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LAND SUITABILITY ANALYSIS FOR URBAN GARDENING USING GIS-BASED MULTI-CRITERIA DECISION-MAKING APPROACH

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Abstract

The application of the Geographical Information System (GIS) extends beyond mapping and includes an analysis of attribute and geographical data, identification of behavioural patterns, and visualisation of positional analysis outcomes. The system provides accurate coordinates, enabling functions such as storage and retrieval, pattern search, and model creation in GIS applications. One widely adopted approach for land-use identification involves utilising GIS operations to establish databases and conduct analyses. Thus, this study utilises ArcGIS software tools to determine the suitability of land and optimal location for the development of community gardens in Shah Alam. Decision-making was based on multiple criteria, and to ensure accurate and comprehensive data, the researchers employed a qualitative method similar to expert interviews. Related government agencies and authorities, as well as experts, provided input through three separate expert interviews. Findings from the interviews highlighted the significance of land slope, elevation, land use, proximity to settlements, road accessibility, and water access as important considerations for site selection in urban gardening or community gardens. The study demonstrates the effectiveness of GIS methods in obtaining such results and recommends that future research focus on assessing the potential for sustainable development by leveraging GIS techniques.

Keywords: Multi-criteria Decision Making, Land Suitability, GIS, Urban Gardening

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INTRODUCTION

Known as urban farming, urban gardening involves growing plants and crops in urban areas, often in small-scale and limited spaces such as balconies, rooftops, or community gardens. Urban gardening plays a significant role in improving food security, particularly for vulnerable and underprivileged communities with limited access to fresh and affordable produce. In Malaysia, people in urban areas typically rely on local supermarkets and wet markets for their food, including vegetables. According to the Food and Agriculture Organization of the United Nations (FAO, 2022), people living in urban areas in Malaysia usually obtain their food supplies, especially vegetables, from local supermarkets and wet markets. Although the country has enough food supply, the FAO has cautioned about the possible difficulties in accessing food, particularly during disasters. Urban gardening can address these issues by increasing food availability and access, thus supporting food security for Malaysia's urban population.

Sustainable urban farming, including urban gardening, is an approach aimed at enhancing food security by increasing food supply and access. However, urban farmers in Malaysia (particularly those in major cities such as Kuala Lumpur, Shah Alam, and Johor Bharu) have faced various challenges. These include limited and suitable land access, water availability, difficulties in accessing financial institutions, lack of commitment, and administrative policies and bureaucracy involving multiple authorities (Ishak, Norziha, et al., 2022). Rapid developments in the urban and suburban regions are limiting the amount of land and green spaces available for recreational and social activities. This expansion has significant repercussions for the ways in which local communities, particularly urban farmers, are involved in the food resources business directly or indirectly. Additionally, the development of community gardens without systematic management can result in a less appealing and conducive urban environment. As a result, multiple guidelines for the establishment of community gardens and urban farming have been issued by various agencies.

The comprehensive and forward-thinking implementation of these guidelines can be further enhanced through the use of a GIS-based Multi-Criteria Decision Making (MCDM) approach. The application of this MCDM method is not limited to a small number of disciplines. It can be used to determine and comprehensively analyse the suitability of land for the development of beneficial and sustainable urban gardening. GIS-based multi-criteria decision analysis is the most common method for agriculture land suitability (Ozsahin, E., & Ozdes, M., 2022). By analysing multiple criteria such as soil type, soil texture, soil thickness, slope, climate properties, and soil structure, land suitability maps can be generated and used as a valuable tool for land use management.

