The hydraulic transfers "Setif-Hodna" to cope with impact of climate change on Setif high plains region

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Abstract

Purpose – The purpose of this paper is twofold: first, to show the impact of greenhouse gas emission scenarios on annual temperature and precipitation changes during three periods of the twenty-first century in Setif region by using two selected GCMs; and second, to show the importance of "Setif-Hodna" hydraulic transfers' project, like a method to adapt to the water scarcity in the future.

Design/methodology/approach – This study investigates likely changes in annual temperature and precipitation over Setif high plains region (North-East of Algeria) under four Special Report on Emission Scenarios scenarios: A1B, B1, A2 and B2, between three time slices: 2030, 2060 and 2090. MAGICC-SCENGEN 5.3v.2 was used as a tool for downscaling the two selected general circulation models.

Findings – The projections of GFDLCM20 and GFDLCM21 indicate that annual temperature will increase under the four scenarios and across the three time slices. GFDLCM20 predictions indicate a general decrease in mean annual precipitation across the four scenarios, with average of −3.02, −2.47 and −1.07 percent in 2030, 2060 and 2090, respectively. GFDLCM21 show a high decrease, with values of −18.72, −27.2 and −31.9 percent across the three periods, respectively.

Originality/value – This work is one of the first to study the impact of greenhouse gas emission scenarios on annual temperature and precipitation changes over the region, and present the hydraulic transfers project "Setif-Hodna" like an adaptive strategy to limit the effect of water scarcity in this region.

Keywords Precipitation, Temperature, GFDLCM21, GFDLCM20, Hydraulic transfers, SRES scenarios

Paper type Research paper

1. Introduction

The future is uncertain and impossible to predict. However, this uncertainty of the future often needs to be assessed in order to understand the size and nature of environmental threats like climatic change (Claussen *et al.*, 2003; Schenk and Lensink, 2007). Modeling of various earth system components is an important activity for synthesizing observations, theory, and experimental results to investigate how the Earth system works and the influences of human activities on it (Sharma and Sharma, 2012). For a comprehensive assessment of the impact and implications of climate change, it is necessary to apply a number of climate change scenarios that span a reasonable range of the likely climate change distribution. The fact that there is a distribution of future climate changes arises not only because of incomplete understanding of the climate system (e.g. the unknown value of the climate sensitivity, different climate model responses, etc.), but also because of the inherent unpredictability of climate (e.g. unknowable future climate forcings and regional differences in the climate system response to a given forcing because of chaos). The "true" climate change distribution is of course unknown, but some sensible guesses can be made as to its magnitude and shape and then make some choices so as to sample a reasonable part of its range (Hulme *et al.*, 2000). North Africa, in particular Algeria, is subject to a high degree of climate variability across different regions and seasons which make it highly vulnerable to climate change impacts. Climate data gathered in the region during the twentieth century indicate heating, estimated at more than 1°C, with a pronounced trend in the past 30 years. The data show a marked increase in the frequency of droughts and floods. The region

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experienced one drought every ten years at the beginning of the century, to a current state of five or six years of drought per ten years.

The GCMs, even though they are not accurate enough for the region, since there is no mesh model, converge to estimate probable warming in the region in the order of two to four degrees in the twenty-first century (Agoumi, 2003). According to the Regional Model REMO, precipitation is likely to decrease between 10 and 20 percent until the year 2050 under Special Report on Emission Scenarios (SRES) A1B scenario conditions (Paeth *et al.*, 2009). Many recent studies reported evidence of climate change in the last years over the Mediterranean and tried to foresee the expected trend and its impact on Mediterranean agriculture and water needs in the future (Milano, Ruelland, Fernandez, Dezetter, Fabre and Servat, 2012; Intergovernmental Panel on Climate Change, 2014; Tanasijevic *et al.*, 2014; Saadi *et al.*, 2015).

The first aim of this study is to show the impact of greenhouse gas emission scenarios on annual temperature and precipitation changes during three periods of the twenty-first century in Setif region by using two selected GCMs. The second objective is to show the importance of "Setif-Hodna" hydraulic transfers' project, like a method to adapt to the water scarcity in the future.

