



Application of Geographic Information Systems (GIS) for Identifying Suitable Sites for Water Reservoirs in the Oued Mina Basin

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Abstract:

Water scarcity is one of the most pressing challenges facing semi-arid regions. The identification of suitable sites for water reservoirs is crucial for improving water management and supporting sustainable agricultural development. This study applies Geographic Information Systems (GIS) to evaluate the spatial suitability for establishing water reservoirs in the Oued Mina Basin. Several thematic layers were integrated, including topography, hydrology, land use/land cover, slope, and soil characteristics. A multi-criteria decision analysis (MCDA) was conducted to classify the basin into different suitability zones. The results highlight priority areas with high potential for reservoir construction, which could contribute to enhancing water storage capacity and reducing the impacts of droughts. This research demonstrates the effectiveness of GIS as a decision-support tool for water resource planning in semi-arid environments.

Keywords: GIS, Spatial suitability, Water reservoirs, Oued Mina Basin, MCDA, Water resource management.

Application des systèmes d'information géographique (SIG) pour l'identification de sites appropriés pour les réservoirs d'eau dans le bassin de l'Oued Mina

Résumé :

La rareté de l'eau est l'un des défis les plus urgents auxquels sont confrontées les régions semi-arides. L'identification de sites appropriés pour la construction de réservoirs d'eau est cruciale pour améliorer la gestion de l'eau et soutenir un développement agricole durable. Cette étude utilise les Systèmes d'Information Géographique (SIG) pour évaluer l'adéquation spatiale à la création de réservoirs d'eau dans le bassin de l'Oued Mina. Plusieurs couches thématiques ont été intégrées, notamment la topographie, l'hydrologie, l'occupation/l'utilisation des sols, la pente et les caractéristiques du sol. Une analyse multicritères (AMCD) a été menée pour classer le bassin en différentes zones d'adéquation. Les résultats mettent en évidence des zones prioritaires présentant un fort potentiel pour la construction de réservoirs, ce qui pourrait contribuer à accroître la capacité de stockage d'eau et à réduire les impacts des sécheresses. Cette recherche démontre l'efficacité des SIG comme outil d'aide à la décision pour la planification des ressources en eau en milieu semi-aride.

Mots-clés : *SIG, Adéquation spatiale, Réservoirs d'eau, Bassin de l'Oued Mina, AMCD, Gestion des ressources en eau.*



Introduction:

Water resources play a critical role in sustaining human activities, agricultural production, and ecological balance. In semi-arid regions, where rainfall is irregular and evaporation rates are high, the availability of water is often limited and unevenly distributed. This situation highlights the urgent need for effective water storage strategies, including the construction of reservoirs, to secure a reliable water supply and mitigate the impacts of droughts. The selection of suitable sites for water reservoirs requires a comprehensive spatial analysis that considers multiple environmental and physical factors, such as topography, slope, hydrology, land use, and soil characteristics. Geographic Information Systems (GIS) provide powerful tools for integrating these diverse datasets and performing spatial modeling, enabling decision-makers to identify optimal locations for water infrastructure development. The Oued Mina Basin, located in northwestern Algeria, represents a strategic area for water resource planning due to its semi-arid climate and increasing water demand. Applying GIS-based spatial analysis in this basin can offer valuable insights for the prioritization of reservoir sites, thereby supporting sustainable water management and agricultural expansion.

Research Problem :

Surface water resources are among the most crucial components for sustainable development. However, rainfall variability in semi-arid regions such as northern Tiaret creates significant challenges for their sustainable

exploitation. The heavy reliance on groundwater, combined with increasing demand for water in agricultural and urban sectors, has made the search for alternatives and modern techniques for rainwater harvesting and storage an urgent necessity.

Within this context, the central question arises:

- **How can remote sensing and Geographic Information Systems (GIS) be employed to identify the most suitable locations for constructing water reservoirs capable of efficiently collecting rainwater?**

A related sub-question emerges:

- **What are the fundamental methodological steps and the geographical and environmental criteria that should be considered to select a spatially and technically suitable site for establishing such reservoirs?**

Addressing this research problem requires integrating natural factors (topography, slope, soil, climate, hydrographic network) with human factors (roads, urban areas, agricultural land use) within a comprehensive analytical framework, enabling decision-making supported by cartographic evidence.

Research Objectives :

This study aims to:

1. **Provide an applied approach** based on remote sensing and GIS techniques to identify and evaluate promising areas for the construction of water reservoirs.
2. **Produce accurate thematic maps** that highlight the degree of spatial suitability of different sites, using composite models that account for the relative



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weights of influential criteria (slope, proximity to streams, soil type, distance from urban areas and roads, etc.).

