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Delineation of Groundwater Potential Zones Using Geospatial Techniques. Case Study: Roman City and the Surrounding Area in the Northeastern Region, Romania

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Abstract: Effective groundwater management is crucial under the current climatic conditions, addressing both qualitative and quantitative aspects. An important step in delineating groundwater potential zones involves remote sensing (RS) data and geographic information systems (GISs), facilitating resource assessment, and the implementation of suitable field data management. This study introduces the delineation of potential groundwater zones using seven layers and the Multi-Criteria Decision Analysis (MCDA) method. Satty's Analytic Hierarchy Process (AHP) was employed to rank the seven selected parameters, contributing to the advancement of groundwater research and resource assessment. All seven thematic layers (Rainfall, Geology, Land Use/Land Cover, Drainage Density, Elevation, Slope, and Soil) were prepared and analyzed to delineate groundwater potential zones. The resulting groundwater potential zone map was categorized into four classes, Very Good, Good, Moderate, and Poor, covering areas of 81.53 km^2 (45.1%), 56.36 km^2 (31.2%), 19.54 km^2 (10.8%), and 23.17 km^2 (12.8%) of the total area, respectively. The accuracy of the output was validated by comparing it with information on groundwater prospects in the area, and the overall accuracy of the method was approximately 72%. High-yield boreholes were drilled and concentrated in the Very Good groundwater potential zones, while low-yield ones were developed in the Poor areas.

Keywords: groundwater potential; multi-criteria decision-maker; AHP; GIS techniques; remote sensing

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1. Introduction

Climate change plays a significant role in and has important implications for groundwater resources and the hydrological cycle [1–4]. In recent decades, due to a growing global population, the demand for freshwater has increased substantially, with the necessity of water for irrigation and industrialization leading to more frequent instances of water scarcity [5–8].

Groundwater is one of the most important resources, stored in various geological formations, showing variations in quantity and quality, as well as different parameters, including temperature, chemistry, flow direction, and interactions with surface water systems [9–13]. Preserving and conserving groundwater resources is a pressing issue of the 21st century, with water management posing a significant challenge for governments worldwide [11,14,15].

The study area is located in the Siret River Basin, and the primary source of supply comes from groundwater, specifically from the ROSI03 aquifer, a phreatic groundwater body, utilized in varying proportions: 67.7% for meeting the population's demands, 2.3% for agriculture, and 30% for industrial sector [16]. The examined region is positioned

upstream from the confluence of two major rivers, namely the Moldova River and the Siret River, situated in the Siret River watershed, and is primarily characterized as an agricultural zone.

The conventional methodologies employed for the identification, delineation, and mapping of groundwater potential zones primarily rely on on-site surveys utilizing geophysical, geological, and hydrogeological tools, but these methods are typically characterized by high costs and time-intensive processes [4,14,17]. The introduction of geospatial tools in the field of geosciences is an efficient approach, particularly when it comes to groundwater exploration before resorting to conventional exploration and exploitation techniques [18]. Remote sensing technologies (RI) and the Geographic Information System (GIS) provide a rapid and cost-effective method for estimating underground resources [19–21]. In the context of delineating groundwater potential zones and mapping them, this study employs a combination of GIS technology and the Analytical Hierarchy Process (AHP). AHP, developed by Thomas Saaty in 1980, proves to be an effective method for simplifying complex decision-making through direct comparisons to a series of pairwise comparisons and for summarizing result integration [22]. Choosing AHP for this study was a decision based on the advantages of the method, particularly its ability to utilize multi-criteria decision-making for integrating diverse thematic layers, which is essential for delineating groundwater potential zones. Although other methods such as Machine Learning, Fuzzy Logic, and Artificial Neural Networks exist, AHP was selected for its simplicity, ease of application, and validation in various studies [14,23,24]. Furthermore, AHP is a suitable technique for ensuring result consistency, thereby minimizing subjective influences in the decision-making process [25]. The GIS was used to perform weighted overlay analysis on the layer maps, considering the priorities determined by the AHP, resulting in the identification of potential groundwater zones [26–28].

Various studies worldwide have focused on identifying potential groundwater zones utilizing GIS and mathematical models. For instance, Shreeya Baghel et al. [14] in their study on groundwater potential in the catchment of the Mahandi Basin, D. C. Jhariya et al. [10] in their paper assessing groundwater potential zones in Raipur city, India, Aysha Akter et al. [21] with the study predicting groundwater potential zones using GIS techniques, and Mustafa et al. [29] in their study of the Demirci district (Turkey) highlighted the effective integration of various factors, including geology, geomorphology, rainfall, land use/land cover (LULC), drainage density, slope, groundwater level depth, and soil texture. These studies employed the weighted index analytical hierarchy process (AHP) method to develop groundwater potential models, contributing to a clear understanding of groundwater potential. These findings affirm the method's utility across varied geographical contexts and suggest that the results obtained are similar to those presented in this study.

Taking all aspects into consideration, the primary goal of this study, which combines AHP with RS and GIS, is to outline, recognize, and map groundwater potential zones to facilitate the sustainable management of water resources in the region.

2. Materials and Methods

The present study was conducted in the northeast of Romania on the east part of Neamț county. The region of interest (ROI) described in this paper is situated in the south extremity of Fălticeni Plateau, to the confluence of two major rivers, Moldova on the west boundary and Siret on the east boundary [30]. The study area has a total surface of 180.6 square km, shown in Figure 1. The coordinate system used in this study is Stereo 70(EPSG31700), specific to Romania and and for all maps used in this article. For better international recognition, the equivalent coordinates in WGS 84(EPSG4326) are provided as follows: the study area is located between latitudes 46°54′28.22″ N and 47°05′30.26″ N, and longitudes 26°46′43.81″ E and 26°58′15.50″ E.

The area comprises the city of Roman, with the highest economic and industrial development, and the surrounding northern municipalities, which, in general, are predominantly

characterized by agricultural activities [31]. The average elevation of the study area varies from 175 to 260 m above the mean sea level.

