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Identification and mapping of potential recharge in the Middle Seybouse sub-catchment of the Guelma region (North East of Algeria): contribution of remote sensing, multi-criteria analysis, ROC-Curve and GIS

Identificazione e mappatura delle aree di ricarica potenziale nel sottobacino del Wadi Seybouse centrale (regione di Guelma, Nord Est Algeria): il contributo di dati satellitari, analisi multicriterio, curve ROC e GIS

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Parole chiave: bacino di Seybouse, infiltrazione delle acque sotterranee, analisi spaziale, modellazione.

Riassunto

A seguito del rapido aumento della popolazione, delle pratiche agricole intensive, e dello sviluppo industriale nel sotto-bacino del Wadi Seybouse centrale nel nord-est dell'Algeria, le risorse idriche sono soggette a stress significativi non consistenti con un loro sfruttamento sostenibile, sia in termini di qualità sia di quantità. L'obiettivo di questo studio è identificare le aree più favorevoli per la ricarica delle acque sotterranee nel sotto-bacino del Wadi Seybouse centrale, circa 770.91 km² di estensione, utilizzando dati satellitari e sistemi informativi geografici (GIS). Sono stati identificati sei fattori che influenzano positivamente la ricarica delle acque sotterranee: precipitazioni, copertura del suolo, topografia, densità di drenaggio superficiale, densità dei lineamenti tettonici, e litologia. In funzione del grado di interazione nel processo di ricarica, questi parametri sono stati riclassificati e valutati mediante l'analisi multi-criterio nota come "*Analytical Hierarchy Process*" (AHP).
La risultante carta di ricarica potenziale delle acque sotterranee dell'area di studio mostra che il 60% di quest'area, nelle zone meridionali e centrali del bacino, presenta un grado di ricarica alto e molto alto. La curva ROC (*Receiver Operating Characteristic*) è stata usata per validare la risultante carta di ricarica potenziale utilizzando i pozzi esistenti nell'area di studio.

Abstract

Due to the rapid population increase in the Middle Seybouse sub-catchment area in North-East Algeria, the intense agricultural practices, and the industrial development, precious water resources proven to be significantly challenged in their sustainable exploitation both in terms of quantity and quality. The aim of this study is to identify the most suitable areas for groundwater recharge in the Middle Seybouse sub-catchment, over about 770.91 km², using remote sensing data and Geographical Information Systems (GIS).
Six factors are recognized to positively affect groundwater recharge: rainfall, land cover, topography, drainage density, lineament density, and lithology. According to their level of involvement in the recharge process, these parameters have been reclassified and then evaluated using the multi-criteria analysis known as "Analytical Hierarchy Process" (AHP).
A potential recharge map of the study area was produced showing that 60% of this area, located in the southern and central parts of the catchment, has a high to very high potential. ROC (receiver operating characteristic) curve is used to validate the resulting groundwater potential recharge map using the existing wells in the study area.

Introduction

The three essential hydrological processes of recharge, runoff, and discharge must be understood and evaluated in order to manage water resources in a sustainable way (Cook et al., 2006; Gleeson, 2009). The capacity to identify the aquifer regions that are susceptible to contamination, as well as their potential for exploitation, and to evaluate the sustainability of the aquifer resource depends on having a thorough understanding of recharge process (Scanlon et al., 2002). Since groundwater flow and discharge are so closely tied to this parameter, recharge is the most important stage in all three processes (Sanford, 2002; Cook et al., 2006). In the literature, there are numerous techniques for calculating recharge, such as hydraulics, isotopes, thermal, and numerical analysis (Healy & Cook, 2002). The topographic depressions are where quick recharging is found. These areas have strong fluxes that significantly outweigh the flux estimated from the yearly water budget (Hayashi et al., 2003). Due to the presence of preferred flow networks in the formation and the ignorance of vertical linkages between fractures, the investigation of recharge zones in fractured settings is exceedingly difficult (Gleeson, 2009). Because of the limited examined area, these favored zones of recharge cannot be detected using experimental approaches (Rodhe & Bockgard, 2006; Praamsma et al., 2009). In fact, only at a regional scale or at a sizable watershed the spatial heterogeneity of recharge can be recognized. The study methods are mostly dependent on spatial tools at this scale, including remote sensing data and GIS (Shaban et al., 2006; Chabane et al., 2019; Lentini et al., 2022). The techniques are centered primarily on the description, categorization, and integration of the key factors influencing elements on recharge, including land use and soil type, geology, fractures, slopes, and hydrographic network. The application of contemporary remote sensing data and Geographic Information System (GIS) techniques has attracted a lot of interest recently because the identification of the most likely locations for water conservation structures requires a large volume of multidisciplinary inputs from various sources (Ramaswamy & Anbazhagan, 1997). Moreover, remote sensing and GIS are cost-effective methods to evaluate spatial data in various geoscience fields (Arulbalaji et al., 2019). The National Remote Sensing Agency (NRSA), Hyderabad's IMSD recommendations are used in this study to help choose the water collecting structure (Naseef and Thomas 2016).

Reviews of the literature indicate that several index methods have been applied to assess groundwater potentials (Rahmati et al., 2015). Several methods have been applied to assess water potentials (Pourghasemi & Beheshtirad 2015; Mogaji et al., 2016), weight of evidence (Tahmassebipoor et al., 2016), Fishers Linear Discriminant Function (Wilson et al., 2018; Chen et al. 2019), logistic regression (Rizeei et al., 2018).

Other methods such as artificial neural network, fuzzy logic, forest, certainty and frequency models (Nayak et al., 2006;Naghibi et al., 2017), also certainty factor models and frequency ratio methods (Hou et al., 2018; Das & Pardeshi 2018), are used to assess groundwater availability

Saaty's (1980) efficient and widely known analytical hierarchy process (AHP) is used in hydrogeology (Kaliraj et al. 2014 ; Razandi et al. 2015; Mandal et al. 2016; Jenifer & Jha 2017; Pinto et al., 2017; Patra et al., 2018; Kordestani et al., 2019; Pande et al., 2019; Das 2019; Swagata et al., 2020).