3. **Support water planning processes** by offering local authorities and planners a practical tool to guide the selection of suitable sites, thereby reducing risks associated with floods or water scarcity.
4. **Contribute to the rational use of water resources** by promoting rainwater harvesting techniques, which enhance long-term water and food security.
5. **Promote environmental sustainability** through reducing water loss, supporting local agricultural and pastoral activities, and achieving a balance between population needs and the natural capacities of the region.

Study Justification :

The selection of the northern part of Tiaret, particularly the **Oued Mina sub-basin**, as a case study is not arbitrary. This area is characterized by:

- **Semi-arid climatic conditions**, where rainfall is irregular and concentrated within a short seasonal period, leading to significant surface runoff and water loss.
- **Topographic diversity**, with elevations ranging between plains, hills, and mountainous zones, which creates favorable conditions for the construction of small and medium-sized reservoirs.
- **Agricultural importance**, as the region is one of the key cereal-producing zones in northwestern Algeria,

in addition to olive and livestock farming activities that heavily depend on water availability.

- **Hydrographic connectivity**, since Oued Mina is a major tributary of the Cheliff basin, the largest river system in Algeria, making water management in this sub-basin critical for downstream areas as well.
- **Developmental and environmental challenges**, where increasing water demand, combined with recurrent droughts, threatens agricultural productivity, food security, and the livelihoods of local communities.

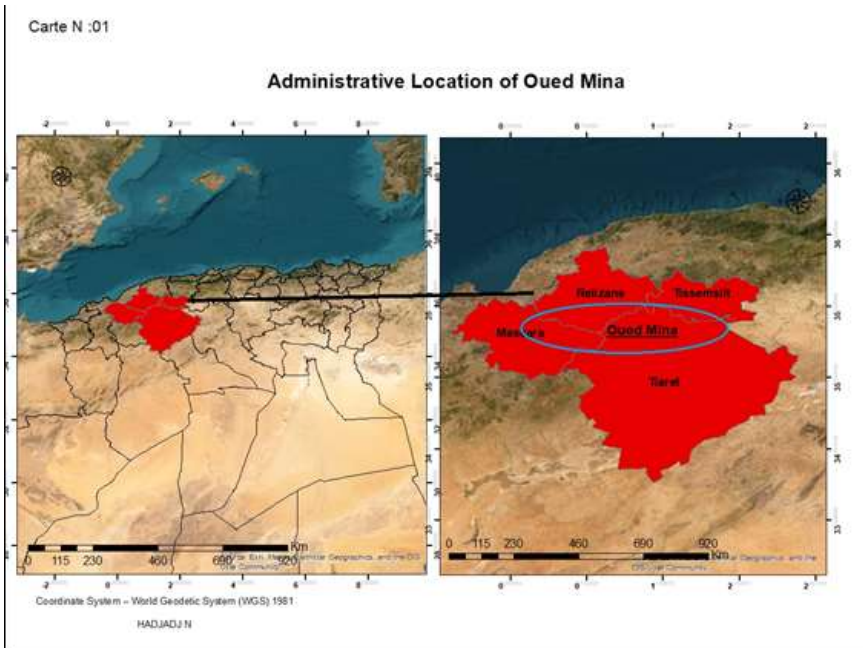
Thus, focusing the study on this region provides an opportunity to apply modern spatial analysis tools (GIS and remote sensing) to address real challenges of water management, while also generating practical recommendations that can be extended to similar semi-arid regions in Algeria and beyond.

Administrative Location of Oued Mina :

The **Oued Mina Basin** is one of the most important hydrological systems in western Algeria, extending across **four provinces (wilayas): Tiaret, Tissemsilt, Relizane, and Mascara** (ANRH, 2018; MRE, 2020). This wide administrative distribution gives the basin a **regional and interprovincial character**, reflecting its significant role in connecting diverse ecological and socio-economic zones.



