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Climate Change Impact on Groundwater in Cheliff-zahrez Basin (Algeria)

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Abstract: Groundwater is a very widely used resource in the Cheliff-Zahrez watershed. However. following the drought in the basin. farmers of the region has resorted to the intense mobilization of groundwater resources. This work allowed us to study the impact of rainfall reduction on groundwater resources in the basin. by studying groundwater and natural infiltration. We have considered the future scenarios to estimate rainfall for 2025 and 2050 and therefore the (groundwater) recharge at those time horizons.

Key words: Groundwater · Climate Change · Infiltration · Cheliff-Zahrez Basin · Algeria

INTRODUCTION

Our work aims to study the impact of climate change on the renewal of groundwater resources in the Cheliff-Zahrez watershed. This study is based on the analysis of relations between climate changes and natural recharge of groundwater. The general trends of climatic variations in the basin are first identified. The impact of this climate changes on aquifer recharge is also discussed in order to complete the identification of climate indicators that managers can use to adapt to changes in groundwater resources. The renewal of this resource depends on the recharge of groundwater which depends on rainfall and evapotranspiration [1]. Several recent studies have shown that climate trends are well correlated with the variations of groundwater level [2. 3 and 4]. The aim of the work to study the impact of rainfall reduction on groundwater resources in the basin. by studying groundwater and natural infiltration.

Geographical and Climatic Framework: The region includes three drainage basins: the Cheliff basin in the north. the Zahrez-Sersou basin in the south and the coastal in the north (Fig.1). It is bounded on the north-west and west by the coastal basin of Oran and the Macta basin and on the east by the coastal basin of Algiers and the Hodna basin. It is characterized by a semi-arid according to temperate climate. The examination of the rainfall map of the Cheliff-Zahrez watershed highlighted two distinct areas: one in the north includes the Cheliff Valley and the Ouarsenis Massif where average rainfall is between 450 and 600 mm. except in the Zaccar Gharbi Massif where we record more than 700 mm. The other is located in the south and includes the plateau of Sersou and Zahrez where rainfall varies between 100 and 300 mm.

Geological and Hydrological Framework: The Cheliff-Zahrez watershed includes two distinct structural units:

- In the north. the Cheliff furrow flanked by the two Tellian chains (Dahra Mountains to the north and the Ouaresnis Massif to the south).
- In the south. the Zahrez basin.

The Cheliff furrow is compartmentalized into three basins (higher. middle and lower Cheliff) separated by two thresholds corresponding to the bedrock. the threshold of Ain defla and the threshold of Oum D'rou further west. Many permeable geological formations contain groundwater. the oldest are assigned to the Jurassic time and the most recent correspond to the quaternary alluvium. In the northern part of the study area. the two Tellian chains are poor resources and it is difficult to exploit them directly. the permeable levels (limestone and sandstone) are generally less developed and encased in powerful formations that have a very low permeability.

In the Cheliff basin. the alluvial plain consists of coarse alluvium and occupies an area of 376 km^2. Many drilling capture this coarse alluvium of 150 m.

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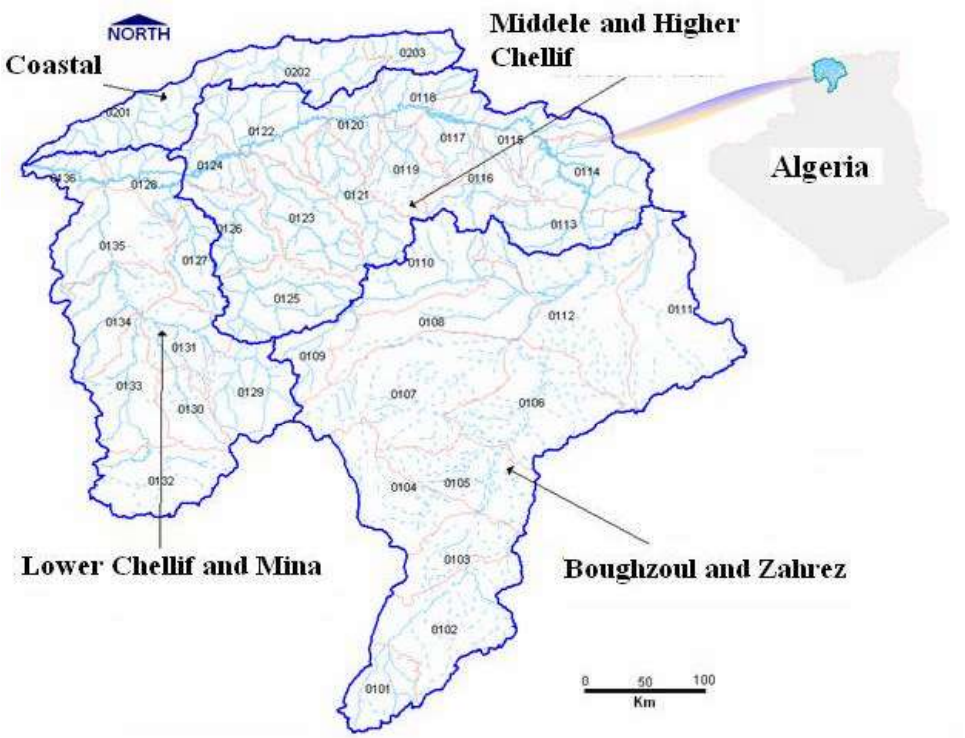

