# Impacts of rapid population growth and climate change on domestic water demand in Setif Province, Algeria: Present and future supply challenges

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**Abstract**

Algeria has made recently tremendous efforts to cope with its water stress thanks to significant achievements in hydraulic infrastructure. Nevertheless, Setif Province remains one of Algerian provinces that are insufficiently supplied with drinking water. The demand may not be met in the short and long term by currently mobilized volumes due particularly to the rapid population growth, the climatic hazards.

Forecasting water demand is an effective tool that can be used to estimate future demand and deepen understanding of its short and long-term trends based on the selected variables. It concretely contributes to improve hydraulic infrastructure dimensioning, thus avoiding overuse of financial funds, and ensuring the sustainable management of natural water resources and their protection.

We focus in this paper firstly on analyzing population growth, water consumption evolution and implemented strategies to meet the demand in Setif Province since Independence Day. Then we expand our work to forecast future needs by 2030 through graphical simulation in order to show critical water shortages in light of rapid population growth and climate change hazards. We propose at the final stage adequate coping solutions that can help government to elaborate sustainable policies to protect water resources from overexploitation and depletion.

***Keywords****: Population growth impact, Domestic water demand, Climate change impact, Water stress, Future supply forecast.*

## 1. Introduction

Fresh water is the source of life and necessary element for human well-being and development, evolution of life was possible thanks to the presence of water [1], any limited access to it generates socio-economic instabilities and unexpected insecurity ramifications. According to the UN report 2019 «World Water Development Report 2019», water use has been increasing worldwide by about 1% per year since the 1980s, driven by a combination of population growth, socio-economic development and changing consumption patterns. It is also expected that the global water demand will continue increasing at a similar rate until 2050, accounting for an increase of 20% to 30% above the current level of water use, mainly due to rising demand in the industrial and domestic sectors. Over 2 billion people live in countries experiencing high water stress, and about 4 billion people experience severe water scarcity during at least one month of the year. Stress levels will continue to increase as demand for water grows and the effects of climate change intensify [2, 3].

Setif Province, with big capability of mass population attractiveness due to its geographical position within the heart of the eastern highlands part of the country and the nature of socio-economical activities prospering within it, is one of the Algerian cities that is experiencing water stress since many years, triggered by severe cyclic droughts due to climatological conditions and exacerbated by the rapid population growth, which resulted in increasing the risk of depletion of the water resources to meet the ever increasing demand and put more pressures on them.

In addition to water resources scarcity, overexploitation, climatic factors, production capacity limitation, supply networks degradation and the financial funds lack for new projects, there are other constraints that worsen situation and limits household water supplies, like pollution hazards that threaten both ground and surface waters and water wastage through the non-sustainable management and use,

especially within such an arid region classified with the driest countries in the world [4, 5]. Algerian provincial authorities and central government leaders have been felt the crisis magnitude and immediately adopted strategic measures mainly based on launching new infrastructure projects, dams and desalination plants to meet the increasing domestic water demand [6-8], realisation of wastewater plants and promoting treated water reuse in order to fight against pollution hazards and protect natural resources [4].

The government has been also focusing on elaborating efficient supply policy that integrates resources saving through controlling the household water use and consumption [9]. Those efforts have contributed to reducing water shortages but the ultimate goal to keep offer pacing with demand was not reached as many parts of the province still facing acute frequent shortages. In this paper we will review domestic water in Setif Province since the independence, then we forecast future situation up to 2030. We start by exposing the demographic growth since1962, we give a historic overview about domestic water in Setif Province, its achievement and the different steps that passed by, we will calculate future water needs and graphically simulate the situation by 2030, then we discuss the results and propose appropriate solutions.

## 2. Demographic growth

Setif Province is located about 300 km to the South East of the capital Algiers and covers an area of 6,549 km². It was formerly attached to the province of Constantine [10], and then emerged from the administrative division of 1974. Setif Province is blessed with numerous geographic, historical and cultural particularities which offer real development assets and grant it the great population attractiveness especially for those who are seeking better living standards. After independence in 1962, Setif Province has gradually expanded especially with the first three-year plan (1967-1970), housing construction programs planned during the period (1970-1986), then with property development projects (1986-2000) in order to receive the ever increasing population which continues to happen to the present day [11]. Figure 1 shows population level and growth rate for Setif Province metro area (capital of the province) from 1950 to 2020 [12].

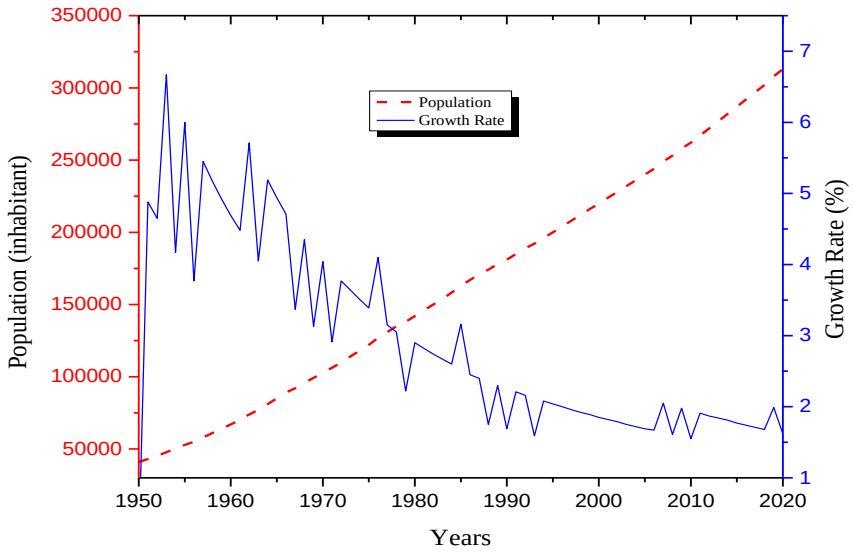

Figure 1: Population growth in the capital city of Setif Province, Algeria (1950-2030) [12]

Setif Province as whole witnessed very high growth rates in the early stages of independence, reaching its peak of 3.81% in the period 1977-1987, and then started to decline gradually until it reached its lowest level in the last census of 2008 (1.25%) where the number of population almost tripled as shown in Table 1.

Table 1: Population growth in the Setif Province (1950-2030) [13, 14]

| | 1962 - 1977 | 1987 | 1998 | 2008 | 2020 |
|---|---|---|---|---|---|
| Population | 686600 | 1000694 | 1311413 | 1482336 | 1897434 |
| Growth ratio | 2.95 | 3.81 | 2.43 | 1.25 | 2.03 |

During that period of time, the population growth of the province has changed a lot due to many reasons especially socio-economic conditions, inner and outer immigration, in addition to the loss of great parts of residents as a result of the administrative division change that was in 1974 and 1984, a several municipalities have been separated from the province and transferred their inhabitants to new ones [13]. The map in Figure 2 below shows the change of administrative boundaries of Setif Province to present day.

