UFAS – SETIF 1

Revue semestrielle – Université Ferhat Abbas Sétif 1

REVUE AGRICULTURE

Revue home page: http.www: http://revue-agro.univ-setif.dz/

Assessment of climate change and its effects on cereal production by 2070 in north Algeria

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ARTICLE INFO

L'histoire de l'article
Reçu :
Accepté : 27/12/2019

Keywords: Cereals, Climate change, RCP scenario, Sétifois.

ABSTRACT

This study aimed at the assessment of climate change and its singular effect on cereal yield in Sétifois region-Algeria by 2070. Two predictive statistical methods namely the Artificial Neural Network (ANN) and the Stepwise Multiple Linear Regression (SMLR) were used, according two Representative Concentration Pathways (RCPs) scenarios (2.6 and 8.5) outputs *that* were *adopted* by the *IPCC* for generation of climate model results for the *fifth* assessment in 2014. Over Sétifois region, climate predictions show a spatial pattern with high trends to drought and warming under RCP 8.5, while, trends are less alarming under RCP 2.6. Predictive statistical models expect a relative association between climate trends and grain yield variations; meaning that the impact on expected yields vary from one province to another. The overall grain yield decline over Sétifois region will be around 33% according to RCP 8.5 outputs and about 16% under the RCP 2.6. Locally, the expected temperature increase and rainfall drop point out that climate change will have a negative impact on water resources and therefore a direct effect on cereal yields, which highlights the need to plan integrated mitigation strategies for the agricultural sector to ensure food security and achieve long-term sustainable development.

1. Introduction

Among human activities, agriculture is undoubtedly among the most directly influenced by Climate Change (CC). Therefore it will impact the biotechnical component of agricultural production processes (Seguin, 2010). CC impacts negatively the agricultural activities in a multifaceted way; it impacts farm household's incomes, farm biophysical compounds and also the collective dynamics of the farming territories, hence it contributes to increasing the vulnerability of poverty (Dugué, 2012). Agriculture is a particularly CC sensitive sector, which can also contribute to its expansion. Organic and inorganic material provided as inputs or outputs in the management of agricultural systems are typically broken down through bacterial processes, releasing significant amounts of Greenhouse Gases (GHGs) namely CO_2, CH_4, and N_2O to the atmosphere. The agricultural sector is the largest contributor to global anthropogenic non-CO_2 GHGs, accounting for 24 % of global emissions in 2010 (IPCC 2014). However, some conservation agricultural practices may also contribute to the reduction of these gases in the atmosphere (Fenni and Machane, 2010). Referring to the ancient or recent texts, the reputation of North Africa as "granary of Rome" seemed well established (Bencherif, 2011). There are even those who have named the region of *Sétifois* in Algeria by this term, given its durum wheat yield potential (Djaouti 2010). Unfortunately, nowadays, this term becomes feeling awkward. Cereal farming is an important component of Algerian agricultural and food economies, as Algeria belongs to the largest group of wheat importers in the world, where it ranks sixth with an average of 5 - 6 million tons in 1990 -92 and 2000-2003 respectively (FAO, 2005). In fact, cereals are located mainly in eastern Algeria,

Where *Sétifois* region holds 42% average of the Utilized Agricultural Area (UAA) (MADR, 2017) and climate, especially rainfall and temperatures are the predominant factors that strongly influence crops (Feliachi, 2000). Locally, the majority of agricultural land is cultivated under rainfed conditions, where annual rainfall is insufficient and unpredictable from one year to another, as well as extreme seasonal temperatures are opposing the development of crops. Several climate models forecast that Algeria will experience decreased rainfall and increased temperatures (MATE, 2001); this will have a direct impact on agricultural productivity and food security.
In this context, this work is carried out; primarily to draw up a starting position of the state of the cereal production in *Sétifois* region by illustrating the geographic potential in terms of areas and yields. Second step is to study the annual rainfall and the maximum and minimum temperature; starting with studying the reference period 1960-90 and then passing to 2070 horizon. Among four Representative Concentration Pathways (RCPs) adopted by the IPCC in its last report in 2014, two RCPs were adopted in this paper namely: RCP 2.6 as an optimistic scenario and RCP 8.5 as a pessimistic one. Some statistical predictive methods such as the Stepwise Multiple Regression (SMLR) and the Artificial Neural Network (ANN) will be validated and then performed for expecting cereal yields in 2070.

2. Materials and Methods

2.1 Geographic situation

The *Sétifois* region covers the administrative territory of five provinces of eastern part of Algeria, namely; *Sétif*, *Béjaïa*, *Bordj Bou Arreridj* (*BBA*), *Mila*, and *M'Sila*. Spread over an area of 35,891 $km^{2,}$ including 248 observation stations. The geographical spread of the *Sétifois* spans between northern latitudes 35°42'-36°45' and eastern longitudes 4°32'-6°15' (Figure 1). The *Sétifois* is a vast geographical area bounded to the north by the Mediterranean Sea and Jijel province, to the east by Constantine, to the west by Great Kabylie and *Algérois* region, to the south By *Djelfa* and *Biskra* provinces. *Sétifois* region being furrowed by The Tellian Atlas to the north, and the Saharan Atlas to the south, encompassing several mountain chains namely the *Biban*, the *Dhahra*, the *Babor* and the *Zemoura* Mountains, this geomorphologic structure plays a paramount role in the distribution of annual precipitations and temperatures. Durum wheat is generally cultivated from October to the June, while Soft wheat and barley have shorter vegetative cycle.

