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ORIGINAL PAPER

Remote sensing, and (GIS) approach, for morphometric assessment and sub-watershed prioritization according to soil erosion and groundwater potential in an endorheic semi-arid area of Algeria

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Abstract
The application of remote sensing (RS), and geographical information system (GIS), has emerged as one of the most useful methods for the assessment of drainage assessment and sub-watershed prioritization for soil erosion and groundwater potential of watersheds. The present study is focused on morphometric characterization and prioritization of Constantine's highland catchment, an endorheic semi-arid basin situated in the east of Algeria. It is subdivided into seven sub-catchments. Using digital elevation model (DEM) and Arc GIS tools showed that all of the sub-catchments except the Gareat El Tarf sub-watershed (07–07) had a good permeability, high infiltration, and high groundwater potential, as the geological structure controls the drainage. Yet, drainage density varies from 0.28 km/km^2 for sub-watershed of Chott Beida (07–01) to 0.41 km/km^2 for the Gareat El Tarf (07–07) sub-watershed. After prioritization of the sub-watershed for soils and groundwater potential, we conclude that a large part of the sub-catchments in the Constantine's highlands showed high erosive levels of soil and a low groundwater potential.

Keywords Constantine's highland catchment · Morphometry · Remote sensing · Sub-watershed · Geographic information system · Prioritization

Introduction

Soils are an ecological resource that is essential and non-renewable which provides vital products and functions for both ecosystems and human life. Soils are essential for agricultural production and filtration of polluted water (FAO 2017). The Mediterranean area has a reputation for being subject of exceptionally high erosive hazards. (Jose et al. 2012). Climate and landscape change under the influence of population pressure and the expansion of cash crops which have contributed to an increase in the exposure of land to the runoff process and consequently to soil degradation through erosion (Vezena and Bonn 2006). Also, water assets are negatively impacted by different anthropogenic activities, including a steadily expanding request and the defilement of both surface and groundwater assets.

In Algeria, three climatic zones with significant contrasts characterize the territory: the coastal area and the mountainous in the north, the Sahara in the south, and the arid desert zone (average rainfall below 100 mm/year). Between these two areas are the high plateaus. They cover about 8.4% of the total area of the country. It is dominated by a semi-arid climate (rainfall between 100 and 400 mm/year). These plateaus are characterized by the fragility of soils caused by wind and runoff erosion, the weakness of water resources, a mainly temporary, and endorheic hydrographic network (Mebarki 2005). In the areas defined as a semi-arid to arid environment, there is a continuous danger of drought, "even in humid areas where the average annual precipitation seems high" (Pérennès 1993). In these parts of the country, it is hard to give new water because of the restricted accessibility of water assets and the dry environment. Three climatic zones with significant contrasts characterize the territory:

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the coastal area and the mountainous in the north, the Sahara in the south, and an arid desert zone (average rainfall below 100 mm/year). In between these two areas are the high plateaus. They cover about 8.4% of the country's total surface area.

For integral watershed planning for better water and land management in the semi-arid region, it is essential to know the morphometry of the watersheds (Everard 2019). Numerical and mathematical investigations of the shape and the size of basins help to understand the structure and the pattern of the world's surface (Reddy et al. 2002). The founders of morphometric watershed analysis are Horton (1932), Miller (1953), Schumn (1956), and Strahler (1957, 1964). Watershed prioritization is the basic piece of sorting out the execution of its improvement and organization programs (Anurag et al. 2018). Lately, the use of remote detecting and GIS strategies in the morphometric examination of watersheds and their prioritization has been demonstrated to be strong methods. This study is carried out on the morphometric portrayal and the hierarchization of the semi-parched endorheic zone of Algeria. The study has two main objectives:

(i) To measure the morphometric parameters of this basin using the digital elevation model (DEM) and Arc GIS tools.

(ii) To prioritize sub-catchments according to soil erosion and groundwater potential, using the statistical ranking technique.

Materials and methods

Study area

The review area is situated in the northeast of Algeria. The Constantine's highland catchment is part of the Eastern High Steppe Plains located between the Tell Atlas in the north and the Saharan Atlas in the south. It lies between 35° 44′ and 36° 15′ North latitude, meridians 05° 57′, and 7° 80′ East longitude. According to the organisation of hydrological units in Algeria, the Constantine's highlands catchment area is part of the Constantine-Seybous-Mellague unit, and its total drainage area is about 9610 km^2, with an altitude ranging from 843 to 2326 m of altitude. Constantine's highland catchment is divided into seven sub-catchment areas: Chott Beida, Medja Zana, Sebkhet Ez Zemoul, Wadi Chemora, Garaet Ank Djamal, Wadi Boulfreis, and Gareat El Tarf (Fig. 1). It contained large saline continental depressions called chotts and sebkhas.

The basin is exposed to a semi-Mediterranean climate. The basin is exposed to a semi-arid climate, it's wet and cold in winter, hot and dry in summer. A climate with monthly temperature ranges between 10 and 35 °C. Rainfall in the basin increases from east to west, with a normal of 320 mm in the east and 500 mm in the west of the basin.

The watershed has a hydrographic network characteristic of semi-arid areas (endoreism), the wadis of the basin flow at the level of the chotts, they are mainly oued El Madher (54 km), oued Chemora (33 km) and oued Boulfreis (52 km). These Wadis have modest flows and are connected to the chotts where evaporation is intense (Mebarki 2010). Steppe soils are portrayed by the presence of limestone aggregation, low natural matter substance, and high aversion to disintegration and debasement (Nedjraoui and Bédrani 2008).

The vegetation is steppe-like, composed of low plants that do not cover the ground well and are adapted to drought: mugwort and esparto grass. The lower slopes of the Saharan Atlas are steppe-like or scrubby or have forests of holm oak and Aleppo pine.

The lithology of the area is dominated by alluvium (Fig. 2), which occupies the major part of the basin, and limestone on the edge (Abdeddaim 2018).

Extraction of the stream networks

To plot the limits of the watershed, we used a digital elevation model (DEM) given by the shuttle radar topography mission (SRTM) with 30-m square mesh resolution. The shape and straight boundaries are treated as two-layered properties of a catchment. In such a manner, they comprise the areal components of a watershed, and it is vital for quantitative morphometric examination of drainage basins. Moreover, mathematical formulas given by various sources are estimated for each sub-catchment separately (Table 1).

Extraction of the stream network is done by Arc GIS hydrological analysis tool. The first step filled sinks to ensure proper delineation of streams, the generation of flow direction and low accumulation as shown in Fig. 3, and finally extraction of the drainage network (Fig. 4).

Prioritization of sub-watershed

Sub-watershed prioritization is a quantitative approach based on multiple morphometric parameters. A statistical ranking of morphometric parameters (Pandey and Das 2016) does this ranking. This was gotten by adding the ranks of the different morphometric parameters and dividing them by the number of parameters used to organize the sub-catchments (Patel et al. 2012). Factual positioning of morphometric qualities is a simple and important tool for getting starting watershed-level priority. This was by adding the positions of the different morphometric boundaries and dividing them by the number of boundaries used to order the sub-catchments.

We have used this method in this research for two main purposes: the vulnerability of soil erosion and to identify groundwater potential.