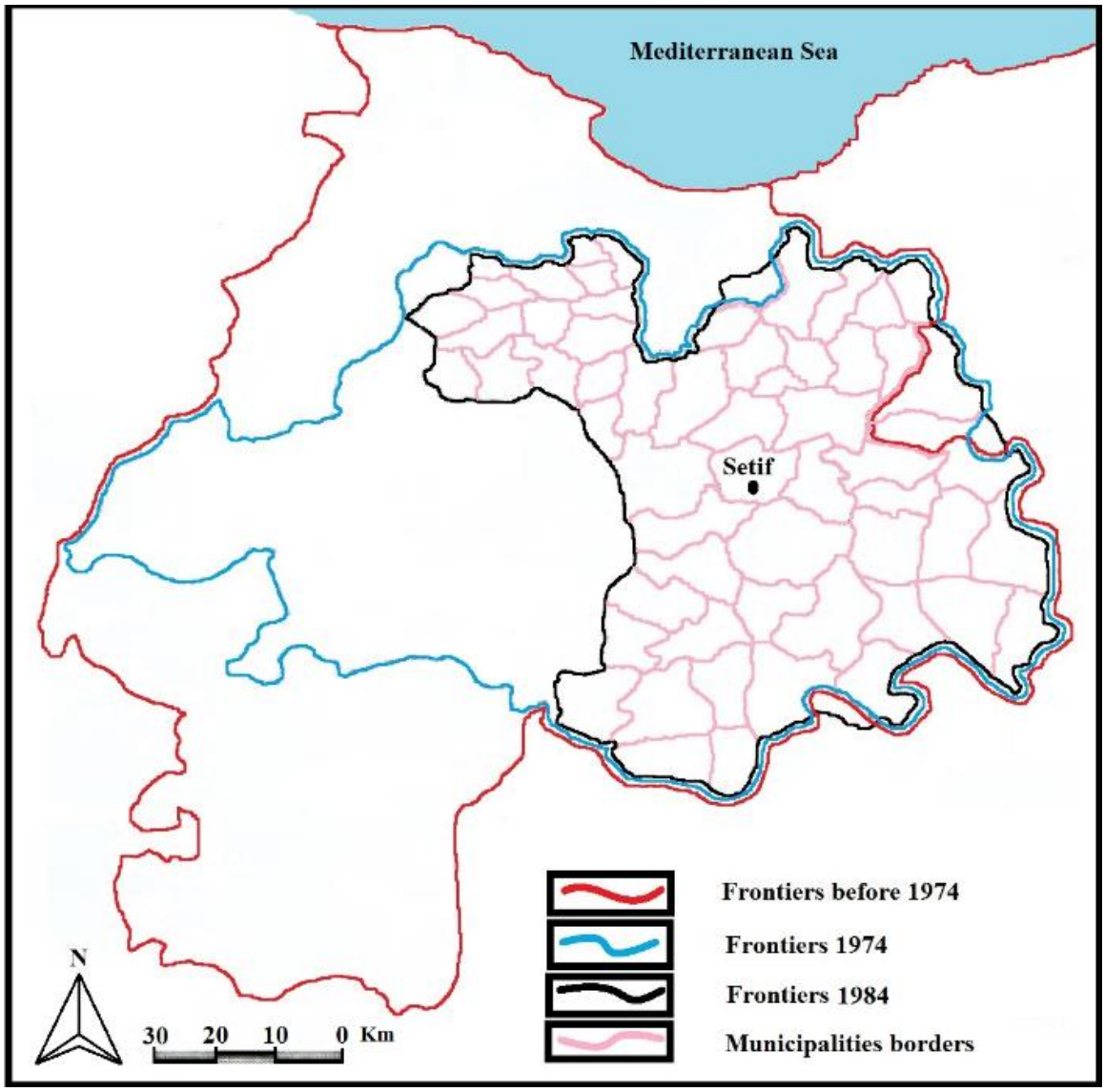


Figure 2: Provincial administrative boundaries reorganization of Setif Province, Algeria from 1962 to 2020 [14]

### 3. Historical overview of domestic water in Setif Province since independence

After Independence Day (1962), the whole country inherited the same difficult socio-economic conditions from the colonial era. Setif Province was not an exception, although that fact, the water resource was largely sufficient to satisfy the demand of the residents, they were supplied from the conventional waters of little abundant surface sources spread on the territories of the province, but the great part comes from underground origins (wells, boreholes) [15]. This situation didn't last longer to be turned upside down due to pressure on those resources, the main reasons were essentially the population growth and water wastage behaviour that appeared among consumers since water was ceded to them at very symbolic prices (Algerian Dinars per cubic meter, DZD/$m^3$) as shows Figure

3, also the absence of any governmental policy or strategy for mobilization of resources and efficiently distribution of domestic waters has exacerbated rapidly that issues.

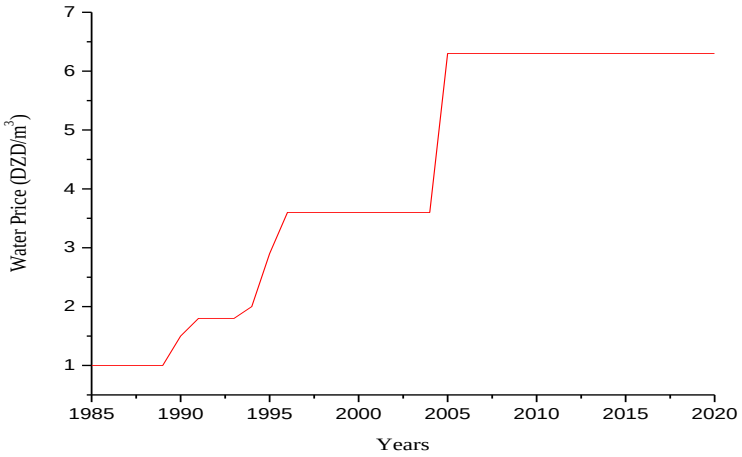


Figure 3: Water price evolution in Setif from 1985 to 2020[1] [9]

The water shortages have been emerged by1976 in Setif Province and their frequency gradually increased the same as in other provinces at national scale. The water demand of ever growing population has become a challenge to be met at that time by the same resources because of the absence of new water mobilization projects. The resources became insufficient and the risk of their depletion increased, especially if we know that a great part of the supply was ensured by underground aquifers which they were exhausted much faster than being replenished. The government tried to set an end to that period of indifference and recklessness by creating on 21st June, 1980 what was called at that time Ministry of Hydraulics (Decree n° 80-173), in hope to reorganize the drinking water and sanitation sector and find solutions for the current issues [16].

As a result, the first strategy of domestic water management and rationing was adopted by 1981, which has opted to heavy investment in water transfer infrastructures and the building of dams as the main vector of water sector development, they allow mobilizing far resources and increasing the capacity of both storage and supply. The central government also published the first law on water n° 83-17 on July 16th, 1983, and created a new company on 1985 called ANBT (decree n° 85-163) for managing water transfers and dams at the national level.

The actions taken by the government had a positive reflection on the local development in the province and the water projects contributed notably to increase water supply for the residents but just for a short period of time. Water allocation disparities, supply disruption and shortages have strongly re-emerged in many municipalities of the province during the period of instability that the country has experienced between 1991 and 2000. It was also combined with a severe financial crisis caused by the drops of hydrocarbons prices that limited the financial revenues and slowed down the realization of several water infrastructure projects and interrupted all plans [17]. This has led to worsen drinking water supply not only in the province of Setif Province but rather in whole country.

By 1992, drinking water supply plan has been set and became necessary to manage water endowments for municipalities, which some among them they can be supplied once every two days or even every three or four days for just few hours per day [18]. By 1998, despite the continuously population growth, allocated resources did not show the same trends and all municipalities were supplied equitably which set a limited daily water endowment to 91 L/(capita·d). The Table 2 below shows daily water allocation in cubic meter for every municipally by 1998.

Table 2: Water endowment in the municipalities of Setif Province by 1998 [14, 19]

| Municipality | Supply ($m^3$/d) | Municipality | Supply ($m^3$/d) | Municipality | Supply ($m^3$/d) | Municipality | Supply ($m^3$/d) |
|---|---|---|---|---|---|---|---|
| Setif Capital | 21767 | Ksar El Abtal | 1881 | Belaa | 1328 | Guidjel | 2538 |
| Aïn Abessa | 1370 | Amoucha | 1794 | Tachouda | 704 | Guenzet | 416 |
| Aïn Arnat | 2742 | Oued El Barad | 274 | Aït Naoual Mezada | 597 | Harbil | 332 |
| Mezloug | 1217 | Tizi N'Bechar | 1703 | Aït Tizi | 715 | Draa Kebila | 1433 |
| Ouricia | 1320 | Serdj El Ghoul | 1005 | Bouandas | 1416 | Hammam Guergour | 1301 |

[1] Water Price is evaluated in Algerian Dinar DZD, 1 DZD = 0.057 Chinese Yuan = 0.0073 Euro = 0.008 US Dollar.

| Municipality | Supply ($m^3/d$) | Municipality | Supply ($m^3/d$) | Municipality | Supply ($m^3/d$) | Municipality | Supply ($m^3/d$) |
|---|---|---|---|---|---|---|---|
| Aïn Azel | 3738 | Babor | 1678 | Bousselam | 1483 | Taya | 850 |
| Aïn Lahdjar | 2718 | Aïn Sebt | 1300 | Beni Hocine | 929 | Tella | 621 |
| Beidha Bordj | 2844 | Beni Aziz | 1630 | Bougaa | 2587 | Hammam Soukhna | 1045 |
| Bir Haddada | 1659 | Maaouia | 817 | Aïn Roua | 1042 | Talaifacene | 1598 |
| Aïn El Kebira | 2922 | Beni Ourtilane | 1089 | Beni Fouda | 1536 | Maoklane | 1383 |
| Ouled Addouane | 728 | Beni Chebana | 1414 | Djemila | 2345 | Boutaleb | 758 |
| Dehamcha | 884 | Aïn Legraj | 1556 | Bazer Sakhra | 2328 | Hamma | 1124 |
| Aïn Oulmene | 5447 | Beni Mouhli | 790 | El Eulma | 10926 | Ouled Tebben | 863 |
| Guellal | 1810 | El Ouldja | 812 | Guelta Zerka | 1284 | Rasfa | 1276 |
| Ouled Si Ahmed | 860 | Bir El Arch | 1911 | Ouled Sabor | 910 | Salah Bey | 1989 |
| Total for Setif Province: 119338 $m^3/d$ | | | | | | | |

After the black decade the political stability has been re-established again by the end of 1999. The socio-economic development train, especially water sector, have been pushed forward by the new government projects and sustained by the oil and gas prices boom. Water sector and all kind of issues related to it (water policy, drinking water supply, wastewater treatment and reuse, building dams and all others water infrastructure projects) have become the main missions of the newly created Ministry of Water Resources on 2000 (executive decree n° 2000-325). A year later two public companies, ADE (executive decree n° 01-101) charged of drinking water supply and ONA (executive decree n° 01-102) charged of water sanitation, were created, and their affiliates were established throughout nearly the whole national territory to ensure the implementation of the national drinking water policy through the management of production operations, transport, treatment, storage, supply and distribution of water, water sanitation, as well as the renewal and development of related infrastructures.