Fig. 1: Studied basins.

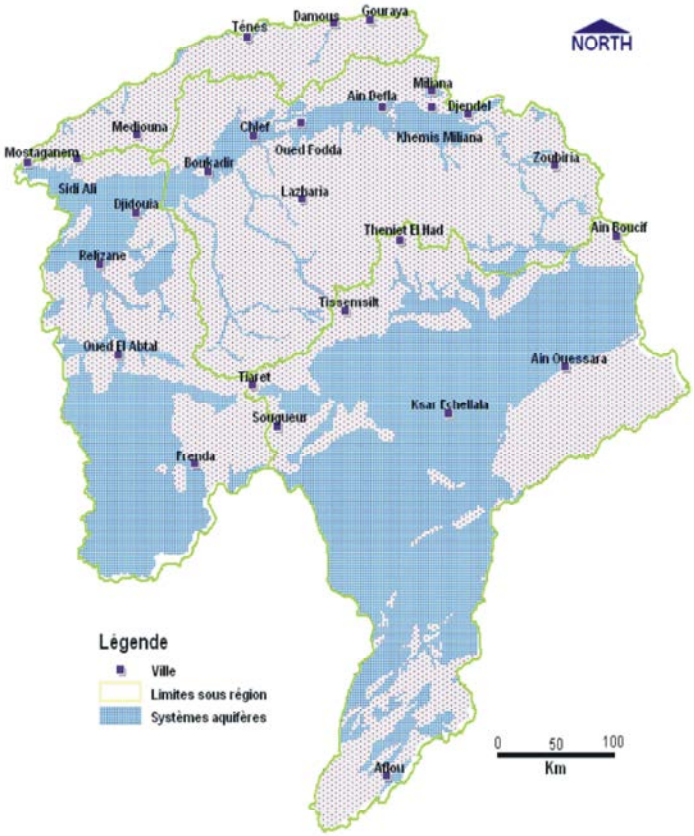

Fig. 2: Locate main Cheliff aquifer

The depth of groundwater is between 20 and 60 m with operating flows in the order of 30 to 70 $L \cdot s^{-1}$. In the Zahrez basin. extends a water table bounded on the north by the Ain Oussera Plain. on the west by the plateau of sersou. on the east by the Chott Hodna and on the south by the Ouled Nail Mountains. The aquifer consists of sands with intercalations of quaternary clays and scree slopes of dunes and alluvium. which reaches a thickness of 200 m in the filling of the two Zaire in the south.

Groundwater: The groundwater of the « Cheliff-Zahrez region » was assessed within the framework of the National Water Plan.

This assessment is based on quantitative hydrogeological studies carried out by the National Agency of Water Resources and the method of rain/infiltration for the non-studied areas.

The number of hydrogeological units in the Cheliff-Zahrez region is 42 units. whose groundwater potential is estimated at 298 Hm^3.

Main Hydrogeological Units: The Higher Cheliff Plain consists of coarse alluvium. occupies an area of 376 km^2. The Middle Cheliff Plain consists of highly permeable Jurassic limestone. occupies an area of 394 km^2.

The aquifer of Doui Massif is made up of primary schist and quartzite with some compartments of Jurassic limestone and the main aquifer of djebel Rouina and djebel Temoulga made up of Jurassic limestone.