The objective of this study is to present an appropriate methodology to evaluate water exploitation potential zones and choosing appropriate locations for water exploitation structures based on the importance of watershed characteristics using remote sensing data, GIS, and analytical hierarchy process (AHP) techniques in the Middle Seybouse sub-catchment of the Guelma region (North East of Algeria).

Geographical and hydrogeological settings

The study area is located in northeastern Algeria, in the watershed of the wadi Seybouse, surrounded by the mountains of Houara, Mahouna and Nador (Latifi & Chaab 2017). It is part of the Alpine chain of eastern Algeria (Laraba & Hadj Zobir, 2009). This mountainous chain is constituted by the superposition of several structural units, whose geological history extends from the Triassic to the Pliocene.

The Seybouse catchment extends for about 6745 km² over a length of 240 km, it is divided into three sub-catchment areas (the Upper Seybouse, the Middle Seybouse, and the Lower Seybouse), by the Agency of Basins Hydrographic (ABH, 2005) and it also crosses almost 86 municipalities in seven departments in the north-east part of the country (Fig. 1).

The middle Seybouse sub-catchment is coded 14-04 according to the classification of the National Water Resources Agency (NWRA) (Fig. 1), and it is also known as the Guelma sub-catchment area. It extends over the entire perimeter of the department of Guelma, for about 770.91 km², and it is drained by the Seybouse River and its tributaries (Shkoun, El Maiz, Zimba, Boussora, and Helia).

Four major aquifer systems are present in the study area (Fig. 2): 1) the "Alluvial aquifer of Guelma", which is located in the middle of the catchment region and is constituted of quaternary alluvium with high permeability; 2) the "aquifer of neritic limestones and marlstones", which is located in the region of Heliopolis and Guelaat Bousbaa; 3) the "aquifer of carbonate formations", which is located in Bouhachana, Ani Larbi and Khezarra regions and it may receive water from the Seybouse River; 4) the "Bouchegouf depression", located at the outlet of the watershed, collecting water from the Seybouse River. According to Brahmia (2019) and Benmarce (2015), these aquifers are the main source of groundwater in the Middle Seybouse sub-catchment.

The available rainfall data were collected from the National Water Resource Agency (NWRA), at Belkheir rainfall station (23 km far away from Guelma) and covering a period of 30 years (1990-2020). The study area has a semi-arid climate, the annual average rainfall is about 600 mm and the annual average temperature is 24°C. Using the Thornthwaite formula, the actual evapotranspiration is close to 490 mm, runoff and infiltration account for 10% and 8% of the total rainfall, respectively (Aissaoui et al. 2018). A rainy and cold winter season runs from late September to early May, and a dry and hot summer season from April to October.

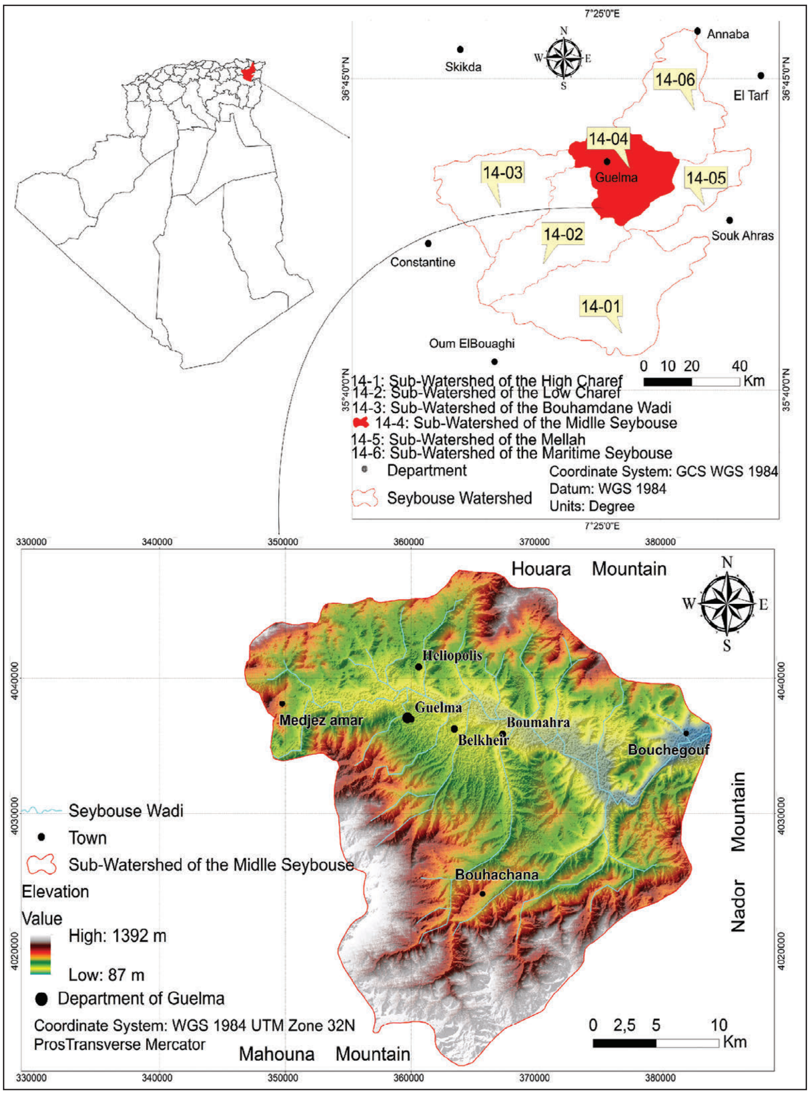

Fig. 1 - Location of the study area.

