J. Soils and Crops 32 (2) 232-239, December 2022

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

ANALYSIS OF THE EVOLUTION OF WHEAT PRODUCTION ACCORDING TO RAINFALL VARIABILITY IN NORTHERN OF ALGERIA

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ABSTRACT

This work aims to study the evolution of cereal productions according to the rainfall variability in the city of Tiaret in Algeria. To do this, an analysis of correlations between cereal production and rainfall was established, the correlation coefficient is about 62%. The linear regression equation makes it possible to estimate cereal production as a function of rainfall. Over the last 30 years (1989-2018), the Mann-Kendall test showed a significant positive trend of about 6 mm year^{-1}. The Pettitt test reveals a 29% increase observed since 2005.

These results correlate with the evolution of cereal production. Indeed, cereal production has increased considerably since 2005 and this can be explained in part by the increase in rainfall in the region. This confirms the strong relationship between these two parameters. These results make it possible to anticipate adaptation measures to cope with the consequences of climate change.

(Key words: Cereal production, rainfall variability, climate models, Tiaret)

INTRODUCTION

Cereals, including durum and soft wheat, maize, barley, and triticale, are considered primary and strategic crops because they are staple foods for most populations around the world. By 2050, a 70-100% increase in cereal supply is needed to feed the projected world population of 9.8 billion people (Godfray *et al*., 2010). Increasing production rates is generally accepted as a solution to meet the growing demand, but historical figures show that current production rates are far from the targets to be met (Ray *et al*., 2013). Furthermore, this problem is further enhanced by a severe reduction in the amount of fertile and arable land available to grow these crops, which is expected to continue to decrease in the future due to current agricultural practices (Hawkesford *et al*., 2013).

In Algeria, cereal growing continues to occupy an important place in Algerian agriculture. The three main cereals (barley, durum wheat and soft wheat) cover annually about 5 million hectares, or 60% of the country's UAA, the majority of these crops are located in semi-arid and arid areas (Mebarki *et al*., 2020). The national cereal production achieved at the end of the 2018-2019 campaign reached 59.5 million quintals (Anonymous, 2020). Despite undeniable progress, cereal yields remain low and very irregular: 13.5 qx ha^{-1} on average over 2001-2010 up to 19 qx ha^{-1} in 2018 (Anonymous, 2018), which is far behind the productivity of Mediterranean countries in Europe, France for example with 72 qx ha^{-1} and the USA with 78 qx ha^{-1}. (Anonymous, 2018).

The national cereal needs are estimated at about 80 million qx year^{-1}, the rest is imported, Algeria is considered one of the most important cereal importing countries in the world. As these figures indicate, Algeria is not able to ensure its food security and relies on imports to meet the needs of a population that continues to grow over the years. The situation of the Algerian cereal growing is very difficult, its production has only slightly increased since independence and today it feeds only one out of three Algerians. Natural conditions, especially climatic, give the Algerian agricultural sector its particular character, and largely determine the rural landscape as well as the production of this or that plant (Fenni and Machane, 2010).

Researchers agree that climate change can have a significant impact on crop yields, and that it is a problem that must be solved to achieve food security (Tripathi *et al*., 2016; Howden *et al*., 2007).

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Indeed, Algeria has experienced over the last 25 years (1975-2000), an intense and persistent drought that has affected the entire territory, and has been particularly severe in the west of the country. The analysis of time series of precipitation indicates a rupture from the 1970s, and the decade 1980 was the most deficient (Medjrab, 2005; Meddi *et al*. 2007; Bekkoussa *et al*., 2008; Meddi *et al*.,2010; Taibi, 2011; Benhalima, 2019). Annual temperatures have also increased by about 0.7°C since the 1980s (Taibi, 2011; Zeroual and Talia, 2017). According to the Intergovernmental Panel on Climate Change (Anonymous, 2013), temperatures are still likely to increase by 1.5°C to 5°C by the end of the 21st century which will cause a 10% to 30% decrease in precipitation in North Africa. Climate models are used to conduct socio-economic and environmental impact studies on agriculture, water resources availability, etc.