2. Methodology

Site description

Setif high plains region is located in the North-East of Algeria. It is situated between 35°-36.5° N and 5°-6° E. The altitude varies from 900 to 1,300 m above sea level. The region has a semi-arid climate, characterized by rainy cold winters and dry hot summers and an annual mean rainfall of 400 mm, varying from 200 to 450 mm at south to north. The hottest month is July, with an average of maximum temperature of 33.6°C. The coldest month is January, with an average of minimum temperature of 1.6°C.The region is of agricultural importance for the country and hence irrigation and water demands drastically increase during summer months when precipitation is few. The soil of the region is calcareous earth classified as a steppic brown soil, with a pH around 8. The dominant farming enterprise is sheep production and the purpose of the cereal cropping is to provide staple food for the farmers' family and feed for ruminants. A fallow-winter cereals rotation occupy every year more than 80 percent of cultivated land.

Model description

In order to generate climate scenario on the Setif high plains region, a relatively simple tool, namely, the MAGICC/SCENGEN 5.3 (version.2) software package was used (Wigley, 2008).

It is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate change scenario generator (SCENGEN). SCENGEN constructs climate change scenarios using the results from MAGICC, and scales the results to predict regional climate changes in 2.5° latitude by 2.5° longitude cells (approximately 240 km on a side). Output from SCENGEN includes changes from historic averages in temperature and precipitation and changes in temperature and precipitation variation. It uses extensive observed climate data sets and outputs of general circulation models to allow users to explore and quantify different aspects of uncertainty with regard to future climate.

The SCENGEN grid boxes around the Setif high plains region are 35° to 37.5° N latitude and 5° to 7.5° E longitude. For impacts work, the use of nine-box averages (7.5°×7.5°) produces less spatially noisy results than using single grid boxes. The nine-cell area average is generally considered a more stable estimate of site changes, since the results for an individual grid cell are subject to more noise than a larger area surrounding the site (Wigley, 2008).

Emission scenarios selection

In order to cover the influence of future greenhouse gas emissions and the corresponding socioeconomic development, the International Panel on Climate Change tried to capture a wide range of potential changes in GHG emissions in its SRES. The SRES scenarios are grouped into four scenarios families (Nakićenović and Swart, 2000) as follows:

- SRES A1: in this story, the pursuit of personal wealth is more important than environmental quality. There is very rapid economic growth, low population growth and new and more efficient energy technologies are rapidly introduced. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), and a balance across all sources (A1B).
- SRES A2: the underlying themes of this story are the strengthening of regional cultural identities, an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development.
- SRES B1: a move toward less materialistic values and the introduction of clean technologies are emphasized in this story. Global solutions to environmental and social sustainability are sought, including concerted efforts for rapid technology development, dematerialization of the economy, and improving equity.
- SRES B2: in this story, the emphasis is on local or regional solutions to socioeconomic and environmental sustainability.

To analyze the expected changes in temperature and precipitation over Setif region for the 2030, 2060 and 2090s; A1B, A2, B1, and B2 emission scenarios are selected because most recent climate change impact studies are focusing on, and are be to be found relevant four developing countries (Bindi and Moriondo, 2005; Paeth *et al.*, 2009; Patricola and Cook, 2010; Conde *et al.*, 2011; Schilling *et al.*, 2011).

