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INTEGRATION OF GIS AND MULTI-CRITERIA HIERARCHICAL ANALYSIS FOR URBAN PLANNING SUPPORT: CASE OF THE WILAYA OF CONSTANTINE

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ABSTRACT

Sustainable urban planning requires effective decision-making tools, especially in contexts of rapid development and increasing environmental pressures, as is the case in the wilaya of Constantine, Algeria. Integrating Geographic Information Systems (GIS) with Analytical Hierarchy Process (AHP) offers a robust methodology to support this decision-making process. This approach has proven useful in interpreting complex spatial issues. By identifying criteria aligned with targeted objectives and mapping geographic and attribute data at the Constantine wilaya scale, it was possible to prioritize identified indicators, quantitatively assess the phenomenon, and compare various development scenarios within the study areas. The study results indicated that, of the total area of 221,819 km², 55.17% (122,382 km²) of barren lands (suitable for habitability) are most suitable for urban development, 26.84% (59,550 km²) are moderately suitable for urban development, 10.56% (23,430 km²) of agricultural areas (non-buildable) are least suitable for urban development, 1.66% (12,771 km²) are forests (non-buildable), and 5.75% (3,686 km²) of these lands are considered unsuitable for urban development (perennial areas, non-buildable) but rather designated for agricultural use or strategic reserves hosting economic or tourist activity areas.
This combination allows for handling complex spatial information and systematically evaluating various criteria, thus promoting optimal urban planning. Additionally, the process enabled visualization on maps of the area's most suitable for urbanization and provided valuable insights to specialists for land use choices, including areas to develop, preserve, or protect.

KEYWORDS

Wilaya of Constantine, Urban Planning, Geographic Information System (GIS), Multi-Criteria AHP

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Introduction.

In the era of the "information revolution and advanced technologies," numerous scientists and strategic experts recognize the significance of these innovations in addressing the growing demands of urban planning. Technologies such as remote sensing, computer-aided design systems, and information systems now facilitate the collection, transfer, and analysis of spatial data, thereby helping decision-makers make crucial decisions with greater accuracy and speed (MAMMERI, .ML,.2013).

Rapid urbanization and its associated challenges, such as increased housing demands, depletion of natural resources, heightened impacts of climate change, and unplanned expansion, require an innovative approach (EL AMRAOUI, et al., 2017). Rather than relying on traditional tools, it is essential to adopt integrated forecasting and management systems capable of handling large volumes of data and providing reliable multi-criteria analysis for sustainable and efficient urban space management.

In this context, the integration of Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) method proves to be particularly promising. GIS enables the mapping and spatial analysis of diverse data, facilitating the identification of strategic areas for urban development, while AHP structures the criteria according to their importance, providing a systematic evaluation of available options. Together, these tools offer a more precise and methodical approach for analyzing the suitability of sites for urban development (HABES S.,2021).

The integration of these technologies into government institutions responsible for planning is therefore crucial for improving and efficiently managing work, while enhancing the performance and accuracy of urban planning. This research highlights the potential challenges in adopting these systems and proposes solutions to overcome these obstacles, exploring application methods that improve the effectiveness of urban planning processes.

In the context of the Wilaya of Constantine, this methodology holds particular significance. Faced with rapid growth and significant pressures on its resources, particularly water, Constantine must adopt planning that supports its economic development while preserving the sustainability of its space and resources. By jointly using GIS and AHP, this analysis helps identify the most suitable sites for urban development, taking into account multiple criteria such as accessibility, water resource availability, climate vulnerability, and existing infrastructure (BENDJABALLAH BOUDEMAGH O,. 2013).

1. Importance of the Research and Its Objectives.

The main objective was to identify lands suitable for urban development based on remote sensing and the multi-criteria analysis method using GIS in the Wilaya of Constantine. This research focuses on the following areas:

- The need to keep up with the technological development of information systems and tools, and to leverage them in planning work as well as in solving urban issues.
- The crucial role of modern technologies and methods, particularly Geographic Information Systems (GIS), for collecting, storing, analyzing, and visualizing spatial data, while linking it to descriptive data. These technologies allow for the creation of models and scenarios for researchers, planners, and decision-makers, thus facilitating urban planning processes.

2. Methodological Approach.

2.1 Description of The Study Area.

Constantine, often referred to as "the city of bridges," is one of the oldest cities in the world, with over 2,500 years of history. It boasts a rich heritage shaped by numerous civilizations and is distinguished by its unique topography. Built on a steep, compact rocky site, it is often described as a natural fortress (URBACO, Constantine,. 2016)

Located in the east of Algeria, at latitude 36.23 and longitude 7.35, Constantine is approximately 437 km from Algiers. It occupies a strategic position between the coastal region of the Tell and the High Plateaus, making it a crossroads in the eastern part of the country. Covering an area of 2,297.2 km², it had a population of 921,893 according to the 2008 census, with the current population estimated at 1.5 million. It is surrounded by the wilayas of Skikda (North), Oum El Bouaghi (South), Guelma (East), and Mila (West). Constantine is well-connected to other cities through a network of national roads: the RN 20 towards Guelma, the RN 10 towards Tébessa, the RN 3 towards Skikda and Annaba, the RN 5 towards Algiers, and the RN 27 towards Jijel and Mila. It also has provincial and municipal roads such as CW 133, 51, and 101. The city is divided into six districts, encompassing 12 communes, and plays a central metropolitan role for eastern Algeria, with significant cultural and industrial functions (URBACO, CONSTANTINE,.2024).