This is the context of our work, which aimed to analyze the impact of climate variability on cereal yields in the semi-arid areas of Algeria, which are the main cereal-producing regions in Algeria. These regions experienced severe and persistent drought during the 1980s and 1990s.

MATERIALS AND METHODS

Presentation of the region studied

It is located at an altitude of 1150 m. Its climate is characterized by two periods: a harsh winter and a hot and dry summer with an average temperature of 37.2°C. A hot and dry summer with an average temperature of 24°C. In normal period, the wilaya (city) of Tiaret receives 300 to 400 mm of rainfall year^{-1}, with a seasonal fluctuation of rainfall ranging from 157 mm in winter to 31 mm in summer. It belongs to the lower semi-arid bioclimatic stage with cool winters where the climate is of the Mediterranean type. The relief is heterogeneous and is materialized by: a mountainous area in the North; high plains in the Center; semi-arid spaces in the South (68.44%). The wilaya conceals important natural potentialities and notably 1,609,900 ha of agricultural land, 142.966 ha of steppe areas and a forest area of 142,422 ha. The total agricultural area is distributed at a rate of 704,596 ha of useful agricultural land including 14,561 ha in irrigated and one million hectares in steppe, rangeland, esparto and forests. The system «cereals - breeding» whose integration constitutes the main part of the agricultural production and the economic growth dominate it. The steppe environment is characterized by high altitudes (1100 men average), the highest steppes reach 1300 m and the lowest oscillate between 1000 and 1100 m, which indicates that the differences in level are not very important, less than 200 m. The substratum is predominantly limestone.

The steppe area is characterized by the aridity of the climate and the low rainfall. It is very sensitive to desertification where the vegetation cover is strongly degraded.

Data used

Observed climatic data and cereal yields

$$r_{xy} = \frac{COV(X,Y)}{\sigma_x \times \sigma_y}$$

$$C\hat{O}V(X,Y) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{n-1} = \frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{n-1}$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \times \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

$$r = \frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sqrt{\sum x_i^2 - n\bar{x}^2} \times \sqrt{\sum y_i^2 - n\bar{y}^2}}$$

Mann-Kendall trend test

The Mann-Kendall test (Mann, 1945; Kendall, 1975) is used to determine with a non-parametric test whether a trend is identifiable in a time series which may include a seasonal component. The null hypothesis H_0 is accepted when the series is homogeneous, which means that there is no significant trend. The null hypothesis is rejected when the series shows a significant positive or negative trend at a significance level á.

Pettitt ruptureTest

Pettitt (1979) proposed a test that is based on the Mann-Whitney (1947) statistic. This test allows us to determine at what date a change may have occurred in the mean of a time series of size N. The null hypothesis (H0) of this test assumes that the time series is stationary. Otherwise, the alternative hypothesis (H1) admits that the series is not stationary and that a change in the mean is observed at a time (t) and for a significance level á.

RESULTS AND DISCUSSION

Analysis of the evolution of cereal production in the Wilaya of Tiaret during the period 1990 - 2018

The data regarding evolution of cereal production as well as the yields in qx ha^{-1} in the Wilaya of Tiaret during the last 30 years are represented in the following figures 2, 3, and 4.

Tiaret is considered one of the largest producing wilayas of wheat in Algeria, it often occupies the first place in terms of volume of production, this is mainly due to the availability of production factors in this wilaya, especially agricultural land. The production curve shows that wheat production in the wilaya of Tiaret follows an average of 1,073,653 qx during the period (1990-2008), while in the second decade this average reaches about 3,139,918 qx, the highest estimated quantity of wheat production was that of 2012 with 4,586,164 qx, while the lowest quantity produced was estimated in 1994 at 31,070 qx.

