Multi-Criteria Evaluation of Land Suitability for Urban Extension Areas Identified in the PDAU of Setif City Using GIS and AHP

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Abstract
Urban planning plays a critical role in sustainable city development by guiding urban expansion efficiently. In Algeria, the master plan for development and urban planning (PDAU) designates specific areas for city growth, yet the suitability of these areas for urban extension often remains unassessed using systematic methods. Most PDAU, including the plan for Setif City established in 2016, rely on planning approaches and data that risk becoming outdated due to rapid urban changes and evolving spatial dynamics. As a result, there is a pressing need to critically assess and validate these designated extension zones using updated, objective analytical tools. This study addresses this gap by applying an integrated approach combining Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) to evaluate land suitability for urban extension in Setif City. Fifteen socio-economic, physical, environmental, and accessibility criteria were applied to assess areas designated in the PDAU. The methodology enables a multi-criteria, data-driven analysis to prioritize zones for sustainable urban growth. About 21.5% of the study area is categorized as very high suitability, and most of these sites are concentrated around the edges of the city. 36.7% is classified as high suitability, according to the suitability analysis for future urban expansion. Moderately and poorly suitable areas make up 23.79% and 13% of the total. Merely 5% of the land is deemed to be extremely unsuitable for the extension. The findings support evidence-based urban planning, offering actionable insights for policymakers and urban planners. This study contributes methodologically by demonstrating the effective integration of AHP with GIS in an Algerian context, encouraging replication and further research in similar urban environments.

Keywords: AHP, GIS, Land Suitability, PDAU, Urban Expansion

1. Introduction

Cities all around the world are quickly changing how their land is used as more people move in, economies grow, and towns expand [1]. Africa's cities are growing rapidly. By 2050, the urban population across the continent is projected to reach 1.4 billion, which is double the number from 2020. This rapid increase means that about 80 percent of Africa's total population growth during this time will take place in urban centers [2]. Urban population growth drives significant impacts, including urban expansion, land use changes, deforestation, ecosystem fragmentation, biodiversity loss, and local climate change. Higher population density also results in higher greenhouse gas emissions and energy consumption. Therefore, future projections about the expansion of urban areas are desperately needed [3][4] and [5]. The issue of urban expansion, one of the oldest research themes related to urban phenomena, remains a topic of major interest. It continues to occupy a central place in discussions about the city and its environment, whether concerning its internal development or its interaction with the broader urban context[6].

Algerian cities have experienced an expansion of built-up areas and rapid urban growth, accompanied by the emergence of diverse urban forms shaped by various housing policies that reflect the economic and social conditions of each period [7].

Setif, as a major urban and economic hub in the region, has experienced substantial demographic growth driven by both rural-urban migration and natural population increase. The city's population surged from 239,195 inhabitants in 1998 to 423,528 in 2022 according to the latest national census data, representing a 77% increase over this period[8] and [9]. This rapid demographic expansion, coupled with Setif's role as a regional education and economic center, has intensified urban growth pressures and accelerated land consumption. Economic activities have further exacerbated the phenomenon of rapid and often unplanned urban expansion, leading to horizontal sprawl and the conversion of agricultural lands into built-up areas[10]. In response to these mounting pressures, local authorities have sought to regulate and direct future urban growth through the designation of specific zones for planned urban expansion, aiming to ensure sustainable development.

Spatial planning serves as a governmental instrument for organizing and allocating resources across different areas. Its primary goal is to harmonize environmental conservation with economic growth, thereby promoting sustainable development both economically and socially. This process is characterized by its authority, broad scope, strategic nature, regional focus, and regulatory influence [11]. Gaining insight into the patterns of urban expansion is a fundamental aspect of urban planning, as these dynamics play a crucial role in shaping political decision-making processes [12]. In many developing cities, rapid population growth leads to unplanned and scattered urban expansion. Therefore, identifying suitable sites for extension while protecting ecosystems is essential for sustainable urban planning [13].

The PDAU, which represents Algerian urban planning, has coincided with a notable acceleration of Algerian cities' urban expansion [14]. It is a key instrument for spatial organization and urban management. It outlines the principal directions for land use and development within the concerned municipalities, taking into account existing development schemes and plans, and provides the framework for land use regulations [15]. Additionally, the plan divides the territory into several sectors, including already urbanized areas, zones designated for imminent or future urbanization, and sectors that are not intended for urban development. This sectoral division helps ensure that land use aligns with both current priorities and long-term planning objectives [16]. This study specifically evaluates these zones designated for imminent or future urbanization, which include sectors programmed for short- to medium-term development (approximately ten years) and future development sectors reserved for long-term urbanization (approximately twenty years) [17].