To get the sub-watershed priority of soil erosion, various ranks were allocated to morphometric parameters. The

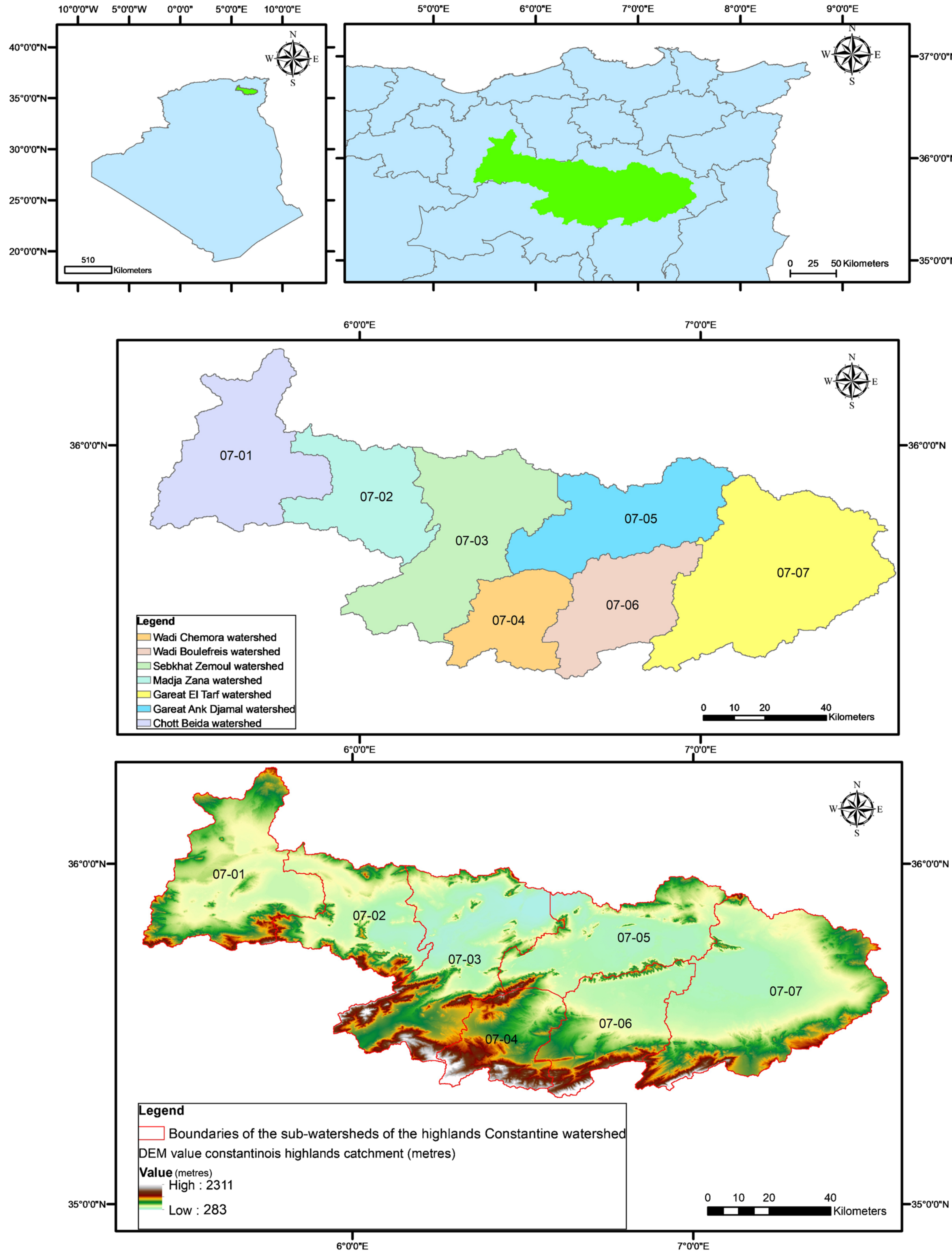

Fig. 1 Location and digital elevation map (DEM) of the Constantine's highland catchment

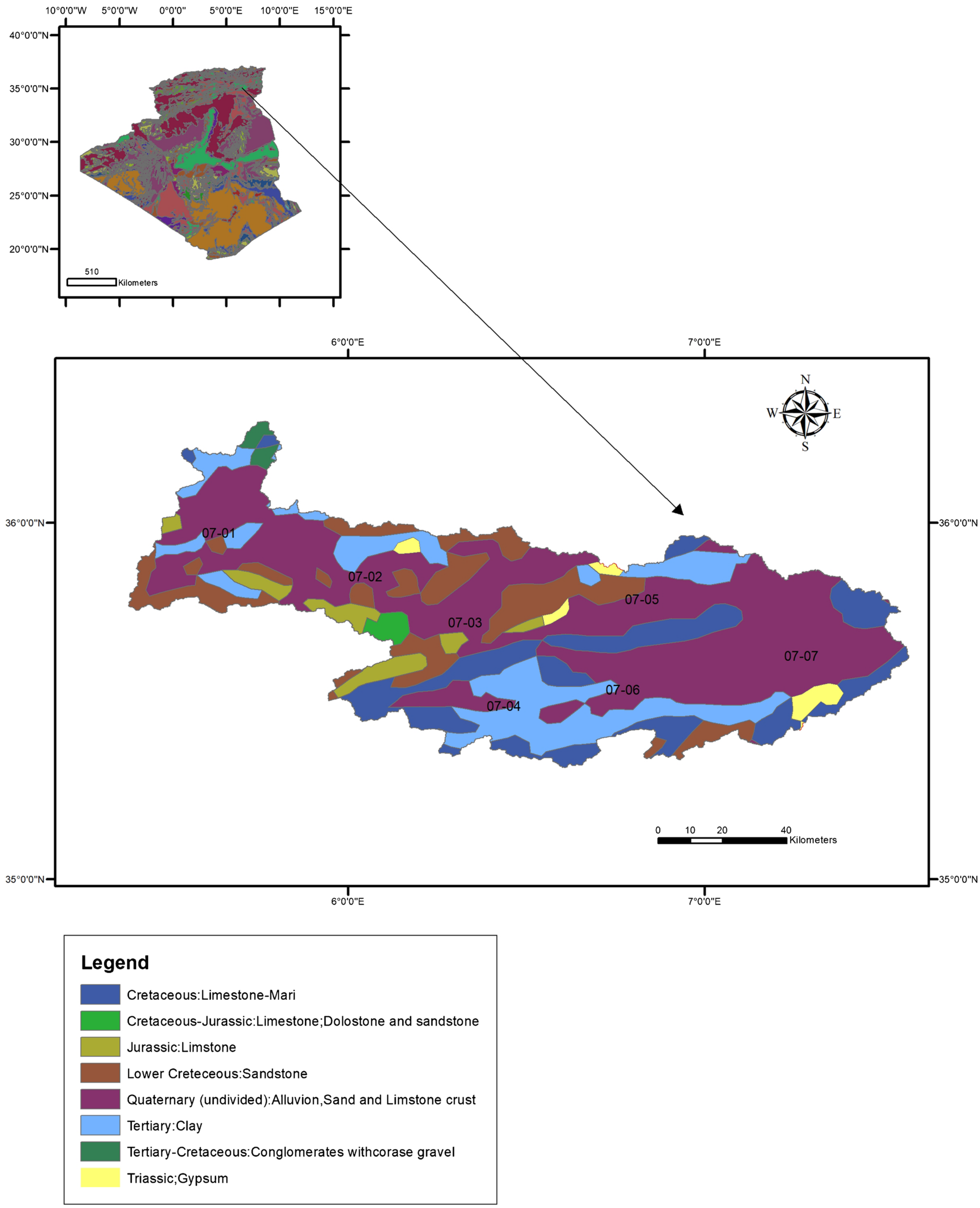

Fig. 2 Geological map shows geological formation along (British Geological Survey 2022)

Table 1 Main morphometric parameters for Constantine's highland catchment and their counting methods