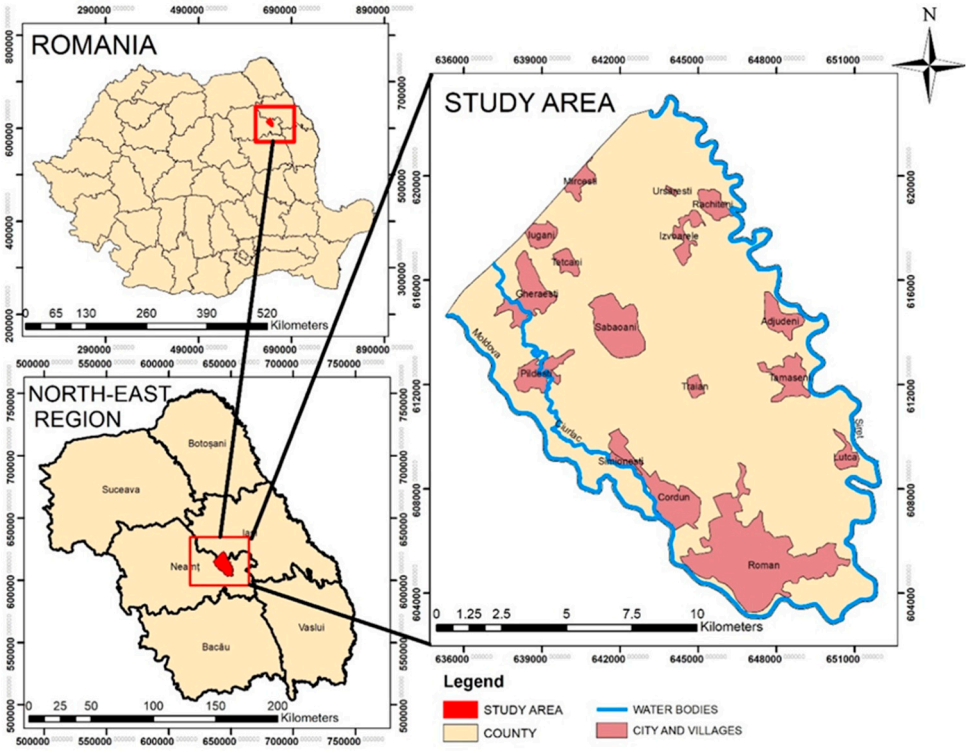


Figure 1. Study area.

2.1. Data Acquisition

In the process of identifying potential groundwater zones within the region of interest (ROI), a variety of geospatial techniques were employed. The methodology involves digital image processing, digital elevation model (DEM) evaluation, and field studies including hydrogeological data.

To delineate the groundwater potential zone (GPZ) for the study area, seven parameters such as geology, rainfall, slope, drainage density, Land Use and Cover (LULC), soil and elevation, as presented in Table 1, were analyzed. One of the datasets required for the study is represented by the digital elevation model (DEM) which has been acquired from the United States Geological Survey through the Shuttle Radar Topography Mission (SRTM) with a resolution of 30 m (cell size = 30 × 30 m/pixel). The DEM was used to delineate the boundaries of the ROI, drainage density and the slope using different techniques and spatial tools in ArcGis 10.8 software. Precipitation data were acquired from pluviometric gauging stations belonging to the Siret River Basin Administration Bacău. The data were processed to create rainfall maps with ArcGIS software using the IDW interpolation tool. The geological data were processed by digitizing the Geological map of Romania, L-25-IX, 13 Piatra Neamț at a scale of 1:200,000, and the soil data were prepared by digitizing the Soil Map of Romania at a scale of 1:200,000. The Land Use and Land Cover (LULC) map was generated from LANDSAT 8 OLI (Operational Land Imager) data from 2020 with a 30 m resolution using supervised image classification in ArcGIS10.8.

The entire workflow process is described in Figure 2 according to the data shown in Table 1. This representation summarizes the steps involved in delineating groundwater potential zones, integrating various data. This visualization aids in effectively communicating the methodology employed and facilitates a deeper understanding of the groundwater potential assessment process.

Table 1. Principal database used in groundwater potential study.

S. No	Data Used	Parameters	Scale/Resolution	Source	Application
1	Elevation Data	Drainage Density, Slope, Location of the study area	30 m	[32]	Boundary Area, Calculate GWPZ
2	Meteorological data	Rainfall map	30 m	[16,33]	Calculate GWPZ
3	Soil Map	Soil Texture, Soil type	1:200,000	[34]	Calculate GWPZ
4	Geological Map	Geology type	1:200,000	[35]	Calculate GWPZ
5	LANDSAT 8 OLI	Land Use and Cover map (LULC)	30 m	[31]	Calculate GWPZ
6	Hydrogeological maps	Hydrogeological data (groundwater table, groundwater flow rate)	1:200,000	[33]	Result Validation