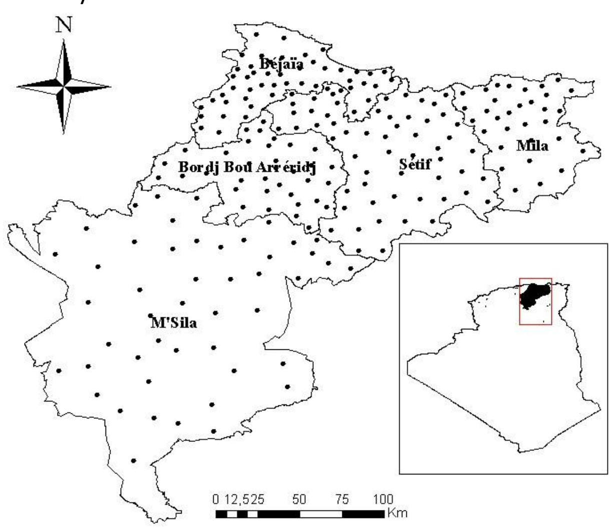

Figure 1. Location of the Sétifois and the geographical spread of the sub-provincial stations

2.2 Sources of data

2.2.1 Cereal data

Cereal Data were provided by the Departments of Agriculture Services (DAS) of the five provinces, where, data network comprises 248 sub-provincial recording points. The observation series are addressing the harvested areas and grain yields for the main cultivated cereals namely: durum wheat, soft wheat and barley. The dataset comprises a series of 27 years (1990-2016) spread over 60 sub-provincial points (municipalities), being the longest series. *Mila* and *Béjaia* series are 16 years and 11 years old respectively. While the series of *M'sila* and *BBA* record some lack of details. The series of *BBA* province extends over 11 years (2006-2016) including 34 municipalities, while the *M'sila* series comprises a dataset of 6 years for 47 municipalities. It should be noted that a preliminary data processing has been carried out in order to fix some digital anomalies and outliers contained in the provided datasets.

2.2.2 Climate data

This work involves studying the effect of CC on cereal yields, to this end, the availability of a complete climate dataset is necessary. This work takes into account both observed and simulated climate data. The local climate dataset is provided by the National Office of Meteorology (NOM)-Algeria. However, simulated climate data were extracted from www.worldclim.org site, WorldClim Version 1.4 is a set of global climatic layers generated from General Climate Models (GCMs), developed by Hijmans et al. (2005), with a very fine spatial resolutions of $1km^2$. These data can be used for mapping and spatial modeling; it is also adopted by various internationally renowned institutions working on CC around the world. Among several GCMs included in Worlclim dataset, we opted for the NOAA Geophysical Fluid Dynamics Laboratory (GFDL). The GFDL Climate Model version 3 (CM3) is a new coupled climate model formulated with effectively the same ocean and sea ice components as the earlier CM2.1 yet with extensive developments made to the atmosphere and land model components (Griffies et al. 2011). In this paper, output of the GFDL CM3 high resolution were used to draw up the climate situation of the current standard period 1960-90 and 2070 horizons.

2.3 Software and Processing of data

Data analysis software comprises a series of tools: primarily, a Geographic Information System (GIS), namely ArcGis 10.0, for the implementation of the thematic maps and for Geostatistical processing, secondly, a statistical processing package SPSS v18 for fulfilling SMLR and ANN analysis. Finally, the Excel 2007 spreadsheet was used for validating and exporting data.

Once the dataset are downloaded from the WorldClim, data are imported by the GIS, where cartographic processing consists of clipping out the study area and representing different climatic patterns for the analysis periods and respective RCPs scenarios.

The international climate modeling community has adopted four RCPs through the IPCC (Cubasch et al. 2013; IPCC 2007, van Vuuren et al. 2011) (Table A1). The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5) which corresponds to a “non-climate policy”.

The impact of climatic trends on cereal yields will be approached through the involvement of both climate data and historical series of cereal records (1990-2016) provided respectively by NOM and DAS in *Sétif* province. Observed cereal grain yield combined with monthly climatic data will be designed for expecting cereal yield in 2070. Where, cereal grain yield will be considered as a dependent variable, however, monthly precipitation and maximum and minimum temperatures from January to June as explanatory variables.

ANN can automatically approximate any nonlinear mathematical function. This aspect of neural networks is particularly useful when the relationship between the variables is not known or is complex and hence it is difficult to handle statistically.

ANN has been used for modeling plant growth. However, most studies reported that it would often perform better than linear models for various agro-ecological applications. Thongboonnak and Sarapirome (2011) carried out a study to develop the ANN modules for agricultural yield prediction; however, Drummond, Sudduth and Joshi (2000) compared ANN outputs to other linear and nonlinear regression models to predict crop yields accordingly to soil, topography and climatic variables. They conclude that ANN offers a better generalization than other methods under consideration. In this study, we attempt to expect cereal yields in 2070 using SMLR and ANN and giving a finding on the efficient model.

3. Results and Discussions

3.1 Cereal areas

Records of cereal areas in the *Sétifois* (Table 1) indicate that the annual areas of all species are irregular and varying significantly from one province to another. The lowest averages are recorded in the *Béjaia* (7003ha) and *M'Sila* (18566ha). *Béjaia* is dominated by a mountainous topography, whereas, *M’sila* is Suffering from chronic annual drought, both reasons prevent cereal crops progress. In *M’sila* province, the annual rainfall level does not exceed 200mm, in such hostile conditions; barley is the more suitable cultivation, it represents the relatively most tolerant cultivated Triticeae species with respect to dehydrative stresses, especially drought and salinity (Colmer, Flowers and Munns, 2006) this represents a major handicap for the rainfed crop of cereals in southern Setifois.

Cereal medium and large scale farming is located in *BBA*, *Mila* and *Sétif* provinces with annual areas of 84 297ha, 99 377ha and 172 790ha respectively. During the last century, these areas were called "*East of Oued Sebaou*" and "*Medjana*" and were too suitable for cereal crops (Gsell, 1913).