Algerian urban master plans, such as the PDAU for Setif enacted in 2016, are frequently reliant on traditional planning techniques and data sets that rapidly become obsolete as urban dynamics accelerate. This gap necessitates systematic validation and re-evaluation using contemporary Multi-Criteria Decision Analysis (MCDA) tools to ensure relevance to current spatial and socio-economic realities [18]. Identifying appropriate sites for urban extension on the outskirts of cities represents a major challenge in land use planning. Achieving sustainable urban growth involves taking into account a wide range of factors, including physical, environmental, demographic, natural, economic, planning, social, and administrative considerations. Integrating all these elements into the decision-making process can be complex [19]. This study therefore relied on these diverse factors to comprehensively evaluate PADU, ensuring a holistic and context-sensitive approach to urban extension planning.

Since the 1970s, the use of GIS technologies has significantly advanced the field of land suitability assessment. With ongoing improvements in data collection and processing methods, land suitability analysis has found applications in a wide range of areas, such as evaluating crop suitability, landscape and hazard planning, water resource management, environmental impact assessment, land use evaluation, and promoting sustainable urban development [20]. Assessing land suitability through GIS involves identifying the most appropriate areas for development while considering environmental sustainability. Various additional tools are combined with GIS methods to establish the significance and weighting of the criteria applied in the analysis. The combination of GIS and MCDA methods is recognized as an effective strategy for land suitability evaluation [14][16] and [17].The AHP is a widely recognized multi-criteria evaluation method that has been integrated into GIS-based suitability analyses to derive the necessary weights for various criteria [16] and [18]. It has also been widely applied in the field of urban planning [21].

The AHP remains widely used due to its reliability and accuracy confirmed by recent studies. It produces results close to or comparable with advanced methods such as Fuzzy AHP, TOPSIS, PROMETHEE, and other MCDA techniques. AHP critically relies on expert opinions to determine the relative importance of criteria[21][22][23][24] and [25], which is essential in contexts like Algeria where participatory and context-specific insights significantly influence planning decisions. This reliance on expert judgment enables AHP to effectively capture localized knowledge and preferences, supporting robust decision-making in complex urban and regional planning environments. Therefore, using AHP is justified by its demonstrated ability to integrate expert knowledge hierarchically while maintaining consistent and actionable prioritization of planning criteria.

The objectives of this study are to systematically reassess the suitability of zones designated for urban extension in the PDAU of Setif, to demonstrate the effectiveness of the integrated GIS-AHP modeling in validating these findings, and to provide decision-makers with updated, evidence-based recommendations for more sustainable city growth. In this context, this research is among the pioneering attempts to apply a comprehensive GIS-AHP approach to reassess the viability of planned extension areas, thereby contributing substantively to sustainable urban development strategies.

2. Study area

The city of Setif was founded in 1847 on the site of the ancient city of Sitifis. It is located in the northeastern region of Algeria within the High Plateaus [20] and [21]. The National Statistics Office (ONS) said that the population in 2022 was about 357,335 people [26]. The city of Setif is geographically defined by distinct natural and infrastructural boundaries. As shown in Figure 1, to the north, it is bordered by the Zenadia Forest and the N75_W117 bypass road, while to the east, it is bounded by the N5_W117 bypass road. The southern boundary of the city is delimited by the East-West highway, and the western boundary by the N75 national road. The city is located at the coordinates 36° 11′ 28.03″ N and 5° 24′ 49.43″ E. These limits and coordinates put Setif exactly where it belongs in its region, giving us a clear foundation for urban planning and geographical research. The yellow color in Figure 1 represents the proposed urban expansion zones as designated in the PDAU for Setif, as defined by the Center for Urban Planning Studies and Implementation (URBA Setif).

3. Materials and Methods

MCDA provides a collection of strategies and tactics to address complex decision-making issues in a hierarchical manner [27]. AHP is among the most widely used MCDA site selection techniques [28]. which is a suitable method of assisting with the evaluation of land suitability [27]. The general workflow of this study is illustrated in Figure 2. It summarizes the main phases followed, from identifying relevant factors and collecting data to processing and analyzing the information and finally producing the urban expansion suitability map.