LITERATURE REVIEW

Urban Gardening and Community Garden

Community gardens are often associated with the revitalisation of urban lands through neighbourhood beautification and restoration (Mccormick, K., 2020). These gardens are located in public spaces or commonly-held land and shared, particularly in an urban setting. Community gardens can be found in several locations, ranging from urban, suburban, and rural areas. They may vary in size, ranging from a few small plots to several acres. The crops planted in community gardens can vary depending on climate, location, and community preferences. Short-term crops such as herbs, leafy greens, and radishes (Zaidi Tajuddin, 2019) are well-suited for urban gardens due to their fast-growing nature, making them suitable for limited spaces and shorter growing seasons. Regarding the suitability of soil type, a few options can be considered, such as container potting mix, raised bed soil, or hydroponic and aquaponic systems. However, it is important to note that the suitability of soil types and crop choices can vary depending on the unique settings of urban gardening, such as the amount of sunlight and water available, as well as the prevailing climate.

Community gardens and urban gardens are typically managed by local residents or civic organisations in the surrounding area. These garden managers may charge minimal fees or solicit volunteer labour (Delshad, A. B., 2022) in exchange for providing access to garden plots and utilities, such as water, composting, and shared tools. Urban gardening offers numerous benefits, including increased access to fresh and healthy food, promotion of physical activity and overall health, fostering social connections, providing valuable educational opportunities, enhancing property values while reducing crime rates, enhancing biodiversity, and contributing to overall environmental improvement (DeMuro, 2021).

Multi Criteria Decision Making Approach (MCDM)

Multi-Criteria Decision Making (known as MCDM) is a method that facilitates informed decision-making when multiple criteria need to be considered or when there is a need to choose among alternatives in which the selection of the most appropriate option is extremely complex (Dehe, B., & Bamford, D., 2015). The method allows for the integration of geographic data and value judgements to assess decision alternatives. GIS-based multi-criteria decision-making is particularly beneficial for complex land-use decision support as the tool offers solutions to various spatial issues.

Analytic Hierarchy Process (AHP)

Developed by Thomas L. Saaty in the 1970s, Analytic Hierarchy Process (AHP) is a widely used method for decision making in numerous fields, including

engineering, finance, transportation and environmental as well as economic land suitability assessment. AHP involves defining objectives, criteria, and alternatives, and then evaluating the relative importance of each criterion and alternative using pairwise comparisons (Saaty, T. L., 1980). This allows decision-makers to incorporate trade-offs between criteria and alternatives. AHP provides a structured approach, flexibility, and the ability to incorporate subjective judgments, making it a suitable method for community garden site selection (Yang, Fang, & Lai, 2017).

METHODOLOGY

This study employed different methods to establish the criteria for community urban garden site selection, determine the most suitable location, and produce a land suitability map. The approaches used include i) descriptive analysis to establish criteria for urban garden site selection; ii) AHP to determine the most suitable area; and iii) spatial analysis to produce a land suitability map indicating suitable areas for urban gardening. AHP is a methodological approach which implies structuring criteria of multiple options into a system hierarchy (Omkarprasad S. Vaidya, 2006), including relative values of all criteria, comparing alternatives for each particular criterion, and defining the average importance of alternatives (Ivan Pogarčić, Miro Frančić, Vlatka Davidović, 2008). The results of the study can be used to identify and assess appropriate land and suitable location for urban gardening, and policymakers can take necessary steps to ensure the sustainability of urban farming initiatives while planning for other development.

Method of Data Collection

This study utilises a set of collected data through open-source databases and related agencies such as the local authority and municipalities. The secondary data contains the current land use data for the District of Petaling, particularly Shah Alam, encompassing roads, industrial areas, commercial areas, residential areas, green areas, forests, water bodies, and infrastructure, as well as raster data containing slope and elevation information.

Expert Interviews

Structured and in-depth interviews were conducted with representatives from the local authority (Majlis Bandaraya Shah Alam) and a town planner with professional certification and more than ten years of experience in GIS application and spatial planning. Three (3) experts were interviewed to obtain exclusive insight regarding the validation and verification of the selected criteria for determining the site suitability for a community garden. A series of structured questions were presented and answers were recorded through scores and notes.

