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RESEARCH ARTICLE

Evaluation of the Land's Suitability for Future Urban Expansion Using the Integration of Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) in the City Of Ain Abid, Algeria

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ABSTRACT

In this research, we aim to exploit the capabilities of Geographic Information Systems (GIS) and hierarchical analysis to propose a methodology for evaluating and mapping an appropriate spatial framework for future urban expansion. The city of Ain Abid is one of the cities in the province of Constantine with an agricultural character that has undergone spatial transformations from the colonial period to the present day. Its spatial growth began in the current city centre, which is characterized by a significant urban expansion in all directions at the expense of agricultural land due to housing projects programmed during the period from 1973 to 2008. The city has reached saturation point, which has led it to expand westwards, creating an urban pole outside the city limits from 2008 to the present day. We have identified a set of criteria to evaluate the spatial suitability of urban expansion in order to guide future expansion towards the most suitable areas for the city of Ain Abid. This was achieved by reviewing previous studies and applying multi-criteria decision analysis using the Analytic Hierarchy Process (AHP) approach and Geographic Information Systems (GIS) technology to determine the weight of each criterion studied. The result is a map of spatial suitability for future urban expansion, which shows significant urban expansion in the northern and southern regions, covering approximately 17% of the municipality's area. Moderate expansion is observed in most areas, accounting for approximately 64% of the area, predominantly high quality agricultural land distributed throughout the municipality. The remaining 19% is considered unsuitable due to natural barriers and existing urban encroachment in the north-west and south-west regions. Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) approach have been shown to be effective in assessing spatial suitability for urban expansion and identifying areas for future expansion.

INTRODUCTION

Urban growth is one of the most pressing issues facing urban planners and administrators, particularly in light of advances in transport technology and infrastructure. Countries, especially the more developed ones, have implemented policies and scientific measures to mitigate the exacerbation of problems that can result from urban sprawl (Abdelkarim et al., 2020). One such policy is the development of an approach to classify suitable areas for urban expansion based on multi-criteria analysis and geographic information systems (GIS). This approach aims to guide decision makers in land use and development, thereby improving the management of urban planning programmers and policies for sustainable urban development (Khelil et al., 2022).

Given the scarcity of land allocated for urban development in the city of Constantine and its surrounding suburbs, it has become imperative to explore new areas capable of accommodating the recent urban and demographic growth (Deliry et al., 2020).

The impossibility of finding large land reserves within the city limits, due to the saturation resulting from the population surpluses of previous periods, made it necessary to search for such reserves in the surrounding areas (Yurdakul et al., 2004). These areas should have conditions such as sufficient space and suitability for development in order to accommodate the population surplus of the Constantine agglomeration while facilitating integration.

As a result of these circumstances, the commune of Ain Abid, one of the communes of the province of Constantine, has undergone significant changes in recent years, particularly in terms of rapid population growth and its associated effects. This includes its significant expansion, facilitated by its suitable geographical location. This expansion could potentially alleviate the saturation problems of the Constantine agglomeration and contribute to regional balance. The central area, where the agglomeration is located, is inhabited by more than 85% of the province's population, while the south-eastern peripheral area offers a vast and generous space that can provide real estate reserves to support the agglomeration. However, the northern peripheral area is unsuitable for development and efforts should be made to preserve its fertile land (Revision du PDAU., 2014; Urbaco. 2024).

In many cases, the problem lies in the selection of spatial expansion axes for the city, without following a proper scientific approach that takes into account the spatial suitability of the best locations for future urban expansion. This has led to the encroachment of large areas of agricultural land through land use encroachment. To address this issue, the research aims to answer the following questions:

1. What are the real potentials of the city of Ain Abid to achieve the primary objective of the strategy to control the growth of Constantine and its urban agglomeration in the long term?

2. What are the ideal areas for the expansion of the city and are there criteria and principles for the selection of these areas?

3. How can Geographic Information Systems (GIS) applications be used to identify suitable expansion sites based on specific criteria?

By answering these questions, the research aims to provide a scientific basis for guiding urban expansion in Ain Abid and similar contexts, thereby ensuring sustainable development and minimising encroachment on agricultural land.

RESEARCH METHODOLOGY

The methodology of this study aimed to apply modern techniques to the study and evaluation of spatial suitability for urban expansion, in order to provide indicators for planners and guide them in drawing the axes of urban expansion for future periods. This was achieved by identifying the most suitable areas for expansion compared to others, using a spatial analytical approach. The criteria were carefully developed based on the shape and characteristics of the study area (Dehimi et al., 2019). The study used the Spatial Analyst application in the Geographic Information Systems (GIS) environment to represent and classify the criteria, assign weights to them, and then perform a weighted overlay analysis based on the assigned weights. This process aimed to evaluate the spatial suitability and obtain the most suitable locations for the spatial expansion of the city (Ghorayeb et al., 2023).