Parameters		Counting	References
Primary parameters	Basin perimeter (P)	Total length of the outer boundary of the drainage basin (km)	GIS environment
	Basin area (A)	Area of the basin (km^2)	GIS environment
	Basin length (Lb)	$\mathrm{Lb} = 1.312 \times A^{0.568}$	Schumn (1956)
Linear aspect	Stream order (u)	Hierarchical rank	Strahler (1964)
	Stream length (L u)	$\mathrm{L}\,u = L1 + L2 + L3 + \ldots ..Ln$	Horton (1945)
	Stream number (N u)	$\mathrm{N}\,u = N1 + N2 + N3 + \ldots Nn$	Strahler (1952)
	Mean stream length (L_m)	$Lm = Lu/Nu$	Strahler (1964)
	Stream length ratio (R l)	$Rl = \frac{L_u}{L_{u-1}}$ where L_u is the complete length of stream of order u, and L_{u-1} is the complete stream length of its next lower request	Horton (1945)
	Bifurcation ratio (R_b)	$R_b = \frac{N_u}{N_{u+1}}$ where: N u is the number of stream segments of a given order N u + 1 is a number of segments of the following higher order	Schumn (1956)
Areal aspect	Circulatory ratio (R_c)	$\mathrm{Rc} = 4\pi.\mathrm{A}/P^2$ $\pi = 3.14$	Miller (1953)
	Length of overland flow (Lg)	Lg = 1/Dd.2 (km)	Horton (1945)
	Drainage density (Dd)	$Dd\frac{Lu}{A}$(km /km^2)	Horton (1932)
	Stream frequency (F_s)	$\mathrm{Fs} = \mathrm{N}u/\mathrm{A}(\mathrm{km}^{-2})$	Horton (1932)
	Drainage texture ratio (Rt)	t Rt = Nu/P (km^{-1})	Horton (1945)
	Form factor (F_f)	$\mathrm{Ff} = \mathrm{A}/L_b^2$	Horton (1932)
	Shape factor (Bs)	$\mathrm{Bs} = L_b^2/\mathrm{A}$	Horton (1932)
	Elongation ratio (R_e)	$Re = (1.128A^{0.5})/L_b$	Schumn (1956)
	Compactness coefficient (Cc)	$\mathrm{Cc} = 0.2821\mathrm{P}/A^{0.5}$	
	Infiltration number (If)	$\mathrm{If} = \mathrm{Dd} \times \mathrm{Fs}$	Zavoiance (1985)
Relief aspect	Maximum relief ($H_{\max}$)	The highest elevation at the source of the basin (m)	GIS environment
	Minimum relief ($H_{\min}$)	The lowest elevation at the mouth of the basin (m)	GIS environment
	Mean relief (H_m)	Statistical analysis (m)	GIS environment
	Relief (Rf)	$R = H_{\max} - H_{\min}$ (m)	Strahler (1952)
	Relative relief (R)	$R = \mathrm{Rf}/\ P$	Melton (1957)
	Relief ratio (R_h)	$R_h = \mathrm{Rf}/L_b$	Schumn (1956)
	Ruggedness number (R_n)	$R_n = D_d \times (\mathrm{Rf}/1000)$	Strahler (1964)
	Hypsometric integral (HI)	$\mathrm{HI} = (\mathrm{Hm} - H_{\min})/(H_{\max} - H_{\min})$	Strahler (1952)

basic strategy is that the sub-catchments are positioned by the morphometric boundary from one to seven, and then, this positioning processes the score of every catchment.

For soil disintegration weakness, morphometric parameters used are mean bifurcation ratio (Rbm), drainage density (Dd), length of overland flow (Lg), stream frequency (Fs), drainage texture ratio (Rt), form factor (Ff), stream frequency (Fs), elongation ratio (Re), compactness coefficient (Cc), and circulatory ratio (Rc). These parameters are known as disintegration risk appraisal, and they have been considered for focusing on sub-watersheds (Biswas et al. 1999). For Dd, Fs, Rt, Lg, Rbm, Fs, and Re, a high value indicates more erodibility. Therefore, a higher value of those parameters was assigned rank one; the next highest value is assigned rank two, until the highest rank is reached. While Ff, Cc, Rc, and Bs, have an inverse relationship with erodibility. A high value signifies less erodibility (Biswas et al. 1999). Therefore, for a lower value was given rank 1, the next lower value was given rank 2.

To obtain the ranking of sub-watershed priority for potential groundwater, the priority ranking was done based on morphological characteristics, which were assessed according to:

(i) Linear aspect including bifurcation ratio (Rbm), areal aspect including stream frequency (Fs), drainage density (Dd), texture ratio (Rt), mean length, Infiltration number (If), form factor (Ff), circularity ratio (Rc), shape factor (Bs), and elongation ratio (Re).

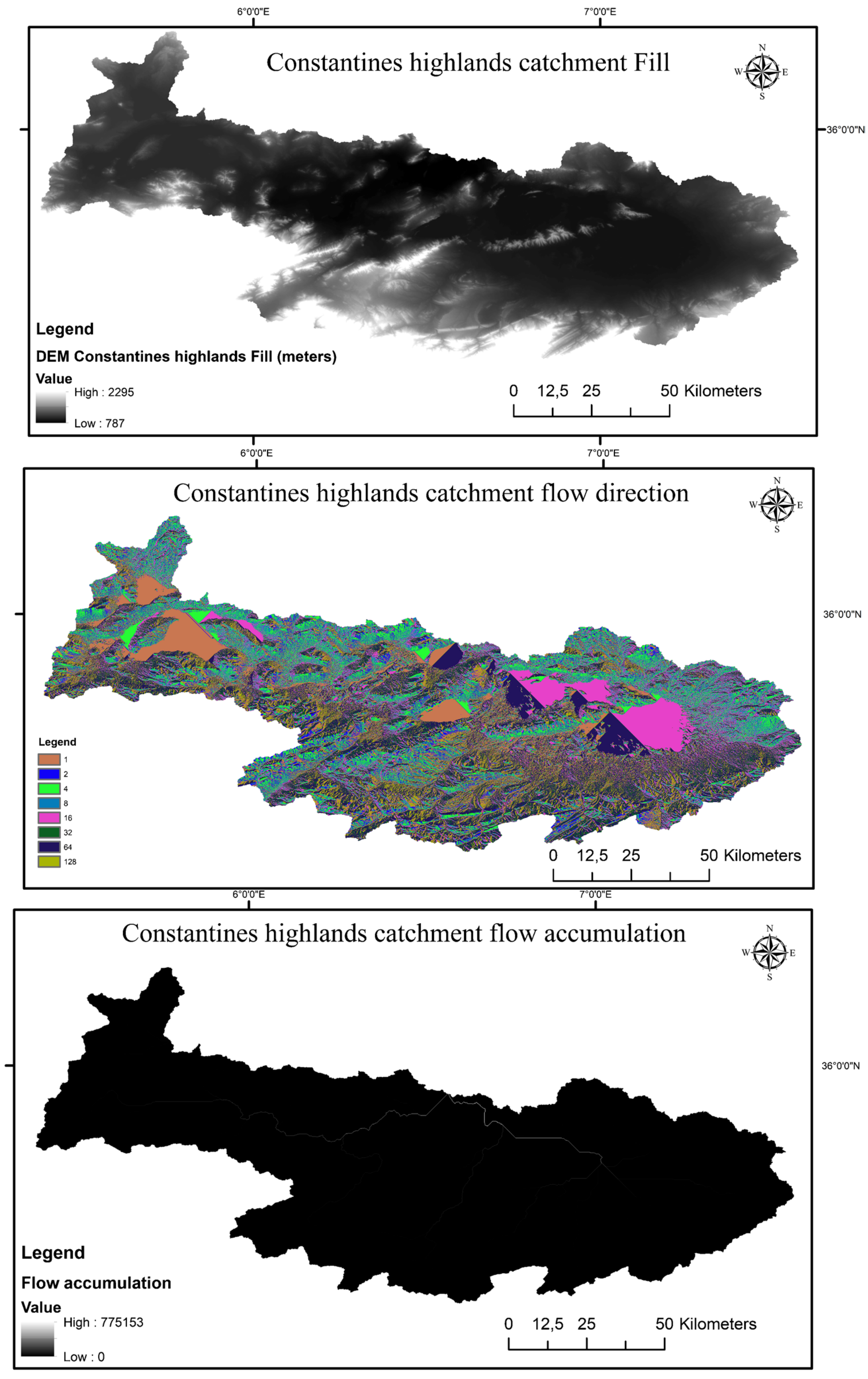

Fig. 3 Automated drainage delineation method, steps of conversion, Constantine's highland basin DEM to fill DEM, flow direction to flow accumulation map of Constantine's highland basin

(ii) Relief aspect including ruggedness number (Rn) and relief ratio (Rh).