The questions were divided into two sections. The first section involved a scoring component where each expert was asked to provide scores ranging from 1 (Not Suitable) to 4 (Most Suitable) and rank the criteria used in selecting the community garden site (Table 1). The second section aimed to gather general insights from the experts regarding their views on the given criteria. The validation of criteria through expert opinions is influential as these experts possess a comprehensive understanding of the criteria selection process and its impact on site selection.

Table 1: Criteria validation for community garden site selection

No.	Criteria	Sub-Criteria	Suitability	Score
1	Slope	<15º	Most Suitable	4
		16º - 25º	Suitable	3
		26º - 35º	Less Suitable	2
		>35º	Not Suitable	1
2	Elevation	<150m	Most Suitable	4
		150m – 300m	Suitable	3
		300m – 1000m	Less Suitable	2
		>1000m	Not Suitable	1
3	Land use	Vacant Land	Most Suitable	4
		Agriculture	Suitable	3
		Open space and recreational	Less Suitable	2
		Commercial, Housing, Industry, Public Facilities, Infrastructure and Utility	Not Suitable	1
4.	Distance from Settlement Area	0m – 200m	Most Suitable	4
		200m – 400m	Suitable	3
		400m – 600m	Less Suitable	2
		>600m	Not Suitable	1
5.	Proximity to Road Accessibility	0m – 50m	Most Suitable	4
		50m – 200m	Suitable	3
		200m – 400m	Less Suitable	2
		>400m	Not Suitable	1
6.	Proximity to Water Access	0 – 150m	Most Suitable	4
		150m – 450m	Suitable	3
		450m – 600m	Less Suitable	2
		>600m	Not Suitable	1

Pairwise Comparison Matrix and Normalize Matrix

The pairwise comparison matrix was utilised to assess and compare each criterion and establish their relative significance (Kou, G., Ergu, D., Lin, C., & Chen, Y., 2016). The tool empowers experts to rank the six (6) criteria, such as topography (elevation and slope), land-use factors, settlement area, road accessibility, and water access, and subsequently assign weightages to them based on their level of importance. A nine-point weighting scale ranging from 1 (least important

criterion) to 9 (most important criterion) was employed to determine their relative importance (Table 2).

Table 2: Pairwise comparison matrix rating scale that has been ranked by the expertise.

Criteria	Water Access	Road Accessibility	Settlement Area	Landuse	Elevation	Slope
Water Access	1.000	**3.000**	**5.000**	**7.000**	**9.000**	**9.000**
Road Accessibility	0.333	1.000	**5.000**	**7.000**	**7.000**	**7.000**
Settlement Area	0.200	0.200	1.000	**5.000**	**5.000**	**5.000**
Landuse	0.143	0.143	0.200	1.000	**3.000**	**3.000**
Elevation	0.111	0.143	0.200	0.333	1.000	**1.000**
Slope	0.111	0.143	0.200	0.333	1.000	1.000
Total	**1.898**	**4.629**	**11.600**	**20.666**	**26.000**	**26.000**

Following the pairwise comparison, the matrix plays a pivotal role in determining the weightage assigned to each criterion (Table 3). The resulting weightage is of utmost importance for conducting spatial analysis as it facilitates the examination of the criteria for site selection.

Table 3: Calculation of normalized matrix

Criteria	Slope	Elevation	Land use	Settlement Area	Road Accessibility	Water Access	Total NM
1	0.346	0.346	0.339	0.431	0.648	0.527	**2.637**
2	0.269	0.269	0.339	0.431	0.216	0.175	**1.700**
3	0.192	0.192	0.242	0.086	0.043	0.105	**0.861**
4	0.115	0.115	0.048	0.017	0.031	0.075	**0.403**
5	0.038	0.038	0.016	0.017	0.031	0.058	**0.200**
6	0.038	0.038	0.016	0.017	0.031	0.058	**0.200**
Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**6.000**

RESULT AND DISCUSSION

Spatial Analysis for Evaluating Land Suitability of Community Gardens

Subsequently, the six (6) criteria were incorporated into multiple layers of geographic data in preparation for spatial analysis using GIS. The application of spatial analysis in GIS-based MCDM is a powerful framework for examining spatial relationships, making predictions, and supporting decision-making (Yang, Fang, and Lai, 2017).