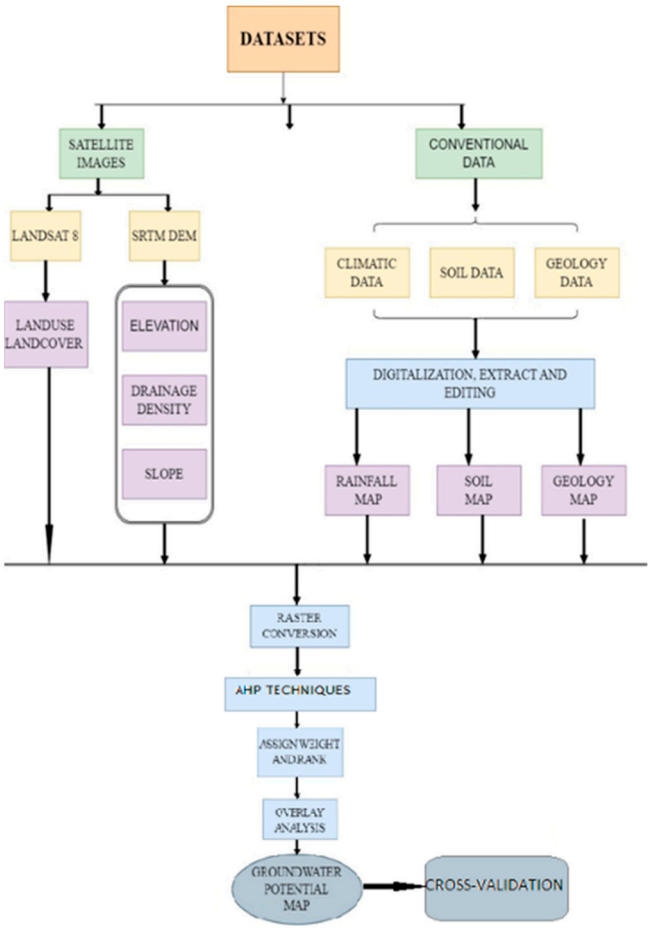


Figure 2. Flowchart.

2.2. Multi-Criteria Decision Analysis Using AHP

Analytical Hierarchical Process (AHP) is one of the most used and well-known GIS method for delineating groundwater potential zones by integrating all thematic layers. In this study, we used seven different layers with sub-criteria that have a different weight in controlling groundwater flow and storage in the area. These factors are weighted according to their local impact on the presence of groundwater and expert judgement/opinion. In the specialized literature, there are studies that establish similar weights for factors, depending on their importance in different hydrogeological contexts [5,10,14].

The Analytical Hierarchy Process (AHP), first introduced by L. Saaty, is a technique for multicriteria decision-making [36]. It utilizes a pairwise comparison matrix to determine

scale ratios between different criteria. According to Saaty's scale, presented in Tables 2 and 3, in pairwise comparisons, a value of 1 is assigned to two thematic layers when they are considered to have equal importance for groundwater potential, while a value of 9 is given to represent extreme importance in such pairs [22]. According to each layer importance, we created a pairwise comparison matrix for seven variables, presented in Table 4. Various weights were allocated to thematic layers, reflecting their significance in terms of water retention capacity. The total weight (TW) was obtained by the total value of the scale weight divided by the cumulative number of parameters for all thematic layers [22]. The Normalized Pairwise Comparison Matrix (NPCM) was constructed by calculating ratios derived from the division of the total value and each individual judgment value within the same column. Following that, the total of these ratio values within each row was divided by the count of parameters in the pairwise comparison matrix [37].

Table 2. Analytical Hierarchy Process scale [22,36].

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the goal
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8 used to express intermediate values preference in weights		

The Consistent Ratio (CR) is used to validate the accuracy of the weights derived from the normalized pairwise comparison matrix. It compares the ratio between the Consistency Index (CI) and a Random Consistency Index (RI) that depends on the number of criteria used [25]:

$$CR = CI/RI \quad (1)$$

where CI is the Consistency Index; and RI is the Random Consistency Index (values obtained from Saaty's standard (Table 3)).

$$CI = (\lambda_{max} - n)/(n - 1) \quad (2)$$

where n is the number of criteria (layers); and λ_{max} is the average value of the Consistency Index (Eigen value).

Table 3. Saaty's ratio index for different values of n [37].

N	1	2	3	4	5	6	7
RI	0	0	0.58	0.89	1.12	1.24	1.32

According to Saaty, if CR is equal to 0.1 or less, it is acceptable to continue the analysis, but if the consistency value is greater than 0.1, it is necessary for the judgment to be revised [36].

$$\text{Maximum Eigen value } (\lambda_{max}) = 7.37$$

$$n = 7$$

$$\text{Consistency Index CI} = (\lambda_{max} - n)/(n - 1) = 0.06$$

$$\text{Random Index} = 1.32$$

$$\text{Consistency Ratio (CR)} = CI/RI = 0.047$$

Table 4. Pairwise comparation matrix for all thematic layers.

Variable	Rainfall	Geology	LULC	Drainage Density	Elevation	Slope	Soil	Normalized Weight
Rainfall	1	2	4	3	2	3	3	0.28
Geology	1/2	1	4	4	1	3	3	0.21
LULC	1/4	1/4	1	1/3	1/4	1/3	1	0.05
Drainage Density	1/3	1/4	3	1	1/3	1/2	3	0.09
Elevation	1/2	1	4	3	1	2	3	0.19
Slope	1/3	1/3	3	2	1/2	1	3	0.12
Soil	1/3	1/3	1	1/3	1/3	1/3	1	0.06

2.3. Weighted Overlay Analysis (WOA)

Following the transformation to a cell size of 30 × 30 m, the thematic layers were reclassified using the obtained weighting values. Weighted Overlay Analysis (WOA) is a method that empowers users to address intricate spatial site suitability factors by integrating diverse input parameters, leading to the delineation of groundwater potential zones (GZPs). In the Weighted Overlay Analysis (WOA) tool, all reclassified raster maps are overlaid and appropriate weights are assigned. The generated raster layer was categorized into four groups of groundwater potential zones (GPZs) using consistent weight ranges in accordance with recommendations from the United Nations' Food and Agricultural Organization [38].

$$S = \sum_{i=1}^{n} (wi.xi), \quad (3)$$

where S is the total GPZ score; wi denotes the weight of the GPZ criteria; xi indicates the sub-criteria score of i GPZ criteria; and n represents the total number of GPZ criteria.

Each sub-criteria in each thematic layer received scores ranging from 1 to 5, taking into consideration favorable conditions and their importance in identifying groundwater zones. The least suitable sub-parameters were assigned a minimum score of 1, and the highest suitable sub-parameters were assigned a maximum score of 5, while sub-parameters of moderate suitability were given intermediate values for groundwater potential zone (GPZ) identification, as presented in Table 5.

Table 5. Percentage influence and scale value of individual themes for the overlay analysis.