For each morphometric parameter used were allocated various positions and compound factors that were determined for each sub-watershed which took an average of the parameter ranks (Choudhari et al. 2018). The watershed with the lowest groundwater potential receives the elevated priority ranking conversely.

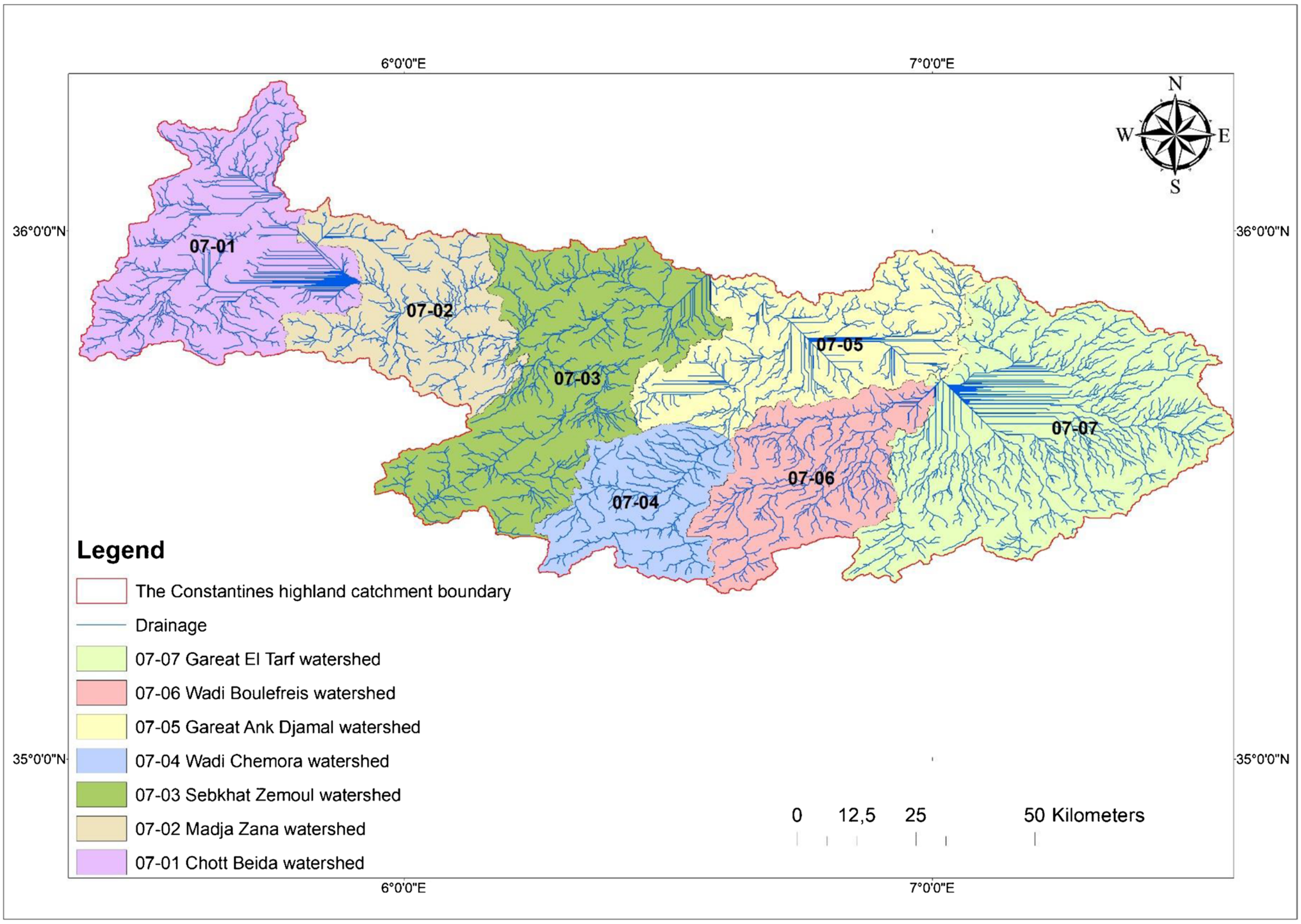

Fig. 4 Drainages of the Constantine's highland basin

Results and discussion

Primary parameters

Area (A) and perimeter (P)

Constantine's highland watershed has a total area of 12017 km^2 and a perimeter of 1101 km. It is divided into seven sub-watersheds areas. The largest is the Gareat El Tarf basin, with a surface area of 2920 km^2, which represents more than 24% of the total surface area and a perimeter of 409 km. While the smallest is the valley of Chemora basin, with only 7% of the total surface area with approximately 920 km^2 as its perimeter is 221 km, and their respective lengths are 12 km for the former and 63 km for the letter (Table 2).

Basin length (Lb)

The longest dimension of the basin is equivalents the principal drainage (km), it's measured along the main route from the basin to the outlet of the watershed (Gray 1961); in our study area, the basin length is about 272.43 km (Table 2).

Table 2 Primary parameters of Constantine's highland catchment

Sub-basin code	Sub-basin name	Area (km^2)	Perimeter (km)	Basin length (km)
07–01	Chott Beida	1888	349.35	95.21
07–02	Medja Zana	1268	306	75.95
07–03	Sebkhet Ez Zemoul	2174	416,149	103.16
07–04	Wadi Chemora	920	221	63.29
07–05	Garaet Ank Djamal	1607	331	86.89
07–06	Wadi Boulfreis	1240	258	74.99
07–07	Gareat El Tarf	2920	409	121.98
Constantine's highland catchment		12017	1101	272.43