The alluvial plain of the Lower Cheliff between Chlef and Boukadir form a plio-quaternary aquifer consisting essentially of a thickness of sands and gravel. ranging from 10 m on the left bank to 350 m on the right bank with many clayey intercalations.

The main aquifers of the Nahr Oussel and Oued Touil Plains are quaternary alluvium. Turonian limestones and Albian sandstones.

Two main aquifers are distinguished in the Mina Plain. the quaternary aquifer and the Astian aquifer.

The Ain Ouassera Plain is made up of quaternary limestones and recent sandy alluvium. cracked limestones and dolomites of Jurassic.

The aquifer of the Medea Plateau is made up of sandstones.

Situation for the Period 1961-1990: The estimation of groundwater potential is established for the same period using the approach based on average rainfall. geological formations (their surfaces and permeabilities) represented by an infiltration coefficient.

Thus. for an average amount of water of 346.5 mm rushed at the level of Cheliff basin. that is to say a water volume of 16 381.9 Hm^3. the groundwater potential is estimated at 299 Hm^3/year. spread over the various aquifers of the Cheliff basin (Table 1).

Data and Rainfall Variability: The available data collected from the National Agency of Water Resources are: climatological and piezometric types. The evolution of the available data in the 221 rainfall stations distributed throughout the Cheliff Zahrez watershed and the boundary sub-basins. depending on the longest operation period. clearly shows the low density of rainfall network before 1966. It has become very important in the late sixties and early seventies. where more than 60% of rainfall stations have the information during the period 1968/1969 to 2001/2002. Thus. the longest observation series are situated between 1968 and 2001. This period was therefore chosen as the reference period. The rainfall regime has changed from the seventies in the Cheliff-Zahrez region. Thus. we are focusing on the emergence of a rainfall deficit from 1970. which continues throughout the decade 80-90 [5]. The pluviometric index shows a great spatiotemporal variability from one decade to another (1950/50 a surplus of 14.5 %). the decade 1980-1990 was characterized by a pluviometric deficit on the whole of the studied zone and this phenomenon persisted during the 1990s [6. 7. 8. 9 and 10 in Morocco) and Mediterranean countries [11. 12] suffered from several periods of drought: the first water shortage was felt from 1943 to 1948 and had a significant impact on crops and livestock; the second one is the one we are suffering from since 1975.

In fact, rainfall decreases as one move away from the east coast to the west coast. The rainiest region is that in the north eastern basin characterized by high altitudes and its exposure to the northern wind. The average annual rainfall varies between 600 to 700 mm. Rainfall doesn't exceed 500 mm in the plain. while in the south of the Cheliff-Zahrez region. the high plateaus and the Zahrez the annual averages range from 100 to 300 mm.

Thus. we can notice a small percentage of areas of high rainfall where rainfall exceeds 700 mm; however areas of low rainfall constitute two thirds of the Cheliff-Zahres basin area.

The analysis of chronics shows that the driest year was observed in 1999 at the Marabout Blanc station (152mm) and the Ghrib dam station with 238 mm. in 1993 at El Khemis station (174mm) and El Asnam (164mm) and in 1981 at Relizane station (161 mm) (Table 3).

Table 1: Groundwater resources for the period (1961-1990)