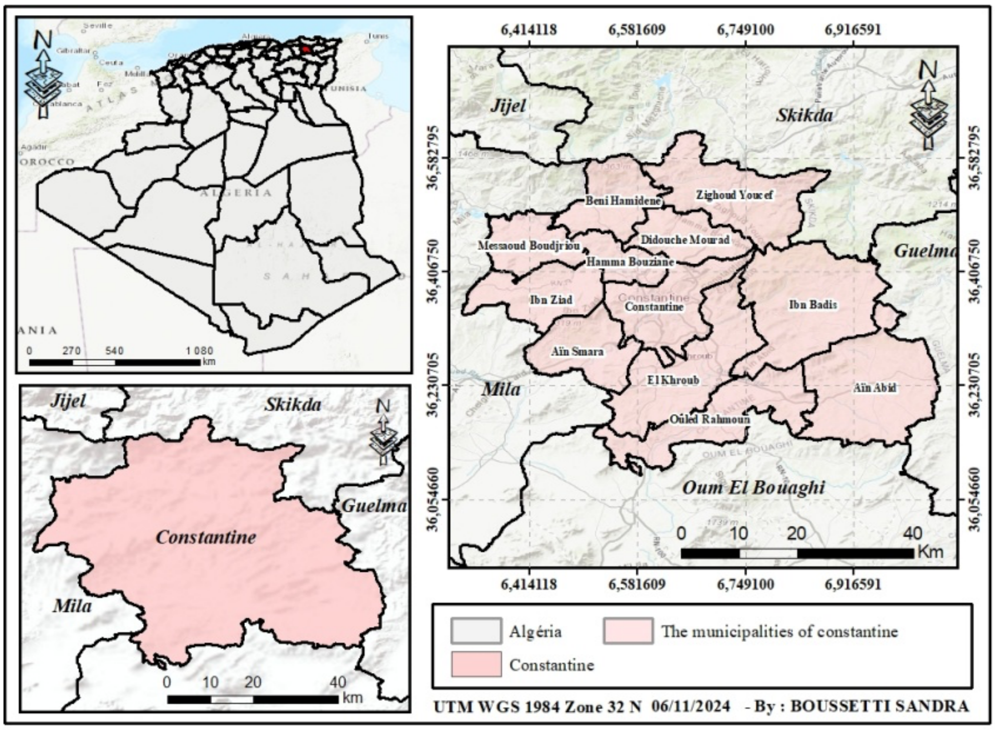


Fig. 1. Geographic Location of the Wilaya of Constantine (Source: Personal Elaboration).

The communes of the Wilaya of Constantine have experienced variable but generally sustained demographic growth. In 1987, the population was 663,372, rising to 888,500 in 1998 and reaching 938,472 in 2008, according to the latest General Census of Population and Housing (O.N.S., R.G.P.H. 2008). However, the annual growth rate has decreased, from 1.82% between 1987 and 1998 to 1.39% between 1998 and 2008. Since 2008, the population has resumed growing at a rate of 1.7% per year, reaching an estimated 1,173,308 residents in 2023.

During the intercensal periods of 1987-1998 and 1998-2008, the population of the Constantine grew by 41.3%, from 664,303 in 1987 to 810,914 in 1998, and then to 938,475 in 2008. The relative growth rates for these periods were 22.1% and 19.2%, respectively (fig. 2).. The population is expected to reach 1,173,308 residents in 2023, although the growth rate has gradually slowed between 1998 and 2008 (O.N.S., R.G.P.H. 2008).