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In **Tiaret Province**, which forms the **core of the basin**, Oued Mina covers several municipalities, including **Tiaret, Frenda, Medroussa, Mahdia, Ksar Chellala, Aïn Dheb, and Takhemaret**, which constitute the main surface water recharge areas (Bouanani & Benslimane, 2016). In **Tissemsilt Province**, the basin extends eastward to encompass **Lardjem, Ouled Bessam, and Lazharia**, which contribute runoff from the surrounding highlands (Belarbi & Hamimed, 2014). Meanwhile, in **Relizane Province**, Oued Mina flows through **Ramka, Djidouia, and Oued Rhiou**, forming one of the basin's principal downstream discharge zones. The **western tributaries** also reach the eastern boundaries of **Mascara Province**, particularly within **Aïn Fares and Lower Ghriss**, highlighting the basin's

hydrological interconnectivity across provincial limits (Bouanani & Benslimane, 2016).

This **multi-provincial extension** reflects the geomorphological and hydrological integration of Oued Mina, emphasizing the necessity of adopting a **regional management approach** to ensure the sustainable use of water resources (MRE, 2020). Consequently, the basin represents not only a **natural hydrological unit** but also a **strategic planning entity** that contributes to **water security, agricultural productivity**, and the promotion of **sustainable development** in western Algeria (Belarbi & Hamimed, 2014).

1. Definition of Analytic Hierarchy Process (AHP) :

The **Analytic Hierarchy Process (AHP)** is one of the most prominent quantitative tools in decision support, as it helps determine the relative weights of factors influencing geographical phenomena. This method is widely applied in spatial suitability studies, enabling planners and researchers to evaluate criteria according to their relative importance and then integrate them into a comprehensive composite model. Furthermore, the integration of this approach with Geographic Information Systems (GIS) provides an effective environment for collecting, organizing, and analyzing spatial data, and allows the construction of accurate suitability models that account for the relative impact of each studied factor (Saaty, 1980; Malczewski, 1999).

2. The Role of Geographic Information Systems in Water Management :

Recent studies have shown that **Geographic Information Systems (GIS)** play a pivotal role in water planning and



hydrological resource management. Their main functions include:

- **Spatial data analysis:** integrating topographic, climatic, environmental, and socio-economic information into a comprehensive database (Burrough & McDonnell, 1998).
- **Risk and threat assessment:** identifying areas prone to flooding, leakage, or high evaporation (Jenson & Domingue, 1988).
- **Water use planning:** directing resources according to priorities and developmental needs (Yeh, 1999).
- **Communication and awareness:** through maps and interactive media that support decision-making among policymakers and local communities (Goodchild, 2007).
- **Predictive modeling:** enabling the anticipation of future changes in water resources and supporting long-term planning (Kundzewicz & Döll, 2009).

3. Adopted Methodology

3.1. Application of the Analytic Hierarchy Process (AHP)

The **Analytic Hierarchy Process (AHP)** was adopted to determine the relative importance of each criterion influencing the selection of suitable sites for the construction of water reservoirs. This methodology involves:

- Identifying the main criteria based on previous studies.
- Assigning relative weights to each criterion according to its level of influence on the studied phenomenon.

- Integrating the results into a comprehensive composite model using spatial analysis tools within Geographic Information Systems (GIS).

3.2. Practical Steps

Phase One: Identification of Influential Criteria

The study considered a set of spatial and environmental factors, including:

- Topography (elevation and slope).
- Hydrographic network (proximity to watercourses).
- Climatic characteristics.
- Land use.
- Distance from urban settlements.
- Distance from the road network.

Phase Two: Building the Spatial Model

- Geographic data for each criterion were collected individually.
- Sub-models of spatial suitability were developed and then integrated using the weights derived from the AHP.
- This integration led to the production of a final model that identifies the spatial suitability zones for reservoir construction.

The study area (northern Tiaret) is characterized by diverse topography, with elevations ranging from a **minimum of 273 m to a maximum of 1274 m**, and a general average of **773.5 m**. This variability reflects a significant topographic diversity that allows for notable differences in suitability levels.