Global climate model selection

The statistics used for evaluating the performance of the different models to reproduce the observed climate at global scale and for the Setif region were: pattern correlation (R), root mean square error (RMSE), bias (i.e. model area average minus observed area average), and root mean square error corrected by bias (RMSE-corr) (Wigley, 2008). All statistics were weighed for the cosine function, in order to consider the change in the area for the squares in the grids that depend on the latitude (Conde *et al.*, 2011). To rank models a semi-quantitative skill score was used that rewards relatively good models and penalizes relatively bad models. Each model gets a score of +1 if it is in the top seven for any statistic over the globe or over the region, and a score of –1 if it is in the bottom seven. The maximum skill score is therefore +8, which would mean that the model was in the top seven for all four statistics over both regions. The worst possible score is –8 (Wigley, 2008). The variable used for ranking is annual precipitation (precipitation is more difficult to model than temperature and models do less well in simulating precipitation than temperature, so using precipitation is a stringent test of model skill). The scores for 20 models in terms of their global and regional performance are shown in Tables I and II. The top seven models for each case are shown in italic type, while the worst seven models in each case are shown in italic blue type. The general scores and the corresponding ranking (Table III) indicate that GFDLCM20, GFDLCM21, and MIROCMED have a better performance than all other models.

The GCMs with higher spatial resolutions can perform reasonable regional climate simulations; consequently, they provide climate scientists with the ability to acquire better

Table I.
Global performance of models

Model	*R* (mm/day)	RMSE (mm/day)	Bias (mm/day)	Corr-RMSE (mm/day)	Score	Rank
BCCRBCM2	*0.793*	1.311	*0.307*	1.275	–2	5
CCCMA-31	*0.888*	*0.949*	*–0.010*	*0.949*	+4	1
CCSM--30	*0.797*	1.327	0.160	1.317	–1	4
CNRM-CM3	*0.772*	*1.438*	*0.540*	*1.333*	–4	7
CSIR0-30	0.814	*1.209*	–0.161	1.198	+1	2
ECHO---G	*0.910*	*0.864*	*0.128*	*0.854*	+4	1
FGOALS1G	0.816	1.226	*0.307*	*1.187*	0	3
GFDLCM20	*0.868*	*1.099*	*0.091*	*1.095*	+4	1
GFDLCM21	*0.857*	*1.149*	*0.215*	*1.128*	+4	1
GISS--EH	*0.733*	*1.512*	*0.340*	*1.473*	–4	7
GISS--ER	*0.774*	*1.430*	0.297	*1.399*	–3	6
INMCM-30	*0.700*	*1.606*	*0.116*	*1.601*	–2	5
IPSL_CM4	0.808	1.269	*–0.090*	1.266	+1	2
MIROC-HI	0.800	*1.340*	*0.281*	1.311	–2	5
MIROCMED	*0.833*	*1.162*	*0.035*	*1.162*	+4	1
MPIECH-5	0.808	1.351	0.247	*1.328*	–1	4
MRI-232A	*0.886*	*0.967*	*–0.084*	*0.963*	+4	1
NCARPCM1	*0.665*	*1.715*	*0.343*	*1.680*	–4	7
UKHADCM3	*0.858*	1.256	0.230	1.235	+1	2
UKHADGEM	0.797	*1.614*	*0.385*	*1.568*	–3	6

Table II.
Regional performance of models

Model	*R* (mm/day)	RMSE (mm/day)	Bias (mm/day)	Corr-RMSE (mm/day)	Score	Rank
BCCRBCM2	*0.831*	*0.479*	*0.467*	*0.106*	–2	6
CCCMA-31	*–0.903*	0.358	0.340	*0.113*	–2	6
CCSM--30	*0.254*	*0.467*	*–0.463*	0.054	–3	7
CNRM-CM3	0.556	*0.108*	*–0.080*	0.073	+2	2
CSIR0-30	0.533	0.339	–0.277	*0.197*	–1	5
ECHO---G	0.479	*0.247*	*–0.180*	*0.170*	+1	3
FGOALS1G	0.525	*0.244*	–0.240	*0.043*	+1	3
GFDLCM20	*0.988*	*0.177*	*0.177*	*0.012*	+4	1
GFDLCM21	*1.000*	*0.177*	*–0.177*	*0.012*	+4	1
GISS--EH	*–0.494*	*0.277*	0.230	*0.155*	–2	6
GISS--ER	*–0.417*	*0.476*	*0.413*	*0.236*	–4	8
INMCM-30	*0.703*	*0.554*	*–0.553*	*0.034*	0	4
IPSL_CM4	*–0.825*	*0.633*	*–0.630*	*0.057*	–3	7
MIROC-HI	*0.983*	*0.900*	*0.900*	*0.022*	0	4
MIROCMED	*0.768*	*0.044*	*–0.030*	*0.033*	+4	1
MPIECH-5	*0.433*	*0.568*	*–0.097*	*0.560*	–2	6
MRI-232A	*0.759*	0.398	*–0.397*	*0.031*	+1	3
NCARPCM1	0.657	0.351	–0.347	0.056	0	4
UKHADCM3	*0.711*	0.286	0.283	*0.040*	+2	2
UKHADGEM	*0.411*	*0.164*	*0.157*	0.050	+1	3