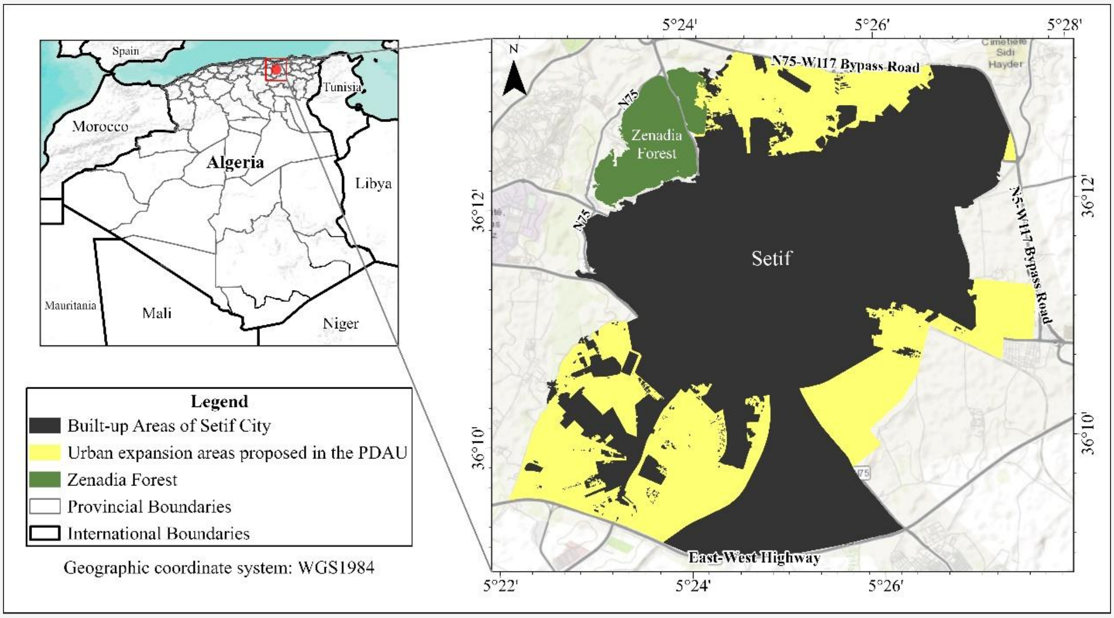

Figure 1: Study area location – current city of Setif, northeastern Algeria

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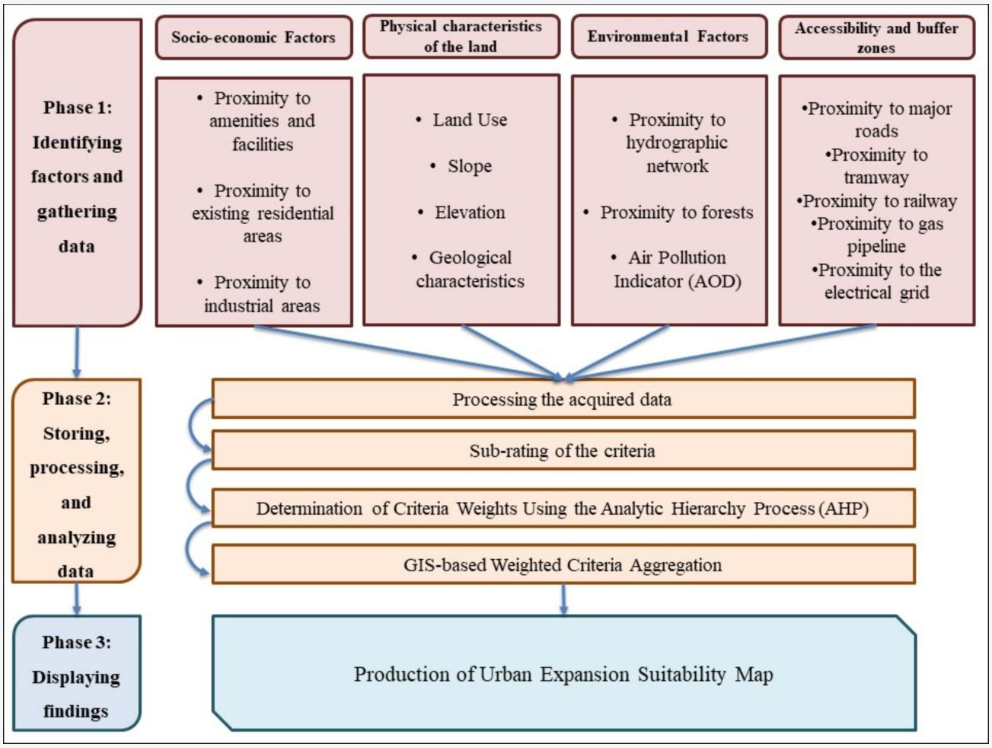

Figure 2: Urban expansion suitability workflow

3.1 Identifying Factors and Gathering Data

In order to understand the factors that influence urban expansion, a set of criteria was identified based on previous local and international studies, as well as personal interviews with professionals in the field. The interviews included specialists such as officials from local directorates involved in the implementation of the PDAU, experts from consulting offices, and university professors. These criteria were grouped into four main categories that are considered to have a direct impact on the development of new urban areas: socio-economic factors, physical characteristics of the land, environmental factors, and accessibility-related aspects. This classification helps to structure the analysis and better understand how each group of criteria contributes to shaping urban expansion.