Table 3 Linear parameters of Constantine's highland catchment

Parameters	Sub-basins code	Linear aspects				
Stream order (*u*)	07–01	1st	2nd	3rd	4th	
	07–02	1st	2nd	3rd	4th	5th
	07–03	1st	2nd	3rd	4th	
	07–04	1st	2nd	3rd	4th	
	07–05	1st	2nd	3rd	4th	5th
	07–06	1st	2nd	3rd	4th	5th
	07–07	1st	2nd	3rd	4th	
	Total	1st	2nd	3rd	4th	5th
Stream number (Nu)	07–01	188	91	41	29	0
	07–02	144	104	33	10	14
	07–03	241	97	70	54	-
	07–04	78	26	23	18	-
	07–05	255	404	210	13	28
	07–06	122	62	37	16	-
	07–07	306	135	88	80	5
	Total	1334	919	502	220	47
Stream length (L_u)	07–01	334.99	190.15	70.84	44.13	0.00
	07–02	236.71	87.64	43.60	18.06	16.28
	07–03	390.94	152.03	55.13	94.28	0.00
	07–04	27.76	43.10	59.66	165.61	0.00
	07–05	293.26	172.95	111.24	4.24	27.98
	07–06	233.48	113.32	77.02	32.30	0.00
	07–07	575.48	331.67	217.71	84.28	3.52
	Total	2092.60	1090.86	635.19	442.91	47.78
Mean stream length (L_m)	07–01	1.85	2.09	1.73	1.52	0.00
	07–02	1.63	0.84	1.28	1.64	1.16
	07–03	1.62	1.57	0.79	1.75	0.00
	07–04	1.54	1.87	2.38	2.12	0.00
	07–05	1.15	0.43	0.53	0.33	1.00
	07–06	1.88	1.83	2.08	2.02	0.00
	07–07	1.88	2.46	2.45	1.05	0.70
	Total	11.55	11.08	11.23	10.43	2.87
Stream length ratio (Rl)	07–01	1.76	2.68	1.61	-	-
	07–02	2.70	2.01	2.41	1.11	-
	07–03	2.57	2.76	0.58	-	-
	07–04	0.64	0.72	0.36	-	-
	07–05	1.70	1.55	26.26	0.15	-
	07–06	2.06	1.47	2.38	-	-
	07–07	1.74	1.52	2.58	23.94	-
	Total	1.88	1.82	5.17	8.40	-
Bifurcation ratio (R_b)	07–01	2.07	2.22	1,41	-	
	07–02	1.38	3.15	3.30	0.71	
	07–03	2.48	1.39	1.30		
	07–04	3.00	1.13	1.28		
	07–05	0.63	1.92	16.15	0.46	
	07–06	1.97	1.68	2.31		
	07–07	2.27	1.53	1.10	16.00	
	Total	1.45	1.83	2.28	4.68	
Mean bifurcation ratio (Rbm)	07–01	1.90				
	07–02	2.14				
	07–03	1.72				

Table 3 (continued)

Parameters	Sub-basins code	Linear aspects
	07–04	1.80
	07–05	4.79
	07–06	1.99
	07–07	5.23
	Total	2.56

*(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tarf

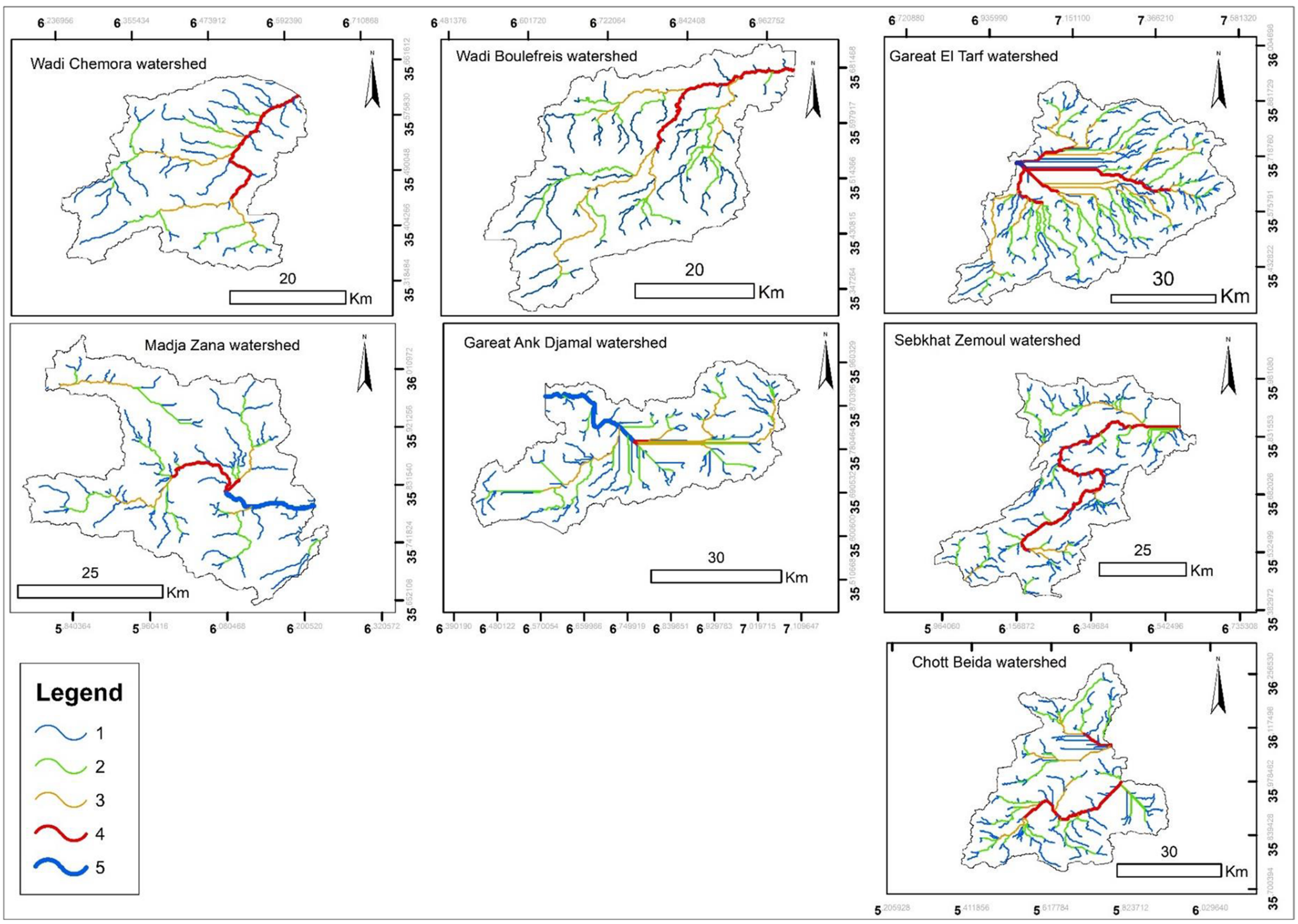

Fig. 5 Stream order map of sub-watersheds of the Constantine's highland basin

Linear aspects of basin morphometry

Stream order (u)

Stream order is the basic parameter of quantitative analysis of drainage. Horton (1945) first endorsed the stream ordering systems, and then in 1952, Strahler proposed this ordering system with some revises. Among the seven sub-watersheds that form the catchment of the Constantine's highlands, three are of the fifth order: they are the Gareat El Tarf (07–07), Zana (07–02), and Ank Djemal (07–05) sub-watersheds. The four remaining sub-watersheds are in fourth order and these are Wadi of Boulfreis (07–06), Wadi of Chemora (07–04), Sebkhet Zemoul (07–03), and Chott Beida (07–01) (Table 3 and Fig. 5). It was noticed that the maximum frequency is in the case

Table 4 Areal parameters of Constantine's highland catchment

Sub-basin code	Drainage density (Dd) (km/km2)	Stream frequency (F_s) (km^{-2})	Drainage texture ratio (*Rt*) (km^{-1})	Length of overland flow (Lg) (km)	Circulatory ratio (R_c)	Form factor (F_f)	Shape factor (Bs)	Elongation ratio (R_e)	Compactness coefficient (Cc)	Infiltration number (If)
07–01	0.28	0.15	0.49	1.79	0.19	0.21	4.802	0.51	12.26	0.042
07–02	0.31	0.24	0.47	1.6	0.17	0.22	4.549	0.53	10.05	0.075
07–03	0.32	0.21	0.58	1.57	0.16	0.2	4.895	0.51	13.15	0.068
07–04	0.32	0.16	0.35	1.55	0.24	0.23	4.355	0.54	8.56	0.051
07–05	0.38	0.57	0.77	1.32	0.18	0.21	4.698	0.52	11.31	0.215
07–06	0.37	0.19	0.47	1.36	0.23	0.22	4.535	0.53	9.93	0.07
07–07	0.42	0.21	0.75	1.2	0.22	0.2	5.095	0.5	15.24	0.087
Total	0.35	0.24	0.57	1.44	0.12	0.16	6.176	0.45	30.92	0.084

*(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tarf

of the first order of the flow and that the frequency of the flow decreased as its order increased.