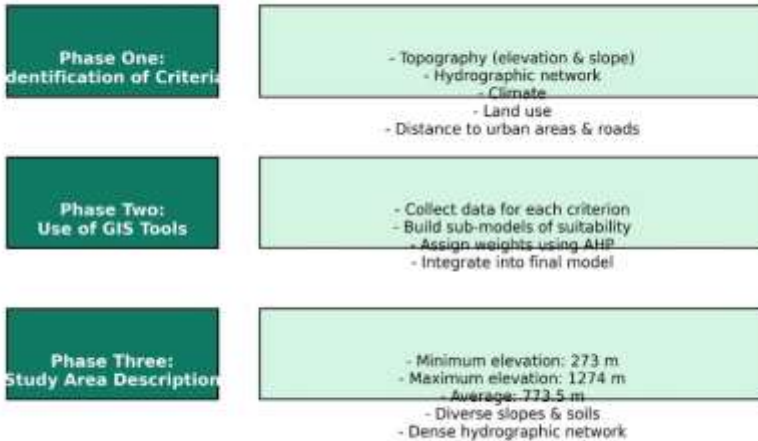


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Workflow and Steps



4. Elevations in the Study Area :

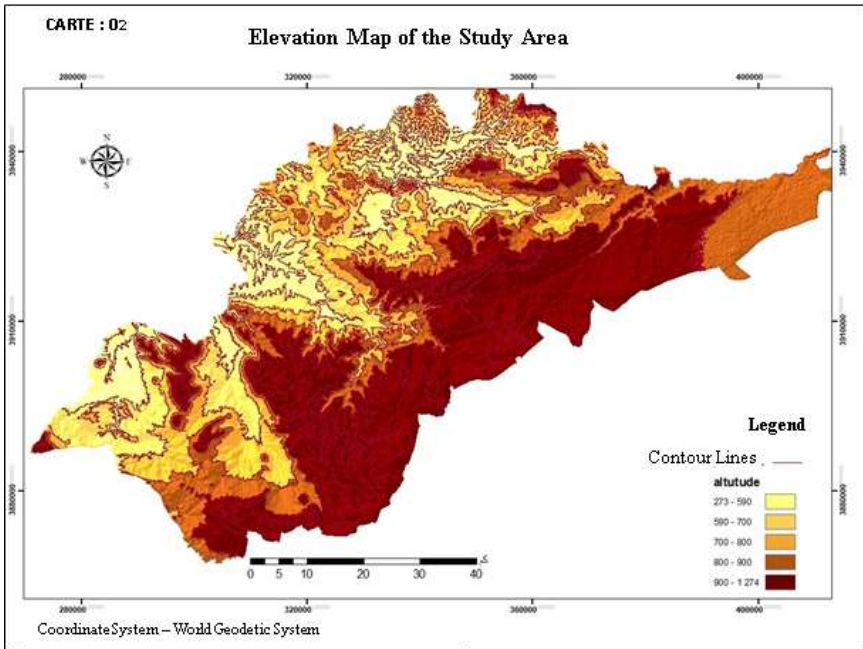
The study area is characterized by clear topographic diversity, with elevations ranging from **273 meters as the minimum** in the lowlands near watercourses and plains, up to **1274 meters as the maximum** in the high mountainous zones located in the northeastern part. The overall average elevation is approximately **773.5 meters**, which reflects a noticeable topographic gradient.

This variation in elevation has direct implications for:

- **Slopes:** The higher the terrain, the steeper the slope, which is a key factor in determining the flow of surface water and the speed of its accumulation (Moore et al., 1991).
- **Distribution of watercourses:** Elevated areas often act as recharge zones for streams, while lowlands function as receiving and collecting areas for runoff (Jenson & Domingue, 1988).

- **Land use:** Flat lands with low and medium elevations are more intensively exploited for agriculture, while high mountainous areas are generally used for grazing and forestry (Burrough & McDonnell, 1998).
- **Suitability for reservoir construction:** Areas with medium and low elevations emerge as the most suitable sites for reservoirs, due to their capacity to receive and store surface runoff, while also considering other factors such as slope and soil type (Malczewski, 1999).

Therefore, the study of elevations is not merely a topographic description, but rather a fundamental indicator for understanding the dynamics of surface water and identifying optimal sites for the construction of water infrastructures such as dams and reservoirs.



(WGS84)

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5. Slope Classification of the Study Area Slopes in the Study Area :