3.1.1 Socioeconomic factors

Urban planning for future expansion must take into account the proximity to amenities and facilities, as this ensures that residents can access essential services such as schools, parks, healthcare centers, grocery stores, and pharmacies. This approach fosters the development of connected, efficient, and livable urban environments [25][29] and [30]. Planning for urban expansion must consider the area's proximity to existing residential areas because this encourages cohesive and connected growth as opposed to dispersed or isolated development. This close proximity eliminates the need for expensive extensions by enabling new developments to take advantage of adjacent infrastructure [31]. Additionally, it promotes more compact and sustainable urban growth by preventing urban sprawl into natural and agricultural areas [32]. Industrial areas are essential for urban growth by promoting economic activity, innovation, and employment [33]. However, their proximity can also cause environmental and health risks such as pollution and noise. Therefore, while accessibility is important, respecting setbacks and buffer zones is necessary to reduce negative impacts and ensure safe urban development [34].

3.1.2 Physical characteristics of the land

Land use is a critical criterion in urban expansion planning. Its conversion to residential, industrial, or infrastructural purposes significantly influences environmental quality, public perception, and socio-economic dynamics. The transformation of agricultural areas often leads to habitat loss, degradation of air and water quality, and increased pressure on essential services [35]. Integrating land use considerations into planning helps promote more balanced, sustainable, and efficient urban growth. The slope and elevation criteria are very important, as they affect construction feasibility, infrastructure costs, and accessibility. Gently sloped and moderately elevated areas are generally preferred for

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development, while steep terrains pose challenges such as erosion risks and higher construction complexity [36]. Geological characteristics are essential in identifying areas suitable for development, as they reveal critical information about soil stability, subsurface conditions, and potential geohazards. Their consideration helps avoid future structural issues and ensures safer, more sustainable land use decisions [37].

3.1.3 Environmental factors

Areas near the hydrographic network play a major role in enhancing the urban environment by improving microclimatic conditions, offering recreational opportunities, and increasing investment attractiveness. However, they also require special protection and regulation through easements to avoid uncontrolled urbanization [38]. Similarly, urban forests and nearby woodland areas provide multiple ecosystem services essential for city sustainability. These include air purification, temperature regulation, biodiversity conservation, and stormwater management. The presence of forests contributes to public health and resilience against climate impacts. Thus, preserving a safe distance from these zones through appropriate buffer areas is crucial [31] and [39]. Aerosol Optical Depth (AOD) reflects air quality, which is directly linked to human health and overall well-being. High levels of atmospheric aerosols can degrade living conditions and hinder the sustainable development of cities. Ensuring good air quality, as indicated by low AOD values [40].

3.1.4 Accessibility and buffer zones

Major roads, tramways, and railways are essential criteria in urban planning. These transportation corridors improve accessibility, encourage compact, mixed-use development, and stimulate growth in surrounding neighborhoods. Areas near this infrastructure tend to support more efficient commuting, reduce travel times, and promote environmentally friendly modes of transportation such as walking and cycling [33][34] and [35]. Furthermore, careful planning must consider buffer zones around these networks to reduce noise, ensure safety, and maintain compatibility with adjacent land uses [20]. Gas pipelines and electricity grids are critical to ensuring energy access to homes and essential facilities in cities. However, their proximity to urban areas also poses security risks, especially in densely populated areas or sensitive uses. Therefore, while proximity to these infrastructures is beneficial, it is essential to consider the creation of buffer zones [36] and [37].

3.2 Data Sources and Types Used in Land Suitability Assessment

This study used GIS and AHP methods to look at a wide range of spatial data sources and formats to see if land was suitable for future urban expansion. The PDAU gave us AutoCAD (DWG) files that showed socio-economic factors like how close amenities, existing residential areas, and industrial zones are to each other. These files gave us detailed vector data for urban infrastructure. Both raster and vector data were used to record the land's physical features. The Copernicus Data Space platform provided access to Sentinel-2 satellite images from 2025, from which land cover data were derived. Slope and elevation data were acquired from the ALOS Global Digital Surface Model (AW3D30), accessible via opentopography.org. Additionally, a 1:50,000 scale geological map detailing subsurface conditions was produced by the Geological Mapping Service of Algeria. Environmental factors included proximity to hydrographic networks and forests, both taken from OpenStreetMap as vector Shapefile. Air pollution indicators, specifically the AOD index, were also obtained as MODIS raster data via Google Engine, which supported the assessment of environmental constraints. The data used in the study, along with their sources, are summarized in Table 1.

Accessibility and buffer zones were addressed using vector Shapefile from OpenStreetMap for features such as major roads, tramways, and railways. Additionally, proximity to essential infrastructure like gas pipelines and the electrical grid was mapped using AutoCAD (DWG) files from the PDAU, ensuring the inclusion of critical utility networks.

3.3 Processing the Collected Data

The data processing stage was initiated after a variety of spatial datasets had been compiled from reliable sources. In order to ensure that the data is compatible with the GIS-AHP technique and is ready for analysis, this step is essential. Data Cleaning and Validation: A comprehensive data cleaning and validation process was carried out to ensure the quality and usability of the spatial layers. This involved checking for completeness, resolving inconsistencies, and correcting spatial or attribute-related errors such as missing values, duplicates, or misaligned features. Most of the data that underwent this process were sourced from OpenStreetMap, which required careful verification to ensure suitability for spatial analysis.