Sub region	Code	Sub Basin	surf KM2	rainfall mm/year	infiltration Mm3/year	Available resource m3/year
Cheliff upstream from Boughzoul	0101	O. Sebgag Berkana	791.3	125.0	7.83	0.65
	0102	O. Namous Chelal	2019	125.0	16.37	5.68
	0103	O. Touil Amont	963.8	128.7	8.55	6.23
	0104	O. Sakni	858.6	215.0	16.17	15.93
	0105	O. Touil Moyen	1403	179.8	32.43	25.30
	0106	O. Touil Aval	2033	196.4	20.33	13.90
	0107	O. Sousselem	2833	284.9	59.79	27.15
	0108	O. Mechti Zerga	1549	334.3	23.66	9.00
	0109	O. Ouassel Amont	699.3	380.7	10.65	1.50
	0110	O. Ouassel Moyen	1403	404.2	26.11	4.48
	0111	Daia el Firania	2339	241.3	29.72	19.07
	0112	Daia Boughzoul	2617	274.6	45.40	22.99
Higher and middle Cheliff	0113	O. Cheliff Djelil	1006	402.4	19.57	4.31
	0114	O. Cheliff Ghrib	1391	436.7	26.47	6.06
	0115	O. Cheliff Harbil	784	464.8	17.06	7.47
	0116	O. Deurdeur	856.6	496.9	17.95	2.61
	0117	O. Cheliff Harrezza	744	463.5	18.86	10.75
	0118	O. Ebda	681.5	566.9	17.84	6.66
	0119	O. Rouina Zeddine	898.5	464.1	5.92	1.81
	0120	O. Cheliff Tikazale	570.5	466.4	11.67	7.05
	0121	O. Fodda	1161	464.0	20.82	2.76
	0122	O. Ras Ouahrane	1421	496.3	23.21	13.26
	0123	O. Sly	1405	446.1	29.06	6.41
	0124	O. Cheliff Ouarizane	564.7	434.5	12.55	5.45
	0125	O. Riou Tiguiguest	1514	378.4	24.94	3.07
	0126	O. Riou Tleta	928.4	391.1	17.69	3.70
lower Cheliff and the Mina	0127	O. Djidiouia	799.4	370.7	13.17	2.50
	0128	O. Cheliff Tarhia	759.6	428.2	13.59	3.04
	0129	O. Mina Amont	1284	337.1	24.05	2.62
	0130	O. Taht	657.6	314.0	24.17	5.60
	0131	O. Mina Moyenne	892.2	327.3	20.44	4.12
	0132	O. Abd Amont	1374	276.4	53.16	9.96
	0133	O. Abd Aval	1229	306.2	42.79	13.40
	0134	O. Mina Haddad	1251	339.1	24.43	7.84
	0135	O. Mina Aval	1463	364.5	30.29	8.58
	0136	Cheliff Maritime	434.2	436.3	8.52	3.07
Coastal	0201	Coastal Guelta	1312	525.9	30.24	3.02
	0202	Coastal Ténès	1324	570.3	22.04	1.87
	0203	Coastal Cherchell	565	554.2	2.49	0.12
Total				870	299	

Table 2: The hydrogeological units per watershed.

Watershed	Hydrogeological unit	Potential (m^3/year)
Coastal Dahra	Alluvium of oueds	1.39
	Cap Ténès	0.07
	Various	2.47
	Oued Damous	0.81
Cheliff Downstream Boughzoul	Oued Abd	6.36
	Alluvium of oueds	0.88
	Cheliff alluvium uptream from the higher Cheliff Plain	5.77
	Limestone Lithothamniés	8.80
	Limestone of Kalaa	0.90
	Zemmoura limestones and sandstones	0.65
	Various	10.70
	Djebel Doui	1.12
	Djebel Guentass	1.57
	Djebel Rouina	0.36
	Djebel Temoulga	0.42
	Djebel Zaccar Rherbi	1.60
	Saida Mountains	26.20
	Oued Ardjem	2.05
	Coastal Oued Cheliff	1.19
	Oued Djidioia	1.17
	Oued Mina	5.60

Table 2: Continued

Watershed	Hydrogeological unit	Potential (m^3/year)
Downstream Cheliff Boughzoul	Oued Rhiou	2.83
	Oued Sly	0.66
	Oued Taht	1.60
	Nahar Ouassel Plain	2.55
	Eghriss Plain	1.69
	lower Cheliff Plain	7.05
	Higher Cheliff Plain	13.76
	Western Middle Cheliff plain	8.96
	Eastern Middle Cheliff Plain	14.41
	Mostaganem plateau	3.60
	Medea Plateau	0.46
Cheliff upstream Boughzoul	Adjeltes	1.84
	Various	2.62
	Djebel Ben Hammad	1.84
	Djebel Nador	17.26
	Oued Sousselem	1.52
	Oued Touil	9.75
	Ain Oussera Plain	17.82
	Nahar Ouassel Plain	21.76
	Zahrez Plain	0.37
	Serssou Plateau	13.10
	Pliocene of nador	15.96
	Syncline of Aflou	19.68
Total		261.17

Table 3: Rainfall characteristics (1968–2000).

Name of the station	X (km)	Y (km)	Altitude (m)	Mean (mm)	Standard deviation (mm) and CV in %
Marabout Blanc	460	316	335	309	67.2 (21.8)
Ghrib Bage	487	318.	460	452	113 (25)
El Khemis	459	328	285	425	110.7 (26.1)
El Esnam	620	336	430	355	119.8 (33.7)
Relizane	305	275	81	273	67.8 24.9)

Table 4: Characteristics of climate projections on Algeria.