Table 1. Annual areas (ha) of the main cultivated cereals in the Sétifois

Province	Durum wheat	Soft wheat	Barley	Total area±sd
Béjaïa (n=11)	4466	177	2360	**7003±93ha**
BBA[a] (n=11)				**84298±612ha**
Mila (n=16)	51651	26889	20836	**99376±661ha**
M'Sila (n=6)	5 352	783	12 431	**18566±5913ha**
Sétif (n=27)	97156	25250	50384	**172790±619ha**

Notes: Figures in the parentheses represent length of time series in years
[a]: Yields of cereal species are not available for BBA province

3.2 Cereal grain yields

Generally, the average grain yields in the *Sétifois* do not vary too much from one province to another. The Maximum weighted grain yield is recorded in *Mila* with an average of 16.80 q/ha, followed by *M'sila* and *Béjaia* yields (13.85q/ha) (13.65q/ha) respectively (Table 2). It should be noted that *Mila* province ranks first and characterized by a very favorable climate for cereals growth, given the annual rainfall that exceeds 450mm in addition to soil fertility. While *M'sila* is dominated by the cultivation of barley compared to durum and soft wheat. Moreover, yields in *M'sila* province are much more influenced by the cultivation techniques, where the majority of cereal areas are irrigated (Mekhalfi and Djellal, 2016), this may positively influence the profitability of farms despite the decline of the annual rainfall which is the lowest in the *Sétifois*. On the other hand, *Sétif* and *BBA* provinces record the lowest yields with 12.82 q/ha and 12.16 q/ha respectively.

Table 2. Annual grain yield (q/ha) of the main cultivated cereals in the Sétifois

Province	Durum wheat	Soft wheat	Barley	Weighted Average
Béjaia (n=11)	14.18	16.16	12.45	**13.65q/ha**
BBA[a] (n=11)				**12.16q/ha**
Mila (n=16)	16.61	18.26	15.41	**16.80q/ha**
M'Sila (n=6)	15.15	13.58	13.31	**13.85q/ha**
Sétif (n=27)	12.25	13.61	13.54	**12.82q/ha**

Notes: Figures between parentheses represent length of time series in years
[a]: Yields of cereal species are not available for BBA province

3.3 Climate pattern during the reference period 1960-90

Temperature and precipitation anomalies are calculated according to the averages of the reference period (1960-90), where the climate was relatively stable during the last century. Indeed, the World Meteorological Organization (WMO) defined a similar reference period for the latter part of the 20th century.

3.3.1 Annual precipitation during the reference period 1960-90

The rainfall map of the reference period (1960-90) shows a south-northward rainfall gradient (Figure 2). The rainfall range varies between 140 to 1171 mm. The littoral zone records a high rainfall level (>850 mm). While the northern mountain chain, including *Babor*, *Kabylie* and *Mila* mountains, has an annual rainfall ranging from 650 to 850 mm. The southern foothills area is characterized by great productive potentialities of cereals, especially the *Medjana* plains, the northern area of *Sétif* and the southern area of *Mila*. This area records an annual rainfall between 450 and 650mm. The rainfall range (250-450mm) extends from the south of *Mila* to the southwest of *M'sila*, passing through the middle of *Sétif* and *BBA* provinces, occupying almost 40% of the *Sétifois*. Given the lack of rainfall, this zone is much more characterized by extensive farming, such as sheep farming, particularly in the mountainous zones of the Saharan Atlas and the south of *Sétif* and *BBA*. Thus, cereal crops are mainly based on the barley that are acclimated and requested for rationing of livestock. The driest zone has an annual rainfall of 140-250 mm, occupying the eastern part of *M'sila*; known as the steppe zone, almost devoid of vegetation cover, except for Drought-tolerant perennial species such as Artemisia and Alfa.

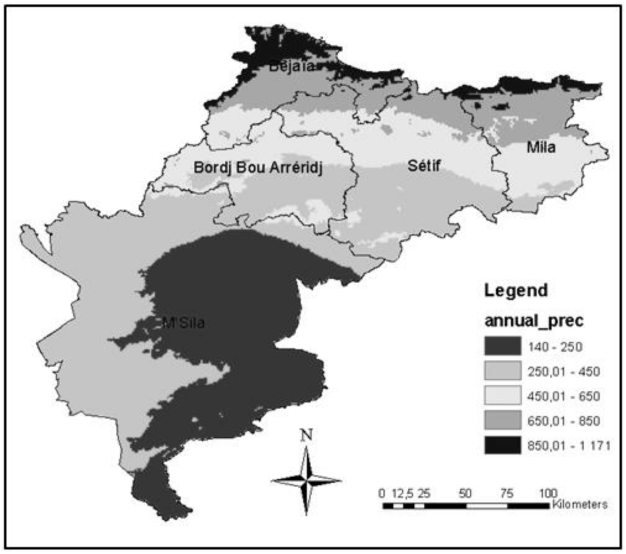

Figure 2. Annual precipitation map during the reference period 1960-90
Source: Author's processing based on GFDL CM3 output

3.3.2 Temperatures during the reference period 1960-90

The maximum and minimum annual temperatures are strongly influenced by the geographical and topographical profile of the *Sétifois*. In fact, the north is cooler than the south, also the annual temperatures budget is affected by latitude and hence by exposure to global solar radiation (Masson-Delmotte et al. 2011). It comes out that the highest maximum temperature varies between 22 and 26°C (Figure 3a). The affected areas are the *Soummam* Valley, a small part of the far south of the *M'Sila* province and its eastern side. The *Beni Haroun* watershed in *Mila* province also records high temperatures. While, the temperature range (20-22°C) occupies a large part over the western *M'sila* and intermittent zones of *BBA*, *Béjaia* and *Mila* provinces. The lowest maximum temperatures (13-20°C) are observed over the plains and mountain ranges of *Sétif*, *BBA* and *Mila* provinces and over the Saharan Atlas in the south.