Table 1: Data sources, data types, and characteristics used for land suitability assessment

Factor Category	Data Source	Data Type	Description / Characteristics
Socioeconomic Factors	PDAU AutoCAD file	Vector (DWG format)	Detailed spatial data showing proximity to amenities and facilities, existing residential areas, industrial zones.
Physical characteristics of the land	Copernicus Data Space (Sentinel-2)	Raster (TIFF format)	Land cover imagery, acquired in 2025
	ALOS Global Digital Surface Model (AW3D30) opentopography.org	Raster (TIFF format)	Elevation and slope data
	Geological Mapping Service of Algeria	Raster (JPEG, 1:50,000 scale)	Geological characteristics
Environmental Factors	OpenStreetMap	Vector (Shapefile format)	Proximity to hydrographic networks and forests
	MODIS (via Google Earth Engine)	Raster (TIFF format)	Air pollution data via Aerosol Optical Depth (AOD) index
Accessibility and buffer zones	OpenStreetMap	Vector (Shapefile format)	Major roads, tramways, and railways proximity
	PDAU AutoCAD file	Vector (DWG format)	Proximity gas pipelines and electrical grid networks

Projection and Coordinate System Standardization: To guarantee spatial consistency across all datasets, each layer was reprojected to a unified coordinate reference system, WGS 1984 UTM Zone 31N. This harmonization step was essential to ensure the accuracy of overlay operations and support reliable spatial analysis throughout the study. Study Area Delimitation: The study area boundaries, encompassing the city of Setif and the proposed areas in the PDAU, were precisely defined and used as a spatial reference for all subsequent operations. Spatial preprocessing: To ensure the appropriateness of the analysis and reduce data volume, all criteria data, such as the AOD index and land use, were cropped and masked according to these boundaries. In addition, geoprocessing tools such as union, dissolve, and merge were used to refine the spatial data and prepare it for the analysis phase. Create an elevation and a slope map using the ALOS Global Digital Surface Model. Data Conversion: All data formats were converted from AutoCAD to Shapefile format and then to raster data, such as proximity to major roads and proximity to amenities and facilities, using spatial analysis tools (Euclidean distance) on the extent of the study area boundaries.

3.3.1 Sub-rating of the criteria

The classification thresholds for each criterion and their corresponding suitability levels (1–5) were established through an integrative methodology involving a literature review, including studies [41] [42] and [43], consultations with local urban planning experts and stakeholders, field surveys, and adherence to Algerian urban planning regulations, including Law No. 90-29 on Urban Planning, Law No. 90-21 concerning real estate easements, Executive Decree No. 04-304 defining urban planning procedures, and Law No. 03-10 regulating land ownership and use, as published in the Official Gazette. In total, seven experts contributed to this process, including three urban planners, two GIS and remote sensing specialists, and two municipal engineers with practical experience in land development and infrastructure planning. To ensure transparency and consistency, expert judgments were collected independently. When differences in opinions occurred, the geometric mean was used to aggregate their pairwise comparisons, following AHP aggregation standards [44] and [45]. This method ensures balanced integration of diverse perspectives and avoids dominance by any single expert. For instance, proximity to amenities was considered highly suitable (level 5) within 500 meters based on accessibility norms and prior urban studies, with suitability decreasing progressively at greater distances. This approach ensured that the reclassification reflects a balanced synthesis of scientific evidence, legal frameworks, local urban realities, and stakeholder perspectives (see Table 2).

After assigning a value to each criterion according to the defined scale of 1 to 5, I applied this classification process to all the criteria included in the study. To do this, I used the Reclassify tool integrated into GIS software, which allows spatial data values to be redefined according to specific classes. Specifically, each layer of geographic information was reclassified to assign each pixel or zone a new value between 1 and 5, according to the previously established criteria. This process standardizes all the spatial data and facilitates the integration and aggregation of the different layers during the multi-criteria analysis stage [46]. The results of this step are presented in Figure 3, which illustrates the reclassification process carried out for all criteria. The colors on the maps represent a suitability scale from 'Very High' (5) in the darkest tone, to 'Very Low' (1) in the lightest tone, allowing readers to easily interpret gradient levels of suitability for each criterion across the areas designated in the PDAU for future urban extension.