insights into climate change impacts on a regional scale (Kang *et al.*, 2009). Taking into account this criterion, GFDLCM20 and GFDLCM21 were selected because they have high resolution (2.0 × 2.5L24) than MIROCMED (2.8 × 2.8L20).

3. Results

Projected changes in annual temperature

The projections of GFDLCM20 and GFDLCM21 over Setif region indicate that annual temperature will increase under the four scenarios and across the three time slices. According to these results, more warming will be experienced in 2090 than in 2030 and 2060 periods.

Model	Score	Ranking
GFDLCM20	+8	1
GFDLCM21	+8	1
MIROCMED	+8	1
ECHO- - -G	+5	2
MRI-232A	+5	2
UKHADCM3	+3	3
CCCMA-31	+2	4
FGOALS1G	+1	5
CSIR0-30	0	6
CNRM-CM3	−2	7
INMCM-30	−2	7
IPSL_CM4	−2	7
MIROC-HI	−2	7
UKHADGEM	−2	7
MPIECH-5	−3	8
NCARPCM1	−4	9
BCCRBCM2	−4	9
CCSM–30	−4	9
GISS-EH	−6	10
GISS–ER	−7	11

Table III. General score and performance of models

The results of GFDLCM20 indicate that the average scenarios of warming are 1.06°C, 1.97°C, and 2.97°C, projected in 2030, 2060, and 2090, respectively. The lowest warming is seen under B2 scenario, with values of 1°C, 1.81°C, and 2.60°C in three periods, respectively. While the highest warming was observed under A1B and A2 scenarios, with values ranging from 1.1°C to 3.04°C for the first scenario and varying from 1.04°C to 3.97°C for the second, across the periods (Figure 1). The results show that GFDLCM21 predictions of warming are higher than GFDLCM20. The average scenarios of warming lie in the range of 1.24°C-3.37°C across the three periods. The smallest increase was observed under B2 scenario, with values varying from 1.17°C to 3.05°C across the times. The largest warming is seen under A1B and A2 scenarios, with increase ranging from 1.3°C to 3.55°C under A1B scenario, and varying from 1.23°C to 4.32°C under A2 scenario (Figure 2).

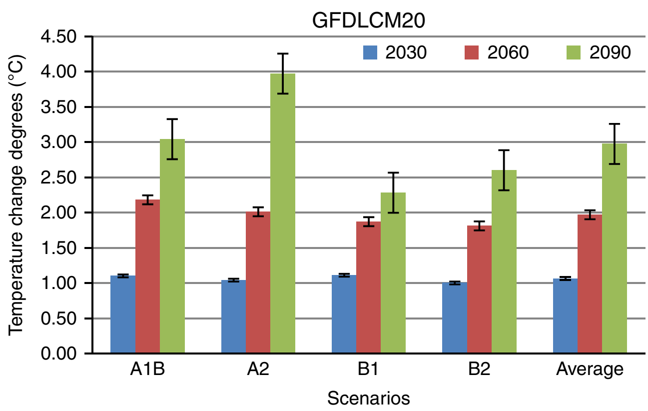

Figure 1. GFDLCM20 projections for changes in mean annual temperature over Setif region under four SRES scenarios with aerosol effects