For the minimum temperatures (Figure 3b), the highest figures (12-14 °C) are observed over the *Soummam* valley, the coastal area and the watershed of *Beni Haroun*. However, the lowest temperatures (2.4 to 8 °C) are noted over the Sétifian plains and the Saharan Atlas. It should be noted that the lowest temperature ranges (<6 °C) are spread over *Babor* and *Boutaleb* mountain chains at the north and south of *BBA* and *Sétif*.

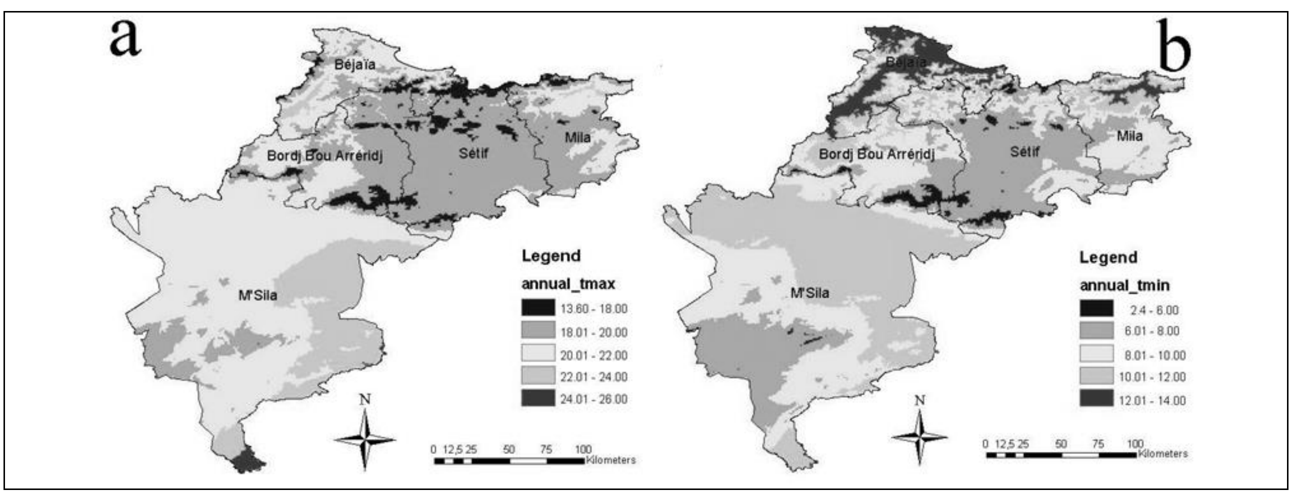

Figure 3**.** Annual maximum temperatures **(a)** and Annual minimum temperatures (**b**) during the reference period (1960-90). *Source: Author's processing based on GFDL CM3 output*

3.4 Expected climate trends for 2070

3.4.1 Expected annual precipitation

The climatic scenarios RCPs 2.6 and 8.5 show very different patterns in 2070 with respect to the distribution of precipitation. RCP 2.6 indicates that the coastal area and the northern part of *Mila* will record the highest annual precipitation (850-1099 mm) (Figure 4a), whereas; RCP 8.5 scenario expects a drop annual rainfall in the same zone (Figure 4b). The rainfall range (450-650mm) remains almost unchanged for both RCPs. However, the 250-450mm range loses part of its extent to the precipitation range of less than 250mm. Adouane and Felloussia (2017) noted that the annual precipitation according to RCP 2.6 will evolved more than 20mm in 2070 compared to 2030. Whilst, under RCP 8.5 annual rainfall will decrease about 74mm in 2070 compared to 2030. In general, precipitations will have a downward trend in both RCPs compared to the reference period (1990-60). The annual rainfall decrease is about 66mm for RCP 2.6 and 154mm for RCP 8.5.

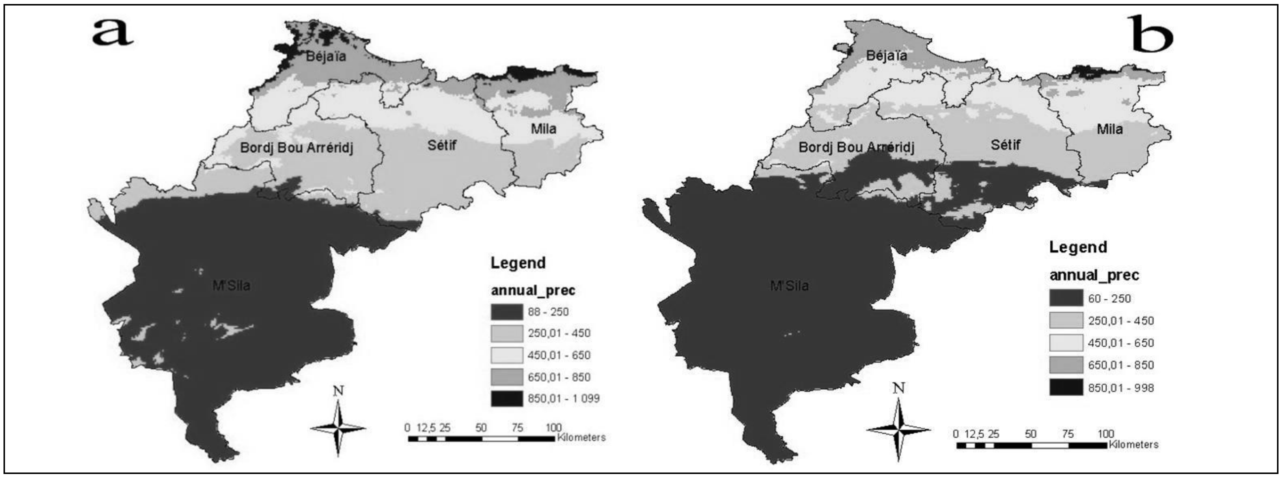

Figure 4. Expected annual precipitation map under RCP 2.6 (**a**) and RCP 8.5 in 2070 (**b**)
Source: Author's processing based on GFDL CM3 output