Fig. 1 - Ubicazione dell'area di studio.

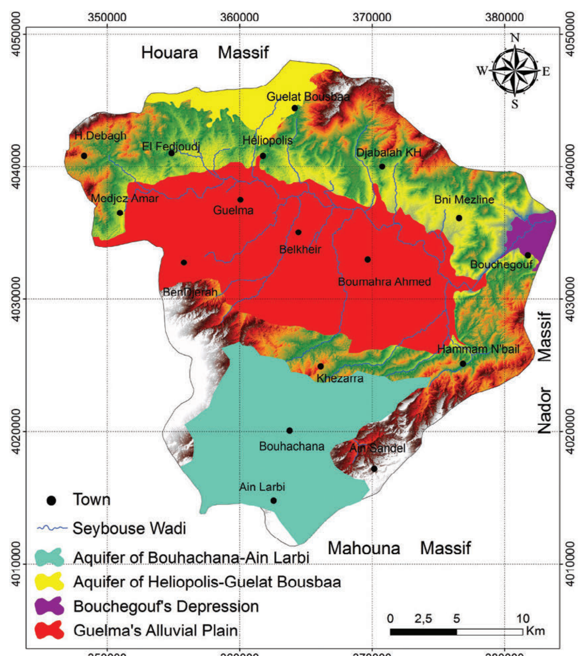

Fig. 2 - Aquifer systems of the study area.

Fig. 2 - Principali sistemi acquiferi nell'area di studio.

Material and Methods

For the purpose of mapping groundwater recharge areas, the methodology consisted in three steps (Fig. 3): 1- Acquiring spatial information related to the various factors that govern the potential recharge of the Middle Seybouse sub-catchment; 2- Using Analytic Hierarchy Process (AHP) method; 3- Model validation and mapping of the potential groundwater recharge.

Data Acquisition

The cartographic documents used in this study were the Guelma geological map with a scale of 1:50,000 and the lithological map of the Middle Seybouse sub-catchment. The satellite data were derived from:

- Shuttle Radar Terrain Mission (SRTM) imagery for the Space Shuttle Endeavor (STS-99) from November 1, 2020, to December 11, 2020, obtained from the Earth Explorer website (USGS, 2017). As a result, the processing of this image produced a digital elevation model (DEM) at 30 m resolution, a slope map, a channel network map, and a drainage density map.
- LANDSAT OLI 8 image of Scene 193-035, acquired on November 1, 2020, which allowed obtaining a land cover map and a lineament density map. Data processing was performed using ENVI 5.1 (Satellite Image Processing) and GIS software.

Analytic Hierarchy Process

Analytic Hierarchy Process method (AHP) represents an accurate approach to quantify the weights of decision criteria. Individual experts' experiences are utilized to estimate the relative magnitudes of factors through pair-wise comparison. Each of the six parameters, such as land use, rainfall, slope, lithology, lineament density and drainage density, compares the relative importance of each pair of items using the AHP matrix.

All parametric maps were produced in grid format with a resolution of 30 × 30 m at a scale of 1/500,000. The parametric maps were combined to create the composite map representing groundwater potential recharge areas. The map overlay computation in GIS environment uses Roy Integration Operational methodology (Garouni et al., 2006), which principle consists in adding the different layers according to their importance. The probability that the groundwater recharge inside a zone is high will therefore be related to the values of the classes of the overlaid parameters according to Equation 1. Thus, the recharge index (RI) is calculated as follows:

$$RI=(LU)w(LU)r+(Dd)w(Dd)r+(Ld)w(Ld)r+(R)w(R)r+(T)w(T)r+(L)w(L)r \quad \text{(Eq. 1)}$$

Where RI is the recharge index, w is the factor weight, and r is the factor rate (i.e., coefficient of correlation); *LU*: land use, *Dd*: drainage density, *Ld*: Lineament density; *R*: Rainfall; *T*: topography; *L*: lithology.

Model validation

The final map of potential groundwater recharge in the study area was first validated considering discharge flow data from 164 water points (boreholes, wells, and springs) collected from the Hydraulic Direction of the Guelma Department (HDW, 2022). From the total number of water points, 90 of them represent the saturated water point ("well yield") and show a flow rate varying from 5 L/s to 150 L/s; the remaining water points ("no yield") represent sites without water. These water points have been plotted on the final map. The second method of validation of the map of potential groundwater recharge areas was processed in SPSS V26 environment by calculating the ROC (receiver operating characteristic) curve. Also known as the sensitivity/specificity curve, ROC was fully developed to assess the accuracy of the result map of the study area (Pradhan 2010; Conforti et al., 2011; Pourghasemi et al., 2012; Rahmati et al., 2014; Saha et al. 2019; Razavi-Termeha et al., 2020).

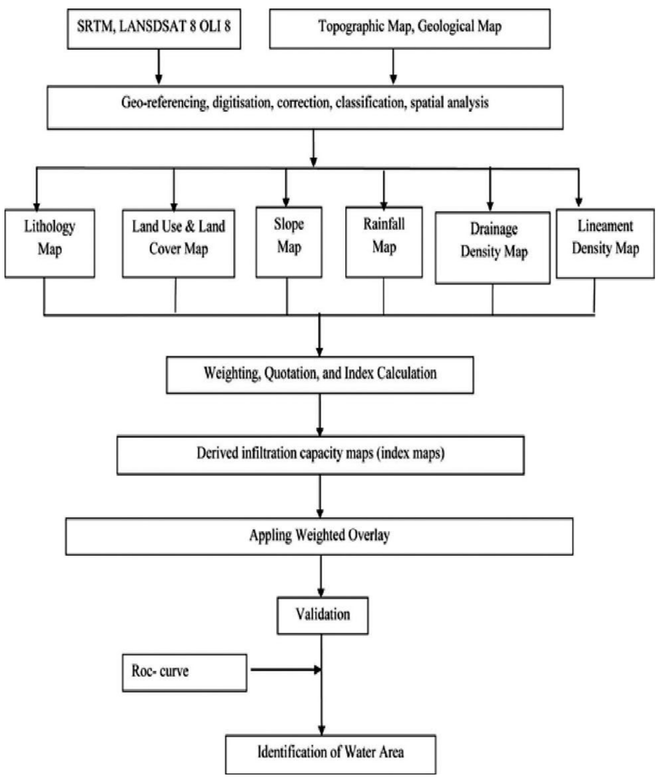

Fig. 3 - Flow Chart for the Methodology.