Cereal yields have been stagnating for the past decade. Most cereals are affected. The most important ones, such as common wheat, durum wheat, barley and triticale, now cover more than 15% of the total national area sown with cereals. The levels certainly fluctuate annually depending on several factors. Cereal productivity reached 53 quintals hectare^{-1} during the record year of 2008, before plunging in 2009. But a stagnation observed over ten years has all the more credibility since it concerns the first Algerian crop. The almost uninterrupted growth of yields goes back to the 9 quintals hectare^{-1} obtained in 2005. The average of the period 2006 - 2018 was 16 qx ha^{-1}, it has doubled compared to the average recorded during the period 1990 - 2005 which was 7 qx ha^{-1}.

Analysis of the impact of rainfall variability on cereal production in the wilaya of Tiaret during the period 1990 - 2018

Analysis of rainfall variability

Rainfall data at Tiaret station are available during the period 1950-2018. To analyze the rainfall variability of the study area we selected two periods a long period from 1950 to 2005 and the 1989-2018 which is consistent with the availability of data on cereal production. The Mann-Kendall trend test and the Pettitt rupture test were applied to the monthly and annual series during the two periods (Figure 5).

The evolution of rainfall over the period 1950-2005 shows two separate periods: a surplus period (1950-1980) followed by a deficit period from 1980 to 2005. A continuous decrease in rainfall was observed since 1980, the majority of the rainfall averages were below average.

At the annual scale, the Mann-Kendall (M-K) test showed a significant negative trend during the period 1950-2005 (Table 02). When the p-value is below the 5% significance level, the data series is not homogeneous, so there was a significant trend. The slope of sen (Sen, 1968) associated with the M-K test corresponds to the median of all slopes calculated between each pair ofh points within the same period, it highlights a decrease of about 5 mm year^{-1} or 50 mm decade^{-1}. These results are confirmed by the Pettitt test which showed a 38% reduction in rainfall at the Tiaret station since 1979.

Over the last 30 years (1989-2018), the Mann-Kendall test showed a significant positive trend of about 6 mm year^{-1}. The Pettitt test reveals an increased of 29% observed since 2005.

These results coincide with the evolution of cereal production. Indeed, cereal production increased considerably since 2005 and this can be explained in part by the increase in rainfall in the region. This confirms the strong relationship between these two parameters.

At the monthly scale (Table 03 and 04), the M-K test showed significant negative trend in the months of November, February, April and May estimated at 68, 65, 97 and 60 mm decade^{-1} respectively. This decrease in rainfall has been observed since 1979 according to the Pettitt test and corresponds to the break date on an annual scale.

We noted that this decrease in rainfall affected the critical stages of the cereal development cycle, namely

- Ø Crop establishment (November-December)
- Ø Emergence of tallage (February)
- Ø Flowering and grain formation (April-May)

During the period 1989-2018, a positive trend observed for all the months, but this was only significant in the months of November, February and March, which showed an increase of 12.5, 8 and 18 mm decade^{-1} respectively (Table 4).

The Pettitt test showed eventually an increase in precipitation of about 47%, 58% and 71% respectively in the months of November, February and March since 2005 (Table 4).

This increase occurs at critical stages of the cereal development cycle, which explains the increase in cereal production since 2005.

Rainfall-Cereal Production Correlation

The graphical and statistical analysis showed that rainfall and cereal production evolve in the same direction. There is therefore a link between these two parameters. In order to quantify this link, we used the Pearson correlation coefficient. The latter highlights a significant positive correlation of 62%, which allows us to represent in the form of a formula the relationship between cereal production and rainfall through a linear regression (Figure 6 and Table 5). This relationship is expressed by the following equation

$$Yi = 5904.5xi - 758820$$

Where Yi is the cereal production and xi is the rainfall in a given year.

The linear regression equation will be used in the determination of the future evolution of cereals as a function of the simulated rainfall by the end of the century.

Analysis of the results of the impact of climatic variability on cereal production in the Wilaya of Tiaret has shown that rainfall is the main factor affecting cereal production over the last thirty years, due to its inter- and intra-annual variability. The analysis of the rainfall regime showed a downward trend of 5 mm year^{-1} between 1979 and 2005. On the other hand, the period of 2005-2018 is characterized by a significant increasing trend of 6 mm year $^{-1}$. This shows that an increase in rainfall positively affects cereal yields, whereas an increase in the frequency of droughts can have negative effects on cereal productivity. Indeed, the Person correlation coefficient showed a significant positive correlation of about 62%.