The study material consists of both data and software. The approach used in this study requires the integration of spatial data, orthophotos and topographic maps at a scale of 1:50,000, satellite imagery and digital alphanumeric data related to land use, topography, demographics and land use. The collection of these data was facilitated by the following:

1. Spatial Reference Database (SRDB).

2. QGIS, AutoCAD, Global Mapper and Google Earth were used for data processing.

3. Preparation of a Geographical Information System (GIS) for the study area.

Study Area

The municipality of Ain Abid is located within the high plains of Constantine, southeast of the Constantine province in Algeria. It is an ancient municipality that did not undergo any administrative upgrades until 1991, when it became the headquarters of the district. It shares its administrative boundaries with the municipality of Reguiba to the east in the Guelma province, and with to the south with the municipality of El Amra in the Oum El Bouaghi province. To the west, it borders the municipality of Ouled Rahmoun, and to the north, it borders the municipality of Ibn Badis. Ain Abid spans an area of 32,380 hectares (Fig. 1).

Ain Abid city, is considered the main urban agglomeration of the district. It is bordered to the east and northeast by the villages of Zehana and Douar El Zennatiya, to the southeast by Bir El Karatas, to the west by Khelachet El Kabir, and to the south by Borg Mahris. The city serves as the capital of the district and municipality, occupying a strategic position on National Highway No. 20, which traverses its urban fabric. This axis ensures connectivity between the provinces of Constantine and Guelma (Revision PDAU; URBACO., 2014).

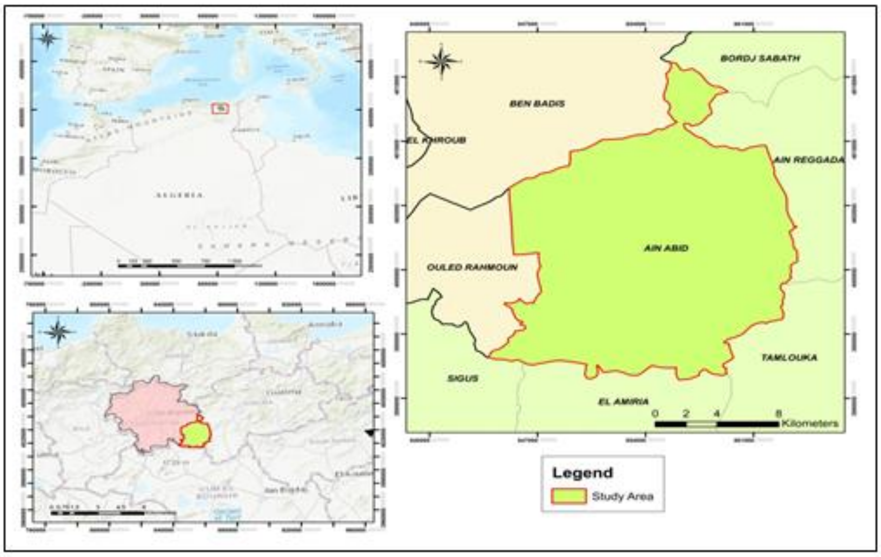


Figure.1: The geographical location of the Ain Abid city

The city of Ain Abid is situated on the eastern side of Mount Mazala. This location is characterized by its flatness, especially in the southern direction, with elevations ranging between 800 - 900 meters above sea level. The elevation gradually increases towards the northwest, reaching up to 1070 meters at the highest point of Mount Mazala. This latter is characterized by its important strategic location and its flat terrain, which have facilitated the presence of a large number of roads that serve as arteries of movement. All of this qualifies it to be a significant urban center. The city is intersected by National Highway (No. 20), linking Constantine and Annaba via Guelma in an east-west direction. Additionally, it is traversed by two provincial roads, 133 and 07, which pass through the city in a north-south direction. Furthermore, there are a considerable number of municipal roads leading to secondary settlements, in addition to the railway line. (Revision PDAU., 2014; URBACO., 2024).

Population Growth and its Relationship to Future Urban Expansion.

The municipality of Ain Abid has undergone spatial transformations since the early 1980 when it was merely a rural settlement. The population growth rate of the municipality during the first decade was 0.99%, which is considerably low compared to the population growth rate of Constantine Province, estimated at 3.69%. This disparity can be attributed to the areas becoming repellent due to the lack of necessary amenities and facilities needed by the population.

However, the growth rate of the municipality increased nearly threefold to 3.65% during the period of 1977 - 1987, yet it remained lower than the province's growth rate of 4.75%. From 1987 to 1998, the growth rate was approximately 2.99%, which is nearly double the province's growth rate estimated at 1.72%. In the period of 1998 to 2008, the growth rate was estimated at 2.46%, consistently higher than the province's growth rate of 1.63%. This is attributed to local development initiatives in the municipality, whether in the construction and public works sector or in agriculture and rural development. (ONS; URBACO, 2024).

Meanwhile, the urban center of the city witnessed significant population growth. In 1987, the population reached 10,471 inhabitants, with an annual growth rate of 9.23%, which is remarkably higher than the provincial urban growth rate estimated at 3.42%. The population increased by 6,141 individuals during that year. By 1998, the population of the city had increased to 17,333 inhabitants, with an additional 6,862 individuals and a growth rate of 4.69%. In 2008, the population further increased to 22,529 inhabitants, with an additional 5,540 individuals and a growth rate of 2.65%.