Stream number (Nu)

In 1945, Horton indicates that the counts of stream segments in each order are in reverse order geometrically to the order number, i.e., the stream number decreases, while the stream order increases. In the Constantine's highland watershed, there are 3022 streams in total, of which 1334 are in the first order and only 47 in the fifth order (Table 3).

Stream length (Lu)

Stream length indicates the contributing surface runoff to the drainage, which has been calculated using Arc GIS software; we calculated the stream length based on the formulation proposed by Horton (1945). The total stream length of our watershed is 8618.70 km, the first-order stream length is 2092.60 km, and the fifth-order stream length is 47.78 km. Stream length and number decrease from the first order to the fifth order. The first-order stream is high in both number and length (Table 3).

Mean stream length (L_m)

The average length of a stream is a length measurement that indicates the characteristic size of the catchment areas (Strahler 1964). The mean stream length of Constantine's highland catchment for the first order is 3.04 km and for the sixth order is 3.86 km. It depends upon the percent change in elevation and topography of the basin (Table 3).

Stream length ratio (R*l*)

The variation in stream length is attributed to the change of slope and topography, which represents the late stage of geomorphological evolution of the waterways in this region (Vittala et al. 2008). Sub-basin showed a change from one order to another, indicating the late stage of geomorphological development of the streams in the inter-basin area. From a lower to a higher order, it indicates their developed geomorphological stage (Vinutha and Janardhana 2014). Only Gareat El Tarf sub-watershed presents a trend of a developed geomorphological stage. The other sub-watersheds showed characteristics of a late stage of geomorphological development (Table 3).

Bifurcation ratio (Rb)

It is a ratio between the number of streams of a decided request and those of the second higher order (Schumn 1956). There are two basic classes of Rb values: under five (5) can

Table 5 Relief parameters of Constantine's highland catchment

Sub-basin code*	Maximum relief (Hmax) (m)	Minimum relief (Hmin) (m)	Mean relief (Hm) (m)	Relief (Rf) (m)	Relative relief (*R*)	Relief ratio (Rh)	Ruggedness number (Rn)	Hypsometric integral (HI)
07–01	1717	877	984.9	840	2170.54	0.0088	0.24	0.13
07–02	1630	803	951.71	827	2702.61	0.0109	0.26	0.18
07–03	2094	781	1013.25	1313	3156.25	0.0127	0.42	0.18
07–04	2287	890	1253.95	1397	6321.27	0.0221	0.45	0.26
07–05	1647	783	893.46	864	2610.27	0.0099	0.33	0.13
07–06	2295	828	1019.87	1467	5686.05	0.0196	0.54	0.13
07–07	2158	825	962.58	1333	3259.17	0.0109	0.55	0.1
Total	2295	781	993.07	1514	650.34	0.0056	0.52	0.14

*(07-01) sub-basin of Chott Beida, (07-02) sub-basin of Medja Zana, (07-03) sub-basin of Sebkhet Ez Zemoul, (07-04) sub-basin of Wadi Chemora, (07-05) sub-basin of Garaet Ank Djamal, (07-06) sub-basin of Wadi Boulfreis, (07-07) sub-basin of Gareat El Tarf

be classified as low and more than 5 (Chandrashekar et al. 2015). Lower branch ratios are characteristic of watersheds that have experienced less severe structural disturbances and drainage patterns that have not been distorted by structural disturbances, whereas the high class means geological structures control the drainage pattern (Vittala et al. 2004). The only sub-catchment with a high Rb value is Gareat El Tarf (07–07) which has Rb slightly above five (Table 3). Thus, the drainage in this catchment is controlled by the geological structure and therefore indicates low permeability and low groundwater potential, while the rest of the sub-catchments had Rb values below five. The low mean bifurcation value in these sub-catchments indicates good permeability, high infiltration, and high groundwater potential; it had less structural control.

Areal aspect

Drainage density (Dd)

According to Horton (1932), drainage density is the total drainage length for each unit area of the catchment. Empirical formulations using drainage density as a major index of catchment functioning have led to advances in the understanding of hydrological functioning (Sarrazin 2012).

Drainage density appears to be a powerful descriptor of the environment, as a hinge parameter between climatic, hydrological, and lithological elements. This essential role is a result of an agent of flow (Humbert 1990). It testifies to the geomorphological and geological history that determines the hydrological efficiency of the catchments and to past processes linked to the climate (Tucker et al. 2001). The value of drainage density of the analyzed drainage is 0.34 km/km^2. It varies from 0.28 km/km^2 for the sub-watershed of Chott Beida (07–01) to 0.41 km/km^2 for Gareat El Tarf (07–07) sub-watershed (Table 4). A low Dd class is an indicator for a basin with a poor drainage and a slower hydrological response. Surface runoff is not rapidly removed from the watershed making it highly susceptible to flooding and gully erosion (Rai et al. 2017).

Stream frequency (F_s)

It is given as the all-out number of flow segments of all orders. The stream frequency of each of the seven sub-watersheds is strongly related (0.14 to 0.24 km^{-2}) indicating low slope and good infiltration (Table 4). Except the sub-watershed of Gareat Ank Djamal (07–05), which showed the highest values for stream recurrence of 0.56 km^{-2}, indeed, it revealed less penetrability and low groundwater potential among the five sub-watersheds.

Drainage texture ratio (Rt)

Horton (1945) characterized the drainage texture ratio as the linear distance between the complete numbers of surges of a given length for each unit area. As indicated by Smith (1950), the order of the five classifications in light of the worth of drainage texture ratio (Rt) is as follows: very fine ($>$8 km^{-1}), fine (6 to 8 km^{-1}), moderate (4 to 6 km^{-1}), coarse (2 to 4 km^{-1}), and extremely coarse ($<$2 km^{-1}). In the current review, the seepage surface changes from 0.35 sub-watershed of Oued Chemora (07–04) to 0.77 for the sub-watershed of Garaet Ank Djamal (07–05) as introduced in Table 4, and this shows that sub-watersheds are exceptionally coarse waste surface.

Length of overland flow (Lg)

It is nearly equal to half the relative density of the drainage (Horton 1945). The length of overland flow will be lower on steep slopes and higher on soft slopes (Rather

Table 6 Estimation of compound factors with priority ranking for erosion

Sub-basin code*	Linear aspect	Areal aspect									Compound factor	Prioritized ranks
	Rbm	Dd	Rt	Lg	Ff	Cc	Rc	Bs	Fs	Re		
07–01	5	7	4	1	3	5	4	7	7	7	5.000	1
07–02	7	6	2	2	5	3	2	6	2	6	4.100	4
07–03	3	5	5	3	6	6	1	5	3	5	4.200	3
07–04	6	4	1	4	7	1	7	4	6	4	4.400	2
07–05	2	2	7	6	4	4	3	3	1	3	3.500	5
07–06	4	3	3	5	2	2	6	2	5	2	3.400	6
07–07	1	1	6	7	1	7	5	1	4	1	3.400	7

*(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tarf

et al. 2017). Constantine's highland catchment computed a high value of the length of overland flow with 1.44 (Table 4).

Circulatory ratio (Rc)

According to Miller (1953), circulatory ratio is the ratio between the surface of the basin to the surface of a circle with the same circumference of the basin, which is dimensionless for our seven sub-watersheds. It varies from 0.15 to 0.21 and is classified as low Rc (Table 4). According to Sukristiyanti et al. (2018), this means that there is no structural control.