Given that 90% of our cereals are rainfed and that the state is not currently ready to launch a vast irrigation program, we are obliged to propose adaptation solutions to these climatic hazards. In this sense, different options are available in the short, medium, and long term, the possibilities of adaptation of the country must pass through a reorientation of certain crops and a modification of production processes to withstand climate variation and meet the growing needs of the population.

Among the measures that must be taken:

Ø The dissemination of new tolerant varieties and early varieties adaptable to climate change.

Ø Conservation agriculture is important to minimize water loss through evaporation. The adoption of no-till or semi-tillage practices will reduce organic matter and water losses through evaporation. The development of crops such as rice in low-lying areas would be an appropriate way to make the most of the flooding caused by climate change.

Ø The recycling of wastewater will increase the amount of water available for various uses, particularly agricultural uses.

Ø The gradual overhaul of traditional agricultural calendars, the optimization of sowing dates according to climate changes.

Ø The use of selected seeds and the choice of short-cycle and drought-resistant varieties, and finally the reconversion and repositioning of crops according to the changing bioclimatic context.

In short, it can be noted that adaptation to climate change requires a shift towards more ecological agricultural practices. In this respect, we can even say that climate change is an opportunity for Algeria, since it will lead to the adoption of agricultural practices based on ecosystems. Conventional agricultural practices that have harmful consequences on the environment will have to regress necessarily for food security and sustainable development to be a reality in Algeria.

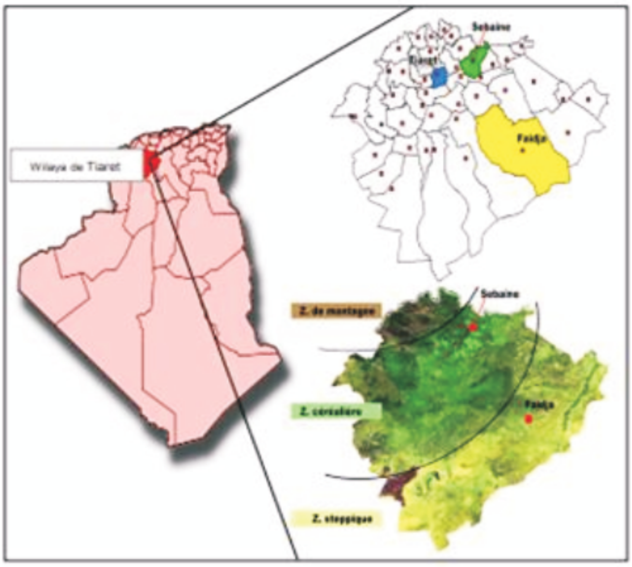

Figure 1. Geographical map of the wilaya of Tiaret (Western Algeria) (Achir Mohammed, Hellal Benchaben, 2016)