Fig. 3 - Descrizione schematica della procedura seguita.

The main factors governing the potential recharge of aquifers

Estimating potential recharge has aroused the interest of many researchers, as Oularé et al. (2014), Saley (2003), Koudou et al. (2013), Ake et al. (2018), Maizi et al. (2020). Their study helped determine the factors driving potential groundwater recharge at the regional scale: lithology, land cover, precipitation, slope, drainage density, and lineament density.

In details:

- Lithology provides an important index for evaluating hydrogeological aspects of rocks (Maizi et al., 2020). The water flow path from the ground surface to the subsoil to groundwater is derived from the permeability of the material (i.e., compaction and sorption of particles, type of cement between particles). Therefore, knowledge of the lithology is essential to know the permeability of the rock. (Kouadio et al., 2008).
- Lineaments. Rock fractures increase permeability and secondary porosity, and correspondingly increase vertical water flow. For this reason, rock fractures (i.e., faults) were considered a critical factor and included in identifying areas of potential recharge (Nouayti et al., 2017).
- Drainage density allows to draw essential conclusions about water runoff and infiltration. Higher replenishment rates can be attributed to denser drainage systems.
- Land cover refers to a number of features present on the soil surface that affect groundwater recharge. From a hydrogeological point of view, the most important aspects are vegetation cover and impervious layers (Boukheir et al., 2008).
- Topography plays a significant role in increasing surface water velocity, which subsequently reduces vertical infiltration and thus impacts recharge processes (Nouayti et al., 2017). The greater the slope, the greater the velocity of flow of surface water, and groundwater is less likely to accumulate.
- Rainfall. The most important element in determining how much water infiltration contributes to recharging groundwater is precipitation. Moreover, temperature, humidity, and air mass movement are only a few of the factors that affect precipitation type and intensity. Precipitation also varies both temporally and geographically.

Results

The parameters' maps

Lithology

The spatial distribution of the different lithologies (Fig. 4) was extracted from the available geological maps by digitalization of the geological map of Algeria, scale 1/500.000, published by Agency of the Geological Service of Algeria in 1951. The Guelma watershed is showed in Figure 4 as being made up of quaternary sediments that have formed a number of terraces filled with alluvium and is divided by the Seybouse River, which creates three terraces (high, medium, and low). The area around Heliopolis is bounded by sandstone to the west and north, an impermeable marl layer to the north, the Bouchegouf depression is located to the east of the Guelma watershed, an impervious marl layer, and Triassic gypsum layers bound the watershed to the south. The highly broken Ypresian limestone deposit is discernible, delimited by strata to the south of the watershed, and secondarily by sandstone. Its characteristics facilitate reservoir formation (Guelma Hydraulic Direction; NWRA, 2009, modified by Aissaoui 2022)

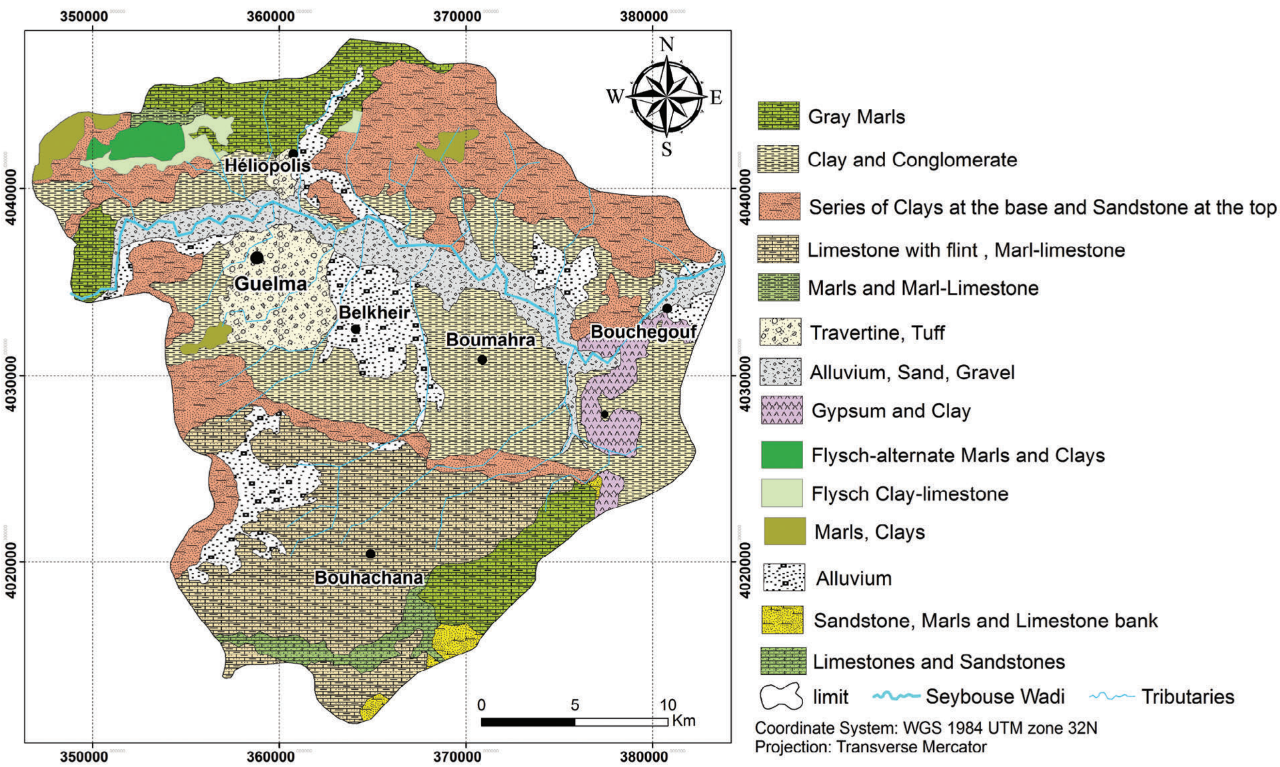

Fig. 4 - Lithology Map.