Parameter	Influence (%)	Sub-Criteria	Feature Weight
RAINFALL	28	650.73–667.57 mm	2
		667.58–681.04 mm	3
		694.52–710.14 mm	3
		681.05–694.51 mm	3
		710.14–728.8 mm	3
GEOLOGY	21	Holocene gravel and sand deposits	4
		Pleistocene diluvial and proluvial deposits	1
		Holocene recent alluvium	3

Table 5. *Cont.*

Parameter	Influence (%)	Sub-Criteria	Feature Weight
LULC	5	Water bodies	3
		High vegetation	3
		Low vegetation	3
		Agriculture land	3
		Built-up area	1
DRAINAGE DENSITY	9	0–0.31 km/km^2	4
		0.32–0.88 km/km^2	3
		0.89–1.4 km/km^2	3
		1.5–2.0 km/km^2	2
		2.1–3.3 km/km^2	1
ELEVATION	19	175.5–189.9 m	4
		190.0–201.2 m	3
		201.3–216.8 m	2
		216.9–233.5 m	2
		233.6–260.4 m	1
SLOPE	12	0.0–1.3%	5
		1.4–3.8%	4
		3.9–8.6%	3
		8.7–16.0%	2
		16.1–53%	1
SOIL	6	Clay and silt loam	2
		Soil with variate texture	2
		Sandy loam	3
		Marshes and pounds	4
		Clayey	1

Verification and validation of the obtained GWPZ map were conducted by comparing the groundwater yield data from eleven boreholes provided by the Siret River Basin Administration in Bacău.

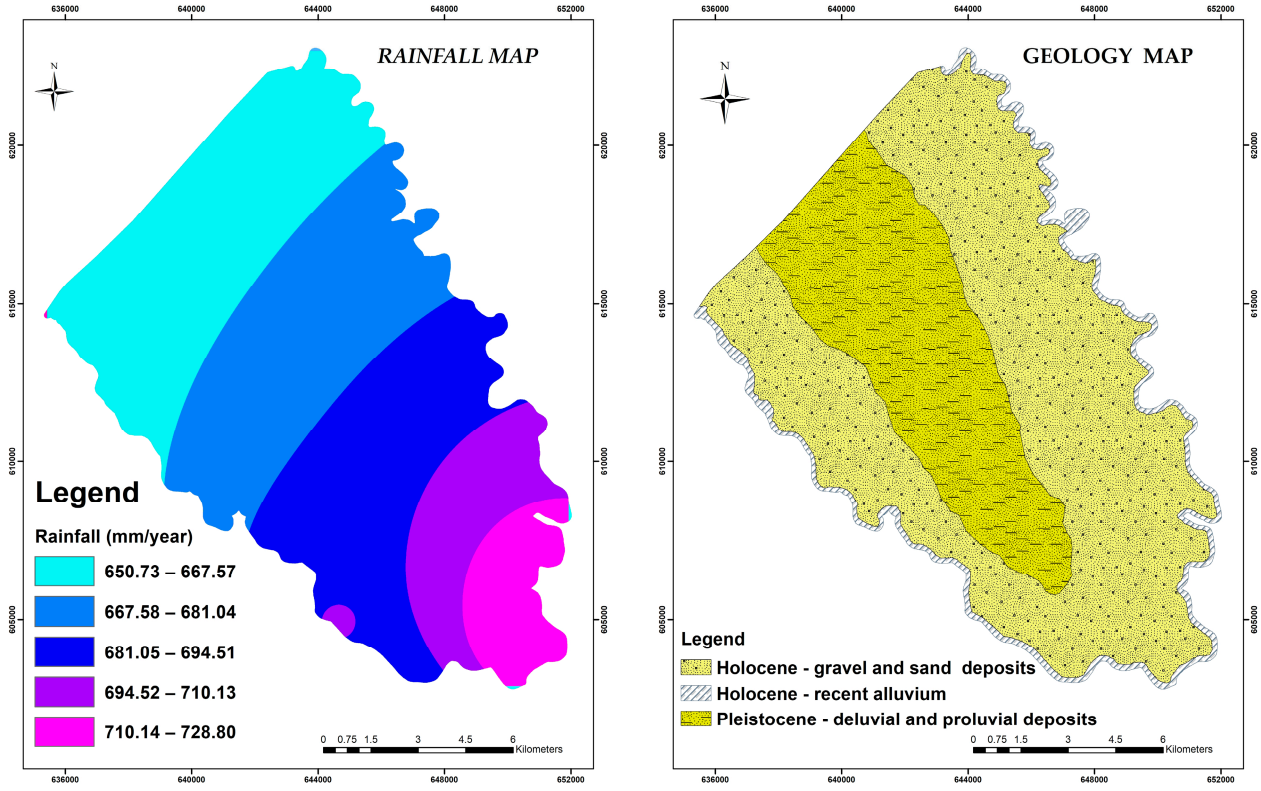
3. Results and Discussion

The following sections explore the outcomes and discussion of this study. This part involves the creation of thematic layers, delineation of groundwater zones, and the evaluation of map accuracy through validation. This is accomplished by comparing actual yield descriptions with the expected yield class derived from the predictive map.

3.1. Rainfall

One of the main factors influencing groundwater recharge in the study area is represented by precipitation. The intensity and duration of rainfall play an important role in infiltration dynamics. High-intensity, short-duration rain events tend to limit infiltration, favoring surface runoff, whereas low-intensity, long-duration rainfall supports greater infiltration, which can be fundamental for groundwater recharge and sustainable water resource management. The spatial distribution of the multiannual rainfall map was classified into five categories, which include (650.73–667.57) mm/year, (667.58–681.04) mm/year,

(681.05–694.51) mm/year, (694.52–710.14) mm/year, and (710.14–728.8) mm/year, as presented in Figure 3a. It is noticeable that the precipitation amounts gradually decrease near the study area's boundary.



(**a**) (**b**)

Figure 3. (**a**) Spatial distribution of precipitation; (**b**) geology map of the interest area.