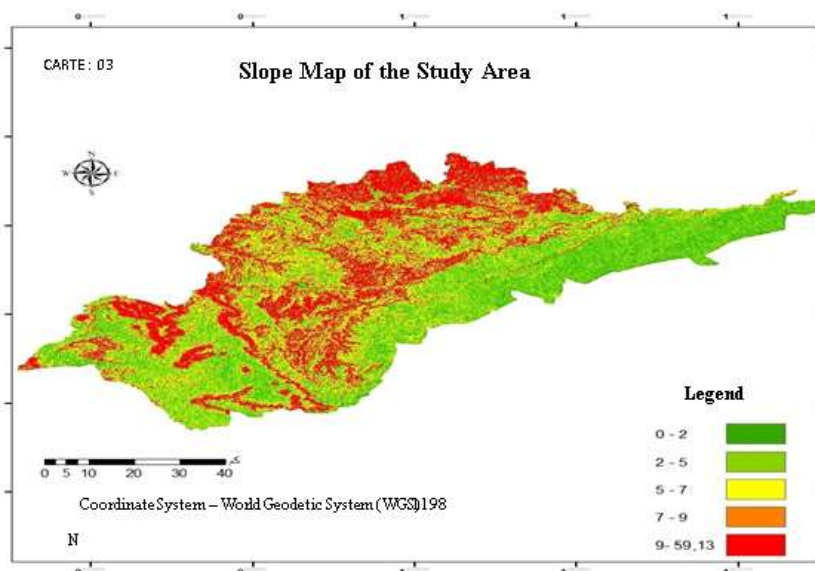
The topographic analysis reveals that the study area is characterized by a clear diversity of slope classes, which directly influences surface runoff dynamics and land use patterns. The moderate slope category dominates, covering 32.20% of the total area, followed by very steep slopes with 26.50%, reflecting the presence of extensive terrains with relatively flat conditions suitable for agricultural and pastoral activities.

Step slopes account for about 21.26%, while gentle slopes represent 18.96%, both of which can be considered

moderately suitable for agricultural exploitation and urban expansion. In contrast, very gentle slopes (0–2°) cover only 1.22% of the area, and are mainly confined to plains and depressions.

Slope Classes of the Study Area:

Slope Type	Percentage (%)	Area (ha)	Slope Degree (°)
Very Gentle	1.22	26,667	0 – 2
Gentle	18.96	415,384	2 – 5
Moderate	32.20	705,426	5 – 7
Steep	21.26	462,880	7 – 9
Very Steep	26.50	580,665	9 – 13.59



This variation in slope gradients highlights the coexistence of flat lands appropriate for farming and



settlement, alongside rugged terrains that require cautious planning for utilization. Moreover, moderate and steep slopes play a crucial role in accelerating surface water runoff and in identifying potential sites for water harvesting structures such as reservoirs.

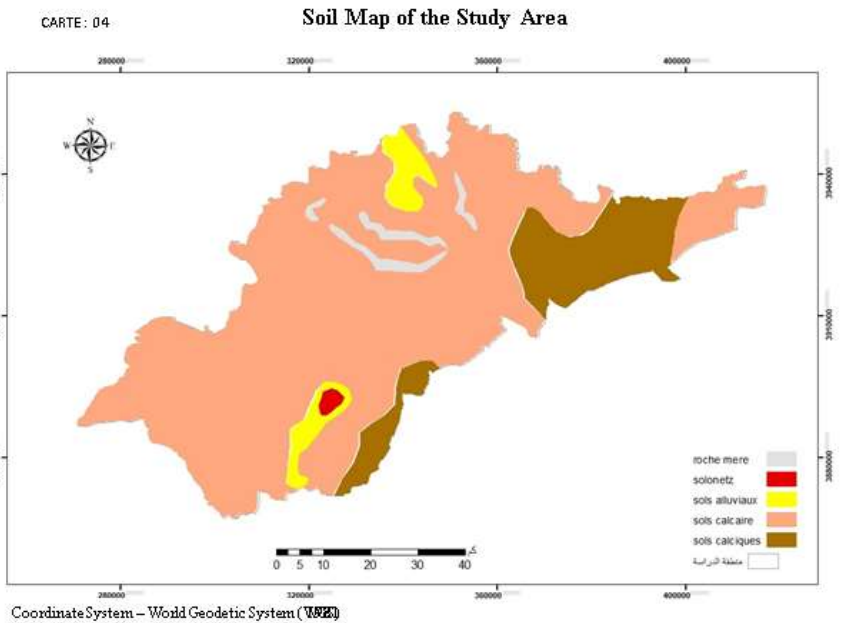
6. Soil Types in the Study Area :

The study area is characterized by a clear diversity of soil types, reflecting the topographic gradient as well as climatic and geological variations in northern Tiaret (Benouadah, Oulbachir, Benaichata, Miara, & Snorek, 2020; Oulbachir & Oustani, 2014). Lowland areas and plains are generally dominated by clay-loam soils, rich in organic matter, making them highly suitable for agriculture, particularly cereals and fodder crops (Benouadah et al., 2020). In contrast, sandy-clay soils are more common in medium-elevation zones, providing good drainage capacity and thus suitable for crops that require well-aerated soils (Chaïeb, Bouderbala, & Hamoudi, 2024).