3.4.2 Expected maximum temperatures

According to the figures describing the predicted situations in 2070, the maximum temperatures will have undergone dramatic variations, notably for RCP 8.5. Meanwhile, the RCP 2.6 illustrates a comparable pattern with the current climate with warm south and fresh north (Figure 5a). However, under RCP 8.5, fresh temperature ranges of less than 20°C disappear completely from the map, meaning that will undergo a minimum increase of around 2°C. Under RCP 8.5, the maximum temperature range will conquer 80% of the whole *Sétifois* area. Some parts will be relatively saved from warming are those located in the central *Sétifois* (Figure 5b). Indeed, the evolution of the maximum temperatures in 2070 shows an increase for both scenarios, it is 3.39 °C for the RCP 2.6, this increase is very discouraged because Scenario 2.6 foresees a stabilization of greenhouse gas (GHG) releases and CC mitigation measures. According to these records, it is impossible to achieve Paris Climate Agreement targets, which are to stay well below 2°C, and pursue efforts to stay below 1.5 °C (IAEA 2016). Really, our backs are to the wall, because we are already above 1 degree °C. Moreover, Maximum temperatures are expected to raise by 6.60°C in 2070 according to RCP 8.5, this situation will be catastrophic for the majority of living beings.

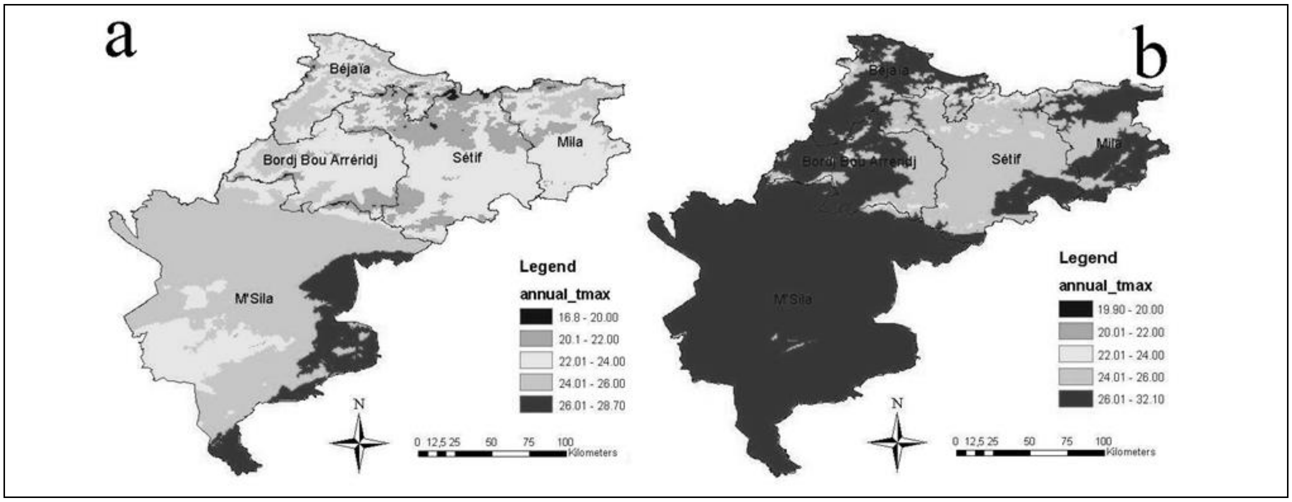

Figure 5. Expected maximum temperature map under RCP 2.6 (**a**) and RCP 8.5 in 2070 (**b**)
Source: Author's processing based on GFDL CM3 output

3.4.3 Expected minimum temperatures

The minimum temperatures will have wide variations in regard to the RCPs by 2070. The minimum temperatures in scenario 2.6 (Figure 6a) will have a pattern similar to the current reference period, while the pattern of RCP 8.5 (Figure 6b) is quite different, due to the disappearance of temperature classes below 10°C. The majority of the zones will be dominated by classes of temperatures above 14°C. In fact, *Sétif*, *BBA* and the southern zone of *M'sila* are less affected by this increase.

Differences in minimum temperatures in 2070 show increases in both scenarios comparatively to reference period 1990-60, it is about 2.87°C for RCP 2.6 and 5.90°C for scenario 8.5.