In order to breathe new life into the water sector, new water law (n° 05-12) was published on 2005 and the national water plan on 2010, also 3 economic programs of revival have been adopted successively since 2001 as the public decision-makers wanted to take benefits from the oil windfall to improve living conditions [17]: The economic recovery support plan PSRE (2001-2004), the complementary growth support plan PCSC (2005-2009) and the five-year development plan (2010-2014). Setif Province benefited from that to achieve some water projects (Figure 4), mainly:
a) The West supply System from Ighil-Emda dam to Mahouane dam (122 $Mm^3/y$): 31 $Mm^3$ for the drinking water supply of the capital city of Setif and neighboring municipalities and 91 $Mm^3$ for the irrigation of 13,000 ha in the High Plains of Setif [20];

b) The East supply System from Erraguène dam to Tabellout dam, then to the newly built dam Draa Diss (191 $Mm^3/y$): 38 $Mm^3$ for the drinking water supply of the city of El Eulma and neighboring municipalities and 153 $Mm^3$ for the irrigation of 30,000 ha [20].

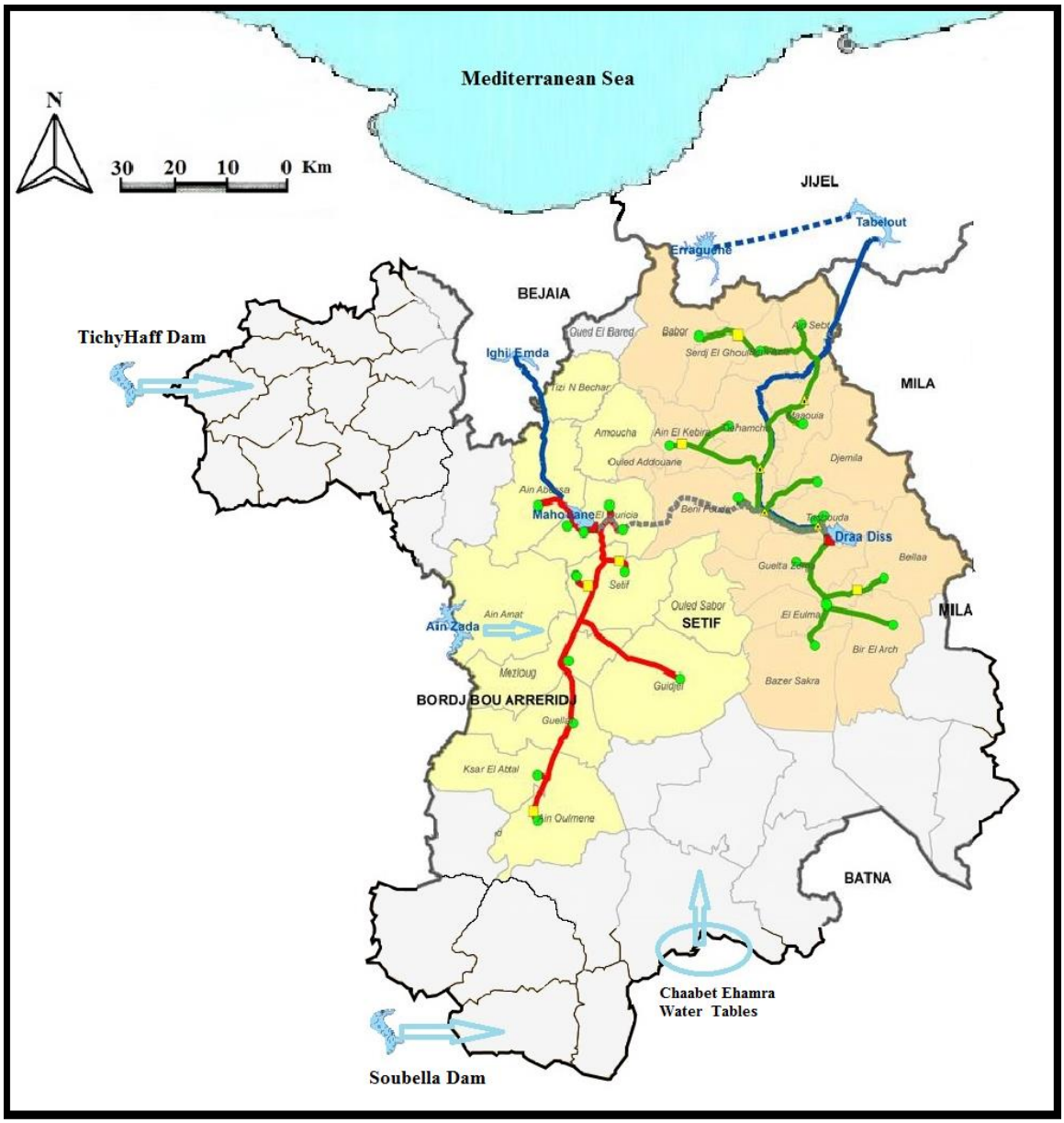


Figure 4: Main water supply systems in Setif Province [21-23],

Implementation of this strategy has contributed to restoring and bring the water sector back again on the right railroad thanks to that infrastructure projects that have been revived. They contributed to transfer huge volumes of waters from dams located in neighbouring provinces to other dams newly constructed within the province. The daily water endowment has been increased consequently in many municipalities (Figure 5).

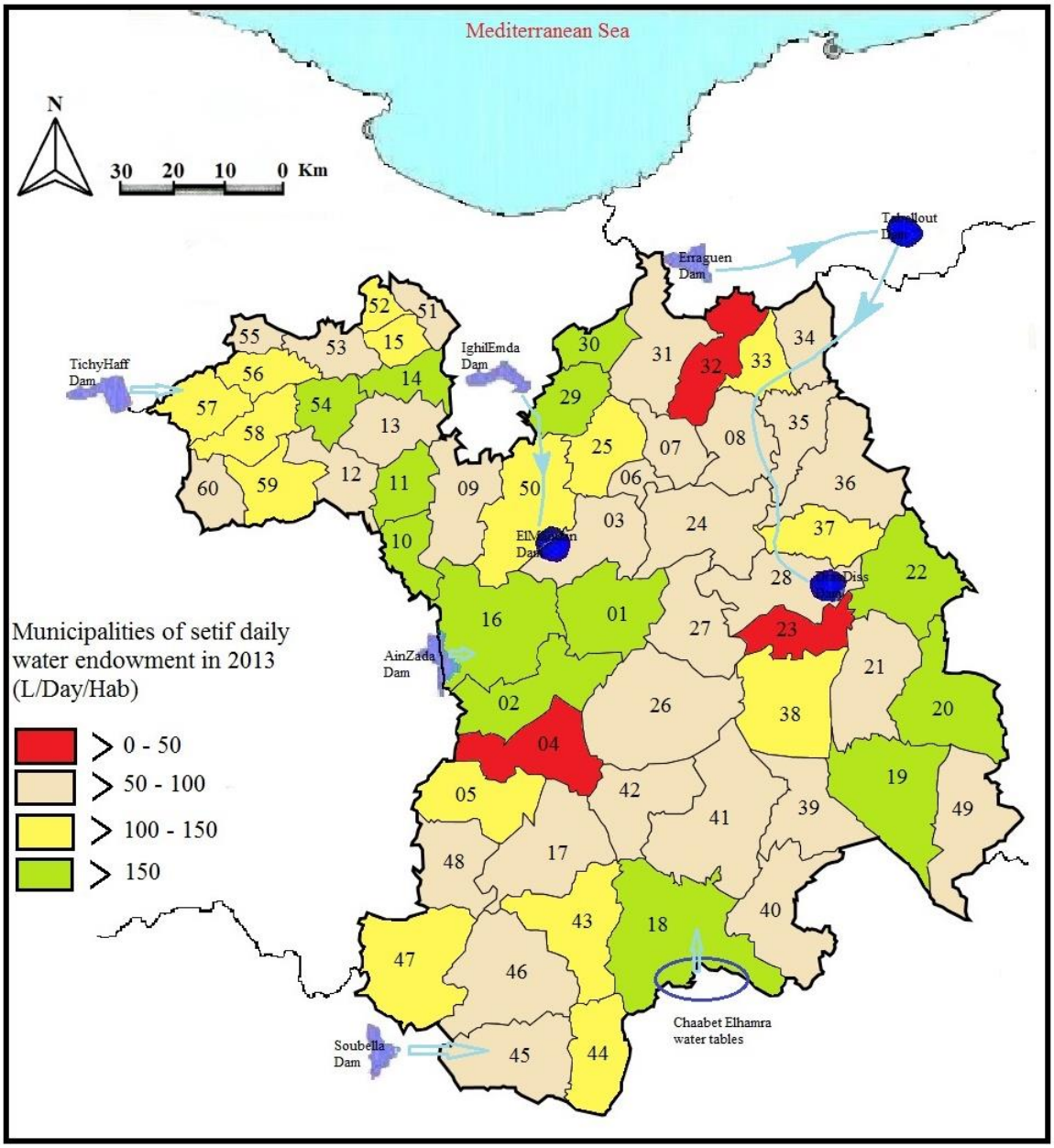


Figure 5: Water endowment in the municipalities of Setif Province by 2013 [19].