As for the future projections of population growth in the city of Ain Abid, they vary depending on the estimated population growth rate provided by (ONS, URBACO de Constantine, 2024). The estimation of the population count was conducted as follows Table 1:

$Pf = Po \times (1 + r)^n$ (1)

Pf : future population

Po : current population

R : growth rate

N : the difference in the number of years for the present and the future.

Selected for every (10) years.

Table.1. Population Estimates for Future Prospects in Ain Abid City

Years	**1987**	**1998**	**2008**	**2020**	**2030**	**2040**
City Population	10471	17333	22529	30369	32569	43892
Growth rate %	%4.69	%2.65	%2.43	%3.10	%3.10	
Manicipalyti Population	18850	25959	31743	45665	51578	60689

Source: ONS; URBACO., 2024

The population growth rate is projected to accelerate in the city in the coming years. We have estimated a constant growth rate of 3.10%. The population of the city was 30,369 in 2020, projected to reach 32,569 in 2030 and 43,892 in 2040. As for the estimated population of the municipality, it was 45,665 in 2020, projected to increase to 51,578 in 2030, and 60,689 with a constant growth rate of 4.45%. This increase will continue at the same pace, leading to future pressures and further depletion of land resources to provide suitable areas for future urban expansion.

Using the AHP analytical hierarchy method to calculate or weigh the criteria used

The most common methods for selecting MCDA (Multi-Criteria Decision Analysis) sites are AHP, which is a suitable method for decision analysis, and proposing a methodology for evaluating and mapping spatial suitability for future urban expansion in the city of Ain Abid through the application of Geographic Information Systems (Boutaghane et al., 2022). We selected six criteria to determine suitable areas for future expansion in the city of Ain Abid.

Figure 2, below illustrates the data used and processed to extract the necessary information for the multi-criteria analysis recognized as representing the essential characteristics for understanding land use for urban development purposes included in the analysis.

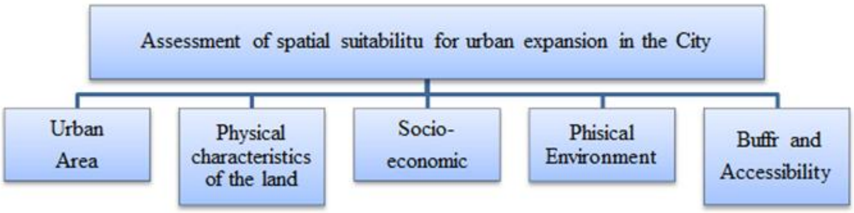
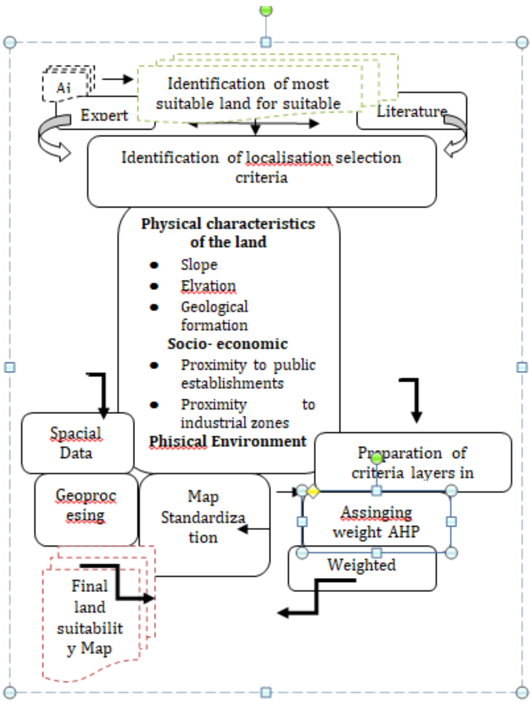


Figure. 2. The selected criteria in the study area. (Saat., 1984).

4.1 Identifying Criteria and Assessing Their Importance

The Analytic Hierarchy Process (AHP) method was adopted, which is one of the most widespread and applied methods for multi-criteria decision-making. It was designed by the mathematician Thomas Saaty and published in 1987 (Khelil., 2022). This technique allows for the numerical quantitative evaluation of qualitative factors with systematic analysis of complex problems within the hierarchy structure (Alkaradaghi et al., 2020). This is done after establishing a database for all previously mentioned factors, arranging alternatives relative to the objective (Bediar et al., 2022), and conducting spatial analysis. AHP plays a role in extracting the weights for each factor studied, and ultimately combining the criteria to obtain the final decision. The method relies on the following stages: Setting the goal along with defining the criteria, creating a matrix and calculating the criteria weights, combining the criteria by computing the consistency ratio (Aburas et al., 2015). Then summarizing all stages in the following (Fig ,3).