Table 2: Reclassification of suitability criteria for urban expansion

Criteria	Level of suitability				
	Very high (5)	High (4)	Moderate (3)	Low (2)	Very Low (1)
Proximity to amenities and facilities (AM)	0-500 m	500-800 m	800-1200 m	1200-1500 m	> 1500 m
Proximity to existing residential areas (ER)	0-200 m	200-400 m	400-600 m	600-800 m	> 800 m
Proximity to industrial areas (IN)	100-900 m	900-1800 m	1800-2700 m	>2700 m	0-100m
Land use (LU)	Vacant land	/	Agricultural areas	Forests	Built-up areas
Slope (SL)	0 - 5 %	5 - 10 %	10 - 15 %	15 - 20 %	> 20 %
Elevation (EL)	1004-1075 m	1075-1150 m	1150-1217 m	/	/
Geological characteristics (GE)	Ypresien-lutetien limestone Maastrichtian campanian Limestone and marl	Quaternary limestone	Detrital rocks Quaternary-arable lands	/	Alluvia
Proximity to hydrographic network (HN)	> 120 m	60-120 m	30-60 m	15-30 m	0-15 m
Proximity to forests (FO)	>500 m	250-500 m	100-250 m	50-100 m	0-50 m
Aerosol Optical Depth (AOD)	0.050 – 0.058	0.058 – 0.066	0.066 – 0.074	0.074 – 0.082	0.082 – 0.091
Proximity to major roads (MR)	30-300 m	300-600 m	600-900 m	>900 m	0-30 m
Proximity to tramway (TR)	15-1000 m	1000-2000 m	2000-3000 m	>3000 m	0-15 m
Proximity to railway (RW)	> 120 m	90-120 m	60-90 m	30-60 m	0-30 m
Proximity to gas pipeline (GP)	30-500 m	500-1000 m	1000-2000 m	> 2000 m	0-30 m
Proximity to the electrical grid (EG)	30-500 m	500-1000 m	1000-1500 m	> 1500 m	0-30 m

Table 3: Saaty's 1–9 standard scale used for judging the relative importance in pairwise comparisons[47]

Value	Importance	Description
1	Equal Importance	Both items are considered equally important for achieving the objective
3	Slight Preference	One item is slightly more important, based on prior knowledge or judgment
5	Clear Preference	One item is clearly more important than the other
7	Strong Preference	One item is strongly favored and stands out clearly in importance
9	Overwhelming Preference	One item is extremely important, supported by convincing evidence or reasoning
2, 4, 6, 8	Intermediate values	These values reflect a middle ground between the main preference levels
Reciprocals	Opposite Preferences	If A is preferred over B with a score of x, then B is less preferred with 1/x

Figure 3: Maps of criteria: (a) proximity to amenities and facilities, (b) proximity to existing residential areas, (c) proximity to industrial areas, (d) land Use, (e) slope, (f) elevation, (g) geological characteristics, (h) proximity to hydrographic network, (i) proximity to forests, (j) AOD, (k) proximity to major roads, (l) proximity to tramway, (m) proximity to railway, (n) proximity to gas pipeline, and (o) proximity to the electrical grid

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3.3.2 Calculation of criteria weights

Weights of criteria In literature relevant to multicriteria decision-making methodology, it is recommended that the pairwise comparison be used to determine the weights of different criteria [48]. This process is based on a numerical scale to indicate how much one criterion is more important or dominant than second one with respect to some property [49]. In the AHP, this comparison is performed through the Saaty scale (or scale 1-9) as shown in Table 3 [50]. With a 9-point scale, decision-makers can indicate preferences based on their experience and understanding. After the comparisons, the matrix is normalized to obtain the priority weights of each criterion. AHP is an absolute scale and designed to be immune to small perturbations in preferences so that uncertainty is minimized in the evaluation process [51].

3.3.2.1 Normalization procedure

The normalization of the comparison matrix is a vital example of when applying the AHP. First, each column of this matrix is summed. Then every entry of the matrix is divided by the sum of its column, generating a normalized matrix, so that all the values are on the same scale and therefore comparable. Finally, the total weights of the criteria are calculated as the average of each element of a column in the normalized matrix [37] and [52]. This is a standardized and objective technique for setting weights for the criteria under evaluation. As shown in Equation 1, the relative weight w_i for each criterion is computed as the average of the normalized values across its corresponding row in the matrix [53].

$$w_i = \frac{1}{n}\sum_{j=1}^{n} a_{ij}$$

Equation 1

Where:

w_i = the value of the relative weight for the row parameter.

a_{ij} = the normalized value of the pairwise comparison matrix element for criterion *i* versus criterion j (obtained by dividing each element by the sum of its column).

n = the total number of criteria included in the analysis.

Based on the results in Table 4, the results show clear differences in the importance of the criteria used to assess land suitability for urban expansion. The highest weight was given to the proximity to main roads, with a value of 0.203, showing that this criterion plays a major role in guiding urban expansion. It was followed by land use and proximity to existing residential areas, which also had high weights. On the other hand, some criteria, like the distance to gas pipelines and railways, received lower weights, which means they had less influence in the spatial decision-making for this study.

3.3.2.2 Calculating the consistency ratio (CR)

3.3.2.2.1 Calculating the eigenvalue λmax

To calculate λmax for a comparison matrix, the original comparison matrix must first be multiplied by the vector of weights assigned to each criterion. The resulting vector is then divided, element by element, by the corresponding criterion weights. The arithmetic mean of the values thus obtained represents λ_{max} of the matrix. This value is then used to assess the consistency of the judgments expressed in the pairwise comparison matrix [54].