Fig. 4 - Carta litologica.

In light of this geological and lithological character, the Middle Seybouse Catchment exhibits a wide variety of hydrogeological zones. The south is therefore dominated by limestone formations, which favor infiltration and supply to the water table. However, there is a layer with low permeability on the left bank of Sea Booth. As a result, in the study, the lithological formations are classified into two classes: permeable and impermeable layers.

Lineaments

Lineaments, such as fractures, faults, shears, etc., truly indicate the terrain's weak points. Due to low soil porosity in hard strata, groundwater potential typically depends on other structural factors (Das & Pardeshi, 2018). Because they increase the amount of infiltration water, lineaments are crucial to the groundwater potential held in reservoirs. High densities indicate areas with good groundwater potential. A lineament density map with a grid size of 1.66 km x 1.66 km was produced using Landsat 8 satellite images. Thus, five main lineament density groups were selected: very low (0.21 km/km^2), low (0.21–0.33 km/km^2), medium (0.33–44 km/km^2), and high (0.44–57 km/km^2), and very high (0.57–0.78 km/km^2).

Rainfall

The analysis of the rainfall amount ranges reveals four classes: a low rainfall class (500-600 mm/year), with low rainfall, which covers the cities of Medjez Amar, Guelma, Boumahra, Hammam N'bails, and Bouchegouf; moderate rainfall amount (600-800 mm/year); shown in the Northern and Southern sides of the catchment a high rainfall class (between 800 and 1200 mm/year), found on the northern and southern sides of the Mahouna and Houara mountains.

Drainage

The catchment's geological and geographical characteristics determine the drainage density (Shaban, 2003). The Middle Seybouse sub-catchment drainage density map was created by directly extracting data from SRTM satellite imagery. As a result, five tributary density classes were established. The Seybouse River flows west to east (Hamam Debagh to Bouchegouf), with the highest storage capacity in the aquifer found around inflow crossings, which become smaller the further they are from the stream.

Land cover

LANDSAT OLI 8 image of Scene 193-035, acquired on November 1, 2020, was supervised and classified to produce the land cover map for the research area. More specifically, visual examination of different remote sensing indices (Normalized Difference Vegetative Index (NDVI), Building Index (BI), and Normalized difference water index (NDWI) and color composition were the first steps in the classification process (principal component analysis, or PCA). Then, color schemes were used in the spectral signatures to distinguish between the four types of land cover: dense forest, barren land, agricultural, and urban areas.

Topography (Slope)

The Digital Elevation Model (DEM) of Guelma Department, which describes the ground surface in three dimensions, served as the basis for the slope map. DEMs were created using SRTM data at a resolution of 30 m. The slopes map displays five classifications (<5°, 5°-10°, 10°- 15°, 15°- 30°, and > 30°), indicating that slopes larger than 5° and less than 30° predominate in the study area.

Reclassification of the parameters

The six factors are mapped using data from many sources (i.e., remote sensing and existing maps) and are chosen among those showing a major effect and more reliable influence on the groundwater potential of an area. The relation between these six factors and their impact on delineating potential groundwater recharge zone is shown in the diagram in Figure 5. Depending on the strength of a parameter and its respective classes the relationship is weighted. A factor with a higher weight value has a greater impact, whereas one with a lower weight value has a smaller impact on possible groundwater potential recharge zone.

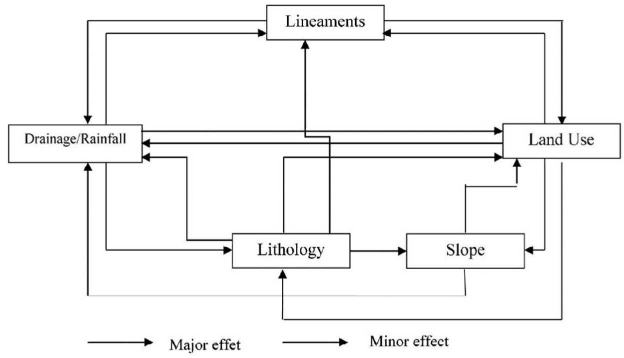

Fig. 5 - Diagram of interactions between factors (modified from Saaty, 1980).

Fig. 5 - Descrizione delle interazioni tra i fattori (modificato da Saaty, 1980).

The diagram in Figure 5 shows two types of relationships: a major relationship marked with a solid line, and a minor relationship marked with a dash:

- If the relationship is major between two factors, the first factor is assigned with a coefficient of correlation 1;
- If the relationship is minor, a coefficient of correlation equal to 0.5 is assigned.

The total coefficients assigned to each factor are as follows:

1. Lithology: Three major relationships and one minor relation (3 × 1 + 1 × 0.5), which gives a coefficient of 3.5;
2. Land Use: One major relationship (1 × 1) and three minor relationships (3 × 0.5), resulting in a coefficient equal to 2.5;
3. Lineament: Two major relations (2 × 1), which gives a coefficient equal to 2;
4. Slope: One major relationship (1 × 1) and one minor relationship (1 × 0.5), resulting in a coefficient equal to 1.5;
5. Drainage: One major relationship (1 × 1) and two minor relations (2 × 0.5), which gives a coefficient of 2;
6. Rainfall: One major relationship (1 × 1) and two minor relations (2 × 0.5), which gives a coefficient of 2.