Criteria development is a crucial stage in identifying potential areas for urban development and future urban expansion using Geographic Information Systems (GIS), which provide data capture functions in digital form. It enables the verification, management, processing, spatial analysis and multi-thematic analysis of reference geographic data (Abdelkarim et al., 2020). These criteria relate to land, terrain and land use. In this study, the spatial suitability for urban expansion is assessed by applying GIS functions that consider sufficiency and overlap based on multi-criteria analysis. (Dehimi et al., 2019). These criteria are assessed using the spatial analysis functions of GIS. Each evaluation produces a map representing, for all primary surfaces, their suitability for the studied criterion (Wong et al., 2007).



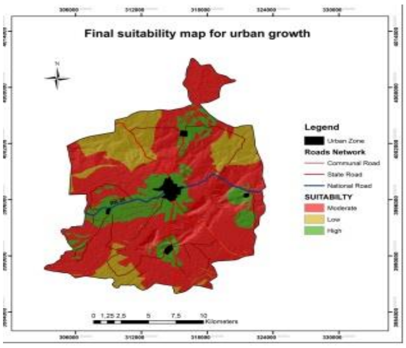


Figure 3 . Overall Scheme of Research Methodology (SAATY., 1980)

4.2 Data Collection Stage for Geographic Criteria.

As mentioned above, the criteria influencing the assessment of spatial suitability for urban expansion were gathered from previous research and expert opinion. Factors determining suitable locations for urban growth were derived from observations made during interviews with various relevant local institutions. (Boutaghane et al., 2022).

A. Topographical Characteristics of Ain Abid City.

Slope and elevation are among the most important topographical factors influencing the dynamics of urban growth. It is difficult to develop areas with high elevations, and areas with gentle slopes are more suitable for urban planning.

The topographical features of the Ain Abid Municipality consist of limestone blocks that form the typical landscapes of the Constantine plateaus. These terrains are characterized by a series of limestone and marly limestone blocks that dominate the plateaus and valleys. (Revision PDAU., 2014; URBACO ., 2024). The most important rock formations include:

To the northwest and north are Mount Um Stass, the highest (1320 m), Kaf El Raghaia (1157 m), and Kaf El Qamar (1064 m).

In the middle is Mount Mazala (1070 m).

The plateaus and valleys located at an elevation of 870-900 m contain materials dating back to the Villa franchian age (limestone shells) and accumulate somewhat fine materials (sand, silt, marl, and clay), which are drained through a series of temporary valleys that flow into the Mehiris and Znati valleys.

B. Slopes

Slopes are formed in the municipality of Ain Abid as follows:

- Slopes with gradients less than 5%: These slopes constitute a very large part of the municipality. Covering gentle slopes, which are almost absent in many places, they encompass approximately 2/3 of the municipality's area and are related to lands located in the central part of the municipality.

- Slopes with gradients ranging from 5-15%: These are the first hills in the municipality, with small scattered areas, primarily in the northeastern part of the municipality.

- Slopes with gradients ranging from 15-20%: Small isolated, and scattered areas mainly exist in the northern part of the municipality.

- Slopes exceeding 20%: These slopes are found on high mountain terrain and hilltops.

C. Geological Characteristics of the Area

The region is dominated by layers of limestone interspersed with marl limestone layers, forming the main rock formations (such as Mount Um Stas and Mount Mazala). Additionally, there are formations of sand and clay in the southeast, south, and west of Ain Abid city.

D. Hydrographic Network

The hydrographic network consists of temporary watercourses, exclusively tributaries to the two main valleys: Ouadi Mehiris, which flows westward, and Ouadi Zanati, which flows eastward.

E. land use

The general distribution of land in the municipality is characterized by:

The importance of the useful agricultural area (UAA) which represents 79.72% of the

total area.

A predominance of cereals which represent 39.43% of the surface area overall.

Forests of Bornaz and Bouzemzem cover a total area of 2490ha, or 8.30% of the territory.

F. Social and Economic Characteristics

One of the most influencing criteria in urban planning is proximity to public services. The closer future urban expansion areas are to these institutions, the easier the lives of citizens and the lower the transport costs. In this study, various public institutions were selected, including educational, health, security, cultural, religious and others. In addition, the criterion of proximity to industrial areas was introduced because of its importance in urban planning, taking into account the constraints of the area that hinder urban expansion.

G. Environmental Characteristics

To preserve the environmental system, the most important environmental criteria in Ain Abid city have been identified. These include land use aimed at reducing vegetation consumption and prioritizing urban expansion in desert lands. The second and third criteria are the distance from valleys and forests, respecting buffer zones, and considering balanced urban growth.

The municipality of Ain Abid has significant natural resources but is highly susceptible to various forms of pollution. There is an uncontrolled public landfill near the town of Ain Abid, to the north of Dribinah. Quarries located just a few hundred meters from the city directly impact the environment.