At higher elevations and mountainous areas, soils tend to be shallow and relatively poor in organic content. These soils are more vulnerable to erosion due to steep slopes, which reduces their suitability for intensive agriculture. Such areas are usually exploited for grazing or covered with natural vegetation and forest cover (Deia, Hasbaia, Şen, & Djoukbala, 2025).

This variability in soil characteristics is a key factor in identifying suitable sites for rainwater harvesting projects. Soil properties such as permeability, storage capacity, and resistance to erosion directly influence the design and

efficiency of water harvesting infrastructures (Chaïeb et al., 2024; Deia et al., 2025).



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7. Analysis and Interpretation of Thematic Maps :

The analysis of the four thematic maps—hydrographic network, land use, distance to urban areas, and distance to roads—reveals significant spatial variability within the study area. This analysis provides valuable insights into the interaction between natural and human factors that shape the pattern of surface runoff and determine the most suitable areas for rainwater harvesting.

-Hydrographic Network Map highlights the density and branching of streams within the basin. A high concentration of watercourses can be observed in the northern and eastern parts of the area due to steep slopes and the overall topographic structure, making these zones promising for



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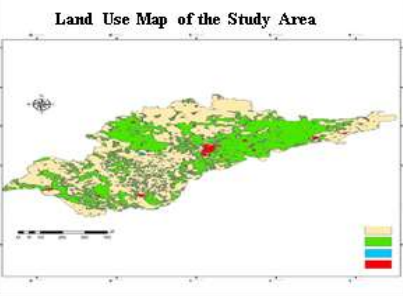
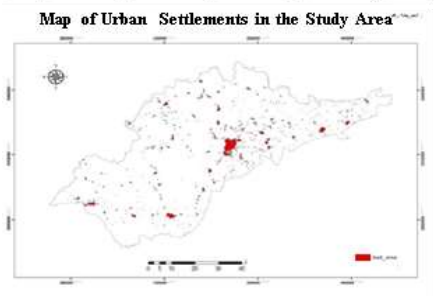
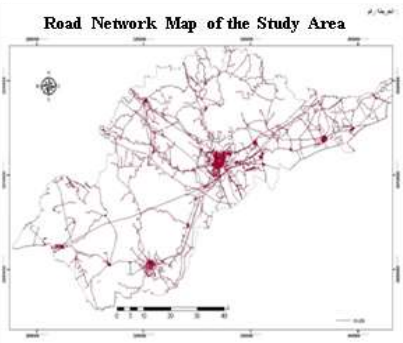
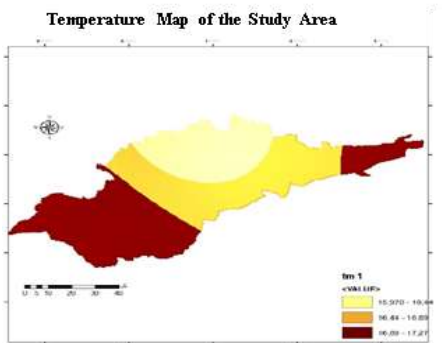
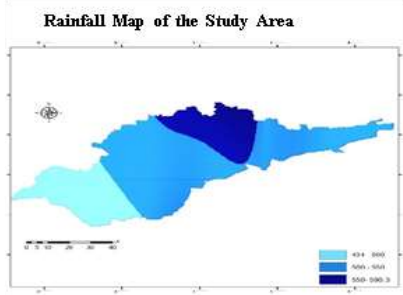
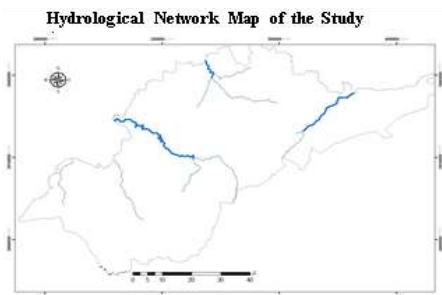
surface water collection. The variation in stream density across the region reflects differences in the natural drainage capacity of the terrain.

-Land Use Map shows that agricultural lands dominate the plains and lowlands, while barren lands and areas covered with natural vegetation prevail in higher elevations. Urban settlements are mainly concentrated in the central part of the area and along the main road corridors, indicating the influence of human activity on the balance between rainfall infiltration and surface runoff.

-Distance to Urban Areas Map illustrates the spatial distribution of population density, where major settlements are concentrated near the main transport axes. The areas located farther from urban centers appear as favorable sites for water-harvesting structures due to their distance from pollution sources and proximity to natural water accumulation zones.