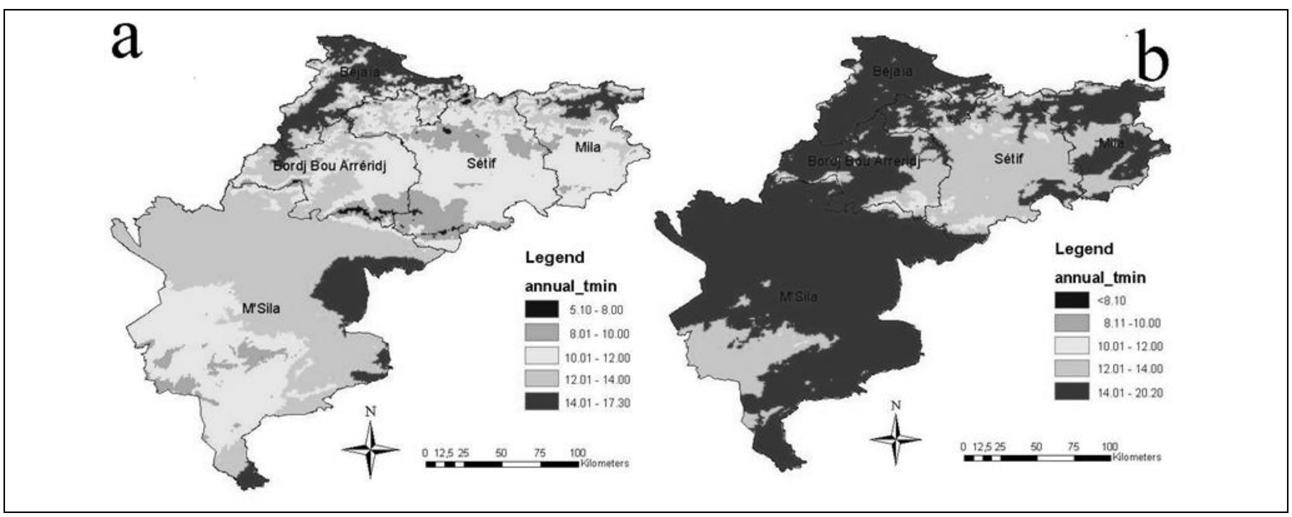

Figure 6. Expected minimum temperature map under RCP 2.6(**a**) and RCP 8.5 in 2070(**b**)
Source: Author's processing based on GFDL CM3 output

3.5 Building and validating predictive models of cereal yields by 2070

Recently, Researchers have developed several forecasting and prediction models of various crop yields in relation to different parameters as influencing factors by applications of ANN and by combining ANN and statistical techniques such as linear regression technique (Raju and Shahin, 2013).

In *Sétifois*, results of SMLR model show that durum wheat is significantly correlated by three influential variables which are April precipitation (Pr4), Mai minimum temperature (Tmin5) and April maximum temperature (Tmax4) (Table 3) while, soft wheat grain yield is associated with (Pr4) and February precipitation (Pr2). However, barley grain yield was correlated only to (Pr4). Yau and Ryan (2013) found a significant correlation between some cereal grain yield and rainfall in March to May and significant negative correlation between grain yields with temperature in May.

The major problems of wheat growing in the semi-arid region are heat and drought stresses which can reduce grain yield significantly; the timing of stress relative growth stages will determine the yield. Growth of wheat during all development phases can be influenced by temperature (Slafer and Rawson, 1994). Indeed, the base temperature for anthesis which occurred in April in *Sétifois* region and other tropical regions is reported as 9.5°C (Slafer and Savin, 1991) or less than 10°C (Russell and Wilson, 1994), while maximum temperature is more than 30°C (MacDowell, 1973) or more than 32°C (Russell and Wilson, 1994). The optimal temperature for wheat growth from anthesis to ripening is 25ºC or lower (Porter and Gawith, 1999). However, temperatures greater than this may induce a significant reductions in grain yield (Zubaidi, 2015).

Table 3. Summary of SMLR Model

Crops	**Climatic predictors**	**Coefficients**	**R^2**	**R^2 adjusted**	**Anova (P value)**
Durum wheat	April precipitation (Pr4)	0.136	0.60	0.54	0.000***
	April maximum temperature (Tmax4)	0.945			
	Mai minimum temperature(Tmin5)	-1.154			
	Constant	0.871			
Soft wheat	April precipitation (Pr4)	0.1	0.51	0.47	0.000***
	February precipitation (Pr2)	0.065			
	Constant	3.60			
Barley	April precipitation (Pr4)	0.153	0.49	0.47	0.000***
	Constant	4.61			

Note : *** denote high significant Anova (p<0.1%)

The SMLR models for cereal grain yield are written as follows:

Durum wheat grain yield = 0.136(Pr4) + 0.945(Tmax4) - 1.154(Tmin5) + 0.871

Soft wheat grain yield = 0.1(Pr4) + 0.065(Pr2) +3.60

Barley grain yield = 0.153(Pr4) + 4.61

It should be noted that the model describing Barley grain yield is not enough reliable, it is a simple linear regression model with little R^2 (<0.50), for this reason, it would be discarded for further analysis.

Across the comparison and the validation of SMLR and ANN models throughout a wheat grain yields series (1990-2016), it appears that ANN outputs are fitting slightly more to the actual grain yields than those of SMLR. ANN outputs are more correlated with the actual yields and variability is best accounted by explanatory variables under ANN than SMLR, where R^2 is greater for all cereals. Moreover, less Mean Square errors (RMSE) values are recorded for ANN (Table 4). Laxmi and Kumar (2011) concluded that ANN models produced better results than statistical models. However, Zaefizadeh, Khayatnezhad and Gholamin (2011) recommended ANN approach due to high yield and more velocity in the estimation to be used instead of regression approach. However, ANN model tends to underestimate both average and the standard deviation (Sd) grain yields compared to SMLR model.

Table 4. Cereal grain yield outputs set by SMLR and ANN models for 1990-2016 period

Crops	**Models**	**Average grain yield (q/ha)**	**Sd**	**R^2**	**RMSE**
Durum wheat	SMLR	10,31	3,80	0,60	2,91
	ANN	10,21	4,30	0,66	2,78
	Actual yield	**10,32**	**4,92**		
Soft wheat	SMLR	10,21	3,37	0,51	3,18
	ANN	10,09	3,45	0,62	2,89
	Actual yield	**10,17**	**4,68**		
Barley	SMLR	11,05	3,80	0,49	3,52
	ANN	10,88	3,73	0,50	3,50
	Actual yield	**11,05**	**5,39**		

ANN and SMLR Models perform better in predicting grain yield of durum wheat than soft wheat yield as reported in figure 7. This accuracy may be due to the number of explanatory variables included in the model. Durum wheat grain yield is expected by three influential variable (Pr4, Tmax5 and Tmin4), while soft wheat grain yield is predicted by only two Variables (Pr4 and Pr2). Both models are less sensitive to predict sudden spikes of yield, for example, actual yield of durum wheat rose suddenly from 4.64q/ha in 2002 to 18.59q/ha (2003) and 21.30q/ha(2004), but both models gave lower predicted values. The same observation is applicable for soft wheat.

