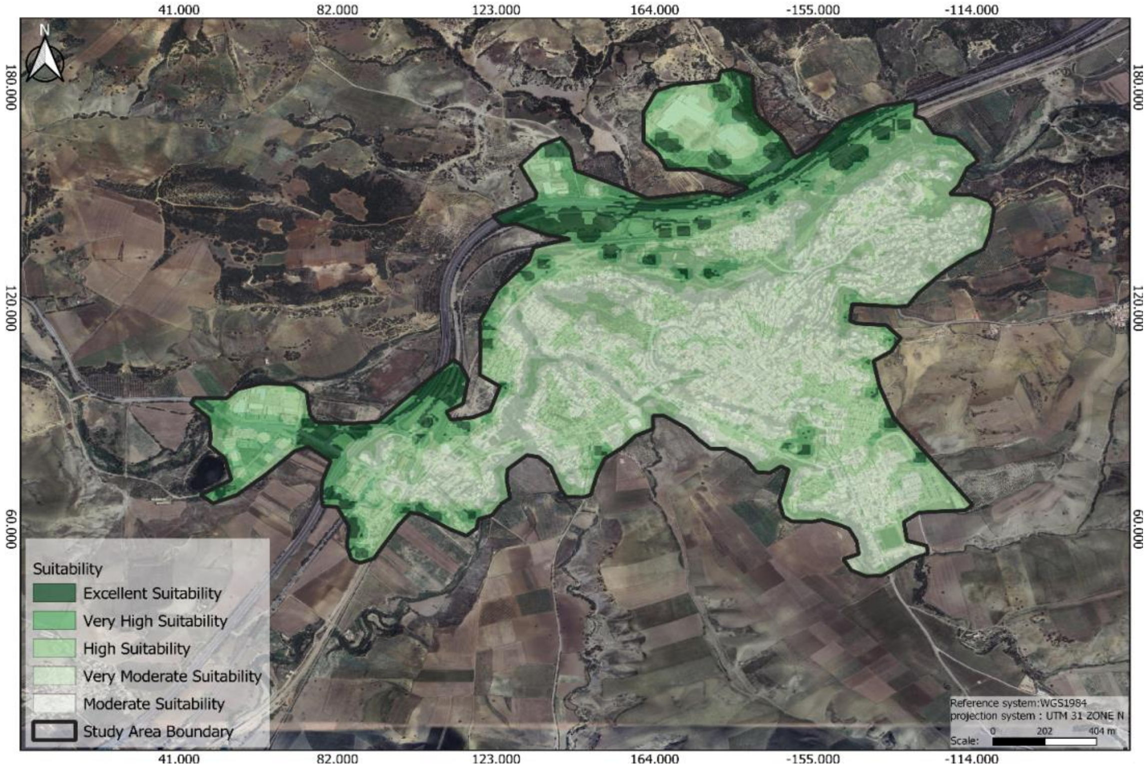

Figure 9. Optimal waste bin locationssource: Benferhat, 2025

5. BARREN LAND

The distance was derived from BARREN LAND by the Euclidean distance tool, the result is a raster layer. in this raster layer the hue is from little princess color to purple color (changed from the properties to clarify), as, where the preference, according to the criteria followed, returns to the classes with the little princess color, followed by the very light purple color, moderate purple, strong purple and the purple color, respectively (Figure 8).

Secondly: the produced datasets were previously reclassified by the objective of the analysis process and the criteria used within 5 weighing ranks so that the value 5 was given to the most appropriate areas and the value 1 to the worst-appropriate areas, and the gradient between them respectively, these suitable sites using the weighted overlay tool located in the overlay toolset from the spatial analyst tools toolbox.

CONCLUSIONS

While this study provides valuable insights into the challenges of solid waste management in Boumedfa, several limitations must be acknowledged to contextualise the findings and guide future

1. Data Availability and Quality: The analysis heavily relied on the availability and accuracy of geographic data related to waste bin placements and population density. Any discrepancies or gaps in this data could lead to misinterpretations of the least suitable locations for waste bins. Future studies should aim to incorporate more comprehensive datasets, including real-time waste generation metrics, to enhance the reliability of the findings.

2. Temporal Constraints: The study was conducted over a specific timeframe, which may not account for seasonal variations in waste generation and disposal patterns. For instance, periods of increased tourism or local events could significantly alter waste production, affecting the effectiveness of waste bin placement. Longitudinal studies that monitor waste management practices over extended periods would provide a more nuanced understanding of these dynamics.

3. Geographic Scope: The focus on Boumedfa may limit the generalizability of the findings to other regions with different demographic, economic, and environmental contexts. While the use of geographic information systems (GIS) allows for localized analysis, the unique characteristics of Boumedfa may not reflect the challenges faced in other municipalities. Comparative studies across diverse settings could yield broader insights into effective waste management strategies.

4. Stakeholder Engagement: The study did not incorporate direct feedback from community stakeholders, including residents and local waste management authorities. Engaging these stakeholders could provide critical qualitative insights into the practical challenges and perceptions surrounding waste bin placement. Future research should consider participatory approaches to gather input from those directly affected by waste management policies.

5. Technological Limitations: While GIS is a powerful tool for spatial analysis, it has inherent limitations in modeling human behavior and decision-making processes related to waste disposal. The study's reliance on GIS may overlook factors such as social norms, cultural attitudes, and individual behaviors that influence waste management practices. Integrating social science methodologies could enrich the analysis and provide a more holistic view of the issues at hand.

6. Focus on Bin Placement: The study primarily concentrated on the placement of waste bins, potentially neglecting other critical aspects of waste management, such as collection frequency, public awareness campaigns, and recycling initiatives. A more comprehensive approach that examines the entire waste management system would be beneficial in identifying interconnected challenges and solutions.

In conclusion, while the findings of this study underscore the need for a strategic reassessment of waste bin distribution in Boumedfa, acknowledging these limitations is essential for framing future research and policy recommendations. Addressing these gaps will be crucial for developing a more effective and sustainable waste management system that meets the community's needs and enhances environmental health (Figure 9).

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