The red color shows that within those municipalities the daily water endowment per capita is extremely low, it is around only 50 L/(capita·d), while the green color indicates that demand in those regions is almost satisfied. To balance the situation between regions supply plans to provide residents with water day by day or even one day after two days have been adopted, these plans are still used until the present day. However, governmental implemented strategy after instability period and accomplishment of water interrupted projects have contributed to increase gradually the daily water endowment for many of those municipalities up to admitted standards but not all, the average daily water endowment for the province is shown in the below (Figure 6).


Figure 6: Annual evolution of daily water endowment in Setif Province 1998-2020 [13, 14, 19]

## 4. Future trends

Sustainable access to water resources is a major concern for local authorities of Setif Province as well as for central government. Those worries are justified by high costs for achieving new projects in addition mainly to the lack of mobilizable resources (Figure 7) and their vulnerability to climate conditions (precipitations and cyclic droughts) as it is shown below in the Figures 8 and 9.

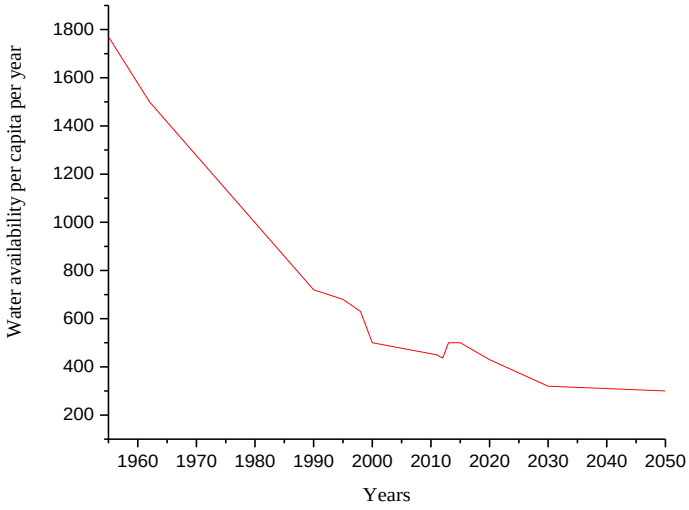


Figure 7: Evolution of the Annual Water availability per capita in Algeria (1955-2050) [9, 24]

There is a big an uneven spatial distribution of surface and groundwater in Algeria from one hydrographic region to another [25], Setif Province belongs to Algiers-Hodna-Soummam hydrographic basin where 0.74 billion $m^3$ of underground water and 3.4 billion $m^3$ of surface waters are concentrated. Within the limits of the province there is 785 $Mm^3$ (615 $Mm^3$ for surface and 170 $Mm^3$ for groundwater), but those potentialities are not well used which necessitates improving exploitation and building dams to block waters, especially in the northern regions. As Figure 7 shows, the availability of water in our country for each inhabitant is estimated at 1500 $m^3/y$ on 1962, it decreased sharply by 1990 to less than half and continued decrease until reached 430 $m^3/y$ by 2020, and it is estimated to be only 320 by 2030.

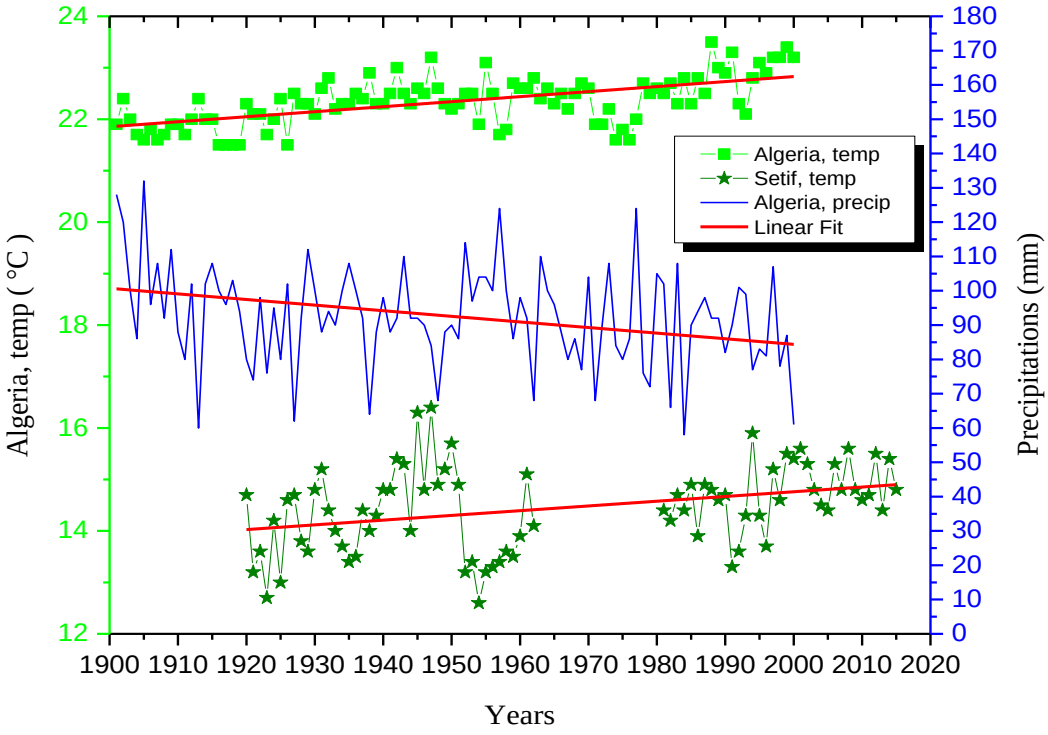


Figure 8: Annual temperature and precipitation variation in Setif Province by 2019[2] [26-28]

The average temperature in Setif Province is 14.4 °C and the average rainfall is 403.8 mm. For comparison, in Tokyo, the average annual temperature is 15.9 °C and the average precipitation is 1525.6 mm. Algeria as whole belongs to the driest region in the world [5, 29] and it falls under the water scarcity threshold internationally defined by UNDP and the World Bank with 1000 $m^3$/(capita·y) [30]. From Figure 8 we can notice clearly that the temperature in Setif Province and whole Algerian territory is increasing while the precipitations are decreasing in the same time. The assessment of the two graphs reveals a drop of 55mm in the annual rainfall from 1981 to 2015 compared with that of 1920 to 1962, and 0.48°C of increase in the annual averages of temperatures [27]. This warming shift would not affect only the seasonal patterns but rather the annual trend that can be moved towards severe arid weather. Indeed, if worldwide the rise was 0.74 °C, that region can reach even more than double. The impact on water resources is estimated about 12% [26, 28].

The phenomenon of climate change in Setif Province specifically and Algeria generally is an issue that rose up real challenges, particularly in terms of water availability where the impact is highly felt. Experts predict at the medium term an increase in temperature of 2 °C would result in 10 to 15% rainfall reduction and increasing frequency of more intensive droughts [31]. The Saharan regions and the highlands where Setif Province is located they occupy 93% of the whole Algerian territory, but receive only 10% of the total flow that is estimated of 12.4 billion $m^3$. The 81 exploited dams in Algeria are used to ensure 35% of water supply by storing 8 billion $m^3$ of that flow, which is nearly the mobilizable potential.

The frequently drought and climatic fluctuations over the past three decades have accentuated the phenomenon of soil degradation, thus caused desertification of most vulnerable agricultural areas used to ensure food security such as steppes and high plains. They have become more exposed to degradation and erosion by intensive flows which in turn reduce the storage capacity of dams by 2 to 3% each year due to siltation [32]. Currently, more than 50 dams are affected by siltation (with 32 × 106 $m^3$/y), and they are also subjected to leaks which affect around twenty dams (with 40 × 106 $m^3$/y), and evaporation (around 250 × 106 $m^3$/y) [33, 34].

The persistent Intensive drought (Figure 9) since the early 1970s reduced rainfall by 30% (50% during the year 2001- 2002), which impacted negatively groundwater reserves of major aquifers in the north as watercourses flow regimes changed and declined. Also,

[2] Some temperature data for Setif Province from 1962 to 1981 are missing due to the interruption of records after the country gained its independence on 1962.

the groundwater aquifers used to ensure up to 63 % of supply are already 90% overexploited or even more in some regions in the northern part of the country. The mineralization ratio increased in many of those aquifers due to the droughts coupled with the overexploitation [35].