		2020		2050	
Season	Climate Parameter	Low	High	Low	High
Autumn	T °C (+)	0.8	1.1	1.2	2.2
	P % (-)	6	8	10	15
Winter	T °C (+)	0.65	0.8	0.95	1.6
	P % (-)	10	10	16	16
Spring	T °C (+)	0.85	0.95	1.25	1.9
	P % (-)	5	9	10	20
Summer	T °C (+)	0.85	1.05	1.25	2.1
	P % (-)	8	13	15	22

Table 5: Groundwater resources for 2020 and 2050.

			Groundwater potential for (Hm3/year)			
			2020		2050	
Sub-region	Code	Sub-basin	Low	High	Low	High
Cheliff upstream from Boughzoul	0101	O. Sebgag Berkana	0.9	0.9	0.8	0.8
	0102	O. Namous Chelal	7.0	6.9	6.8	6.6
	0103	O. Touil Amont	8.3	8.1	7.8	7.4
	0104	O. Sakni	18.3	17.8	17.2	16.2
	0105	O. Touil Moyen	19.9	19.4	18.8	17.6
	0106	O. Touil Aval	16.3	15.8	15.3	14.4
	0107	O. Sousselem	27.1	26.5	25.7	24.3
	0108	O. Mechti Zerga	8.4	8.2	7.9	7.4
	0109	O. Ouassel Amont	1.3	1.3	1.3	1.2
	0110	O. Ouassel Moyen	3.9	3.8	3.7	3.5
	0111	Daia el Firania	14.2	13.8	13.4	12.5
	0112	Daia Boughzoul	16.8	16.4	15.9	14.9

Table 5: Continued

			Groundwater potential for (Hm3/year)			
			2020		2050	
Sub-region	Code	Sub-basin	Low	High	Low	High
Higher and middle Cheliff	0113	O. Cheliff Djelil	2.6	2.5	2.5	2.3
	0114	O. Cheliff Ghrib	6.5	6.4	6.1	5.8
	0115	O. Cheliff Harbil	9.4	9.2	8.9	8.4
	0116	O. Deurdeur	2.2	2.1	2.0	1.9
	0117	O. Cheliff Harrezza	15.1	14.8	14.3	13.5
	0118	O. Ebda	7.6	7.4	7.2	6.8
	0119	O. Rouina Zeddine	2.0	2.0	1.9	1.8
	0120	O. Cheliff Tikazale	8.6	8.5	8.2	7.7
	0121	O. Fodda	2.2	2.1	2.0	1.9
	0122	O. Ras Ouahrane	11.7	11.4	11.0	10.4
	0123	O. Sly	4.9	4.8	4.6	4.4
	0124	O. Cheliff Ouarizan	4.0	4.0	3.8	3.6
	0125	O. Riou Tiguiguest	2.6	2.6	2.5	2.3
	0126	O. Riou Tleta	3.2	3.2	3.0	2.9
Lower Cheliff and the Mina	0127	O. Djidiouia	2.2	2.2	2.1	2.0
	0128	O. Cheliff Tarhia	2.0	1.9	1.9	1.8
	0129	O. Upstream Mina	2.8	2.8	2.7	2.5
	0130	O. Taht	6.2	6.0	5.8	5.5
	0131	O. Middle Mina	4.3	4.2	4.1	3.8
	0132	O. Upstream Abd	8.8	8.6	8.3	7.8
	0133	O. downstream Abd	13.6	13.3	12.9	12.1
	0134	O. Mina Haddad	7.3	7.1	6.9	6.5
	0135	O. Downstream Mina	7.5	7.4	7.1	6.7
	0136	Coastal Cheliff	2.4	2.3	2.3	2.1
Coastal	0201	Coastal Guelta	1.8	1.8	1.7	1.6
	0202	Coastal Ténès	1.7	1.6	1.6	1.5
	0203	Coastal Cherchell	0.1	0.1	0.1	0.1
Total	285.7	279.3	269.9	254.9		

Table 6: Reduction of groundwater potential by horizon.