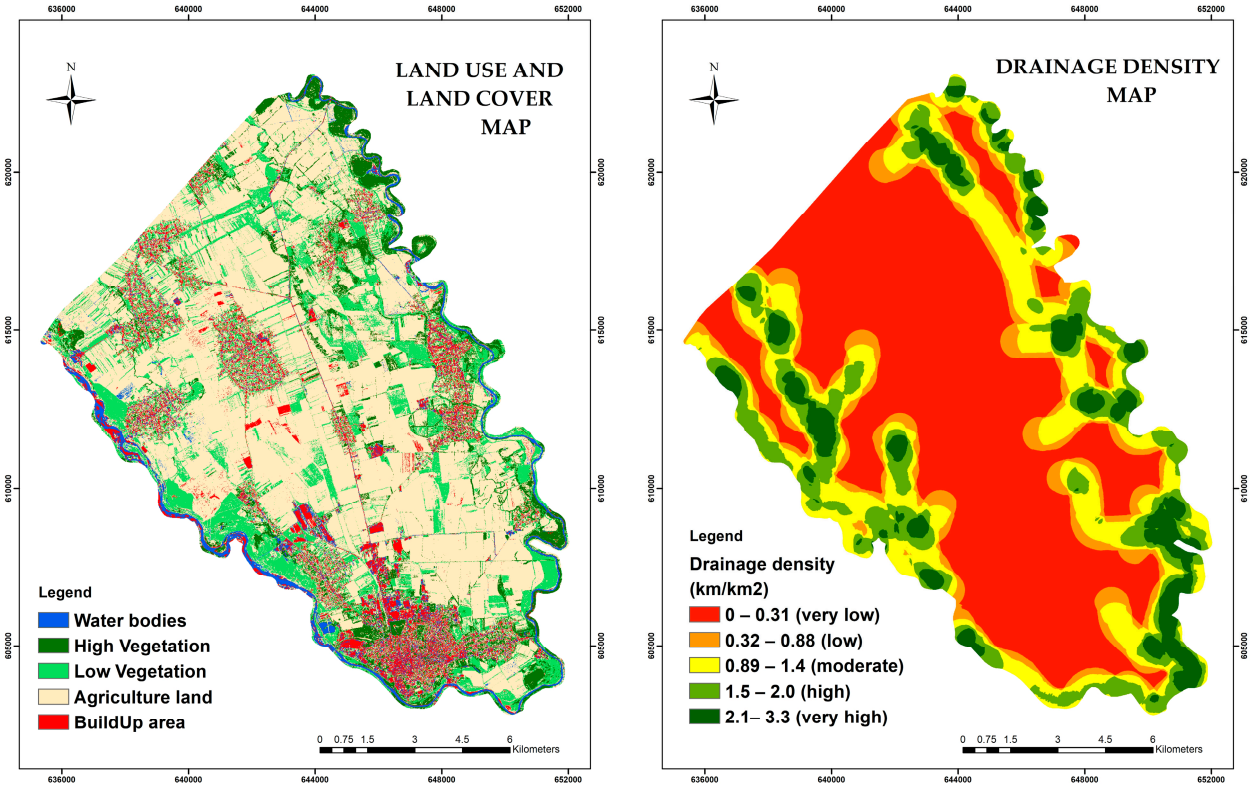
3.2. Geology

Geology plays a critical role in determining the characteristics and distribution of groundwater, influencing the porosity and permeability of groundwater potential in an area, and is used in various analyzed studies where geological maps are integrated into GIS. A comparison between the geological layer used in this study and those in existing literature shows significant similarities in methodology and application [10,14]. A substantial area within the study region, presented in Figure 3b, is marked by Holocene gravel and sand deposits, while higher elevation zones display Pleistocene diluvial and proluvial deposits. According to the lithological characteristics, a higher feature weight was assigned to Holocene deposits, while a lower weight was assigned to Pleistocene deposits.

3.3. Land Use Land Cover (LULC)

Land Use and Land Cover (LULC) data are important in providing essential information regarding infiltration, soil moisture, groundwater, and surface water, and these offer perspectives on groundwater requirements. The study area's land classification was categorized into five classes, which included water bodies, high vegetation, low vegetation, agricultural land, and built-up areas presented in Figure 4a. The predominant category in the study area is represented by agricultural land, accounting for 60.2% of the total area, with a concentration in the central part of the region. Built-up areas are notably prevalent in the southern part, particularly around the Roman city and its adjacent counties. The land use and land cover were validated using Google satellite images and ground-truthing data, with a Kappa coefficient of 0.71, and the overall classification accuracy was found to be 76%, as previously reported in other studies [31]. Based on various criteria such

as water transmission and storage capacity, the "Built-Up Area" category received a low feature weight score of 1, while the remaining classes were assigned higher feature weights in general.



(**a**) (**b**)

Figure 4. (**a**) Land use and Land Cover map; (**b**) drainage density map.

3.4. Drainage Density

Drainage density is obtained by dividing the total length of all the rivers in a drainage basin by the total area of the drainage basin [39]. It is a fundamental indicator of hydrological landscapes, and it serves as a valuable tool for analyzing landforms in the context of groundwater potential [10]. It plays a crucial role in determining both infiltration rates and the characteristics of the underlying lithology [40]. In this context, a region with low drainage density is more favorable for high groundwater potential compared to a region with high drainage density. This is why, in this research, a higher weight was assigned to areas with low drainage density. The drainage density was reclassified and sorted into the following categories presented in Figure 4b: Very low (0–0.31 km/km^2), Low (0.32–0.88 km/km^2), Moderate (0.89–1.4 km/km^2), High (1.5–2.0 km/km^2), and Very high (2.1–3.3 km/km^2).

3.5. Elevation

The elevation information collected by the Shuttle Radar Topography Mission (SRTM) was used to create visual representations or maps of the terrain using ArcGis software. To verify the accuracy of the SRTM data with a 30 m resolution, the digital model (DEM) was compared with ground control measurements taken in 206 points using a GNSS RTK system. The maximum error observed was 0.7 m at point P198, while the minimum error recorded was −1.3 m at point P68, resulting in a median error of −0.19 m. This error can be considered acceptable for this type of digital terrain model, as illustrated in Figures 5 and 6.