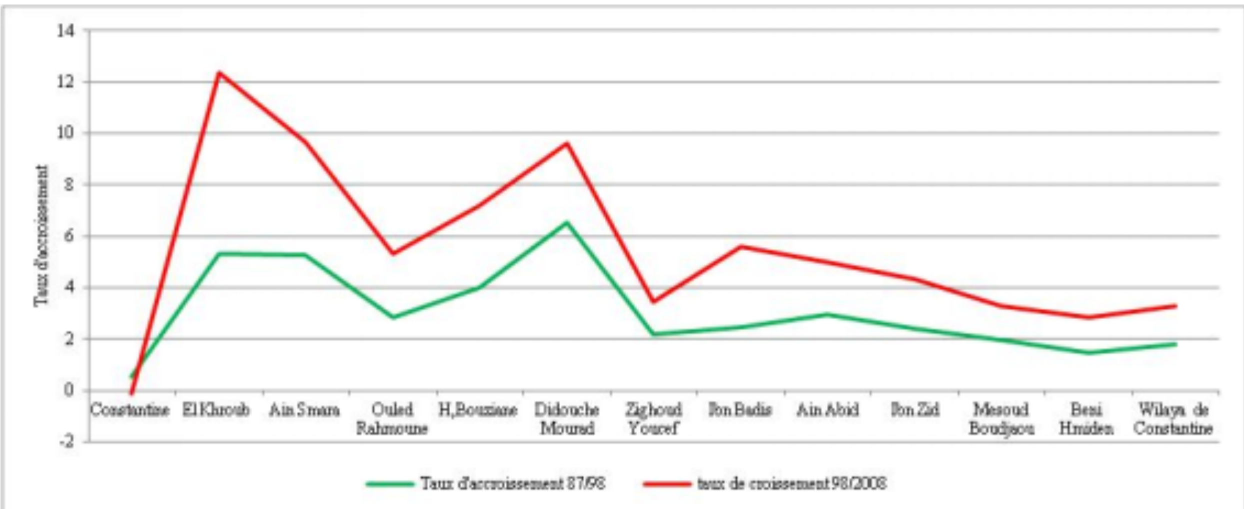


Fig. 2. Evolution of Population Growth Rates in the Wilaya of Constantine (Census data: 1987 to 1998 and 2008)

In Constantine, the population growth rate has reached -0.66%, indicating that the relocation program of residents to nearby cities is underway. This decline is the result of operations to relocate residents from informal settlements and substandard housing. However, some communes have recorded growth rates exceeding 3%, above the average for the wilaya (O.N.S., R.G.P.H. 2008).

The majority of the population, 95.5%, resides in primary and secondary urban areas. In the commune of Constantine, the city center accounts for 76.37% of the total population, while the secondary urban area houses 19.13%. The rural population represents only 4.5% of the total population of the wilaya. The five main urban centers of the wilaya Constantine, El Khroub, Hamma Bouziane, Ain Smara, and Didouche Mourad together account for approximately 839,570 inhabitants, or 84.13% of the local population (URBACO, CONSTANTINE,.2024).

The city center of Constantine hosts 93.45% of the commune's population, due to its larger facilities and its role as a regional hub in the northeast of the country. The urban population of the commune of El Khroub, the second largest after the city center, decreased from 72.55% in 1998 to 49.85% in 2008, due to the emergence of the new cities of Ali Mendjeli and Massinissa. In Hamma Bouziane, the share of residents in the city center was 52.46% in 2008, decreasing in favor of the secondary urban area of B'kira, which accounted for 30.81% of the urban population that same year. In the communes of Ain Smara and Didouche Mourad, urban concentration also increased, rising from 83.18% and 85.15% in 1998 to 86.65% and 90.81% in 2008, respectively.

As of the 2008 census, the wilaya of Constantine had 938,475 inhabitants spread over a total area of 22,972 km², giving an average population density of 408.53 inhabitants per km². However, this density varies significantly across communes. In the central core of the wilaya, in Constantine itself, the density exceeds 2,450 inhabitants per km². The urban communes that make up Greater Constantine, such as Hamma Bouziane, El Khroub, Didouche Mourad, and Ain Smara, also have high densities, ranging from 300 to 1,123 inhabitants per km². In contrast, more rural or less populated communes, such as Zighout Youssef, Ibn Ziad, Ain Abid, Messaoud Boujeriou, Beni Hamiden, and Ibn Badis, have low densities, often below 137 inhabitants per km² (O.N.S., R.G.P.H. 2008).

The wilaya also benefits from a developing transportation network, suitable for high traffic flows. It is served by a dense road and rail network, including a railway station that serves as a hub linking the main cities of eastern Algeria. The East-West highway runs through the southern part of the Constantine agglomeration, near the airport and the Mentouri University.

2.2 Material and Data Used.

The material used includes a wide variety of data and software to carry out the study. This research relies on a methodology that integrates spatial information such as cartographic surveys, topographic maps at a 1:50,000 scale, satellite images, as well as alphanumeric data on land, topography, demographics, and land use. Through this data collection, a Spatial Reference Database (SRD) was created. The software tools QGIS, AutoCAD, Global Mapper, and Google Earth were used to process this information and develop a geographic information system (GIS) tailored to the studied area. Figure 2 shows all the data used and the processing carried out to extract the essential information for the multicriteria analysis (ROY, B,1985; (1985EL AMRAOUI , et al,.2017).

3. Application of Multicriteria Hierarchical Analysis for Urban Planning Support.

The approach to optimizing the use of land resources in urban planning relies on the use of Geographic Information Systems (GIS) and the AHP (Analytic Hierarchy Process) method. This combination allows for structuring spatial data, integrating multiple layers of information, and conducting multicriteria analysis by overlaying various factors. The AHP method helps compare criteria in pairs and assign a weight to each, facilitating the evaluation of different options based on sub-criteria (LAARIBI,. 2000; SALOMON,.2001).