Table 4: Pairwise comparison matrix with criteria weights (CW)

	AM	ER	IN	LU	SL	EL	GE	HN	FO	AOD	MR	TR	RW	GP	EG	CW
AM	1	3	6	2	3	8	7	5	8	7	2	4	9	9	6	0.203
ER	1/3	1	3	1/2	1	6	5	2	6	5	1/3	1	7	7	2	0.089
IN	1/6	1/3	1	1/4	1/4	3	2	1/2	2	1	1/5	1/2	3	4	1/2	0.034
LU	1/2	2	4	1	1	7	6	3	6	5	1/2	3	7	8	3	0.121
SL	1/3	1	4	1	1	7	6	3	6	5	1/2	3	7	8	3	0.113
EL	1/8	1/6	1/3	1/7	1/7	1	1/2	1/4	1	1/2	1/8	1/4	1	2	1/3	0.016
GE	1/7	1/5	1/2	1/6	1/6	2	1	1/3	1	1/2	1/6	1/4	2	3	1/3	0.022
HN	1/5	1/2	2	1/3	1/3	4	3	1	4	2	1/4	1/2	6	6	1	0.053
FO	1/8	1/6	1/2	1/6	1/6	1	1	1/4	1	1/2	1/7	1/4	2	3	1/3	0.020
AOD	1/7	1/5	1	1/5	1/5	2	2	1/2	2	1	1/6	1/3	3	3	1/2	0.029
MR	1/2	3	5	2	2	8	6	4	7	6	1	3	8	8	5	0.160
TR	1/4	1	2	1/3	1/3	4	4	2	4	3	1/3	1	6	6	2	0.068
RW	1/9	1/7	1/3	1/7	1/7	1	1/2	1/6	1/2	1/3	1/8	1/6	1	1	1/4	0.013
GP	1/9	1/7	1/4	1/6	1/8	1/2	1/3	1/6	1/3	1/3	1/8	1/6	1	1	1/5	0.012
EG	1/6	1/2	2	1/3	1/3	3	3	1	3	2	1/5	1/2	4	5	1	0.047

3.3.2.2.2 Calculating the consistency index (CI)

The consistency index is calculated by subtracting the number of criteria from the λ_{max}, then dividing this result by the number of criteria reduced by one, as shown in Equation 2 [55]:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Equation 2

Where:

λ_{max} = represents the principal eigenvalue of the comparison matrix

n = denotes the total number of criteria

The Consistency Ratio (*CR*) is an indicator that measures the consistency of a set of judgments or comparisons. Where *CI* denotes the consistency index and *RI* corresponds to the random consistency index. A *CR* less than 0.1 generally indicates that the consistency of the judgments is satisfactory. However, if the *CR* exceeds this threshold, it is advisable to reexamine the judgments to improve the consistency of the comparison matrix [19] and [56]. According to Saaty, the values of the random index (*RI*) have been calculated up to 15 criteria [57]. In this study, the value of 1.59 was adopted. *CR* is determined based on the formula given in Equation 3.

$$CR = \frac{CI}{RI}$$

Equation 3

The CR obtained is 0.03, which is clearly below the usual threshold of 0.10. This shows that the pairwise comparisons are reasonable, and the results can be trusted.

4. Results and Discussion

It is important to emphasize that this study does not aim to delineate or propose new urban extension areas for Setif City. Rather, it critically assesses the suitability of areas previously designated for urban extension in the PDAU, which was approved in 2016 based on conventional planning approaches and datasets available at that time. The Raster Calculator tool in GIS was used to combine the different criteria maps and produce the final map [58], which shows how suitable the proposed lands in the PDAU are for future urban extension. Each criterion was multiplied by the weight that reflects its impact, and the results were then aggregated to produce a final map showing five distinct levels of spatial suitability. By reassessing these predefined zones using a contemporary multi-criteria methodology that integrates GIS and the AHP, the present research provides an objective diagnostic of their actual suitability under current urban and environmental conditions. "As such, the findings should be interpreted as a systematic assessment of the suitability of PDAU-designated urban extension areas, reflecting the rigor and relevance of the applied evaluation methodology with respect to current urban and environmental conditions. The land suitability map for urban expansion in the areas identified by the PDAU reveals five levels of spatial suitability as illustrates in Figure 4.