-Distance to Roads Map displays the layout of the primary and secondary road networks covering most of the study area. Sites located at moderate distances from roads are considered the most suitable from a practical standpoint, as they combine accessibility with minimal direct human disturbance.

Overall, the interpretation of these thematic maps contributes to a detailed spatial understanding of the study area and supports the identification of priority zones for the establishment of rainwater-harvesting projects.



8. Creation of the Pairwise Comparison Matrix and Calculation of Criteria Weights :

At this stage, a pairwise comparison matrix was constructed to determine the relative importance of each of the six criteria used in assessing the spatial suitability for water reservoir construction—namely, slope, elevation, hydrographic network, land use, distance to urban areas, and distance to roads. This matrix was developed using the



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Analytic Hierarchy Process (AHP) proposed by Saaty (1980), through systematic pairwise comparisons between all criteria based on the Saaty scale (1–9), which represents varying levels of preference between one factor and another. After entering the comparison values into ArcGIS or Expert Choice, the principal eigenvector was calculated to extract the relative weights of each criterion. The Consistency Ratio (CR) was then computed to ensure the logical coherence of the judgments, with results showing CR values below 0.1 – indicating a high level of consistency and reliability. The findings revealed that slope is the most influential factor in identifying suitable sites for rainwater harvesting, followed by elevation and hydrographic network, while distance to roads and distance to urban areas were found to have a lesser impact. This confirms the predominant role of topographic factors in controlling surface water distribution and guiding the selection of optimal locations for reservoir construction.

Table: Criteria Weights Derived from the Analytic Hierarchy Process (AHP)

Criterion	Weight	Rank	Description
Slope	0.30	1	Steeper slopes enhance runoff direction and affect water accumulation potential.
Elevation	0.20	2	Influences flow direction and water retention capacity in lower areas.

Land Use	0.15	3	Determines surface permeability and infiltration rate based on land cover type.
Hydrographic Network	0.15	4	Indicates proximity to natural drainage channels suitable for water collection.
Distance to Urban Areas	0.10	5	Ensures water reservoirs are located away from pollution sources.
Distance to Roads	0.10	6	Reflects accessibility for construction, maintenance, and monitoring.

Consistency Ratio (CR): 0.06 – *Acceptable (CR < 0.1)*

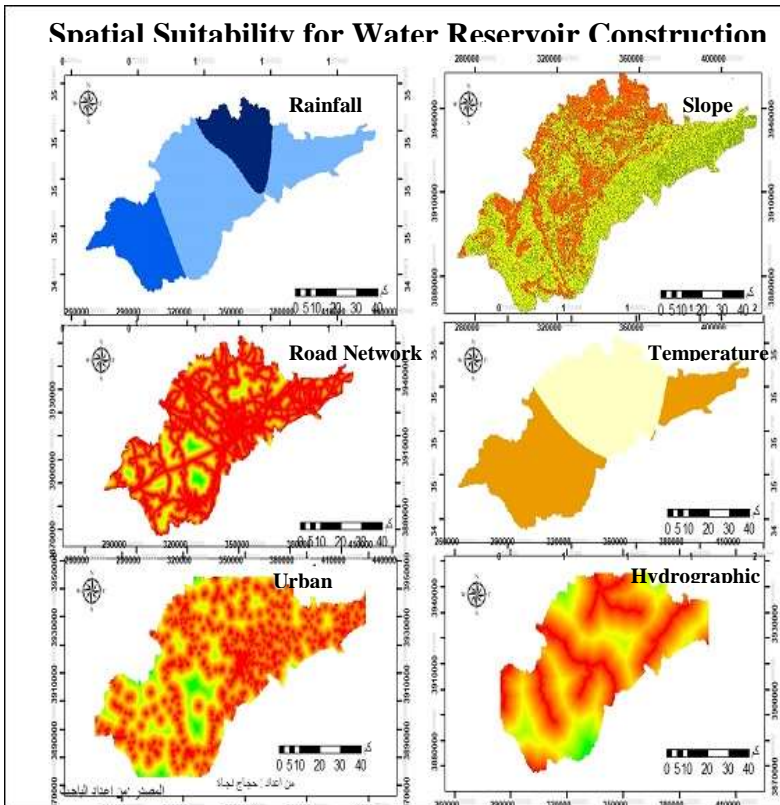
9. Extraction of Individual Suitability Models :

After preparing the thematic maps corresponding to each of the six criteria, the next step involved the extraction of individual suitability models, which represent the degree of suitability of each factor independently for the construction of water reservoirs.