Projected changes in annual precipitation

Except for A1B scenario when an increase of 0.1 percent can be observed in 2090 and an increase of 0.2, 3.3, and 6.2 percent under B1 scenario in 2030, 2060, and 2090, respectively, the projections of GFDLCM20 indicate a general decrease in mean annual precipitation across the four scenarios (Figure 3), with the average of −3.02, −2.47, and −1.07 percent in 2030, 2060, and 2090, respectively. The highest decrease is expected under A2 with values of −5.8, −9.4, and −8.1 percent across the three time slices, while the smallest reduction is observed under B2 scenario with values lies in the range of −1.3−2.5 percent. GFDLCM21 indicates a general decrease in mean annual precipitation with average scenarios of −18.72, −27.2, and −31.9 percent in 2030, 2060, and 2090, respectively (Figure 4). The largest decrease is observed under A2 scenario with values ranging from −21.6 to −44.9 percent. The smallest decrease is expected under B1 scenario with a range of −14.2, −18.3, and −18.5 percent in three periods, respectively.

4. Discussion

These results are in accordance with most assessment studies analyzing future climate changes over Mediterranean region. Hulme *et al.* (2001) reported that the annual temperature

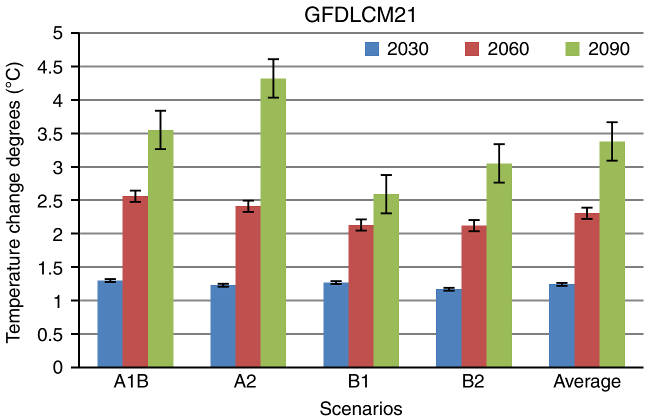

Figure 2. GFDLCM21 projections for changes in mean annual temperature over Setif region under four SRES scenarios with aerosol effects

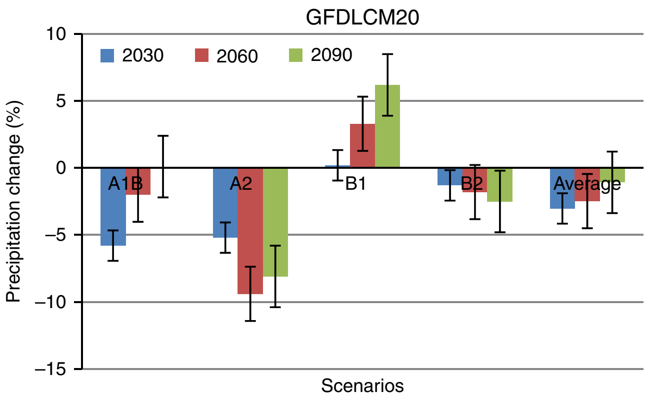

Figure 3. GFDLCM20 projections for changes in mean annual precipitation over Setif region under four SRES scenarios with aerosol effects