Topography (Slope)

Based on the analysis, it can be inferred that the most suitable area for the community garden is characterised by slopes below 15º. This particular area encompasses a total of 28,779.70 hectares, accounting for approximately 94.95% of the overall suitable land area (Figure 1).

Topography (Elevation)

Elevation plays a crucial role in determining the suitability of land for a community garden as it directly affects the availability of sunlight, water, and other essential plant-growing resources. Land that is characterised by an elevation below 150 metres is classified as "Most Suitable" for a community garden due to its proximity to water sources and comparatively, flat terrain or lower elevations are typically preferred for community gardens. This "Most Suitable" land covers 99.60% of the total analysed area, which amounts to 30,188.41 hectares. Additionally, land with an elevation ranging from 150 metres to 300 metres is deemed "Suitable" for a community garden, representing 0.40% of the total area or 122.31 hectares (Figure 2).

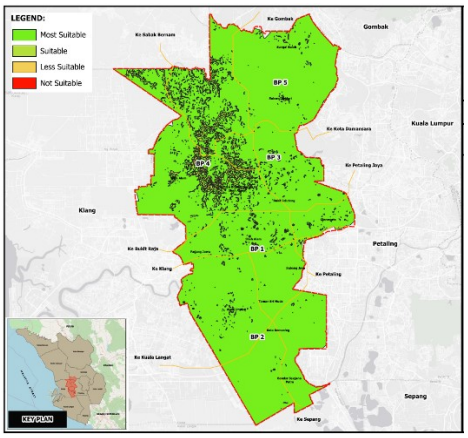

Figure 1: Slope

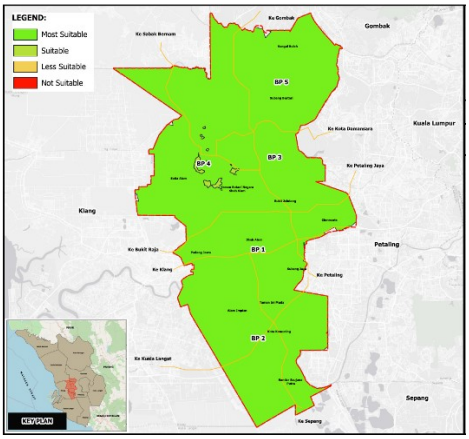

Figure 2: Elevation

Land Use

Based on the data analysis, the "Vacant land" category is identified as the most suitable, covering 15.40% of the total analysed area, which is equivalent to 4,669.26 hectares. On the other hand, land classified as "Commercial, Housing, Industry, Public Facilities, Infrastructure, and Utility" is deemed not suitable for a community garden, occupying 77.47% of the total area, which is equal to 23,482.87 hectares. The analysis encompasses a total area of 30,310.72 hectares (Figure 3).

Settlement Area

The proximity to housing is used to determine the distance from the settlement area. The analysis reveals that areas situated within 0-200 metres from housing are classified as "Most Suitable" for settlement, encompassing 56.04% of the total analysed area, equivalent to 16,985.22 hectares. Areas located more than

600 metres from housing are considered "Not Suitable" for settlement and cover 17.01% of the total area, with a total of 5,155.80 hectares (Figure 4).