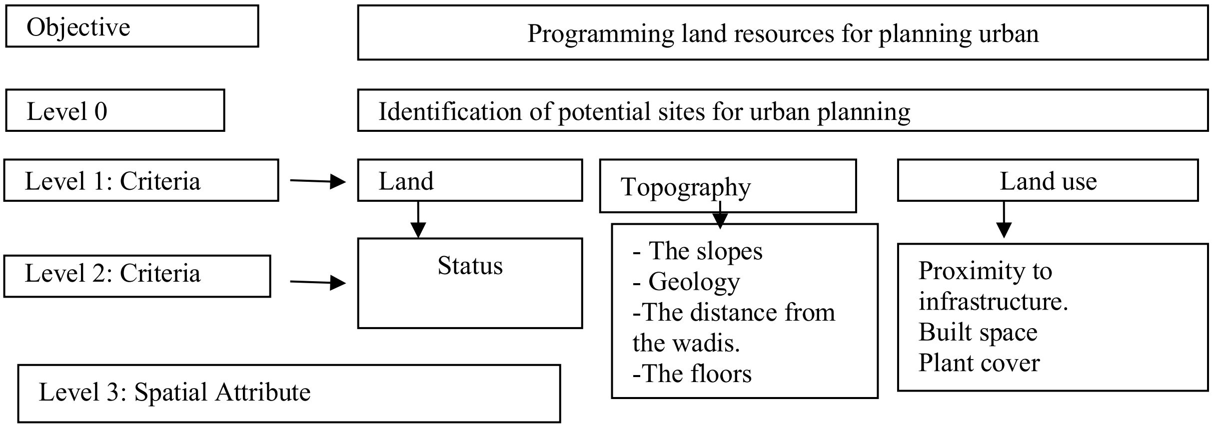
The evaluation of land suitability is based on cartographic modeling. It uses specific operations applied to maps of an area to create a spatial model that identifies the most suitable sites for urban development (LAARIBI,. 2000). The analyses are carried out on vector data or raster models, taking into account factors such as accessibility, slope, and soil quality. This process facilitates the selection of optimal areas for specific activities, such as residential development.

The methodological approach includes concepts and theories related to the field, a comparison of approaches, and a critical analysis. It also aims to answer key research questions, such as data collection techniques, the model used for analysis, and the presentation of results.

3.1. Representation and Modeling of Spatially Referenced Data.

Data regarding land status, protection, area, and market value are collected in the land layer, which is essential for assessing land use. The topographic layer, including slope and aspect maps, is produced from a digital elevation model (DEM) with ASTER DEM data at a 30-meter resolution. For land-use planning, a land-use map is used to guide the planning process and establish the guidelines for regional development (LE GALL, 2009). This map integrates various documents, such as development plans, topographic maps, and data from the Ministry of Agriculture (EL AMRAOUI , et al,.2017).

The selection of criteria is based on work conducted within three expert committees in each field (land and urban planning). The criteria that were identified as representing essential characteristics in understanding the land-use process for urbanization needs were incorporated into the analysis. The result is a classification of all the selected attributes or criteria following a hierarchical structure, which subsequently allows for the application of the AHP method. The decomposition of the decision problem into an ordered hierarchical structure of criteria and sub-criteria is shown in Figure 4 below:



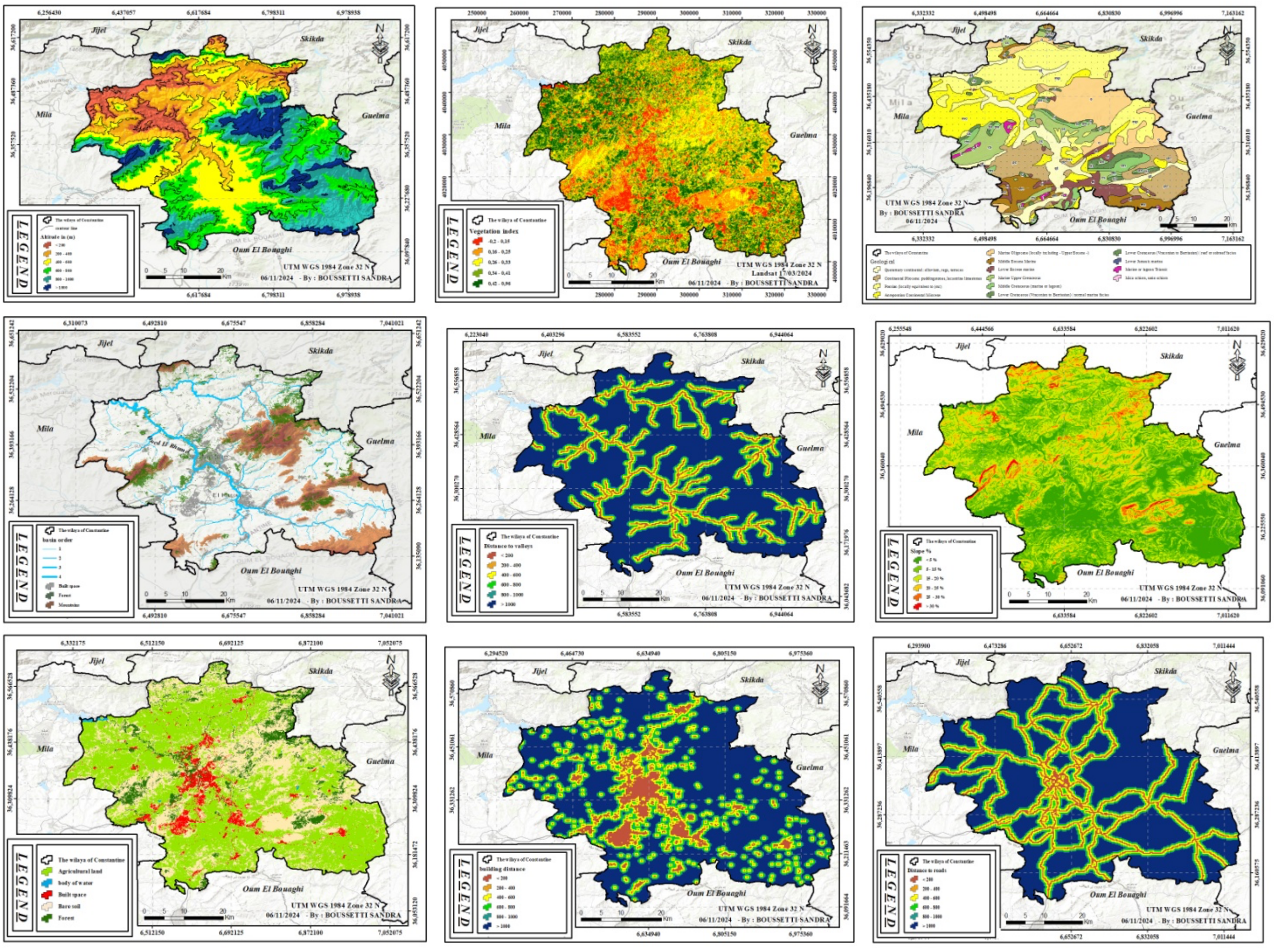


Fig. 3. Graphical Representation of the Hierarchical Levels of Criteria: (Topographic Criteria: a. Altitude, b. Slope, c. Geology, d. Wadis, e. Distance from Wadis, g. Land Use Criteria: h. Bay Area, i. Proximity to Infrastructure, f. Vegetation Coverage).

3.2 Multicriteria Hierarchical Formulation and Development of Different Criteria.

AHP techniques rely on the decomposition of a complex system into a hierarchical structure, where each level consists of specific indicators, whether simple or combined. This hierarchy allows for the determination of the criteria that have the greatest impact on the final decision (LE GALL, 2009). The development of the criteria was the result of collaboration between three groups of experts, specializing in land and urban planning. The analysis considered the criteria deemed essential for evaluating the land use process for urbanization purposes. The classification of criteria and sub-criteria into a hierarchical structure facilitates the application of the AHP method (MAMMERI, ML, 2013). Figure 4 below illustrates the division of the decision-making problem into a hierarchy of criteria and sub-criteria.

a. Land Use

The land use map plays a crucial role in guiding land development decisions and defining the main lines of urban development in the region. Land exploitation is a fundamental element for assessing the capacity of urban areas, as the distribution of various land use categories creates significant constraints for land planning. The analysis of the land in the study area was carried out using a Landsat 8 satellite image and by applying a supervised digital classification of the images (remote sensing). This classification was performed using Google Earth Engine and a categorization algorithm based on machine learning, utilizing the SVM (Support Vector Machine) method.

b. Proximity to Roads

The road network plays a very important role in urban development. Road networks are digitized using Google Earth. As more and more settlements develop near road networks due to transport and easy access to neighboring places and city centers, the main road map was prepared for the study area using OSM (Open Street Map). The road network in the wilaya of Constantine plays a crucial role in regional connectivity and economic development. Located in a mountainous region with steep terrain, Constantine benefits from roads that overcome these natural obstacles and ensure connectivity between different parts of the wilaya as well as with neighboring wilayas (URBACO, CONSTANTINE, 2024).

c. Topography

Constantine is located on a limestone plateau, surrounded by deep gorges, notably those formed by the Oued Rhumel, which spectacularly crosses the city. This plateau, situated at an altitude of about 600 meters, is dominated by rugged mountainous terrain to the north of the wilaya, where elevations can reach between 800 and 900 meters. The landscape is primarily composed of the Numidian mountain range, which extends northeastward with the Djebel Ouahch massif, covering an area of 500 km² across several municipalities of the wilaya. Other notable geological formations include the Chettaba anticline to the west, the rock of Constantine, characterized by steep escarpments, and Oum Settas to the south. The inland region of the wilaya is marked by the extension of the Mila basin, particularly around the commune of Messaoud Boudjeriou, as well as by basins like those of Hamma Bouziane and the depression of Didouche Mourad. These varied reliefs fragment the territory, creating a mosaic of terrains that strongly influences population distribution and land use. This topography has favored the emergence of the city on a natural promontory but also makes development challenging, particularly for transportation and urban infrastructure (URBACO, CONSTANTINE, 2024).

d. Slope

The Digital Elevation Model (DEM) was used to create a slope map of the study area using ArcGIS tools. Steeper slopes increase construction costs, indicating the need to define specific areas to promote sustainable urban development and the continuity of growth. The distribution of slope zones in the wilaya is divided into four categories: low-slope areas (0-5%), moderate-slope areas (5-15%), steep-slope areas (15-30%), and very steep-slope areas (>30%) (URBACO, CONSTANTINE, 2024). Figure 3 presents this classification of the different slopes in the study area. Slopes also make some areas vulnerable to landslides and increase the cost of urban expansion. This situation presents challenges for land use planning and agricultural development, as it requires soil stabilization and the adoption of farming practices suited to sloped terrain.

e. Hydrographic Network

The hydrographic network of the wilaya of Constantine is complex, shaped by the mountainous relief and the semi-arid climate of the region. The Oued Rhumel, the main watercourse, along with its tributaries, such as Oued Boumerzoug and Oued Smendou, flow through the plateaus and valleys, actively contributing to the landscape's configuration URBACO, CONSTANTINE, 2024). To accurately represent this hydrographic network, it is necessary to use a Digital Elevation Model (DEM) or an elevation raster. These tools allow for the mapping of watercourses and their interrelations based on the region's relief and topography.

d. Vegetation and Forest Cover

The forest cover is relatively sparse, concentrated in the hilly areas where species such as Aleppo pine and some Mediterranean shrubs are found. However, forested areas are not dense due to anthropogenic pressures, such as deforestation for agriculture and urban development. This low vegetation cover contributes to soil erosion in the sloped areas.