A weight, which ranges from 1 to 10, is given to each unit or class based on how the hydrogeological interpretation or infiltration capacity of the various cartographic units (Fig. 6). Then, a coefficient is assigned to each class in accordance with its relative relevance to other factors. In fact, some parameters have a greater impact on recharging than others (Fig. 5). Thus, the coefficients assigned to each unit or class of each factor are tabulated in Table 1.

The parameters selected according to their importance (i.e., influence percentage in Table 1) to groundwater recharge in the Middle Seybouse sub-catchment are classified as follows:

$$LU>Ld=Dd>R>T>L \qquad \text{Eq.2}$$

(LU: land use, Dd: drainage density, Ld: Lineament density; R: Rainfall; T: topography; L: lithology).

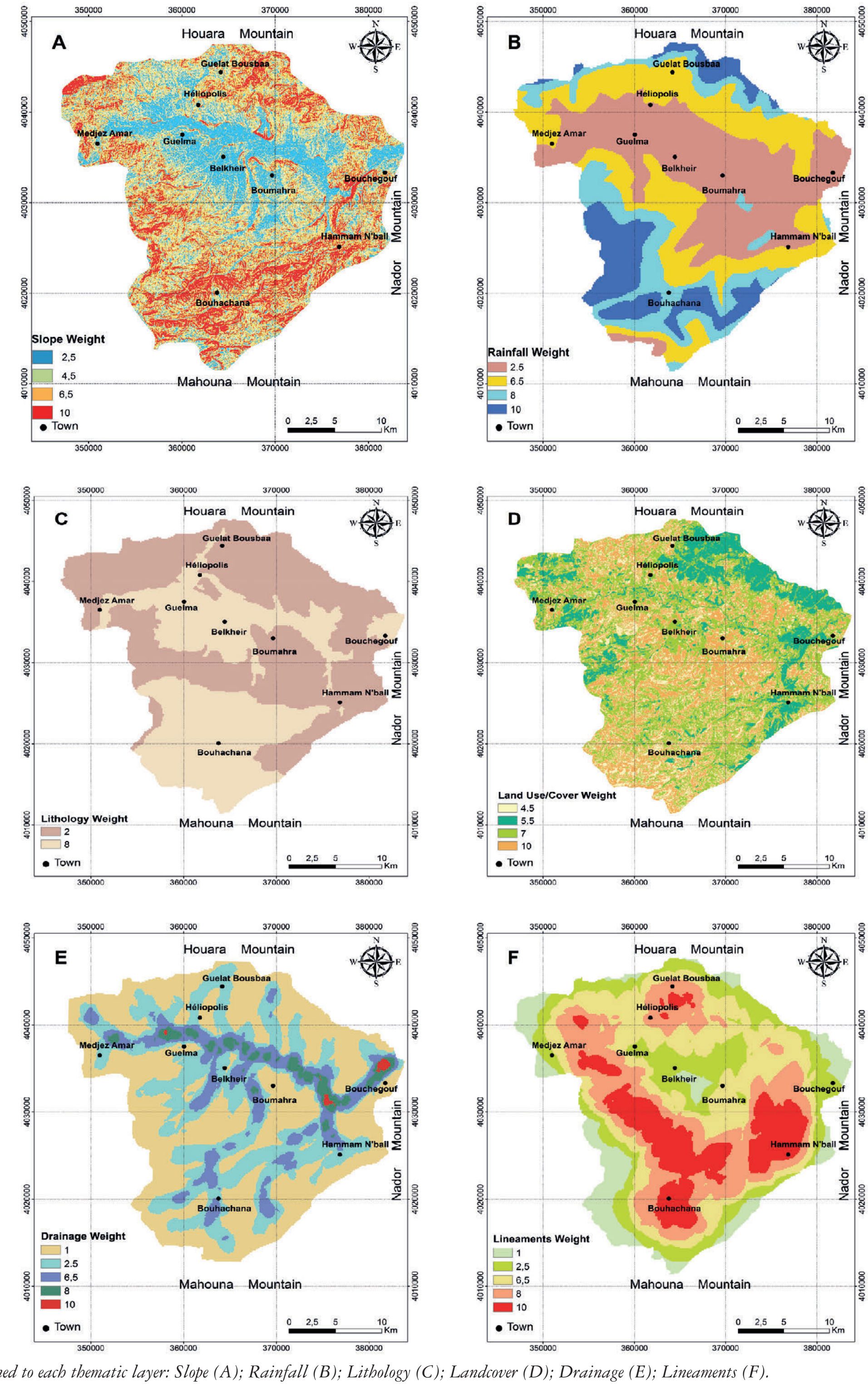

Fig. 6 - Weight assigned to each thematic layer: Slope (A); Rainfall (B); Lithology (C); Landcover (D); Drainage (E); Lineaments (F).

Fig. 6 - Pesi assegnati a ciascun fattore: pendenza (A); precipitazioni (B); litologia (C); copertura del suolo (D); drenaggio superficiale (E); lineamenti tettonici (F).

Tab. 1 - Values for weight and rate for the selected factors.