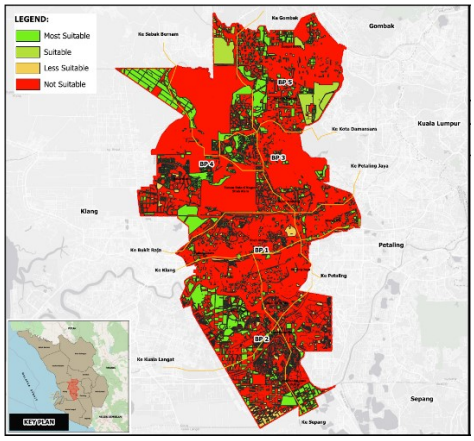

Figure 3: Land Use

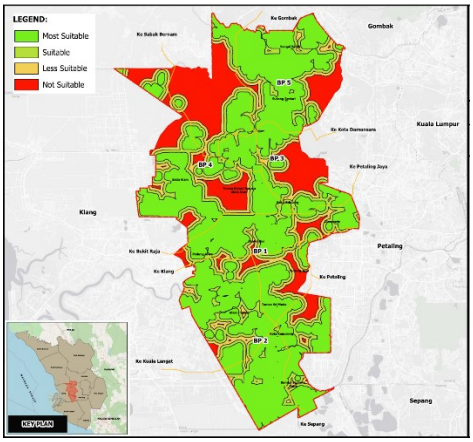

Figure 4: Settlement Area

Road Accessibility

The evaluation of proximity to road accessibility is conducted by measuring the distance to the nearest road. According to the data analysis, areas situated within 0-50 metres from a road are classified as “Most Suitable” for development, encompassing 61.52% of the total analysed area, equivalent to 18,617.53 hectares. “Less Suitable” for development, accounting for 6.46% of the total area, or 1,958.25 hectares. Lastly, areas located more than 400 metres from a road are deemed “Not Suitable” for development, covering 7.03% of the total area, with a total of 2,130.38 hectares (Figure 5).

Proximity To Water Access

The evaluation of proximity to water access involves measuring the distance to the nearest natural water body, such as a river, due to data limitations regarding water mains, waterlines, and water sources near adjacent houses. Based on the data analysis, areas situated within 0-150 metres from a water source are classified as “Most Suitable” for development, encompassing 12.91% of the total analysed area, equivalent to 3,914.47 hectares. Conversely, areas located more than 600 metres from a water source are categorised as “Not Suitable” for development, covering 61.91% of the total area, with a total of 18,763.97 hectares (Figure 6).

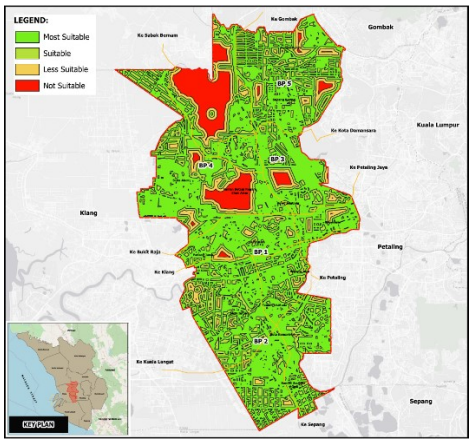

Figure 5: Road Accessibility

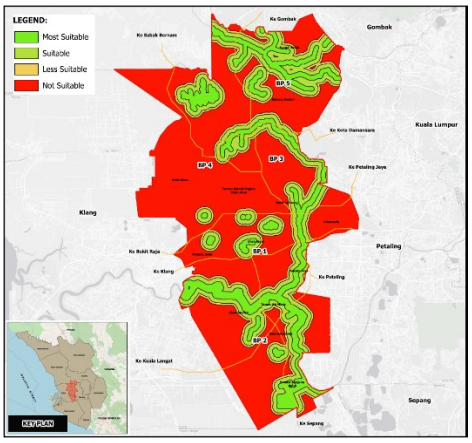

Figure 6: Proximity to Water Access

Urban Community Garden Suitability Map

The AHP analyses were utilised to calculate the weights of selected criteria, and the scores of subcriteria were assigned to map the suitability of land for an urban community garden. The land suitability for urban gardening was categorised into four classes: highly suitable, moderately suitable, marginally suitable, and not suitable. About 0.56% land of the reviewed area was classified as "Highly suitable" for urban gardening. The lands classified into this class have gentle to moderate slopes and are closed to water access and retention. However, approximately 60.88% of the area was classified as being lower or marginally suitable for urban and community gardening. An additional 13.50% of the area is categorised as not suitable for a community garden (Figure 7).