3.3 Categorization and Standardization of Evaluation Criteria

The process of calculating the relative importance of criteria for identifying areas suitable for urbanization, known as the standardization of criteria (SAATY, 1984), involves assigning a relative weight to each factor relevant to land suitability for urbanization. The criteria are selected based on their relevance and include aspects such as land tenure, slope, population density, and proximity to infrastructure.

For each criterion, a criterion map is produced, indicating the suitability level of each spatial unit based on the specific criterion. The maps are then combined into a weighted sum to produce a final suitability map for urbanization. Each criterion is standardized on a suitability scale from 0 to 10 (0 indicating the least suitable areas and 10 the most suitable). This approach allows for the visualization of each area's capacity to be optimally developed for urban projects. In the case studied, nine sub-criteria were selected, based on expert advice, to evaluate and map areas suitable for urbanization (BEKHETARI M C, 2015).

Table 1. Categorization of assessment criteria

Sub-criterion	Value	Justification: Parameters and Type of Criterion
Classification of plots according to land status	9	Private
	7	State-owned property
	6	Collective
	1	Forest domain
	3	Public domain
	1	Other
Land use	9	Urban
	8	Forest
	2	Bare land
Slope (Classification according to the terrain slope))	9	Low slope : 0% - 5%
	8	Moderate slope : 5% - 10%
	3	Steep slope: 10% - 30%
	1	Very steep slope : >30 %
nfrastructures (Classification according to the distance from the road network)	1	< 700m
	3	700-1200
	4	1200-5000
	5	5000-10000
	7	>10000m
Population Density (Classification according to population density)	1	< 500
	3	500-1000
	5	1000-2000
	7	2000-4000
	9	>4000

3.4 Weighting of Evaluation Criteria.

The fourth phase uses the AHP (Analytic Hierarchy Process) method by Saaty (1980) to compare the elements within a hierarchical level and evaluate their contribution to solving the problem. The criteria established in the multicriteria hierarchical structure help achieve the objective while considering land management indicators for urbanization. These indicators represent the available options for the project. By comparing them based on their relative importance, a pairwise comparison matrix is obtained. This method relies on expert judgments, assigning a weighting coefficient based on Saaty's scale (Tabl. 2).

Table 2. Scale proposed by SAATY (Source: Thomas SAATY scale table (1984)).

Degrees of importance	Explanation
1	Equal importance: Two characteristics contribute equally.
3	Low importance: Personal experience and judgment slightly favor one characteristic over another.
5	Strong or decisive importance: Experience and judgment strongly favor one characteristic over another.
7	Very strong or proven importance: One characteristic is strongly favored, and its dominance is confirmed in practice.
9	Absolute importance: The evidence favoring one characteristic over another is as convincing as possible.
2-4-6-8	Values associated with judgments when a compromise is necessary.

The comparison results in a square matrix where each element takes a value between 1/9 and 9. The elements on the diagonal of the matrix are always equal to 1, while the elements outside the diagonal reflect the relative importance of one feature compared to another.

Once the comparison matrix is established, its eigenvalues and the corresponding eigenvector are calculated, which hierarchize the criteria being studied. This vector shows the relative importance of each criterion and is essential for evaluating the probability. The eigenvalue is also used to check the consistency of the judgments, thus ensuring the quality of the solution. Then, the matrix is normalized so that the sum of the weights equals 1. A consistency measure is crucial to validate the results, as consistent judgments increase the reliability of the criteria weightings (Tabl. 3).

Table 3: Comparison matrix and the relative importance weights of the evaluation criteria.

	Land Use	Topography	slope	Distance from rivers	Soil	Proximity to infrastructure	Built-up areas	Vegetation cover	Weight
Land Use	1	3	5	7	3	1	5	3	0.2528
Topography	1/3	1	3	5	3	1/3	5	3	0.1509
slope	1/5	1/3	1	3	1/3	1/7	3	2	0.0818
Distance from rivers	1/7	1/5	1/3	1	1	1/9	1	1/3	0.0285
Soill	1/3	1/3	1/2	3	1	1/5	3	1	0.0693
Proximity to infrastructure	1	3	7	9	5	1	7	5	0.3156
Built-up areas	1/2	1/5	1/3	1	1/3	1/7	1	1/3	0.0318
Vegetation cover	1/5	1/3	1/2	3	1	1/5	3	1	0.00693
		N=8							1.00
λmax = 8.378		**IA=1.41**				**CI= 0.054**	**Rc = 0.0383**	**λmax = 8.378**	

3.5 Consistency Check

The evaluation of consistency in pairwise comparisons, according to Saaty's method (1980), relies on the adherence to the transitivity of judgments. The consistency index (CI), calculated using the mathematical formula (1), measures the reliability of the comparisons in terms of consistency. The higher this index, the more inconsistent the judgments in the comparison matrix, and vice versa.