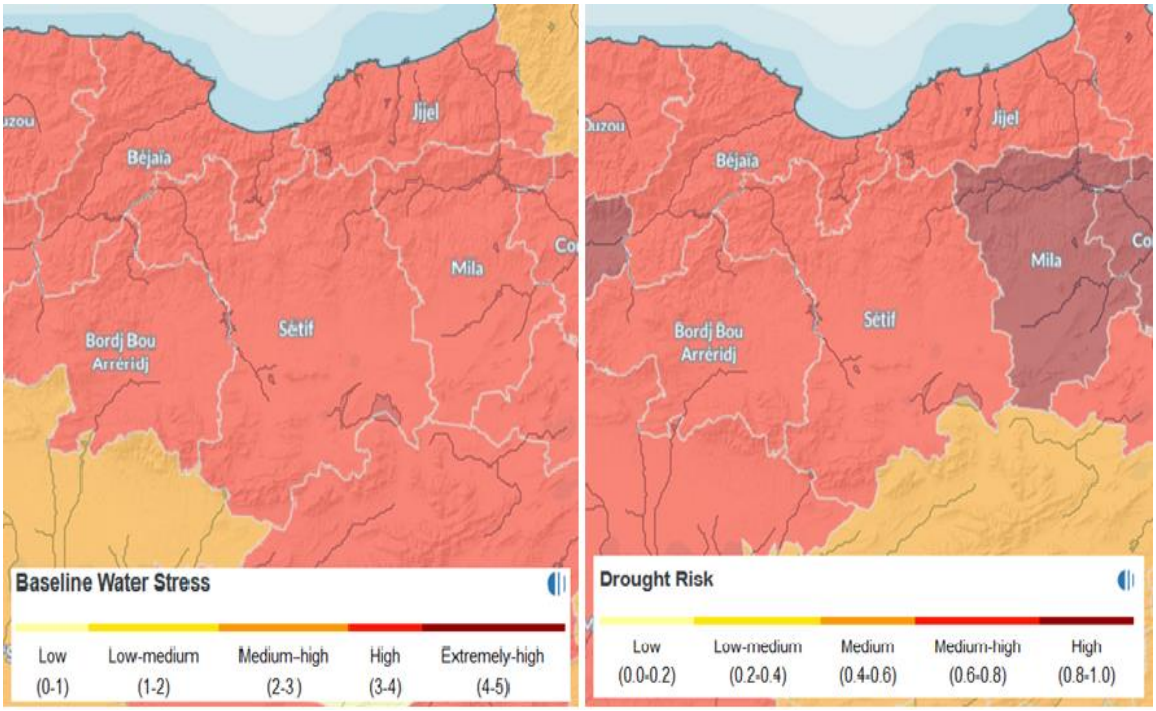


Figure 9: Baseline water stress and drought risk in Setif Province [29].

The drinking water needs increased in the province of Setif Province with the population's growth up. Comparing to the national average standard that allocates 186 L/(capita·d), the province was suffering from a flagrant deficit in 1998 as it was providing only 91 L/(capita·d) for its inhabitants, and thus an enormous amounts are required to quench the residents thirst. The situation continued until 2005 where the supplies started to be improved but the gap persisted until 2015 and even to present day (Figure 10).

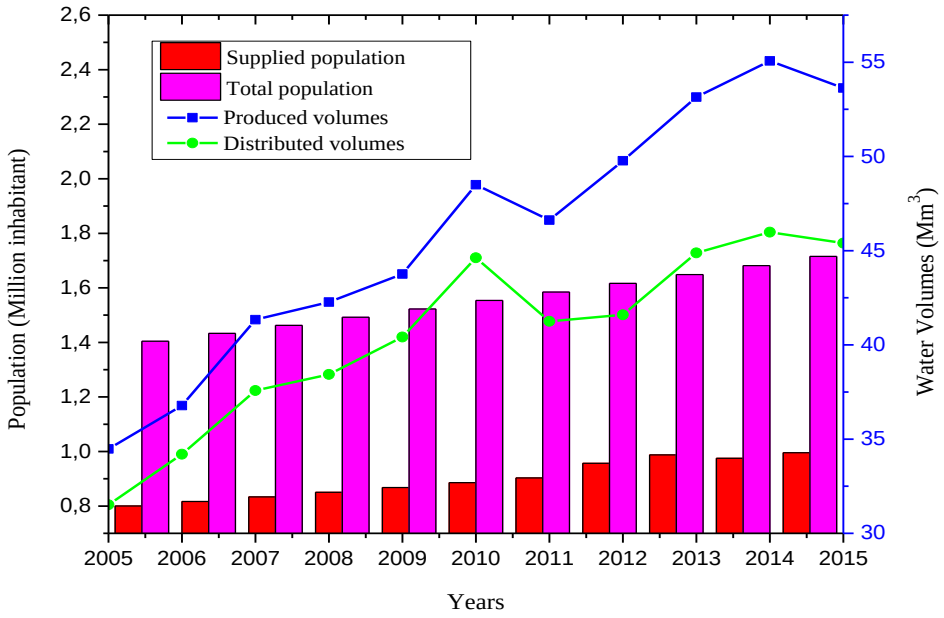


Figure 10: Drinking water supply vs population growth in Setif Province (2005-2015) [19].

Despite the reasons that led to that fact, reaching satisfactory level in terms of drinking water supply does not seem easy to achieve in the nearest horizon due to the challenges facing it. Simulation of the future demand of water is very important tool for the best water resources management and decision making, in the following part we will simulate future water needs against population growth up in Setif Province using GIS mapping software to show drinking water supply critical situations under a climate change risks, and then we suggest solutions to avoid future disruptions and shortages.

We will perform our simulation up to 2030, for this reason we need annual population growth coefficient and population statistics for every municipality to calculate firstly the annual total population using the following equation:

$$Pn = P0 \times (1 + \alpha)^n \quad (1)$$

where Pn is the future population value for the year n, P0 is the initial population for the year (n-1) and α is the annual growth rate.

We need also daily endowment (d) for each province to finally calculate the future water needs for the corresponding population at any future year using the following equation

$$Qn = Pn \times d \times 0{,}001 \quad (2)$$

where Qn is the daily average water needs in ($m^3$/d) for the corresponding calculated population Pn at a given future year n and d is statistical data of the daily water allocation (L/d). (For our calculations we take α = 1.8% and d = 137 L/(capita·d) as a latest values). The results of the application of the equation (1) and equation (2) are given in Table 3.

Table 3: Evolution of the population and water needs in Setif Province until 2030 [36].

| Code | Municipality | Pop 1998 | Pop 2008 | Pop 2020 | Q2020 ($m^3$/d) | Needs ($m^3$/d) | Deficit ($m^3$/d) | Pop 2030 | Q2030 ($m^3$/d) | Needs ($m^3$/d) | Deficit ($m^3$/d) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Setif Capital | 239195 | 288461 | 367344 | 50326 | 68693 | -18367 | 439087 | 60155 | 82109 | -21954 |
| 2 | Mezloug | 13373 | 16976 | 21618 | 2962 | 4043 | -1081 | 25840 | 3540 | 4832 | -1292 |
| 3 | Ouricia | 14507 | 18087 | 23033 | 3156 | 4307 | -1152 | 27532 | 3772 | 5148 | -1377 |
| 4 | Guellal | 19886 | 21385 | 27233 | 3731 | 5093 | -1362 | 32552 | 4460 | 6087 | -1628 |
| 5 | Ksar El Abtal | 20667 | 23833 | 30350 | 4158 | 5676 | -1518 | 36278 | 4970 | 6784 | -1814 |
| 6 | Ouled Addouane | 7998 | 9613 | 12242 | 1677 | 2289 | -612 | 14633 | 2005 | 2736 | -732 |
| 7 | Aïn El Kebira | 32113 | 36295 | 46220 | 6332 | 8643 | -2311 | 55247 | 7569 | 10331 | -2762 |
| 8 | Dehamcha | 9709 | 9141 | 11641 | 1595 | 2177 | -582 | 13914 | 1906 | 2602 | -696 |
| 9 | Aïn Roua | 11454 | 11499 | 14644 | 2006 | 2738 | -732 | 17503 | 2398 | 3273 | -875 |
| 10 | Beni Hocine | 10210 | 11220 | 14288 | 1957 | 2672 | -714 | 17079 | 2340 | 3194 | -854 |
| 11 | Bougaa | 28431 | 30987 | 39461 | 5406 | 7379 | -1973 | 47168 | 6462 | 8820 | -2358 |
| 12 | Hammam Guergour | 14295 | 15853 | 20188 | 2766 | 3775 | -1009 | 24131 | 3306 | 4512 | -1207 |
| 13 | Maoklane | 15201 | 15715 | 20012 | 2742 | 3742 | -1001 | 23921 | 3277 | 4473 | -1196 |
| 14 | Talaifacene | 17555 | 20337 | 25898 | 3548 | 4843 | -1295 | 30956 | 4241 | 5789 | -1548 |
| 15 | Bouandas | 15556 | 16966 | 21606 | 2960 | 4040 | -1080 | 25825 | 3538 | 4829 | -1291 |
| 16 | Aïn Arnat | 30129 | 43551 | 55461 | 7598 | 10371 | -2773 | 66292 | 9082 | 12397 | -3315 |
| 17 | Aïn Oulmene | 59855 | 73831 | 94021 | 12881 | 17582 | -4701 | 112384 | 15397 | 21016 | -5619 |
| 18 | Aïn Azel | 41073 | 48487 | 61746 | 8459 | 11547 | -3087 | 73806 | 10111 | 13802 | -3690 |
| 19 | Hammam Soukhna | 11481 | 13439 | 17114 | 2345 | 3200 | -856 | 20456 | 2803 | 3825 | -1023 |
| 20 | El Ouldja | 8921 | 8592 | 10942 | 1499 | 2046 | -547 | 13079 | 1792 | 2446 | -654 |
| 21 | Bir El Arch | 21004 | 24995 | 31830 | 4361 | 5952 | -1592 | 38047 | 5212 | 7115 | -1902 |
| 22 | Belaa | 14593 | 14666 | 18677 | 2559 | 3493 | -934 | 22324 | 3058 | 4175 | -1116 |
| 23 | El Eulma | 120068 | 155038 | 197435 | 27049 | 36920 | -9872 | 235995 | 32331 | 44131 | -11800 |
| 24 | Beni Fouda | 16876 | 17667 | 22498 | 3082 | 4207 | -1125 | 26892 | 3684 | 5029 | -1345 |
| 25 | Amoucha | 19714 | 22767 | 28993 | 3972 | 5422 | -1450 | 34655 | 4748 | 6481 | -1733 |
| 26 | Guidjel | 27891 | 33685 | 42897 | 5877 | 8022 | -2145 | 51274 | 7025 | 9588 | -2564 |
| 27 | Ouled Sabor | 10005 | 12510 | 15931 | 2183 | 2979 | -797 | 19042 | 2609 | 3561 | -952 |
| 28 | Guelta Zerka | 14110 | 15472 | 19703 | 2699 | 3684 | -985 | 23551 | 3226 | 4404 | -1178 |
| 29 | Tizi N'Bechar | 18719 | 21086 | 26852 | 3679 | 5021 | -1343 | 32097 | 4397 | 6002 | -1605 |
| 30 | Oued El Barad | 3013 | 2333 | 2971 | 407 | 556 | -149 | 3551 | 487 | 664 | -178 |
| 31 | Babor | 18445 | 15762 | 20072 | 2750 | 3754 | -1004 | 23992 | 3287 | 4487 | -1200 |
| 32 | Serdj El Ghoul | 11044 | 9311 | 11857 | 1624 | 2217 | -593 | 14173 | 1942 | 2650 | -709 |
| 33 | Beni Aziz | 17913 | 19383 | 24684 | 3382 | 4616 | -1234 | 29504 | 4042 | 5517 | -1475 |
| 34 | Aïn Sebt | 14290 | 14798 | 18845 | 2582 | 3524 | -942 | 22525 | 3086 | 4212 | -1126 |
| 35 | Maaouia | 8976 | 7005 | 8921 | 1222 | 1668 | -446 | 10663 | 1461 | 1994 | -533 |
| 36 | Djemila | 25765 | 24145 | 30748 | 4212 | 5750 | -1537 | 36753 | 5035 | 6873 | -1838 |
| 37 | Tachouda | 7735 | 7578 | 9650 | 1322 | 1805 | -483 | 11535 | 1580 | 2157 | -577 |
| 38 | Bazer Sakhra | 25586 | 27996 | 35652 | 4884 | 6667 | -1783 | 42615 | 5838 | 7969 | -2131 |
| 39 | Tella | 6826 | 7562 | 9630 | 1319 | 1801 | -481 | 11511 | 1577 | 2152 | -576 |