	Groundwater potential for (Hm^3/year)			
	2020		2050	
Sub- region	Low	High	Low	High
Cheliff upstream Boughzoul	142.3	138.9	134.6	126.8
Higher and middle Cheliff	82.6	80.9	77.9	73.9
Lower Cheliff and the Mina	57.2	55.9	53.9	50.9
Coast	3.6	3.5	3.4	3.2
Total	285.7	279.3	269.9	254.9
Reduction (%)	4.4%	6.6%	9.7%	14.8%

The wettest year was recorded in 1971-1972 with precipitation of 630.5 mm at El Asnam station and 711 mm at El Khemis station and 439 mm at Marabout Blanc station and 660 mm at Ghrib dam station. Overall. the wettest months are: November, December, January and February, However, the months of July and August are almost completely dry. A filter of 3-years moving averages was applied in order to highlight the main trends. The following figures show that the periods 1980-1994 and 1998-2001 are characterized by a significant rainfall deficit recorded on the different stations. Thus. the average annual rainfall recorded is below the average reported in the period 1968-2001.

Evolution of Groundwater Potential for 2020, 2025 and 2050: To study the impact of climate change on water resources. we have used the seasonal climate projections on Algeria for 2020 and 2050 obtained by the UKHI model (United Kingdom Meteorological Office High Resolution) by adopting the «IS92a» scenario of GIEC with both high and low assumptions (Table 4).

Impact of Climate Change on Groundwater: We have estimated the groundwater potential for 2020 and 2050 (Table 5) using the approach rain/infiltration and taking into account the different climate scenarios.

The potential decreases for 2020 from 4.4% (low scenario) to 6.6% (high scenario).

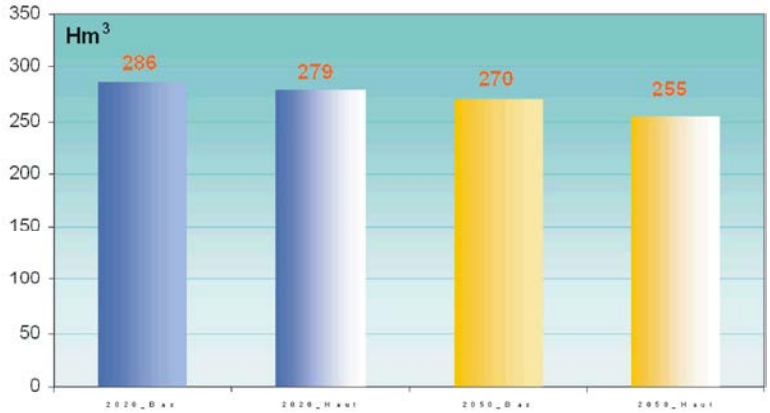

Fig. 1: Evolution of groundwater potential in the Cheliff basin (2020 and 2050).

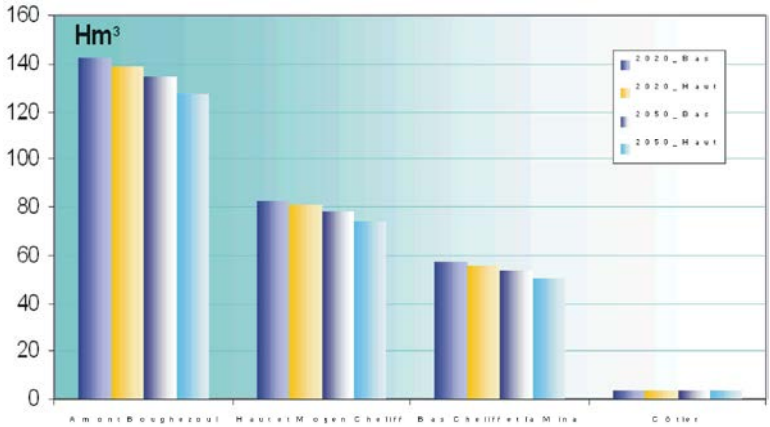

Fig. 2: Distribution of groundwater potential in the Cheliff basin (2020 and 2050).

For 2050 (high scenario), the groundwater potential of the Cheliff region would be 255 Hm3 that is to say a reduction of 15% compared to the reference period 1961-1990 (Fig. 2 and 3). For the low scenario, the potential would be reduced by about 10% for 2050.

Summary: The reduction of rainfall over the past four decades has resulted in a decrease of the water volumes stored in dams. This situation has led to overexploitation of groundwater particularly for agriculture. In general, the evolution of groundwater potential was closely linked to rainfall fluctuations; these have also affected the management of these resources which had a negative impact on the groundwater level.

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