H. Connectivity (Accessibility to the City Center)

The distance to main roads, highways, tram lines, and airports is considered accessibility to transportation due to the lack of public transportation. Additionally, proximity to electricity and gas networks facilitates energy delivery to new urban areas while considering their respective buffer zones. Access to public facilities usually indicates the city's sustainability because all citizens must have access to their basic needs.

The road network in the municipality is somewhat dense, providing satisfactory access to all towns and squares, but it remains in moderate condition, with some parts of communal roads in poor condition. Its total length is 159.134 km, including 12.46% national roads, 23.57% provincial roads, and 63.97% communal roads. The roads crossing the municipality are major regional transport and transit arteries (R.N°20, C.W 133).

I. Proximity

The highway RN 20, the provincial road, the railway line crossing the municipality from west to east parallel to highway RN20, high-and medium voltage power lines passing through the municipality, and the gas pipeline traversing the municipality from east to west parallel to Highway RN20. The city, located on the western side parallel to highway RN20 will require three cemeteries within the main town. The main AEP pipeline, tanks, and water towers must have a buffer zone with a radius of 10 meters. (Revision PDAU; URBACO., 2014). After identifying the factors influencing urban planning, the necessary data were collected from various sources and transferred to the processing stages (Boutaghane et al., 2022).

4.3 Data Processing and Analysis

In this stage, the data obtained from various sources was processed using geographic information systems (GIS) and remote sensing tools, as follows (Alkaradaghi et al ., 2020):

Creating a geographic database to store the data;

Defining a unified coordinate system for the geographic database using geographic referencing tools;

Pre-processing of vector and raster data using tools such as Clip, Union, Dissolve, and Merge;

Generating elevation and slope maps using the SRTM digital elevation model;

Conducting supervised classification of Sentinel-2 imagery to obtain a land use map after radiometric correction, based on remote sensing tools, with the calculation of the kappa index to assess classification accuracy;

Converting all vector data to raster data using Euclidean distance and conversion tools.

4.4 Reclassification of Criteria Data

The selection of criteria and their sub-criteria is a crucial step in the AHP process as it affects the judgement by separating the criteria from each other and at the same time giving more weight to one criterion over others.

The table below shows the reclassification and normalization of the criteria, divided into sub-criteria ranging from 1 to 5, to create a map representing all the primary surfaces of the study area based on their suitability level. (Akbulut et al., 2018). Each criterion and its sub-criteria were classified according to their weight. (Table. 2).

Table 2. Selected criteria and sources of data Ain Abid city

Criteria	Sub-criteria	Level of suitability	Ranking
Slope	0 – 5% 5 – 10 % 10 – 15%	Highly suitable Suitable Moderately suitable	5 4 3
	15 – 20% > 20%	Poorly suitable Unsuitable	2 1
Elevation	900-1000 1000-1100 1100-1200 >1200 0 – 800m	Highly suitable Suitable Moderately suitable Unsuitable Highly suitable	5 3 2 1 5
Proximity to public establishments	800 – 1600m 1600 – 2400m 2400 – 3200m > 3200m	Suitable Moderately suitable Poorly suitable Unsuitable	4 3 2 1
Proximity to the industrial zone	0 – 50 50 – 2000	Unsuitable Poorly suitable	1 2
	2000 – 4000 4000– 6000 > 6000 m	Moderately suitable Suitable Highly suitable	3 4 5

Land use	Urban areas Agricultural lands Forest lands Building area Cours	Suitable Moderately suitable Unsuitable Unsuitable suitable	5 3 1 1 4
Distance from river	0 – 50m 50 – 250m 250 – 500m 500 – 750m >750m	Unsuitable Poorly suitable Moderately suitable Suitable Highly suitable	1 2 3 4 5
Distance from Forest	0 -50m 50 – 100m 100 – 150m 150 -200m >200m	Unsuitable Poorly suitable Moderately suitable Suitable Highly suitable	1 2 3 4 5
Distance from main roads	0 – 30m 30 – 700m 700 – 1400m 1400 – 2100m >2100m	Unsuitable Poorly suitable Moderately suitable Suitable Highly suitable	1 2 3 4 5
Distance from railway	0 – 10m 10 – 1500m 1500 – 3000m 3000 – 4500m >4500m	Unsuitable Poorly suitable Moderately suitable Moderately suitable Suitable	1 2 3 4 5
Distance from the electricity network	0 – 30m 30 – 500m 500 – 1500m 1500 – 2500m >2500m	Unsuitable Highly suitable Suitable Moderately suitable Poorly suitable	1 5 4 3 2
Distance from the drinking water network	0 – 30m 30 – 500m 500 – 1500m 1500 – 2500m >2500m	Unsuitable Unsuitable Suitable Moderately suitable Poorly suitable	1 5 4 3 2
Distance from gas network	0 – 30m 30 – 500m 500 – 1500m 1500 – 2500m >2500m	Unsuitable Unsuitable Suitable Moderately suitable Poorly suitable	1 5 4 3 2

Distance from PTT network	0 – 30m 30 – 500m 500 – 1500m 1500 – 2500m >2500m	Unsuitable Unsuitable Suitable Moderately suitable Poorly suitable	 1 5 4 3 2

After determining the weights of the criteria and their sub-criteria (Fig. 4; Table.2) based on expert opinions and previous studies (Ghorayeb et al., 2023), all raster maps were reclassified using a reclassification tool into five categories, with values ranging from 1 to 5. A value of 5 was considered highly suitable, while a value of 1 was deemed unsuitable for all the criteria considered. By employing this method, all measurements will be able to obtain an equivalent value before applying any weights.