| Code | Municipality | Pop 1998 | Pop 2008 | Pop 2020 | Q2020 ($m^3$/d) | Needs ($m^3$/d) | Deficit ($m^3$/d) | Pop 2030 | Q2030 ($m^3$/d) | Needs ($m^3$/d) | Deficit ($m^3$/d) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | Beidha Bordj | 31250 | 35276 | 44923 | 6154 | 8401 | -2246 | 53696 | 7356 | 10041 | -2685 |
| 41 | Aïn Lahdjar | 29871 | 34338 | 43728 | 5991 | 8177 | -2186 | 52268 | 7161 | 9774 | -2613 |
| 42 | Bir Haddada | 18233 | 20860 | 26564 | 3639 | 4968 | -1328 | 31753 | 4350 | 5938 | -1588 |
| 43 | Salah Bey | 21855 | 27175 | 34606 | 4741 | 6471 | -1730 | 41365 | 5667 | 7735 | -2068 |
| 44 | Hamma | 12353 | 13223 | 16839 | 2307 | 3149 | -842 | 20128 | 2757 | 3764 | -1006 |
| 45 | Boutaleb | 8328 | 9456 | 12042 | 1650 | 2252 | -602 | 14394 | 1972 | 2692 | -720 |
| 46 | Rasfa | 14025 | 16075 | 20471 | 2805 | 3828 | -1024 | 24469 | 3352 | 4576 | -1223 |
| 47 | Ouled Tebben | 9482 | 10385 | 13225 | 1812 | 2473 | -661 | 15808 | 2166 | 2956 | -790 |
| 48 | Ouled Si Ahmed | 9456 | 10238 | 13038 | 1786 | 2438 | -652 | 15584 | 2135 | 2914 | -779 |
| 49 | Taya | 9346 | 10302 | 13119 | 1797 | 2453 | -656 | 15681 | 2148 | 2932 | -784 |
| 50 | Aïn Abessa | 15058 | 16770 | 21356 | 2926 | 3994 | -1068 | 25527 | 3497 | 4774 | -1276 |
| 51 | Aït Tizi | 7859 | 6983 | 8893 | 1218 | 1663 | -445 | 10629 | 1456 | 1988 | -531 |
| 52 | Aït Naoual Mezada | 6562 | 5630 | 7170 | 982 | 1341 | -358 | 8570 | 1174 | 1603 | -428 |
| 53 | Bousselam | 16302 | 16095 | 20496 | 2808 | 3833 | -1025 | 24499 | 3356 | 4581 | -1225 |
| 54 | Draa Kebila | 15748 | 14977 | 19073 | 2613 | 3567 | -954 | 22798 | 3123 | 4263 | -1140 |
| 55 | Beni Mouhli | 8678 | 8521 | 10851 | 1487 | 2029 | -543 | 12970 | 1777 | 2425 | -649 |
| 56 | Beni Chebana | 15534 | 13174 | 16777 | 2298 | 3137 | -839 | 20053 | 2747 | 3750 | -1003 |
| 57 | Beni Ourtilane | 11969 | 10591 | 13487 | 1848 | 2522 | -674 | 16121 | 2209 | 3015 | -806 |
| 58 | Aïn Legraj | 17100 | 14668 | 18679 | 2559 | 3493 | -934 | 22327 | 3059 | 4175 | -1116 |
| 59 | Harbil | 3650 | 3675 | 4680 | 641 | 875 | -234 | 5594 | 766 | 1046 | -280 |
| 60 | Guenzet | 4571 | 3541 | 4509 | 618 | 843 | -225 | 5390 | 738 | 1008 | -270 |
| | Total for Setif Province | 1311412 | 1489980 | 1897434 | 259948 | 354820 | -94872 | 2268007 | 310717 | 424117 | -113400 |

## 5. Discussions

From Table 3, we can see that total population in Setif Province will reach 2268007habitant by 2030, with an increase of19.53% comparing to 2020. The distribution of population is shown on maps (Figures 11). As for water endowment, the province is globally supplied with 259948 $m^3/d$, while in the fact it needs 354820 $m^3/d$, it is suffering from a deficit of 94872 $m^3/d$ to reach the national average of daily water endowment which is187 L/(capita·d). This deficit will be further aggravated by 2030, it will grow to 113400$m^3/d$ as the needs according to the same national average daily endowment will reach 424117 $m^3/d$, but supplies will be limited to 310717 $m^3/d$ for whole province.

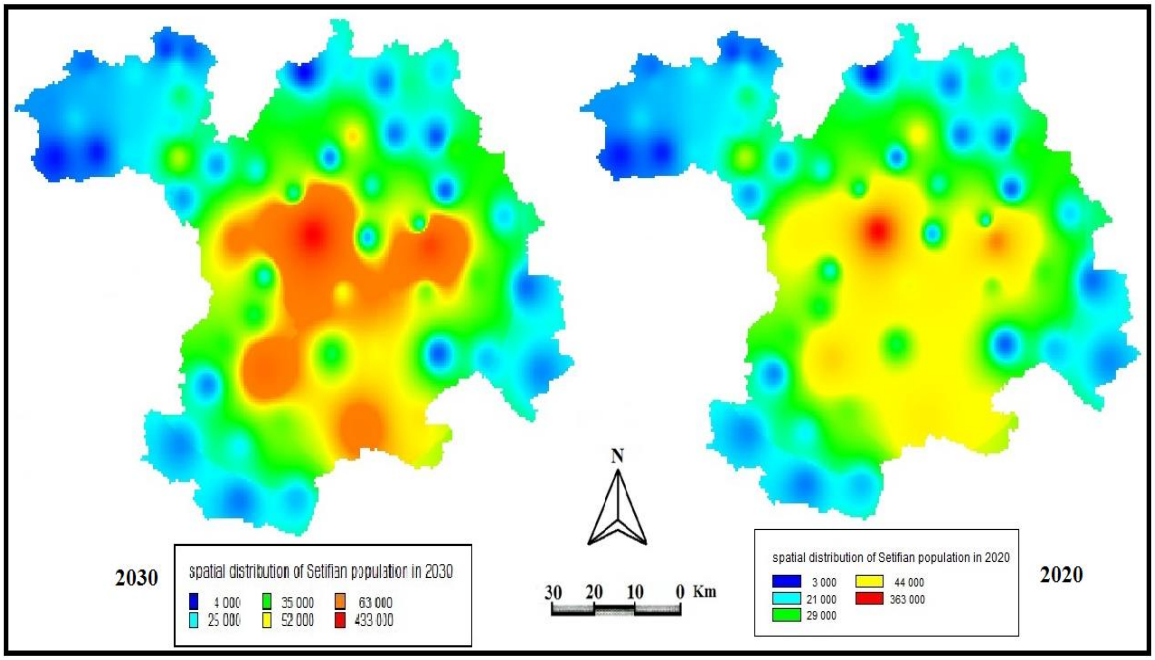


Figure 11: Spatial distribution of Setifian population by 2020

Those two maps illustrating the regions of high population growth showed in red color and concentrated mainly around the center, which represents the capital of the province and the neighbouring big agglomerations. As we move far the color turns to green indicating less growth factor, while the blue shows more less population growth.