IC =(λmax −N)/ (N−1)

Where (N) is the number of elements being compared and λmax,is a value calculated based on the average of the matrix values from Saaty's eigenvectors. Saaty's (1990) experimentation introduced the consistency ratio (CR), defined as the ratio between the consistency indexes (CI) and the random index (RI) of a matrix of the same size. This ratio, obtained through a specific formula, verifies the logical consistency of expert judgments in the pairwise comparison method by evaluating the relative importance of the criteria. As a general rule, for matrices with fewer than 9 elements, a tolerance threshold of 10% is applied, this is a commonly accepted limit in multi-criteria analysis. For larger matrices, a slightly higher tolerance may be allowed. The consistency ratio thus reflects the likelihood that the matrix was filled randomly.

RC = IC/ IA

Where (IA) is the random index determined based on the number of criteria listed in Table 4.

According to SAATY, if the consistency ratio (CR) exceeds 0.1, it indicates inconsistency in the pairwise comparisons, and the comparison matrix should be reevaluated. In our case study, the results of the calculations for the different parameters are as follows: λmax= 8.378, consistency index (CI) = 0.054, random index (RI) = 1.41, and consistency ratio (CR) = 0.0383, which is below 0.1. This allows us to conclude that the judgments regarding the assessment of the criteria are consistent (Table 4).

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):

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

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

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

a_i: sum of the percentages of the preference values for a row parameter.
n: the number of criteria considered in the analysis.

Table 4. Random index based on the number of criteria (Source: SAATY, 1980).

N	5	6	7	8	9	10	11	12
IA	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

4. Results and Discussions.

The analysis of the impact of various factors on urban planning in Constantine is crucial for understanding the challenges the city faces in managing urbanization, mobility, natural resource management, and environmental risks. The use of the multicriteria analysis (AHP) method combined with geographic information systems (GIS) has provided decision-making support for assessing the land potential for urbanization. The result of aggregating the different criterion maps according to their weight allowed the study area to be ranked on an 8-point scale, where a high-value pixel corresponds to an ideal area for urbanization.

Furthermore, the AHP weight calculation reveals that land tenure is considered the most important factor by experts, with proximity to infrastructure accounting for over 31%, followed by land allocation for urbanization at over 25%, and topography at more than 15%. Additionally, the consistency ratio calculated in the pairwise comparisons is RC = 0.0383 (value < 0.10), indicating that the expert judgments are reasonably consistent. In this context, the multicriteria evaluation with spatial reference has helped identify territorial entities that should be prioritized for the rational utilization and development of land resources in the study area. The multicriteria aggregation process (weighted sum method), based on the weights calculated for the nine criteria according to SAATY's method, allows us to distinguish five differentiated spatial units displayed on the global synthesis map (fig 4).

The classification was carried out based on expert opinions after overlaying it with previously collected thematic data, such as the urban master plan for Constantine, land-use plans, PDAU, POS, etc. It was also compared with real-world conditions by juxtaposing with images from Google Earth and Bing Maps. The resulting synthesis map, through its legend, shows the aggregation values of the different parameters, organized into five classes, ranging from the first rank, suitable for urbanization, to the fifth rank, which should be protected or excluded from the urbanization priority.

The final results obtained for the overall suitability map reveal that the potential sites for urbanization are properties characterized by a land tenure system and status that are easily mobilizable and close to areas equipped with urban planning documents or infrastructure. This aligns well with the weights resulting from the criteria after pairwise comparison weighting.

An aptitude map was created based on the adopted approach. The study focused on the use of integrated remote sensing and AHP multicriteria analysis with GIS to determine the suitability of urban expansion in the wilaya of Constantine. The results of this study indicated that out of the total area of 221,819 km², 55.17% (122,382 km²) of barren lands (suitable for habitability) are most suitable for urban development, 26.84% (59,550 km²) are moderately suitable for urban development, 10.56% (23,430 km²) of agricultural areas (non-buildable) are least suitable for urban development, 1.66% (12,771 km²) are forests (non-buildable), and 5.75% (3,686 km²) of these lands are considered unsuitable for urban development (perennial areas, non-buildable) but rather designated for agricultural use or strategic reserves hosting economic or tourist activity areas (fig. 4).