At the end, the comparison forms a square matrix where each element's value ranges from 1/9 to 9. The elements on the diagonal of the matrix always equal 1, while the off-diagonal elements indicate the relative importance of one characteristic compared to another (Saaty., 2008). This comparison allows for highlighting the differences between different characteristics and helps prioritize and make decisions accordingly. The pairwise comparison matrix can be used in various fields to analyze data and make important decisions (Deliry et al., 2022).

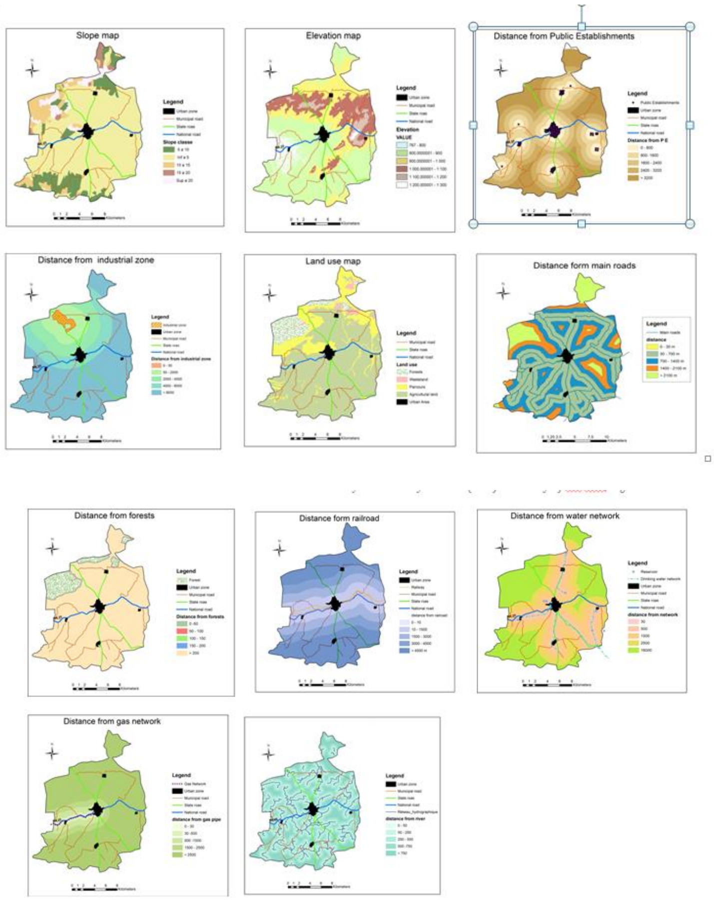


Figure .4: Thematic layers that have been geographically processed, reclassified, and used in the analysis of multi-criteria land suitability based on geographic information system (Boussetti.; GIS., 2024)

Using Geographic Information Systems in Building the Spatial Suitability Model for Future Urban Expansion.

The objective of the assessment process is to determine the optimal area or direction for the spatial expansion of the city, taking into account the interrelationship with different areas within the city. It provides spatial information (both qualitative and quantitative) on the impacts associated with each land use, its sustainability potential and its operational requirements. Therefore, sustainable land assessment and land use planning can be built on a sustainable basis by integrating urban suitability with economic viability and environmental impact assessment for different land uses (residential, commercial, industrial, administrative, etc.) to support land use planning efforts.

5.1. Using Analytic Hierarchy Process (AHP)

The AHP process begins by structuring the problem into a hierarchical structure of interrelated elements. The objective is placed at the top of the hierarchy. The relative importance of alternatives for all decisions is then determined by capturing and uncovering elements through pairwise comparisons between criteria within the same hierarchical level.

5.2 Creating the Comparison Matrix and Weighting Criteria

In this stage, a pairwise comparison matrix is created based on expert judgments. Experts compare all factors according to their relative importance (Table.3). The quantitative scale for importance, developed by Saaty in 1980, is utilized to convert evaluations into numbers that can be used for comparing criteria.

Table. 3. Fundamental scale of pairwise comparisons

Importance	**Definition**
1	Equal Importance
3	Moderate importance of one over of the other
5	Strong importance
7	Very High importance
9	Extreme importance
2, 4, 6,8	Intermediate values between two adjacent to refine judgments

source: Saaty., 1980

By prioritizing the relative importance of one criterion over another using a nine-point digital scale, pairwise comparisons were conducted in the matrix for all criteria. The relative weights are determined using the formula developed by Saaty (1980):

$$= 1 \ a_{ij} \ W_i = 1/n \sum_j^n \quad \overline{}$$

Where: Wi : the value of the relative weight for the row parameter.

$$=1 \qquad 1/n \sum_j^n$$

$\overline{ai}$: sum of the percentages of the preference values for a row parameter.

n: the number of criteria considered in the analysis.