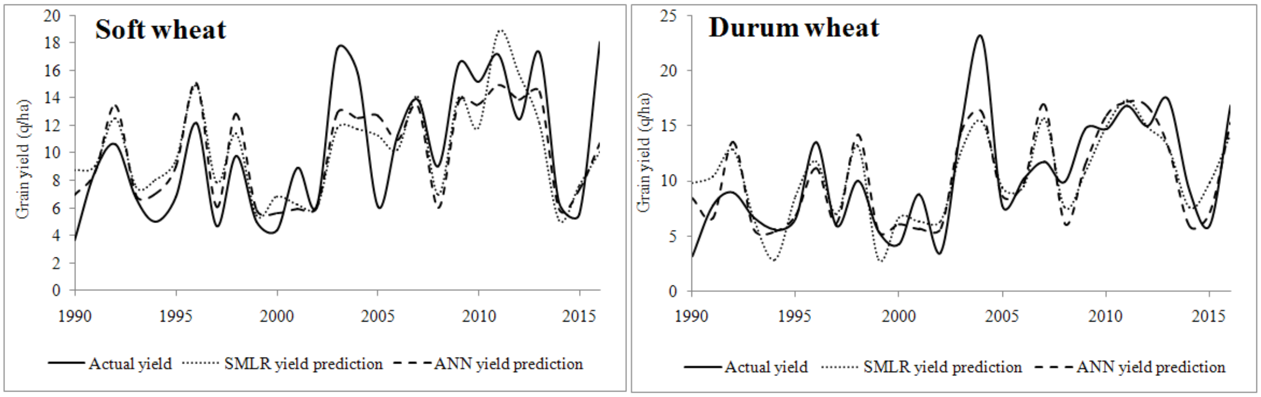

Figure 7. Fit of the interannual variation of actual cereal yields to SMLR and ANN models

3.6 Prediction of wheat grain yield in 2070

Through the preliminary examination of the models outputs, it can be observed that the models are relatively comparable as shown in figure 8a and figures 8b. However, predicted yields are more sensitive under RCP 8.5 scenarios, recording high rates of grain yield decrease by 2070. Some expected records could be compensable for some provinces especially under RCP 2.6. However, the majority of expected decreases under RCP 8.5 are insurmountable, such as *M'sila* and *BBA* provinces.

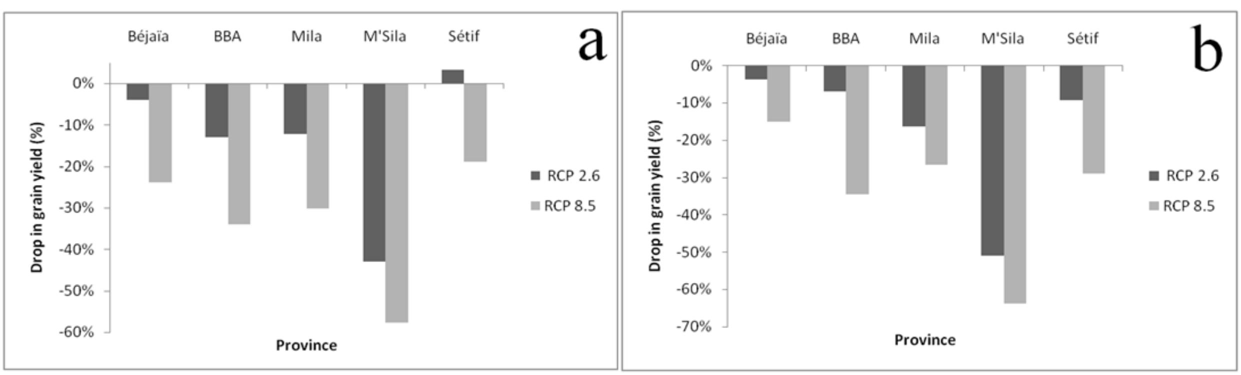

Figure 8. Average expected drop of yield for durum wheat (**a**) and soft wheat (**b**) in 2070 according to SMLR and ANN Models.

Exceptionally, SMLR model under RCP 2.6 show upwards rates for durum wheat yields in *Sétif* (13%) and *Béjaia* (3%), while in *BBA* province, grain yield remains unchanged (Table A2). This finding reports to the above results, stating that areas of central *Sétifois* including *Sétif* and *BBA* provinces will be less affected by the increase of temperature, which can protect crops from heat stress. Conversely, temperatures that are only slightly below freezing can severely injure wheat at reproductive stages and greatly reduce grain yields (Warrick and Miller, 1999). According to GFDL Climate outputs, April rainfall in *Sétif* province is expected to increase by 33.45% under RCP 2.6 in 2070, which would be the cause of grain yield increase. However, all remained cases expect a downward rate, arriving up to half yield loss. The average decrease in durum wheat yield in whole *Sétifois* began from -5% to -31% for SMLR model and from -22% to -35% for ANN model, this says that ANN model overestimate yield drop by 19% compared to SMLR model. However, decrease of soft wheat yield began from -15% to -35% for SMLR model and from -20% to -33% for ANN model (Table A3).