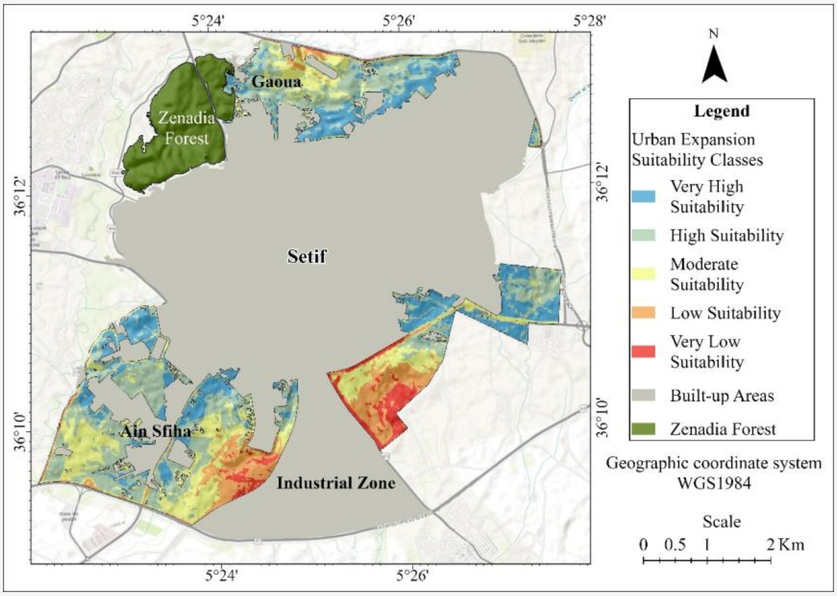

Figure 4: Evaluation map of future urban extension zones identified in the PDAU

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These categories are the result of our analysis, which combined 15 carefully selected and objectively weighted criteria through the application of GIS techniques combined with the AHP approach. As shown on the map, the areas with very high suitability are mostly concentrated around the urban core, covering about 257.4 hectares, or 21.49% of the total area. Highly suitable areas are mostly found in the Ain Sfiha area and the far western part of Setif, with a significant portion also located in the Gaoua area. This category represents around 36.72% of the study area.

Moderately suitable areas make up 23.79% of the total and are mainly found in the southern and southwestern parts of the study area, close to Ain Sfiha, with a smaller presence in the northern parts. Finally, areas with low and very low suitability represent 12.97% and 5.03%, respectively, and are mostly located along the eastern and western edges of the industrial zone. The high suitability zones around the urban core reflect compact city and smart growth principles that encourage densification in serviced areas. In contrast, the low suitability in the eastern industrial zone results from land-use incompatibility and environmental constraints. The concentration of suitable areas in Ain Sfiha highlights its accessibility and proximity to major transport routes, consistent with urban planning concepts promoting connectivity and efficient mobility. In Setif, urban extension is challenged by rapid and unplanned urban sprawl, which has resulted in fragmented growth and significant loss of agricultural land. This disordered expansion hinders the implementation of PDAU proposals, as dispersed settlements increase infrastructure costs and reduce land-use efficiency, while also reinforcing car dependency and undermining sustainable urban development principles.

5. Conclusion

This study critically evaluated the suitability of urban extension areas defined in the PDAU for Setif using an integrated GIS-AHP approach and 15 spatial criteria. The findings reveal that the majority of zones proposed in the plan possess moderate to high suitability, mainly concentrated near the urban core and key infrastructure, suggesting a relative effectiveness of the PDAU's initial allocations. Nevertheless, some areas were found to be poorly suited due to proximity to industrial zones, steep terrain, and incompatible land uses, highlighting the need for regular re-evaluation and adaptive management. Importantly, the original PDAU relied predominantly on conventional planning techniques and historical data, which may not capture recent urban dynamics or local constraints. The adoption of a GIS-AHP methodology in this study provides a transparent, objective tool for validating and optimizing master plan proposals, and reveals both strengths and limitations in the current allocation of urban extension zones.

For urban planning practice and society, this integrative approach empowers authorities and planners to make evidence-based decisions that are more adaptable to contemporary challenges, thereby supporting sustainable and equitable urbanization. At the societal level, the study contributes to improving citizens' quality of life by promoting balanced urban growth, reducing land use conflicts, and encouraging efficient service distribution. The methodology can be readily applied to similar urban contexts elsewhere, aiding periodical reviews and improvements to spatial planning frameworks. Limitations of this study include the reliance on available datasets and pre-established criteria. Future research should incorporate advanced spatial data, broader socio-economic considerations, and innovative technologies to further refine the evaluation of urban master plans and their spatial strategies.

6. Future Work Recommendations

While this study successfully evaluates the suitability of urban extension areas proposed in the PDAU of Setif City using an integrated GIS-AHP approach, several avenues for future research merit attention. First, complementary research should focus on identifying new potential urban expansion zones. This future work will employ random sampling techniques for validation and compare model outputs with actual field observations. Additionally, the Frequency Variance Method (FVM) will be applied to enhance the multi-criteria evaluation process and compare its performance with the AHP approach. Second, directional analysis of urban expansion from the city center will be conducted using advanced GIS techniques to determine spatial patterns of suitability in buffer zones surrounding the urban core. These analyses will provide urban planners with clearer insights into optimal spatial growth patterns, complementing the current assessment of predetermined extension zones.

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