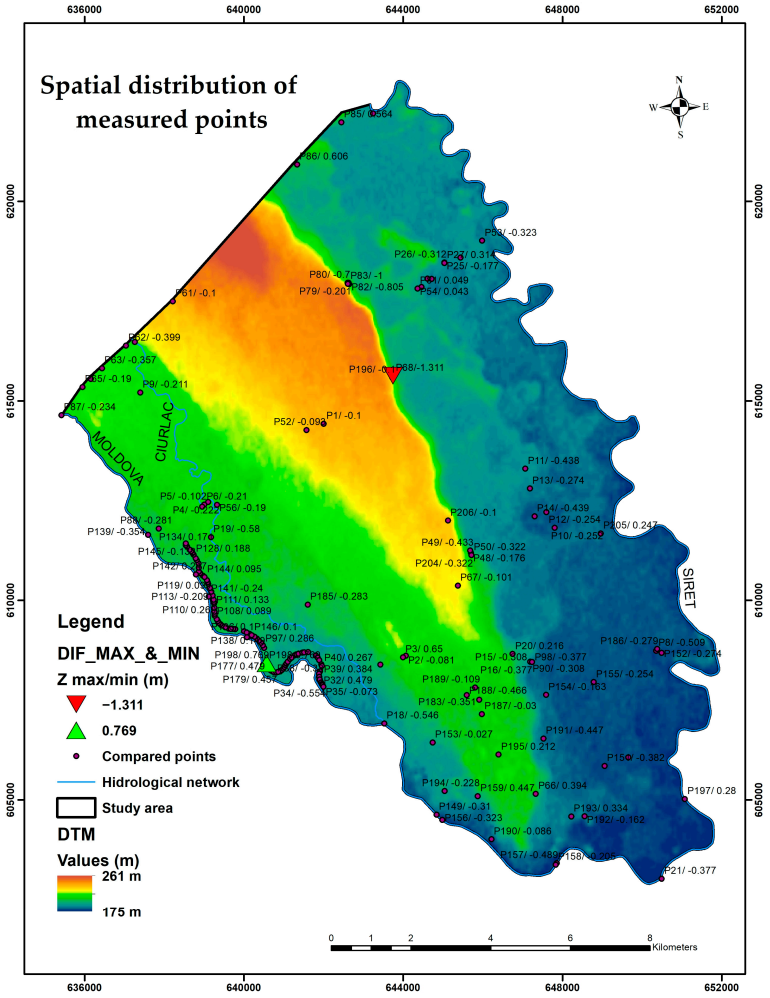


Figure 5. Spatial distribution of compared points.

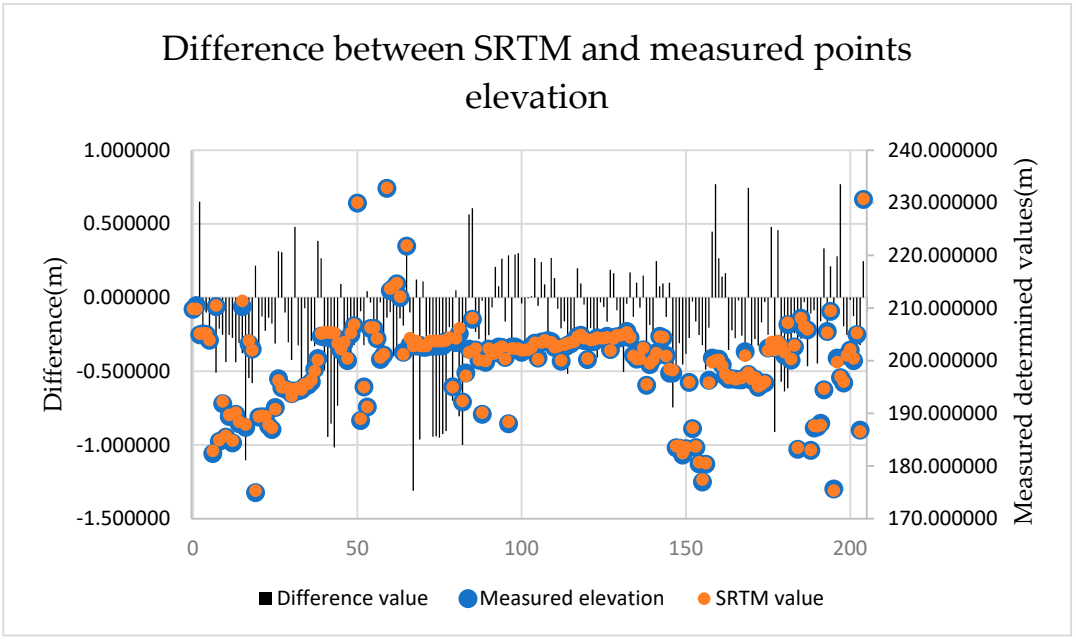
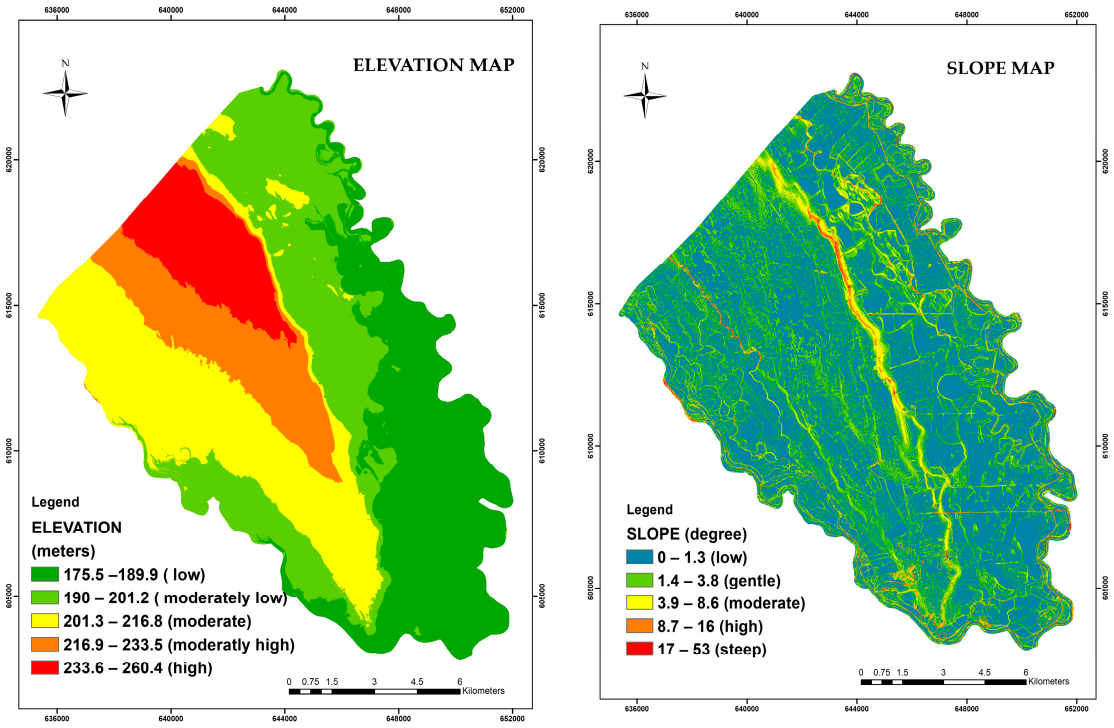