This process was carried out through the Reclassification of spatial data layers within the ArcGIS environment, where the original values of each criterion were converted into standardized ratings ranging from 1 to 5, representing different suitability levels from “*very low*” to “*very high*” (Malczewski, 1999). This classification was based on previous studies that emphasized the importance of



standardizing the scales of heterogeneous criteria before integrating them into a composite model (Eastman, 2001). This step allows for the assessment of the spatial influence of each factor separately, thereby facilitating the subsequent weighted overlay process, in which all the individual models are combined according to the relative weights obtained through the Analytic Hierarchy Process (AHP) (Saaty, 1980). Moreover, this procedure helps minimize subjective bias and ensures a higher level of objectivity in spatial evaluation (Chen et al., 2010).



10. Results and Discussion :

The results of the study led to the production of a final spatial suitability map illustrating the spatial distribution of the most suitable areas for the construction of water reservoirs within the sub-basin of Oued Mina. This map was generated by combining the individual suitability models using the weights derived through the Analytic Hierarchy Process (AHP) within the Geographic Information System (GIS) environment, allowing for a comprehensive representation of the spatial interactions among topographic, hydrological, and anthropogenic factors.

The findings revealed that areas with gentle slopes and medium to low elevations are the most suitable sites for water harvesting, as they provide favorable conditions for water retention and reduced surface runoff velocity. Furthermore, proximity to the hydrographic network was found to be a key determinant of suitability, since the main and secondary streams serve as natural pathways for rainfall accumulation.

On the other hand, the areas located away from urban settlements but relatively close to the road network were identified as the most suitable from both environmental and logistical perspectives, due to their accessibility and reduced risk of pollution or urban encroachment. Additionally, agricultural and barren lands were found to have higher suitability levels compared to urban and industrial zones, which are less favorable for water reservoir construction. The final suitability map categorized the study area into five main suitability classes:

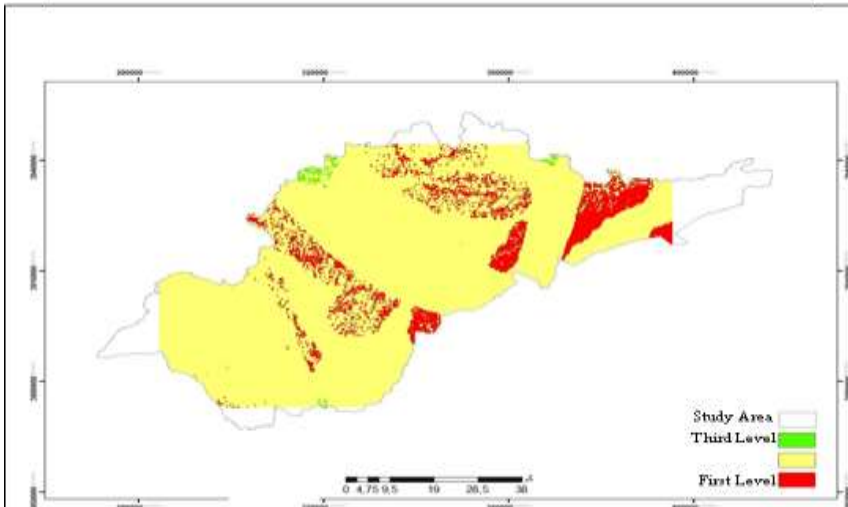
- **Very high suitability**, representing limited zones with the greatest water-harvesting potential.



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- **High suitability**, concentrated mainly in the central and northeastern parts of the basin.
- **Moderate suitability**, covering the majority of plains and gently sloping terrains.
- **Low suitability**, corresponding to steep or rocky areas.
- **Very low suitability**, mainly located in mountainous or urbanized regions.

Overall, the study demonstrates that the integration of Remote Sensing and GIS techniques with the AHP multi-criteria decision-making approach is a highly effective tool for supporting water resource planning and management. It enables the precise identification of priority areas for the construction of rainwater-harvesting reservoirs, thereby contributing to sustainable water resource management and environmental conservation at the basin scale.



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Conclusion :

In light of the above, it becomes clear that the use of Remote Sensing and Geographic Information System (GIS) technologies provides effective tools for identifying suitable locations for rainwater harvesting. These tools enable precise spatial analysis that contributes to the optimal management of water resources, the reduction of water loss, and the enhancement of water security in areas vulnerable to drought.

It is hoped that this study will contribute to supporting future development projects in the water sector and open new perspectives for applied research in Algeria, particularly in the field of sustainable water management and environmental planning.

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