Form factor (Ff)

The form factor is calculated as the ratio of the catchment area to the square of the catchment length and is determined as the shape of the catchment (Horton 1932). For the seven sub-watersheds, we obtained a value between 0.16 and 0.22, which indicates that not all of these sub-catchments are circular but elongate in shape with low flow intensity (Table 4).

Elongation ratio (Re)

As indicated by Schumn (1956), the elongation ratio is given as the proportion of a measurement of a circle of the equivalent surface region to the extreme basin length. The upsides of Re fall into three particular classes specifically (a) roundabout (>0.9), (b) oval (0.9 to 0.8), and (c) less prolonged (<0.7) (Vittala et al. 2004). The elongation ratio of sub-watersheds of Constantine's highland watershed is 0.45, which is represented by the watershed elongated. The lowest Re (0.50) in our case indicates the presence of severe slopes (Table 4).

Compactness coefficient (Cc)

It is one of the main morphometric parameters in groundwater potential assessment. On the contrary with Cc values above, flood peaks were reduced, and groundwater recharge was enhanced (Kadam et al. 2019). All catchments in the currently selected catchment area had Cc values >1, indicating a lower susceptibility to both floods and erosion of soil (Table 4).

Shape Factor (Bs)

Shape factor (Bs) is determined as the relation between the mainstream length to the diameter of a circle having the same area as the watershed (Horton 1945). The Bs for our study (Table 4) varies between 4.355 for sub-watershed number (07–04) and 5.095 for the sub-watershed number (07–07).

Infiltration number (If)

The infiltration number of a watershed is a product of the surface drainage density and the frequency of watercourses. The infiltration number gives the result of the rate of infiltration, the impermeable lithology, and the hilly area, which contributes to the surface overflow or groundwater re-energize. The higher upsides of infiltration number offer back a low penetration rate and more overflow (Sahu et al. 2018). Sub-basins of Constantine's highland catchment had a low infiltration number, and it was varied from 0.042 (sub-basin of Chott Beida) to 0.215 (sub-basin of Garaet Ank Djamal). Therefore, all sub-basins in our study area had a high recharge capacity and a low runoff.

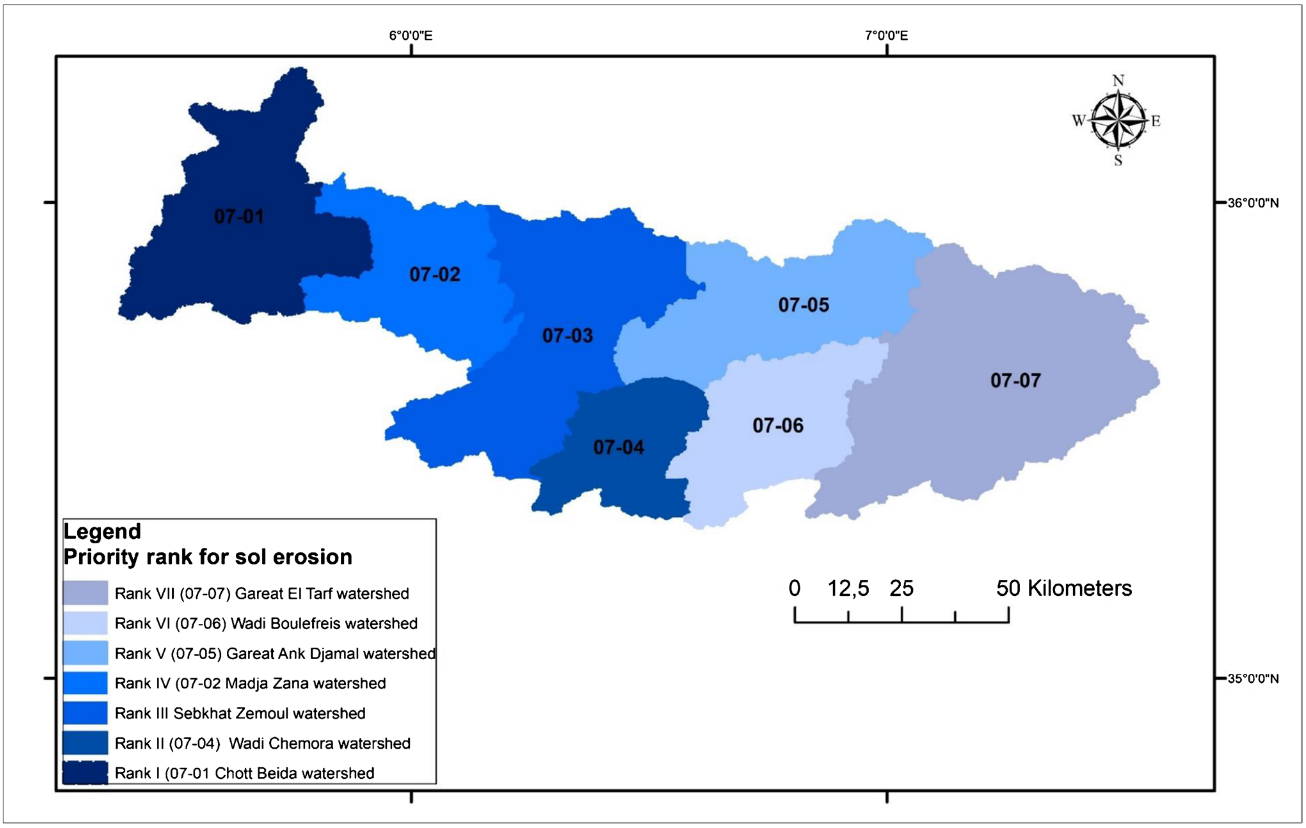

Fig. 6 Priority map of sub-watersheds of Constantine's highland basin on the basis of erosion. *(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tarf

Relief aspect

Relief (Rf)

It helps to interpret the geomorphic processes and landform characteristics (Pandey and Das 2016). In the current study, the basin's maximum height is obtained at 2295 m, and the minimum height is obtained at 781 m. Total relief is 1514 m; this high value means steep slope and high relief.

Relative relief (R)

It is determined by using perimeter and total basin relief (Melton 1957). The highest relative reliefs are about 6321 and 5686 m measured at the level of sub-watersheds of valley of Chemora (07–04) and valley of Boulfreis (07–06), respectively. However, the lowest values recorded are 2170, 2610, and 2702 measured at Chott Beida, Garaet (07–01), Ank Djamal (07–05), and Medja Zana sub-watersheds (07–02). Therefore, the relative relief in all seven sub-catchments is high. The highest relative relief marked the southeastern part of the catchment, which is a mountainous area with altitudes that can exceed 2000 m. The high relative relief value indicates resistant rocks in the drainage basin.

Relief ratio (Rh)

The relief ratio is the ratio of the maximum relief of a catchment to the largest size of the catchment paralleling the principal flow line (Schumm 1956). The Rr of Constantine's highland catchment is 0.0005.The Rh values of the sub-basins are shown in Table 5. Sub-watershed of Chott Beida (07–01) had the lowest Rr value, which is 0.0021, whereas the valley of Chemora (07–04) and the valley of Boulfreis (07–06) sub-catchments had a higher Rr with 0.0063 and 0.0056, respectively. The low relief ratios were principally the result of the strong basement rocks of the basin and the low degree of gradient (Pareta and Pareta 2011).