Figure 6. Difference between SRTM elevation and measured point elevation.

In the study area, the elevations range from a minimum of 175 m to a maximum of 261 m. In this case, low rankings were assigned to areas with higher elevations, while high rankings were designated for those with lower elevations. This ranking takes into account various hydrological characteristics, such as infiltration rates, run-off patterns, and slope steepness. The elevation was reclassified into five categories, ranging from low to high, as illustrated in Figure 7a. Different feature weights were assigned to these categories: a weight of 3 for the lower elevation zones, which range from 175.5 m to 201.2 m; a weight of 2 for the moderate elevation zones, spanning from 201.3 m to 216.8 m; and a weight of 1 for the highest elevation zone, covering the range from 233.6 m to 260.4 m.



(**a**) (**b**)

Figure 7. (**a**) Elevation map; (**b**) slope map.

3.6. Slope

Slope, a crucial determinant of runoff and infiltration rates, is influenced by the spacing of contour lines. In general, closely spaced contours in vector representation indicate steeper slopes, while in raster representation, each cell provides a slope value where lower values suggest a flatter terrain and higher values denote steeper slopes. The slope values were reclassified and grouped into five categories, like in Figure 7b: Low (0–1.3), Gentle (1.4–3.8), Moderate (3.9–8.6), High (8.7–16.0), and Steep (17–53). Higher slopes result in reduced recharge as precipitation water quickly flows down steep slopes during rainfall events. Therefore, a lower weight (1) was assigned to steep slopes, while a higher weight (3) was allocated for low-to-gentle slopes.

3.7. Soil

Soil serves as a crucial parameter for identifying potential groundwater occurrence zones. In the study area, five soil types are present, including sandy loam, soil with variable texture, clay and silt loam, clay soil, and marshes and ponds (as shown in Figure 8). The soil's texture plays a vital role in controlling surface runoff and the infiltration of rainwater. Sandy soil has a low runoff rate and high groundwater potential, whereas clay and silty loam soil have a high runoff rate and very low groundwater storage capacity.

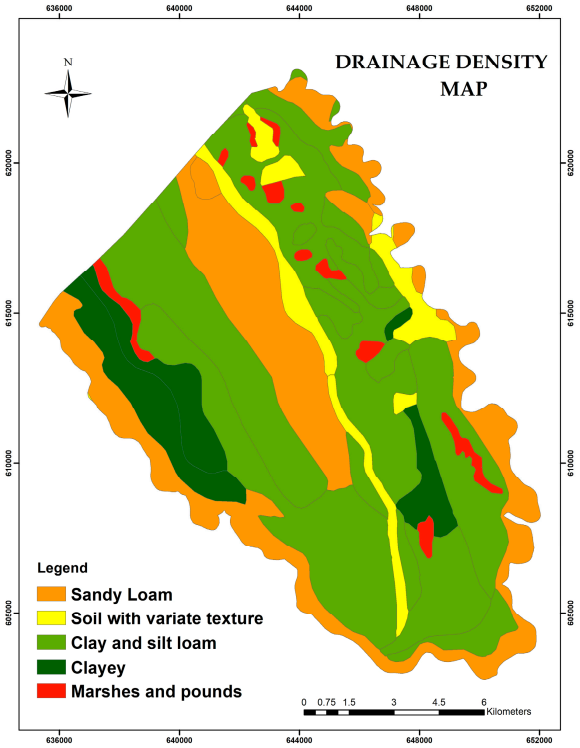


Figure 8. Soil map.

3.8. Ground Water Potential Zones and Validation

Ground Water Potential Zones

The result of the groundwater potential map in the study area indicated four distinct zones, representing areas with Very Good, Good, Moderate, and Poor groundwater potential, as shown in Figure 9 and Table 6.