Tab. 1 - Pesi e punteggi assegnati ai fattori selezionati.

actors	Subclasses	Description Rank	Subclass weights	Coefficient of correlation	Total weight	Influence percentage
Slopes	<5%	Excellent	10	1.5	15	13%
	5-10%	Very good	6.5		9.75	
	10-15%	Good	4.5		6.75	
	15-30%	Moderate	2.5		3.75	
	>30%	Low	2.5		3.75	
Rainfall	800-1200	Excellent	10	2	20	17%
	700-800	Very good	8		16	
	600-700	Good	6.5		13	
	500-600	Moderate	2.5		5	
Land Cover / Land Use	Bare soil	High	10	2.5	25	22%
	Agriculture	Very good	7		17.5	
	Forest	Good	5.5		13.75	
	Buildings	Moderate	4.5		11.25	
Lineament Density	0.57-0.78	Excellent	10	2	20	18%
	0.45-0.57	Very good	8		16	
	0.33-0.45	Good	6.5		13	
	0.21-0.33	Moderate	2.5		5	
	0-0.21	Low	1		2	
Lithology	Permeable	Good	8	3.5	28	12%
	Impermeable	Low	2		7	
Drainage Density	5.59- 7.06	Excellent	10	2	20	18%
	4.19-5.59	Very good	8		16	
	2.79-4.19	Good	6.5		13	
	1.39-2.79	Moderate	2.5		5	
	0-1.39	Low	1		2	

Groundwater potential recharge map

The synthesis map was prepared by integrating all the factors' maps in raster format (Fig. 7). For that we used the Roy's operational approach via GIS software (as described in par. "Analytic Hierarchy Process"). The maps were overlaid after being weighted by AHP to get the recharge index (RI) as follows:

$$RI = 2.5\ (LU)w+2(Dd)w+2(Ld)w+2\ (R)w+1.5\ (T)w+3.5(L)w \quad \text{(Eq. 3)}$$

Where the values represent the weighting coefficient by AHP and *RI* represents the sum of the weighted scores calculated for each raster pixel of the six parameters' scores (Eq. 1).

The combined effects of land cover, lineaments, drainage, rainfall, slope, and lithology influences on potential groundwater recharge in four potential zones (Fig. 7): "very high", "high", "moderate" and "low".

Discussion

The map shown in Figure 7 was created by superimposing and integrating parameters affecting groundwater recharge in the study area. The result shows that 34% of the total watershed area (770.91 km²) belongs to the areas with the very high recharge potential degree, 26% of the catchment area has high recharge potential degree, 22% belongs to the moderate potential recharge degree, and 18% of the catchment area has low potential recharge degree.

Therefore, this distribution explains the potential groundwater richness of the central Seybouse sub-catchment. Nevertheless, the reliability of the results should be investigated and verified.

Validation of estimates of potential groundwater recharge areas in the Middle Seybouse sub-catchment was performed by comparison with the discharge flows of 164 water points (boreholes, wells, and sources), as shown in Figure 8.

In reality, the majority of the boreholes, wells, and sources in the high recharge area are found in the fractured carbonate layer in the Bouhachana area to the south of the Guelma region and in the Middle Seybouse sub-center watershed in the Guelma alluvial plain. This is due to the good permeability of the geological formations. Additionally, areas around Heliopolis and He Guelaat Bousbaa (Limestone Tables) to the north as well as the Bouchegouf depression to the east of the city of Guelma contain high recharge zones. Besides, places with low restoration potential can be found

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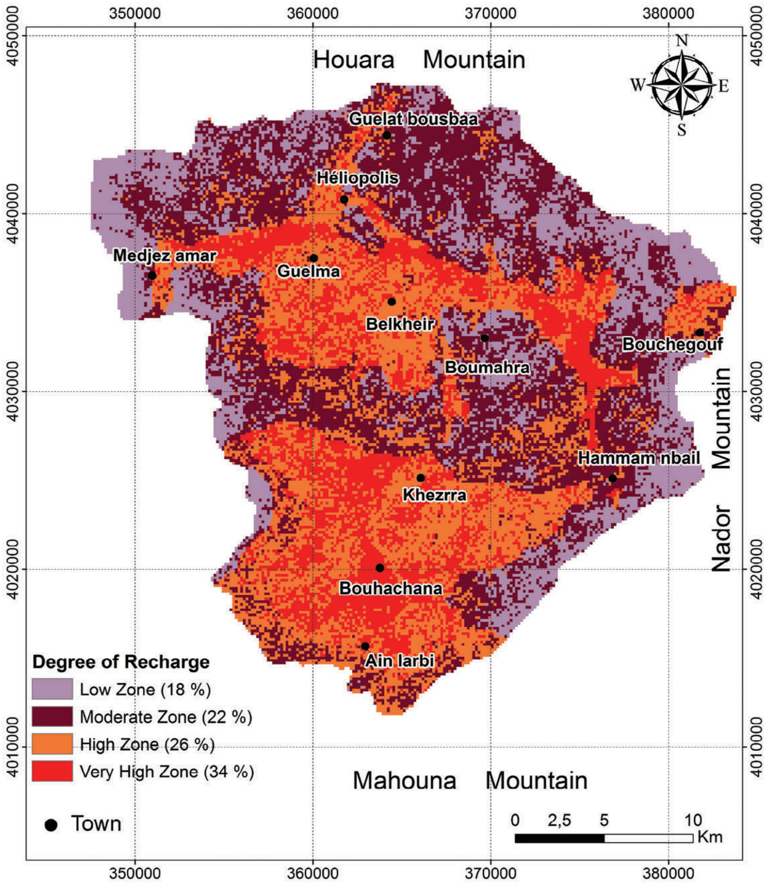

Fig. 7 - Potential recharging area.

Fig. 7 - Area di ricarica potenziale.