Calculation of weights Criteria used in the analysis:

Table .4 . Suitability for urban extension

Criteria	Physical characteristics of the land	Physical characteristics of the land	Physical characteristics of the land	Physical characteristics of the land

Physical characteristics of the land	1	0,11	0,33	0,2
Socio-economic criteria	9	1	7	0,14
environmental criteria	3	0,14	1	0,125
Buffer and accessibility	5	8	7	1
Total	18	9,25	15,33	1,47

Criteria weights are calculated by averaging each row of the normalized matrix. For each criterion, we must multiply the initial matrix by the priority vector and divide by the corresponding weight:

Table .5. Weight of Criteria

Criteria	**Physical characteristics of the land**	**Physical characteristics of the land**	**Physical characteristics of the land**	**Physical characteristics of the land**	**Weight**
Physical characteristics of the land	0,056	0,012	0,022	0,136	**0,0564**
Socio-economic criteria	0,500	0,108	0,457	0,097	**0,2905**
environmental criteria	0,167	0,015	0,065	0,085	**0,0831**
Buffer and accessibility	0,278	0,864	0,457	0,681	**0,5700**

After conducting pairwise comparisons, the sum of each column is calculated. Then, each value in the pairwise comparison matrix is divided by the sum of its respective column (Table.,4,5). Next, the average values of the rows are calculated to obtain the weights of the criteria under consideration, as illustrated in the following table (Saaty., 1980).

To ensure consistency within the pairwise comparison matrix and validate the weights, the consistency ratio (CR) is calculated, which should not exceed 0.1. The Consistency Index (CI) and the Average Inconsistency (IA) are also computed, where IA represents the set of random indices based on the number of criteria included. According to Saaty, if the inconsistency index exceeds 0.1, there is inconsistency in the pairwise comparisons, and the resulting matrix from the comparisons should be re-evaluated.

CI= λ max-n/n-1

Where : λ max he principal eigenvalue of the matrix,n: the number of criteria

After that, the Consistency Ratio (CR) is calculated to determine the likelihood of randomly creating the matrix evaluations..

CR= CI/ RI

Where R is the random consistency index based on the number of criteria selected from

Table 6. Values of previous indicators in the study

λ_{max}	4,08546
CI	0,0284858
RI	0,9
CR	0,03165

The pairwise comparison of the applied criteria in the case study we conducted, as well as the calculations related to the different criteria, yielded the following results (Table.,6) : λmax 4.08, consistency index CI = 0.02, random index IA = 1.47, consistency ratio CR = 0.01 < 0.1. Since the consistency ratio is less than 0.03165, this allows us to confirm that the judgments of the criteria estimation were consistent and can be relied upon (Saaty., 1980).

Using the Geographic Information System (GIS) tool Raster Calculator, the criteria maps were aggregated and overlaid to create the final map illustrating the suitability of the land for urban growth (Yurdakul, Tansel ., 2004). To identify the most suitable land for sustainable urban development, a multicriteria decision evaluation method based on GIS was employed by integrating the Analytic Hierarchy Process (AHP) and Weighted Linear Combination (WLC) to analyze and assess the degrees of the selected criteria (Fig.6). Each criteria map was preprocessed and prepared for spatial geographic analysis using Arc GIS spatial analysis tools (Wang et al., 2022). Utilizing the measured result values, the maps were converted to grid format, and suitability maps were derived using the weight values obtained from AHP and the Weighted Overlay function of Arc GIS software. The resulting overlay scores were classified into five categories: highly suitable, moderately suitable, low suitability, very low suitability, and unsuitable (Khelil et al., 2022).

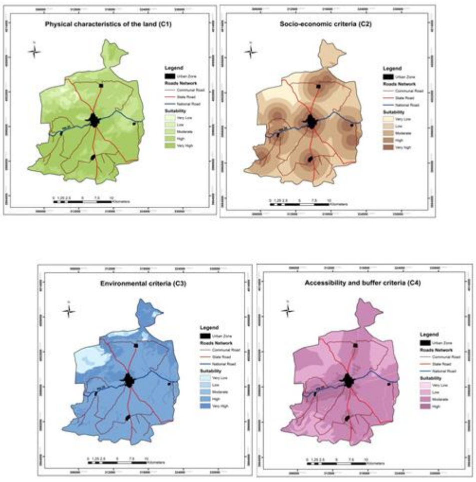


Figure.5. Suitability map based on similar factors: (C1) weighted Physical characterization of the land; (C2) weighted socio-economic map; and (C3) weighted ecological & environmental map. (C4) weighted Accessibility and buffer (Boussetti, GIS., 2024).

The final map of land suitability was computed and produced by aggregating all factor maps and their calculated weights using the weighted linear combination approach (Saaty., 2008). Figure 7 illustrates the final suitability map for sustainable urban development.