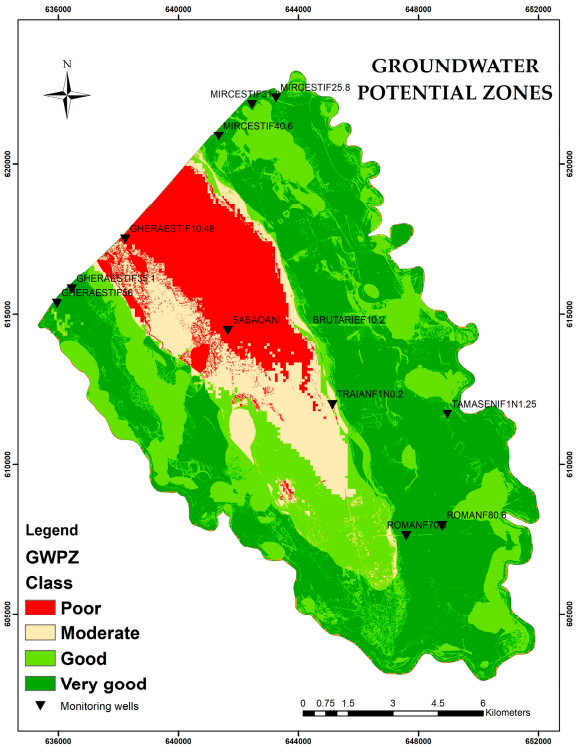


Figure 9. Groundwater potential map of the study area.

Table 6. Groundwater potential zones area.

Class	Area (sq. km.)	Area (%)
Poor	23.17	12.8
Moderate	19.54	10.8
Good	56.36	31.2
Very Good	81.53	45.1

Regions with Very Good and Good groundwater potential are generally located in low-altitude areas, such as along rivers, and on their terraces, and in regions with low slopes. Precipitation is a significant factor in the classification of these areas, but the values are relatively close between classes due to the relatively small size of the study area. Geology plays a crucial role, with areas characterized by lithology with high permeability and water storage capacity, such as sandy deposits, sand, or recent alluvial deposits primarily on terraces and riverbeds, indicating a higher potential for groundwater resources.

The accuracy assessment of the forecasting model is crucial to avoid errors and enhance the decision-making process in environmental studies. The potential zones derived from the integration of various techniques, including Remote Sensing (RS), Geographic Information Systems (GISs), and Multi-Criteria Decision Analysis (MCDA), were cross-validated with data from eleven boreholes in the study area. The spatial distribution of the 11 boreholes can be classified as plausible, considering that they are spread across the entire area, in zones with different geology, exposed soils with various characteristics, and in areas with significant elevation differences. The comparison between the predicted and actual yield data from the pumping test, as outlined in Table 7, highlights the accuracy of the prediction, standing at 72.7%. This validation confirms the reliability and precision of the methodology utilized in this study.

The accuracy verification of the predicted values is determined as follows:

Total number of boreholes = 11.

Number of boreholes with matching values between actual and expected yield = 8.

Number of boreholes with differing values between actual and expected yield = 3.

Prediction accuracy = $(8/1) \times 100 = 72.7\%$.

Table 7. Validation of groundwater potential zones area.

S. No.	Borehole	Longitude	Latitude	Top Aquifer	Aquifer Bed	Yield from Drilled Borehole (L/s)	Actual Yield Description	Expected Yield Class from the Prediction Map	Agreement Between Expected and Actual Yields
1	Roman F7	647,590.50	607,626.57	4.30	6.30	1.71	Good	Good–Very Good	Agree
2	Roman F8	648,789.46	607,947.26	3.60	6.30	0.60	Moderate	Good–Very Good	Disagree
3	Tamaseni F1N	648,965.90	611,672.02	5.30	8.90	1.25	Good	Good–Very Good	Agree
4	Traian F1N	645,126.58	611,998.20	23.40	27.80	0.20	Poor	Poor–Moderate	Disagree
5	Gheraesti F5	635,949.01	615,347.45	1.40	6.50	6.00	Very Good	Very Good	Agree
6	Gheraesti F3	636,440.61	615,816.37	4.00	7.90	5.10	Very Good	Very Good	Agree
7	Gheraesti F1	638,219.22	617,495.75	9.80	14.80	0.48	Poor	Poor	Agree
8	Mircesti F4	641,338.54	620,925.06	11.20	12.80	0.60	Moderate	Good–Very Good	Disagree
9	Mircesti F3	642,450.36	621,983.51	5.70	7.50	1.30	Good	Good–Very Good	Agree
10	Mircesti F2	643,245.01	622,203.72	6.50	9.80	5.80	Very Good	Good–Very Good	Agree
11	Sabaoani B1	641,640.80	614,460.89	21.80	22.60	0.20	Poor	Poor	Agree

4. Conclusions

The present study aims to delineate groundwater potential zones in the eastern part of Neamț county, where groundwater plays a crucial role, particularly for domestic use. Additionally, groundwater is utilized in the industrial sector, with the city of Roman being a focal point due to its significant economic and industrial development. The study area is predominantly characterized by agricultural land, accounting for 60.2% of the total region, with a concentration in the central part. This sector relies on both river and groundwater, making efficient water management essential. The groundwater potential map classifies areas into Very Good (45.1%), Good (31.2%), Moderate (10.8%), and Poor (12.8%) potential zones. The demarcation of these zones is notably influenced by factors such as precipitation, geology, and elevation. The validation of this model was conducted using observation boreholes, resulting in an accuracy assessment of 72.7%.

The obtained result is comparable with similar studies in the literature that used the same techniques. For example, a study conducted in the Ambo area of the Blue Nile Basin in Ethiopia achieved an accuracy of 69.5% [23], and another study on landslides in the Upper Wabe–Shebele River Basin of Southeastern Ethiopia reported a higher accuracy of 81% [24].

Even though the hydrogeological conditions, climate, hydrology, and geographical location differ, by applying the same techniques, which take into account the weight of various factors, it is observed that the obtained results show good accuracy. This strengthens the case for using these techniques in the delineation of groundwater potential zones.

Identifying areas with groundwater potential is critical for the economic development of the region. This research represents an important step in making decisions regarding the selection of sites for water consumers, as well as in the sustainable use of resources. Additionally, it is essential for regional development planning to understand how to manage resources and reduce the risks associated with their depletion.

Therefore, it can be concluded that these results are valuable for planning new projects and expanding existing ones that involve groundwater utilization in the study area, making significant contributions to the sustainable planning and development of water resources in the region.

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