Despite the fact that Setif Province is located in the northern part of the country which benefits from higher water potentialities comparing to the southern desert part, but it stills suffering from water insufficiency and unequal supply as show the two maps below (Figure 12).

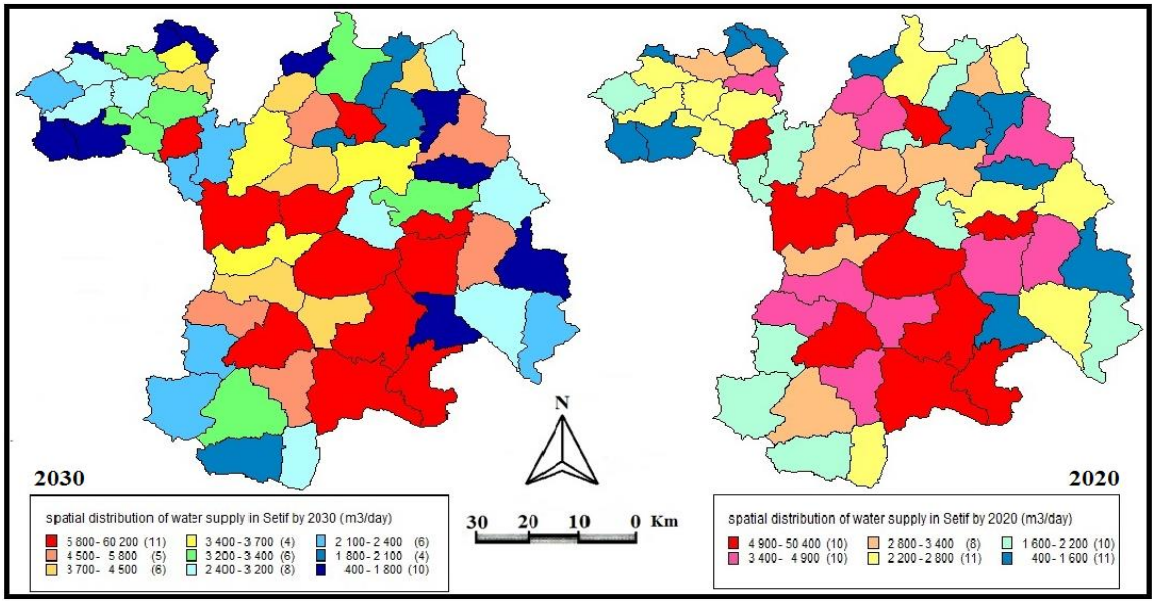


Figure 12: Spatial distribution of water supply in Setif Province by 2020

By 2020, the entire province is supplied with 137 $m^3$/(capita·d) less than the national average standard (187 $m^3$/(capita·d)), but as shows the maps (Figure 12) this factor is very different from region to another, about 10 municipalities shown with red color are located among very low supplied category, this number will increase to 11 by 2030. Also the number of municipalities slightly satisfied with water supply will decrease from 11 by 2020 to only 10 by 2030, the rest 50 (over 60 the total number of Setif's municipalities) show very high contrast in terms of drinking water supply. The supply (offer by 2030) which must be at least at the same level of the national standard is compared to the demand (2030) and is shown on the map below (Figure 13).

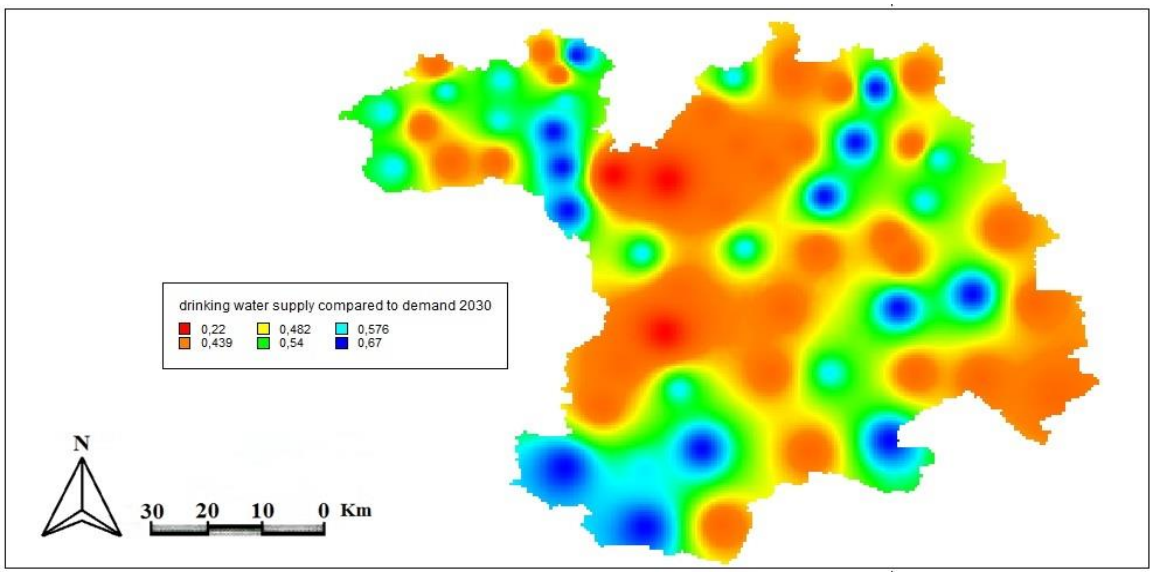


Figure 13: Spatial distribution of water supply/demand in Setif Province by 2030

As we can notice from the map (Figure 13) the supply/demand ratio by 2030 is far smaller than ``1`` for all municipalities, this means that the offer is covering just a portion from the real needs of residents which is the case of whole province. The red color indicates more severe shortages and is dominating great parts of the map, the regions falling under this color are supplied just with about quarter of their needs, while the fewer regions painted blue are experiencing a less severe shortages and their needs are satisfied up to 75 %.

## 6. Challenges

With no change of actual water resources potentialities and production capacities, the projection of domestic water in Setif Province shows that by 2030 more serious shortages problems will be encountered to satisfy the increased water needs driven by population growth and the negative impacts of climatic changes on resources. The ramifications would not be related only to the depletion of current available resources but the well-being and socio-economic development would be also affected. Since the appearance of water shortages and supply disruptions the Setifians have been protesting in many regions of the province to urge local authorities for finding solutions to reduce the magnitude of that chronic dilemma and to make drinking water more available for them.

Realisation of new large-scale projects for mobilizing more water resources requires big investments that generate environmental, social and economic costs, and this can be beyond the government capacities, especially, when oil and gas prices fall down. The Algerian economy is about totally depends on their revenues, and this would greatly affect the water sector in the country and all services related to it. In addition to that, many other factors can heavily threaten the resources in the province as well as in the entire country, among those challenges we find.

The rapid population growth put huge continuous pressures on resources, and as a result the high demand reduces water quality and exposes resources to more depletion vulnerably especially non-renewable ones due to the overexploitation.

All kind of pollution problems (solid or liquid) discharged directly into the environment will contribute to water quality degradation and decrease consequently surface and groundwater potentialities in the future.

Setif Province is located in the world driest region and characterized by semi-arid climate which make it highly vulnerable to water stress. The high temperatures increase evapo-transpirations and droughts intensity, and the low precipitations due to climate change reduce the surface flows that are necessary for the replenishment of both surface water bodies and underground aquifers. The siltation of dams is also another phenomenon occurs due to corrosion and results in reduction of stored volumes which can affect much more water mobilization capacities and therefore the supply.

Setif Province is supplied at the expense of its neighbouring as a great part of Setifians water needs brought to them from dams located in bordering provinces through huge pipes. Supply from remote regions generates high costs and promotes losses through the poor connections and obsolete distribution networks. The percentage of those leakages in Setif Province is estimated at 30% in addition to waters of theft scourge through bypassing metering systems. Wastage is also another aspect of water sector issues in the province which is turned up due to the low water price subsidized by government up to 70% to make it affordable for low-income consumers (Table 4).