Subject to the reliability of expected climate data used in this paper, the resulting figures plot a dramatic and uncertain future for cereals production in the *Sétifois* in particular for RCP 8.5. More than 30% of the yield failure by 2070 means a very serious risk to the country's food security and additional burdens on the import bills of cereals. This situation should be well thought out; indeed the screening of high yielding and drought resistant cereal cultivars is a primordial task, which would be undertaken incessantly. The increase of the cereal land use by resorbing the annual of fallow, via the adoption of no-till technology, which is becoming more popular locally (Rouabhi *et al*.,2016). Indeed, every new adopted technology should be followed by an upgrade of mastering levels in mechanization in order to minimize crop operating costs and waste in harvesting processes. Moreover, the sensitization of CC and food security threats; could play an important role in the rationalization of natural resources such land and water. Locally; several opportunities arise for operating within the RCP 2.6 framework, likely to mitigate the effects of global change and to enhance the adaptation capacities of farmer, such as the mobilization of surface water by building dams and transferring water to the neediest areas. Locally, a new mega project funded by the state which cost more than 1.2 billion US $, consist of transporting water from the "*Ighil Emda"* dam in *Béjaia* province and "*Iraguen*" dam in *Jijel* province to the eastern and western parts of *Sétif* province. This mega project aims at recovering the supply of drinking water by 2040 and irrigating 40000 hectares. Farmers will benefit from equitable water sharing and a controlled management of irrigation water, such as adopting water saving irrigation strategies for cereal crops.

4. Conclusion

Cereals occupy a prominent position in agricultural research programs in Algeria and especially in *Sétifois* region; this concern is the more important as the country aspires to achieve sufficient and stable cereal production for a growing rate population. Results show reductions in expected durum and soft wheat yields by 2070 under the singular effect of climate trends. The potential regions such as *Mila* province was among the most affected regions. However, *Sétif* and *Béjaia* provinces were the least affected by warming and hence by wheat grain yield decrease. Yields could be maintained at acceptable levels if more rigorous environmental and resource conservation measures are taken as part of RCP 2.6 strategies. It should be noted that the assessment of the climate change effects on wheat yield may be erratic, if it bases on few climatic parameters as in the present study (rainfall and temperature). Climate change is multifaceted; it can affect soils biophysics, crop management, crop health, water supply, food security and biophysical cycles, hence, considering maximum of variables is paramount to best forecast its effects. Algeria renews its commitments to work together with the international community to achieve the objectives of the United Nations Framework Convention on Climate Change (UNFCCC). Algeria's Intended Nationally Determined Contribution (INDC) covers the (2021-2030) period. It involves the sectors of energy, agriculture, industry, housing, transport, forestry, construction and waste sectors. According to the Algerian NCD report in 2015, Algeria faces several challenges related to food security, ecosystems and agriculture resilience, where the anthropogenic effects aggravate those caused by natural characteristics, which could hinder the achievement of its commitments. In this study an attempt has been made to assess the climatic impact on the local cereal sector and to highlight possible recommendations for efficient future adaptation in the framework of the Algerian INDC. Given the alarming results of the expected declines in wheat yields, many things are to be made urgently, basing on the improvement of capacity building for water sector management, by the increase of the total dams capacity, recycling water and using water rationally and efficiently for irrigation. Moreover, increasing land use for agriculture and forestry could lead to better carbon sequestration and biodiversity. However, conservation agriculture namely no-till technique used for annual crops (cereals and legumes) seems to be a good solution for ensuring food security at the long term, this technique allows optimizing economic gain and valuation of uncultivated land and fallow. Indeed, the implementation of an integrated analysis based on agronomic, economic and social models seems to be the more appropriate manner to deal with such complex items.

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Appendices

Table A1.Comparison of RCPs

RCP	Description	CO_2 concentration (ppm) equivalent	Pathway	Scenario severity
2.6	A peak in radiative forcing of approximately 3 W/m² before 2100, declining to 2.6 W/m² by 2100.	Peak of ~490 and then decline by 2100	Peak and decline	Lowest
4.5	Stabilization at 4.5 W/m² by 2100 without overshoot.	650 (stabilized after 2100)	Stabilization without overshoot	Medium-low
6.0	Stabilization at 6 W/m2 by 2100 without overshoot.	850 (stabilized after 2100)	Stabilization without overshoot	Medium-high
8.5	Rising pathway resulting in 8.5 W/m² by 2100. Radiative forcing continues to rise beyond 2100.	>1,370 in 2100	Rising	Highest

Sources: Cubasch et al. 2013; IPCC 2007; Moss et al. 2010; van Vuuren et al. 2011

Table A2. Evolution of durum wheat grain yield (%) according to SMLR and ANN

Province	SMLR under RCP 2.6	SMLR under RCP 8.5	ANN under RCP 2.6	ANN under RCP 8.5	Average RCP 2.6	Average RCP 8.5
Béjaïa	3%	-22%	-11%	-26%	-4%	-24%
BBA	0%	-30%	-26%	-38%	-13%	-34%
Mila	-7%	-28%	-17%	-32%	-12%	-30%
M'Sila	-34%	-58%	-51%	-57%	-43%	-58%
Sétif	13%	-16%	-7%	-22%	3%	-19%
Average Sétifois	**-5%**	**-31%**	**-22%**	**-35%**	**-14%**	**-33%**

Table A3. Evolution of soft wheat grain yield (%) according to SMLR and ANN

province	SMLR under RCP 2.6	SMLR under RCP 8.5	ANN under RCP 2.6	ANN under RCP 8.5	RCP 2.6	RCP 8.5
Béjaïa	4%	-16%	-11%	-14%	-4%	-15%
BBA	-9%	-34%	-4%	-35%	-7%	-35%
Mila	-11%	-26%	-22%	-27%	-17%	-27%
M'Sila	-48%	-67%	-54%	-61%	-51%	-64%
Sétif	-9%	-30%	-10%	-27%	-9%	-29%
Average Sétifois	**-15%**	**-35%**	**-20%**	**-33%**	**-18%**	**-34%**