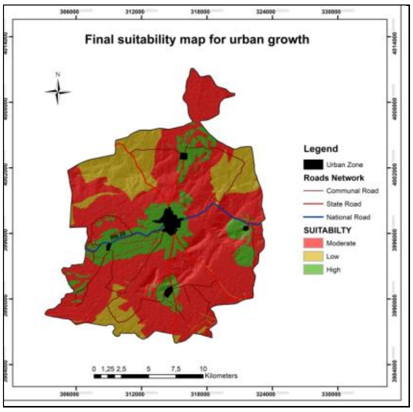
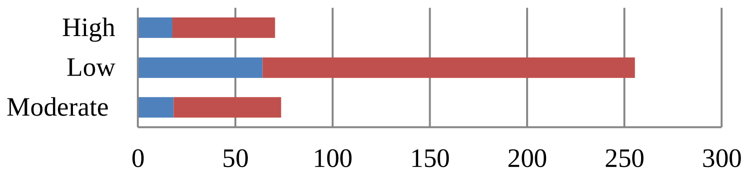


Figure. 6. Final suitability map of sustainable urban development in Ain Abid City.

Figure (6) illustrates the percentage and size of the areas depicted in the final suitability map. Based on specific criteria, the results of this study showed that the largest area is spatially suitable with low suitability, accounting for 63.95% of the total area, while moderate suitability areas represent 18.41% of the total area (Byun., 2001). Suitable lands with high suitability for future expansion were estimated to be a small percentage, approximately 17.64%.



	Moderate	Low	High
Surface (%)	18.41	63.95	17.64
surface (Km2)	55.08	191.34	52.77

Figure .7. Suitable lands for future expansion in Ain Abid city.

After obtaining the final suitability map, along with analyses by varying the criteria numbers and corresponding weights, visual observations were conducted to evaluate and validate the results. The results were consistent with our field observations (Yurdakul et al., 2004). The city has undergone spatial transformations since the colonial period until today. Its spatial growth started with the current urban agglomeration center, characterized by significant urban expansion in all directions at the expense of agricultural lands due to residential projects programmed during the period from 1973 to 2008. The city became saturated, prompting its expansion towards the west to establish the urban pole outside its urban perimeter from 2008 until today (Revision du PDAU., 2014; URBACO., 2024). Areas with high and moderate suitability are close to the area located in the south and southwest of the city, as well as major roads, educational services and, these areas are not located in agriculturally protected areas and are not prone to natural risks. Future urban expansion has been programmed over an area of 1000 hectares, characterized by moderate agricultural potential, located west of the urban agglomeration of Ain Abid municipality, easily accessible via National Road No. 20, Provincial Road No. 133 (Ain Abid, Ibn Badis), and, the proposed railway line connecting (El Khroub , Ain Abid) known as the site of Mochta Ouled Jibnoun (Fig.8).

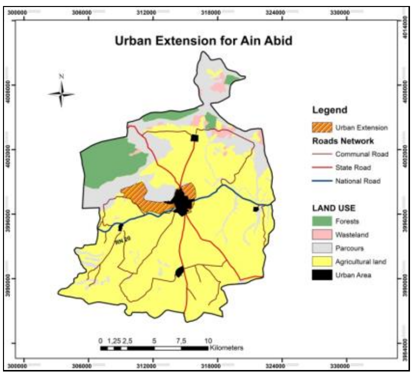


Figure .8. Urban extension for Ain Abid city.

The results reveal that unsuitable and less suitable areas such as mountainous regions, forests, and agricultural lands cover nearly half of the city's area, indicating that using AHP techniques and Geographic Information Systems can significantly assist in preserving the ecosystem and setting future sustainable development plans. This will lead to a significant reduction in negative impacts on the ecosystem and the environment (Revision PDAU.,2014; URBACO., 2024). The results also reveal that the main obstacles to city development are the proliferation of settlements, protected agricultural areas, and geological risks such as geological fractures due to poor geotechnical conditions and steep slopes, as well as flood-prone areas.

CONCLUSION

As a conclusion of this study, a comprehensive land suitability analysis was conducted using Geographic Information Systems, based on a deep understanding of the challenges and opportunities available for future urban expansion through a comprehensive analysis of influencing factors and spatially suitable conditions for sustainable urban development in the city of Ain Abid. The results of the analysis revealed significant challenges related to urban expansion in the city, including natural and industrial constraints, with more than 191 square kilometres of the total area, mostly agricultural land, being used for future urban expansion.

Integrated and effective land use planning requires multidisciplinary studies and sufficient data to protect the natural environment and mitigate risks. Failure to do so can lead to catastrophic risks and failure of planning structures.

Despite differences in criteria from one study to another, the results of this study generally indicate that the integrated approach of AHP and GIS can be an effective tool for analyzing and evaluating spatial suitability to preserve the sustainability of natural resources, in addition to providing numerous solutions to ensure organized and balanced urban development.

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