Ruggedness number (Rn)

It is a combination of drainage density and Relief (Rf) (Strahler 1968). Areas with high drainage density and low relief are as rough as areas with low drainage density and high relief. The studied area had a ruggedness number of 0.52

Table 7 Estimation of a compound factor with priority ranking for groundwater potential

Sub-basin code*	Linear aspect	Areal aspect							Relief aspect			Com-pound factor	Prior-itized ranks
	Rbm	Dd	Fs	Rt	If	Ff	Rc	Bs	Re	Rh	Rn		
07–01	5	7	7	4	7	3	4	5	2	7	7	5.273	7
07–02	7	6	2	2	3	5	2	3	6	5	6	4.273	5
07–03	3	5	4	5	5	2	1	6	3	3	4	3.727	3
07–04	6	4	6	1	6	7	7	1	7	1	3	4.455	6
07–05	2	2	1	7	1	4	3	4	4	6	5	3.545	2
07–06	4	3	5	3	4	6	6	2	5	2	2	3.818	4
07–07	1	1	3	6	2	1	5	7	1	4	1	2.909	1

*(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tarf

(Table 5). This demonstrated that the region was less powerless against soil erosion and had an integral structure complexity in combination with the relief and density of drainage.

Hypsometric integral (HI)

The hypsometric integral (HI) represents the area under the hypsometric curve. In our study, the value of HI lies in the interval from 0.10 to 0.14 (Table 5). It indicates that these catchments are mature.

Prioritization of sub-watershed for soils erosion

The sub-watershed has the lowest compound factor value and is very vulnerable to soil erosion. In this study, the sub-catchment with the highest value of the compound factor of 5.0 was a sub-catchment number (07–01); it had a low ranking. Therefore, it needed soil conservation measures for effective catchment management and planning. Sub-watershed numbers (07–06) and (07–07) were very highly prioritized with the lowest compound factor value of 3.4. This basin is the least exposed to the risk of soil erosion (Table 6) and (Fig. 6).

Prioritization of sub-watershed for groundwater potential

The sub-watershed of Gareat El Tarf (07–07) had the lowest value of the compound factor. It showed the highest groundwater potential and required omitting. On contrary, the sub-watershed number (07–01) had the highest compound factor value of 5.182 (Table 7 and Fig. 7). This implies measures for the conservation and protection of groundwater.

Conclusion

In this review, we conclude that the application of remote detecting and GIS for morphometric evaluation and prioritization of sub-catchments as per their soil erosion susceptibility and groundwater potential is a significant methodology approach for a better comprehension of hydrological aspects and effective catchment management planning. In total, the seven sub-catchments that composed the Constantine's highland basin have 1688 river segments. The stream order went up to the fifth order for Medja Zana (07–02), Garaet Ank Djamal (07–05), and Wadi Boulfreis (07–06) sub-watersheds and the fourth order for the remaining sub-watersheds. Bifurcation results showed that almost all of the sub-catchments except Gareat El Tarf sub-watershed (07–07) have good permeability, high infiltration, and high groundwater potential. It has a less structural control. Drainage density varies from 0.28 km/km^2 for sub-watershed of

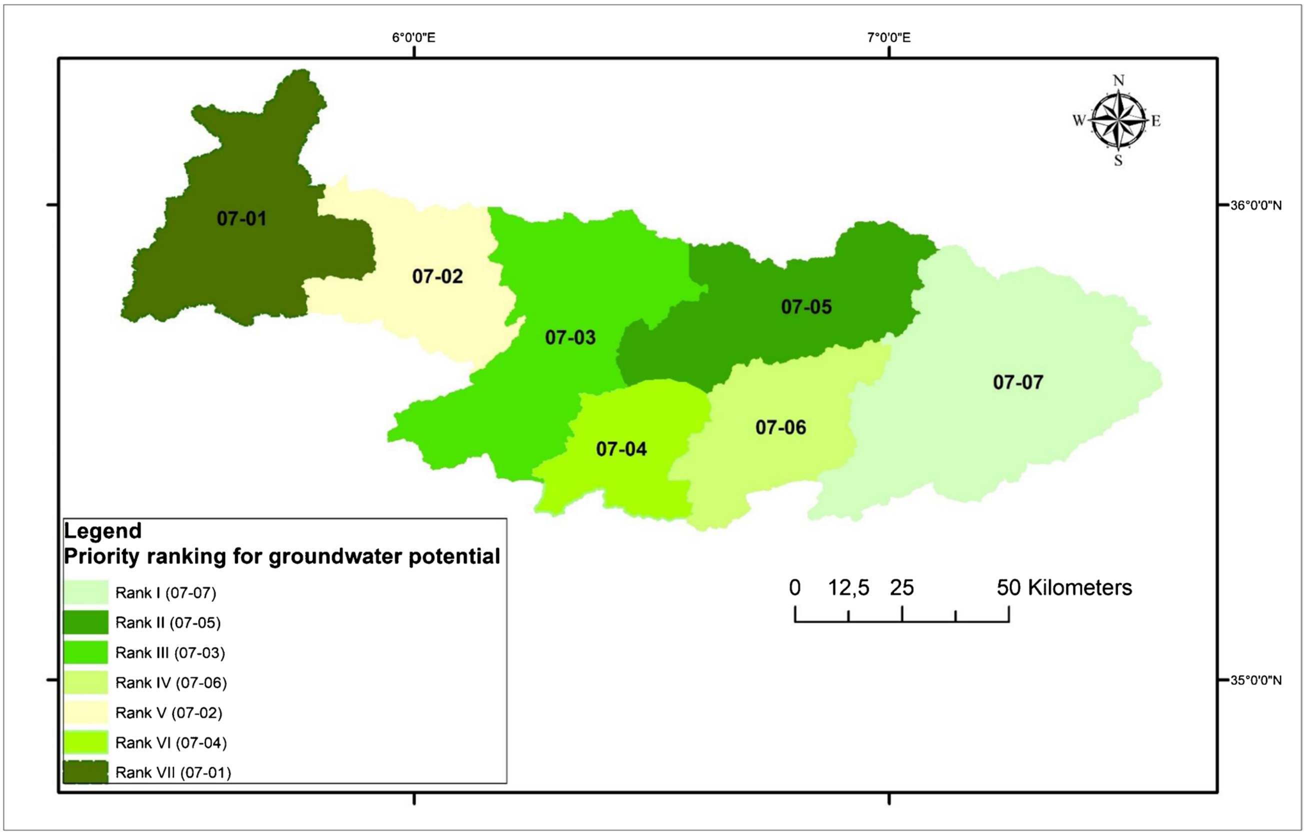

Fig. 7 Priority map of sub-watersheds of Constantine's highland basin based on groundwater potential. *(07–01) sub-basin of Chott Beida, (07–02) sub-basin of Medja Zana, (07–03) sub-basin of Sebkhet Ez Zemoul, (07–04) sub-basin of Wadi Chemora, (07–05) sub-basin of Garaet Ank Djamal, (07–06) sub-basin of Wadi Boulfreis, (07–07) sub-basin of Gareat El Tar

Chott Beida (07–01) to 0.41 km/km^2 for Gareat El Tarf (07–07) sub-watershed. This low class of Dd indicated that the catchment was not draining well and had a weak hydrologic response. The investigation with an estimation of a compound factor for prioritization demonstrated that sub-watershed numbers (07–01), (07–02), (07–03), and (07–04) had very high vulnerability to soil erosion followed by sub-watershed numbers (07–06) and (07–07). For the prioritization of groundwater potential, the sub-watershed of Gareat El Tarf (07–07) showed the highest groundwater potential. This prioritization study can become a very useful tool for decision support in soil and groundwater management in the high plateaus catchment of Algeria.

Data Availability The data discussed here are calculated and detailed above in the results and discussion section.

Declarations

Conflict of interest The authors declare no competing interests.

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