will rise at 0.9°C, 1.4°C, and 1.7°C in Algeria, over 2025, 2050, and 2075 respectively. The study of Giannakopoulos *et al.* (2005) showed that the temperature will increase from 1°C to 3°C between 2031 and 2060 over the Mediterranean region, under A2 and B2 scenarios. Saadi *et al.* (2015) indicated that the temperature in the Mediterranean region may rise by 1.57°C until 2050, under A1B scenario and the annual precipitation is expected to decrease by 39.1 mm, with the greatest reductions in Portugal (108.4 mm), Lebanon (98.1 mm), Morocco (92.5 mm), Greece (92.1 mm), and Spain (88.1 mm). Tanasijevic *et al.* (2014) reported that under A1B the increase of annual mean temperature might vary from 0.8 to 2.3°C, being the largest in some areas of Northern Africa and Middle East, and in Southern Turkey; the total annual precipitation is expected to decrease by 5.7 percent over 2050. A decrease in precipitation and an increase in temperature over the Mediterranean are projected, with high inter-annual variability and a greater occurrence of heat waves and dry spell events (Lionello and Giorgi, 2007; Abdelhakim *et al.*, 2008; Giorgi and Lionello, 2008). According to the analysis of the four GCMs (CSIRO-MK3.0, HadCM3.0, ECHAM/MPI-OM, and CNRM-CM3.0) outputs, temperatures are expected to rise by 0.5-1.5°C in the Mediterranean basin by 2025 and by an extra 1°C by 2050. Rainfall should be decrease by 10-30 percent in the whole region (Milano, Ruelland, Dezetter, Ardoin-Bardin, Thivet and Servat, 2012). According to the Regional Model (REMO), the temperature in the Maghreb will rise between 2°C and 3°C by 2050, and precipitation is likely to decrease between 10 and 20 percent, under SRES A1B scenario (Paeth *et al.*, 2009). Patricola and Cook (2010) found that the annual temperature will increase to 6°C in Northern Africa, over the end of the twenty-first century. An assessment of precipitation changes within the IMPETUS project shows that Moroccan rainfall might be reduced in the period 2011-2050 between 5 and 30 percent for the SRES A1B scenario and by 5 and 20 percent for the B1 scenario (Fink *et al.*, 2010). Macdonald *et al.* (2009) reported that Africa is very likely to warm throughout the twenty-first century; precipitation is likely to reduce in the Northern Sahara and Southern Africa. According to Schilling *et al.* (2011), projections of future climate change for Africa show considerable uncertainties, both the risk and the duration of droughts are likely to increase in Northern Africa.

The general circulation models, even though they are not accurate enough for the region because there is no mesh model focusing on the area, converge to estimate probable warming in the region of 2°C-4°C in the twenty-first century, according to studies conducted for Morocco and Algeria (Agoumi, 2003). Mearns *et al.* (2012) reported that it is difficult to determine which models perform best given the inherent spatial and temporal

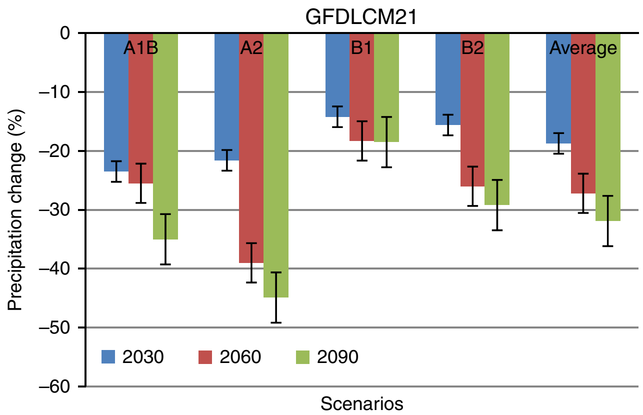

Figure 4. GFDLCM21 projections for changes in mean annual precipitation over Setif region under four SRES scenarios with aerosol effects

variability of the climate. Performance of the models varies substantially from one sub region to another, but they all simulate temperature more accurately than precipitation.

For these reasons, no unique model is considered accurate (Hulme *et al.*, 2000; Shongwe *et al.*, 2009). The justifications for the use of a multi-model average are twofold. First, as has already been demonstrated, multi-model averages are less spatially noisy. Second, by many measures of skill, multi-model averages are often better than any individual model at simulating present-day climate (Wigley, 2008). Miranda *et al.* (2002) indicated that it is difficult to predict the future GHG emission scenarios. They depend intrinsically on many socioeconomic parameters, such as the size of the future demography, the levels of development, and evolution of technology. At each stage of an impact assessment, there should be a full and proper discussion of the key uncertainties in the results, including those attributable to the input data, impact models, climate scenarios, and non-climatic scenarios (Carter *et al.*, 1999; Palmer *et al.*, 2005). A rigorous sensitivity analysis can be very helpful in identifying some of the major uncertainties. It is also recommended that users should design and apply multiple scenarios in impact assessments, where these multiple scenarios span a range of possible future climates, rather than designing and applying a single "best-guess" scenario (Hulme *et al.*, 2000). For instance, it is necessary to gain a better understanding of climate change in this region, which involves the inclusion of specific feedback mechanisms, e.g., of land use change (Schilling *et al.*, 2011).