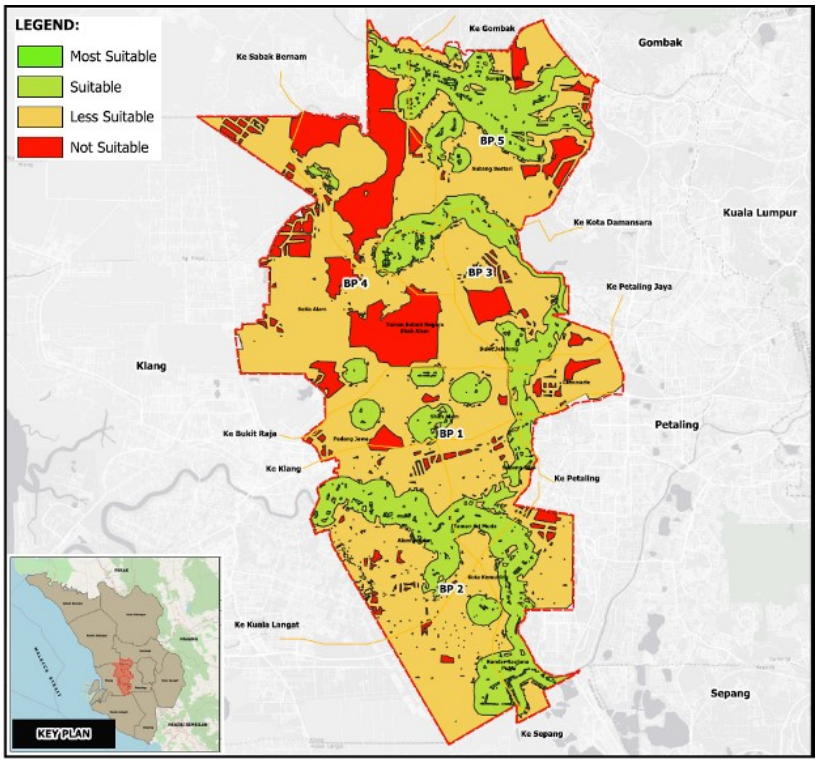

Figure 7: Urban Community Garden Suitability Map

The study was conducted in the Petaling District in Shah Alam which is known to locate highly urbanised areas in the Selangor State. The land in this area is scarce and characterised by medium to dense development, featuring a variety of land uses. Due to these factors, the land is less conducive to urban community gardening activities, particularly in the city centre. The types of land uses present can significantly influence the suitability of an area for an urban garden. For instance, vacant lots, whether privately or publicly owned, offer excellent potential for establishing community gardens. These underutilised spaces can be transformed into thriving urban community gardens.

CONCLUSION

The study utilised a combination of AHP, descriptive analysis, and spatial analysis techniques to assess the suitability of land for an urban community garden and generate a site suitability map. As indicated, only a small percentage of the total area can be categorised as either very suitable or acceptable for a

community garden. The vast majority of the land, on the other hand, falls into the categories of either less suitable or not suitable for a community garden. This information holds valuable insights for decision-makers tasked with identifying an appropriate site for a community garden.

By considering the criteria and attributes of land slope, elevation, land use, proximity to settlements, road accessibility, and water access in land suitability analysis, the selection of locations for the development and establishment of community gardens can be carried out more easily and systematically. In addition, this data can serve as a basis for future research and analysis to identify potential enhancement areas and evaluate the viability of alternative sites.

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