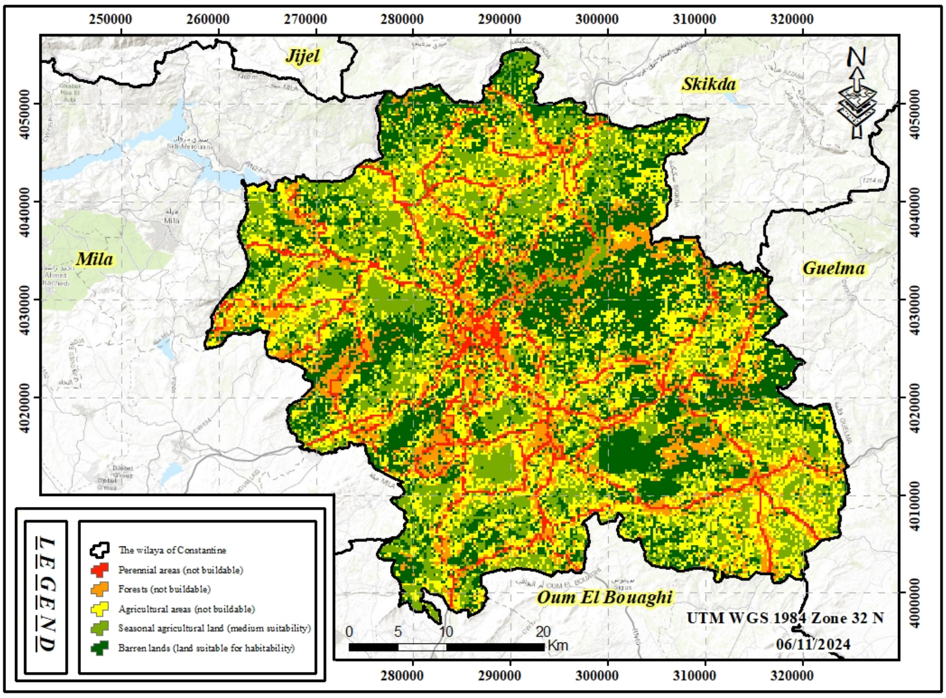


Fig. 4. Final Urban Land Suitability Map

Urban planning in this Wilaya is heavily influenced by a complex topography and a rich historical heritage, presenting both challenges and opportunities for designing innovative and ecologically responsible projects. With rapid population growth, Constantine has expanded beyond the old city into peripheral areas. This urban sprawl has led to the creation of new residential neighborhoods, often poorly planned, resulting in infrastructure and connectivity issues. The region's steep topography complicates access to these new urban areas and presents challenges for transportation and public services. While areas with moderate slopes allow for both urban and agricultural development, steep slopes limit these possibilities and incur additional costs for road infrastructure and construction. The future of urban planning in Constantine depends on the ability to build resilient infrastructure, integrate sustainable development principles, and promote controlled urban growth.

Sloping topography requires special planning and significant investments to make certain areas accessible, particularly through the creation of new roads, the improvement of public transport networks, and the development of infrastructure for water treatment. However, this remains complex and costly in a mountainous environment.

In this step of the multicriteria analysis for decision support, the best potential interpretation of the results is assisted by experts and stakeholders in the land domain. The use of the AHP method by SAATY for calculating the weighting assigned to each criterion yields reliable results for the scale of the studied area, thereby confirming what we previously stated about potential areas for urbanization. The final weighting related to the factors determining the urban suitability of a space allowed the production of thematic maps for each criterion and a final synthesis map combining the nine criteria based on their weights. The established maps represent only spatial variations at a given moment, yet they still allow for the assessment of the suitability of lands in the Wilaya of Constantine for urbanization. Indeed, the results obtained are valid, and their reliability depends on the accuracy of the data and information used. The combined use of AHP and GIS helped identify potential areas for urbanization. However, challenges were encountered in this study. One of the difficulties of this method is the choice of the boundaries for the factor classes.

The work has allowed for an understanding of the state of transformations in different urban zoning assignments and for mapping the suitable land use in the Wilaya of Constantine for urbanization needs through the use of GIS combined with the AHP multicriteria analysis method. Certainly, the results obtained are valid, and their reliability depends on the information used and the criteria adopted.

The synthesis map of potential urbanization zones created using this approach can serve as a fundamental tool for the prospecting of areas to be equipped with urban planning schemes or development plans to regulate urbanization and optimize the use of resources. Indeed, GIS combined with AHP constitutes one of the best decision-making tools for land development. Strengthening the means of advancing in the evaluation of development projects within an integrated and structured framework is a necessary element to promote sustainable development.

Conclusions.

Urban planning is a complex field, intrinsically linked to the territory, socio-economic context, and even local political dynamics. Finding the right balance between an automated and manual approach is not easy. In most land-use planning projects, it is recommended to implement tools that are flexible and adaptable to different contexts. To ensure the consistency of planning policies, it is essential for decision-makers to adopt a comprehensive and coordinated research approach. While stakeholder consultation improves the quality of studies, it often complicates the increase in the number of participants involved. The GIS-MCA system (Geographic Information System and Multi-Criteria Analysis) appears to be a suitable solution to ensure the consistency of documents and harmonize sometimes conflicting interests. Each of these tools has its own advantages and limitations, but their combination helps to compensate for the weaknesses of one with the strengths of the other. Research on this topic is still in its early stages, but the development of integrated GIS-MCA systems is becoming increasingly common in various software programs, thus transforming GIS into a true decision-making tool.

Our research relies on the integration of AHP (Analytic Hierarchy Process) with GIS to assess the suitability of sites in the municipality of wilaya of Constantine. This study highlights the advantages of land suitability analysis based on GIS, which facilitates complex decision-making. The land-use strategy must consider the suitability of lands to meet anticipated future needs and evolving demands. Understanding the importance of certain lands for specific uses pertains to the physical or economic suitability of the soil, meaning that it is not only about whether an area is useful for a particular purpose, but also whether it is physically suitable for that purpose.

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