5. The hydraulic transfers project "Sétif-Hodna"

The mega project for hydraulic transfers to Setif high plains region derives from a forward-looking vision which will give a concrete content to the notion of "hydro-solidarity" when it comes to transporting water resources from a coastal region, where the average annual precipitation exceed 900 mm/year, to a semi-arid region where rainfall does not exceed 400 mm/year. This large hydraulic transfer project comprises two distinct developments.

The East system consists of transferring water from the existing Erraguene dam to Tabellout dam (situated in the wilaya of Jijel), then to Draâ-Diss reservoir dam (located on the Medjez river, 11.5 km North-East of El Eulma city, East of Tachouda commune), via 42 km of pipes, five pumping stations and a 13 km tunnel.

Tabellout dam is an important component of the system "Setif-Hodna." It is among five biggest hydraulic structures in Algeria in terms of storage capacity (about 294 million m^3). According to RAZEL-BEC (2017) group, the gravity dam was built using 1 million m^3 of roller compacted concrete RCC (was prepared with aggregates made on site from the alluvium of the Djen-Djen river, on which the dam is constructed), with 115 meters height, 366 meters long, and 8 meters wide at the crest, it includes a free-threshold stepped spillway with an effective width of 60 meters and 2 bypass tunnels, each of which is 6 meters in diameter and 400 meters in length.

Draâ-Diss reservoir dam is designed to transfer an annual water volume of 191 million m^3; to supply 38 million m^3 of drinking water to 780,000 inhabitants of El-Eulma city, and the irrigation of 31,700 ha of the South plains with a volume of 153 million m^3 (Agence Nationale des Barrages et Transferts (ANBT), 2017).

The Western system relies on the transfer of water from the existing Ighil-Emda dam (wilaya of Béjaïa) to the Mahouane reservoir dam, through 22 km of pipes and three pumping stations. This system is intended to supply drinking water to 12 communes in the western part of Setif region with a volume of 56 million m^3 and the irrigation of 13,000 ha of the setifian plain with a volume of 66 million m^3.

This project has a particular importance, considering its great dimension planned, both by their technical and economic parameters and by the social objectives that will be assigned to them. At the completion of this project, a volume of 313 million m^3 will be transferred to supply drinking water to a population of about two million inhabitants, in

28 municipalities of Setif region over 2020, as well as the irrigation of about 43,000 hectares of agricultural land (Rabei, 2014), which will enable to quintuple the agricultural production in the region, while reducing fallow and increasing national production by around 20 percent. In addition, 100,000 jobs in agriculture will be created in the wake of this project (ANBT, 2017).

6. Conclusion

It can be concluded that predictions of the precipitation change are more uncertain than temperature. More warming and drought will be experienced under A2 scenario than others. The results indicate that the pressure on Setifian's water resources will increase, leading to greater competition for surface water, and that domestic and agricultural demands will not be met by the year 2090. The significant challenges posed by climate change increase the importance of adaptation in Setif high plains region. The most effective strategies are likely to be to reduce present vulnerability and to enhance a broad spectrum of capacity in responding to environmental, resource, and economic perturbation. A broad range of sectoral mitigation options is available that can reduce GHG emission intensity, improve energy intensity through enhancements of technology, behavior, production and resource efficiency and enable structural changes or changes in activity. In addition, direct options in agriculture, forestry and other land use involve reducing CO_2 emissions by reducing deforestation, forest degradation and forest fires; storing carbon in terrestrial systems; and providing bioenergy feedstocks.

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