Table 4: Water price in Setif Province [19].

| Consumption | 0-25 $m^3$/trimester | 25-55 $m^3$/trimester | 55-82 $m^3$/trimester | > 82 $m^3$/trimester |
|---|---|---|---|---|
| Price (DZD/$m^3$) | 6.3 | 20.48 | 34.65 | 40.95 |

## 7. Recommendations

To face this situation and meeting the rapid increasing water demand in this province at the medium and long range a management plan must be implemented to reduce the effects of these issues, and different measures have to be taken to diversify the resources and ensure their sustainability, such as:

Developing infrastructures to collect and increasing storage capacities is a necessity as well as the interconnection of dams to ensure equilibrium distribution between regions;

Developing and adopting the best strategy and sustainable integrated management techniques to rationalize consumption and supply, to increase water potentialities and ensure resources sustainability;

Resorting to the non-conventional resources such as treated waters reuse is an important alternative solution for protecting the environment and increasing available volumes for especially agricultural and industrial purposes. Also desalinated waters are regarded as a good option to quench the resident thirst despite the relatively high costs compared to underground and surface water withdrawals;

Conducting serious studies to better understand demand patterns and determinants for best future planning and infrastructures dimensioning;

Water price can be an option to control used volumes among large consumers once adopting progressive scale with a large gap between pricing classes, henceforth saving wasted quantities due to the overuse. Also raising public awareness about water scarcity will serve the same goals;

Seasonal precipitations result in important surface flows that are lost mainly through streams that bring them back to the sea. The artificial aquifers recharge techniques can take benefits from that to renew, increase and even improve underground waters quality by dilution its salinity. Also promoting the use of the rain harvesting systems will contribute to collect enormous amounts that can serve many domestic purposes especially if it is jointly used with efficient household equipment, therefore safe important volumes of high quality drinking waters.

## 8. Conclusions

In regions with semi-arid climate which is very changeable like Setif Province, high temperatures and irregular precipitations directly affect the abundance of natural water resources used to supply residents. Also, the lack of means that allow mobilize and protect those resources can worsen situation and result in negative reflection on socio-economic development and human well-being. In this context, simulation of future needs by 2030 in Setif Province showed significant offer/demand gap due population growth and climate vagaries. It is a milestone in the elaboration of adequate integrated sustainable policies for resources management. The challenge is about the implementation of the proposed measures to overcome or at least minimize that gap in a short term.

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## References

1. Chema K, Fatima B, Fouad Z, et al. , *Situation actuelle de la réutilisation des eaux usées traitées en Tunisie: connaissances, attitudes et pratiques.* Algerian Journal of Arid Environment "AJAE", 2017. **7**(2): p. 37-48.
2. Mebarki, A. *La région du Maghreb face à la rareté de l'eau. L'exemple du défi algérien: mobilisation et gestion durable des ressources*. in *ICID+ 18 2nd International Conference: Climate, Sustainability and Development in semi-arid regions August*. 2010.
3. WWAP, *The United Nations World Water Development Report 2019: Leaving No One Behind*. 2019, UNESCO Paris.
4. Bennabi F, Ghomari S, Bennabi L, et al., *Approche de gestion des ressources en eau: cas de la région de Sidi Bel Abbés.* Afrique SCIENCE, 2016. **12**(1): p. 205-213.
5. Rutger W, Paul R, Leah S. *17 Countries, Home to One-Quarter of the World's Population, Face Extremely High Water Stress*. August 06, 2019 feb 10, 2020]; Available from: https://www.wri.org/blog/2019/08/17-countries-home-one-quarter-world-population-face-extremely-high-water-stress
6. Kadi, A, *La gestion de l'eau en Algérie.* Hydrological sciences journal, 1997. **42**(2): p. 191-197.
7. Mozas M, Ghosn A, *État des lieux du secteur de l'eau en Algérie*, in *Institut de Perspective Économique du Monde Méditerranéen (IPMED)*, Istitut de Prospective Economique du Monde Mediterraneen IPEMED, Editor. 2013.
8. Remini, B, *La problématique de l'eau en Algérie du nord.* LARHYSS Journal P-ISSN 1112-3680/E-ISSN 2602-7828, 2010(8): p. 27-46.
9. Sofiane, B, *La gestion durable des services d'eau potable et d'assainissement en Algérie*. 2018, Université de Sfax.
10. Philippe H, Gilles H, *Départements français, typologie et histoire*. 10/04/2005, 1994-2005 Philippe & Gilles HOUDRY: Publication électronique VIFRANCE. p. 15.
11. Claude, S. *1er Colloque International : "L'Aménagement Urbain à l'heure des rétroactions écologiques"Biodiversité, métabolisme urbain, changements climatiques, injustices environnementales, Vers une seconde nature des villes, 27-29 octobre 2015, Sétif - Algérie.* . 2015 Jan 25, 2020]; Available from: http://www.univ-setif.dz/SETIFECO2015/index.php/infos-pratiques/la-ville-de-setif
12. Macrotrends. *Setif, Algeria Population 1950-2020*. Jan 02, 2020]; Available from: https://www.macrotrends.net/cities/20037/setif/population.
13. Nabil, S, *Design and implementation of a geographic information system project to manage the field in Setif Province*, in *Faculty of Earth Sciences, Geography and Urban Planning*. 2009, Mentouri University of Constantine.
14. Atef, S, *Elaborating development plan within environmental dimensions for the province of Setif*, in *Faculty of Earth Sciences, Geography and Urban Planning*. 2004/2005, Mentouri University - Constantine.
15. Boubou, N, *Eau, environnement et énergies renouvelables: vers une gestion intégrée de l'eau en Algérie*. 2015, thèse de doctorat, université Abou Bakr Belkaid Tlemcen.
16. Baghli, N, *Élaboration d'une méthodologie d'organisation de l'information pour une meilleure gestion des ressources en eau*. 2018.
17. Akli S, Bedrani S, Benmihoub A, *Le financement de la politique de l'eau en Algérie: analyse du budget d'équipement du secteur de l'hydraulique de 1990 à 2013.* les cahiers du cread, 2016. **118**: p. 51-76.
18. GHACHI, A, *L'eau urbaine en Algérie.* Sciences & Technologie. D, Sciences de la terre, 2013(37): p. 51-56.
19. Provincial Directorate of Water Resounces, Algerian Company for Water Supply, Setif, *Daily water supply for the municipalities of Setif Province (Excel program file)*. 2019.
20. Samia, B, *Ressources en eau et développement durable cas de la région Annaba et Tarf (nord-est algérien)*, in *Faculté des Sciences de la Terre Département de Géologie*. 2017, Universite Badji Mokhtar Annaba.
21. Bouchedja, A, *La politique nationale de l'eau en Algérie*, in *10ème Conférence Internationale, Euro-RIOB 2012*. octobre 2012: Istanbul – Turquie.
22. ANBT, Agence Nationale des Barrages et des Tansferts, *Barrages et bassins versants, Etude d'actualisation du Plan National de l'Eau*.
23. S.A, SGI Consulting. *Etudede l'AEP des localites situees sur les couloirs des systemes de transfert Est et Ouest des hautes plainnes Setifienne*. Available from: https://www.sgigroupe.com/projets/ch000017.
24. N, Kherbache, *La problématique de l'eau en Algérie: enjeux et contraintes.* Mémoire de magistère, Univ. Bejaia, Algérie, 2014.

25. Bouchaala L, Charchar N, Gherib A, *Ressources hydriques: traitement et réutilisation des eaux usées en Algérie.* Algerian journal of arid environment, 2017. **7**(1): p. 84-95.
26. B, Abderrahmani, *Les risques climatiques et leurs impacts sur l'environnement*. 2015, thèse de doctorat en sciences, Université des sciences et de la technologie.
27. Rouabhi A, Hafsi M, Monneveux P, *Climate change during the last century in Setif province, Algeria.* Agriculture, 2018. **8**(4): p. 60-75.
28. M, Tabet-Aoul, *Impacts du changement climatique sur les agricultures et les ressources hydriques au Maghreb.* Les notes d'alerte du CIHEAM, 2008(48): p. 1-6.
29. Atlas, Aquaduct Water Risk, *Baseline Water Stress and Drought Risk* World Resources Institut WRI.
30. Organisation Mondiale de la Santé, *L'utilisation des eaux usées en agriculture et en aquaculture: recommandations à avisées sanitaires.* Rapport d'un groupe scientifique de l'OMS. Organisation mondiale de la santé, série de rapports techniques, 1989(778).
31. Sahnoune F, Belhamel M, Zelmat M, et al., *Climate change in Algeria: vulnerability and strategy of mitigation and adaptation.* Energy Procedia, 2013. **36**: p. 1286-1294.
32. Mohammed T, Al-Amin A, *Climate change and water resources in Algeria: vulnerability, impact and adaptation strategy.* Economic and Environmental Studies, 2018. **18**(1): p. 411-429.
33. B, Remini, *L'évaporation des lacs de barrages dans les régions arides et semi arides: exemples algériens.* LARHYSS Journal P-ISSN 1112-3680/E-ISSN 2602-7828, 2005(4): p. 81-89.
34. Saggai S, Boutoutaou D, Saker M, *Réduction de l'évaporation des eaux dans les barrages: une stratégie pour augmenter le stockage de l'eau dans les régions arides algériennes.* Hydrological Sciences Journal, 2016. **61**(8): p. 1548-1554.
35. Nichane M, Khelil M, *Changements climatiques et ressources en eau en Algérie vulnérabilité, impact et stratégie d'adaptation.* Larhyss Journal, 2015. **21**: p. 15-23.
36. Statistics, National Office for, *Algerian demographics reports, census 1998 and 2008*.

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