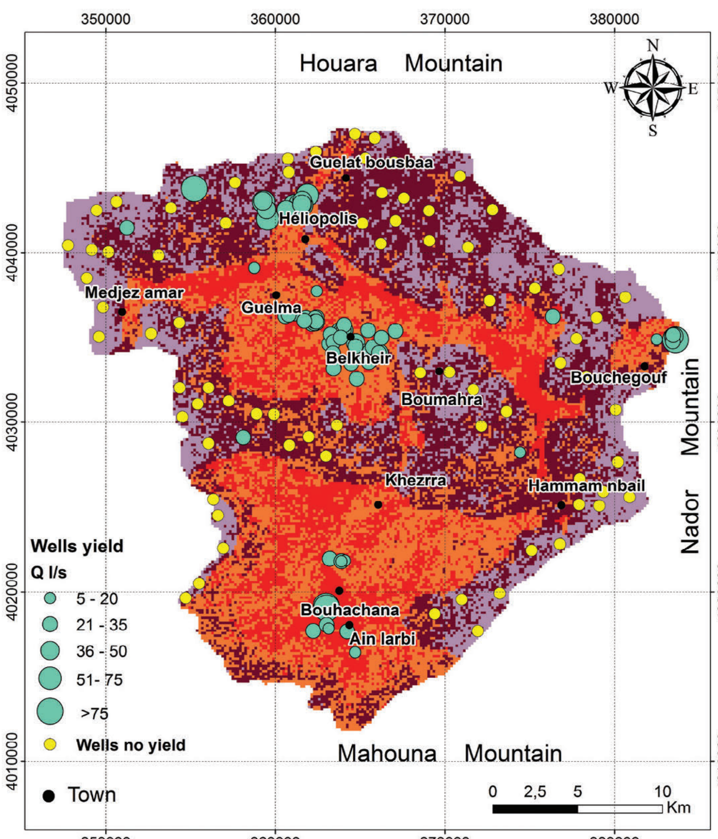

Fig. 8 - Validation Map.

Fig. 8 - Carta di validazione.

in urban areas with relatively low slopes and forest areas with hydrophobic soils. This can be due to the clayey properties of hydromorphic soils, which have high retention capacity and limited permeability, reducing infiltration despite low gradients as well as evapotranspiration under forest cover. Low gradients favor infiltration, according to Jourda et al. 2007. However, infiltration is shown to be primarily related to lithologic formation and vegetative cover.

To determine the accuracy of the synthetic map of the study area, a Receiver Operating Characteristics curve (ROC-AUC – Area under Curve) has been elaborated by tracing the True Positive Rate (TPR) compared to the False Positive Rate (FPR) at various threshold settings. More to the point, this aims to describe the proportion of all water yield points correctly classified as potential recharge areas, and the proportion of non-water yield points incorrectly classified as unsaturated areas (Rahmati, 2019; Arabameri et al., 2020).

The ROC curve generally shows a good result, as it is entirely above the diagonal line of reference; likewise, the ROC diagram is illustrated in Figure 9.

Additionally, we calculated the area under the curve (AUC), standard deviation, and confidence level of the model. An AUC equal to 0.9 was obtained, which indicates great accuracy (Tab. 2).

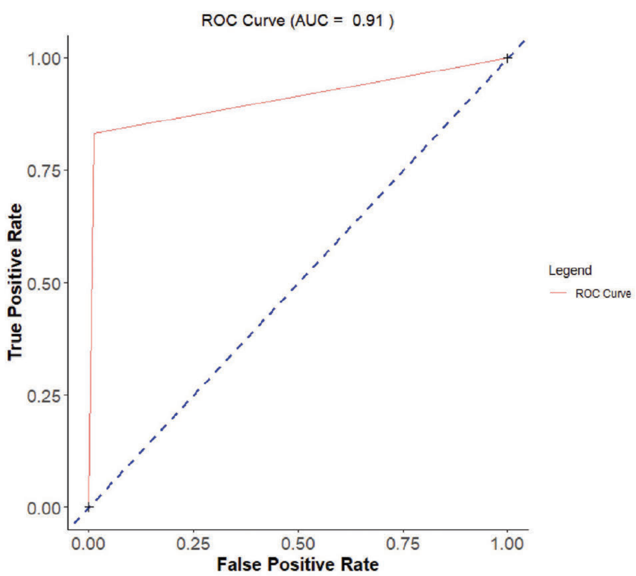

Fig. 9 - The ROC curve.

Fig. 9 - Validazione ROC.

Tab. 2 - ROC-curves.

Tab. 2 - Validazione ROC.

Test result variable	AUC	St-Error	Asymptotic	Lower bound	Upper bound
ROC-Curve	0.910	0.025	0.000	0.861	0.959

Conclusion

The problems linked to water supply in regions with an arid or semiarid climate increase as demand increases. This means that potential recharge is particularly important in all hydrogeological studies. Accurate identification plays a key role in the quality of answers to questions related to environmental issues, agriculture, tourism, industry, urbanism, etc. This study aimed to identify the potential recharging areas in Guelma erase watershed (Eastern Algeria).

The sedimentary rocks have regions with a high potential for groundwater recharging (alluvial plains). Additionally, locations with a lot of lineaments are thought to be prospective locations for groundwater recharge.

Data were used to validate the overlay analysis findings (wells and boreholes). Additionally, they note that the wells point data are highly correlated and that a weighted exponential superimposition analysis yields a groundwater recharge potential zone map.

The results of this study could have a significant impact on how governments and commercial organizations choose appropriate exploration and development sites for managing groundwater resources, planning for land cover, and protecting the environment in the studied area.

While this approach has certainly proven to be relevant for the investigation of potential groundwater recharge areas at particular locations, further investigations are needed to confirm its validity. Alternatively, the approach adopted in this study could be applied to the investigation, evaluation and capture of groundwater from geological formations with comparable hydrogeological, topographical and climatic conditions to satisfy water supply.

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Competing interest
The authors declare no competing interest.

Author contributions
AISSAOUI Marwa, MAIZI, Djamel: GIS elaborations. AISSAOUI Marwa, MAIZI, Djamel, BENHAMZA Moussa.: manuscript writing. Collaboration in process validation and manuscript editing. MAIZI Djamel, AZZOUZ Khalid. BELAROUI Abdelhakim, BENGUSMIA Djamel.: coordination of activities.
All authors read and approved the final manuscript.

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