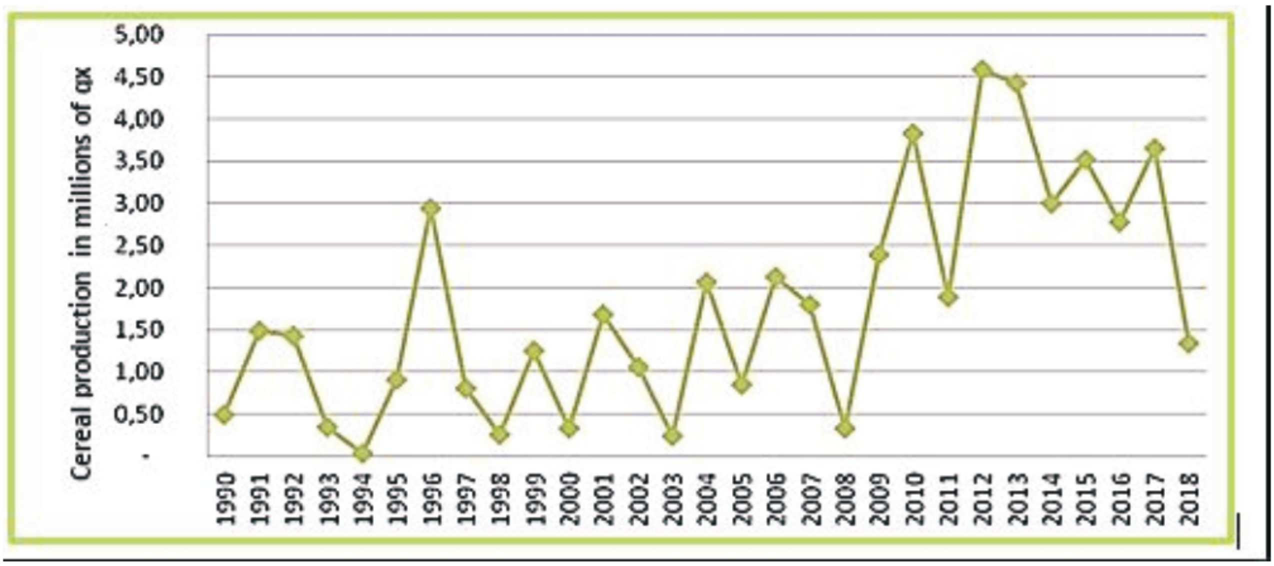

Figure 2. Evolution of cereal production during the period 1990 – 2018

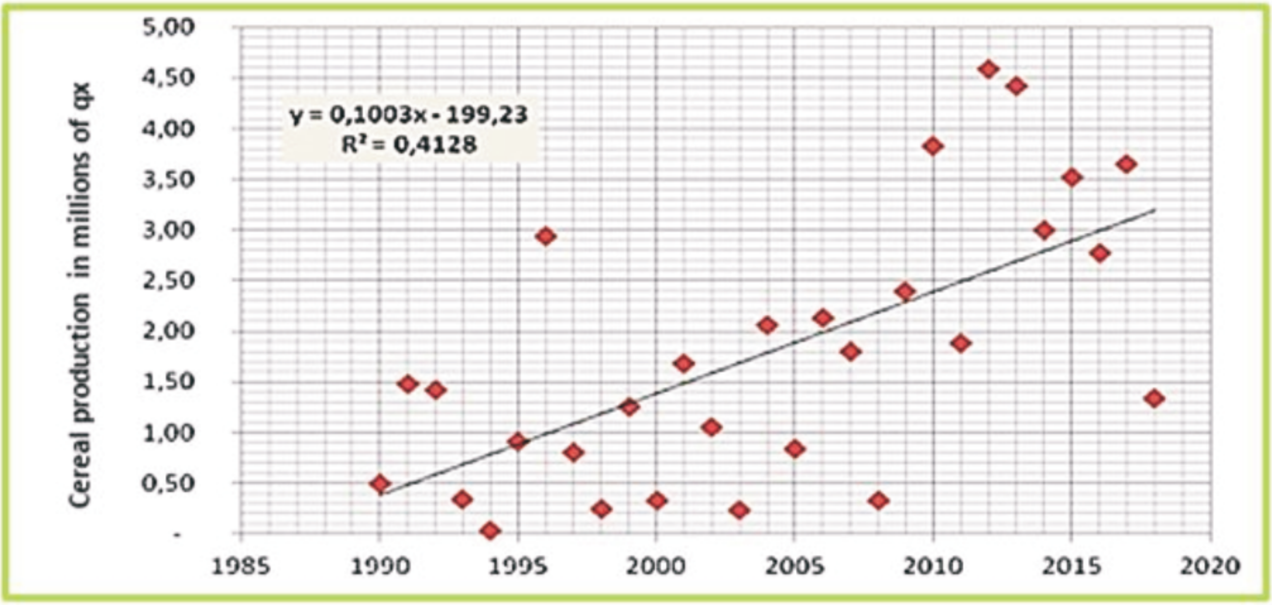

Figure 3. Trend of cereal production during the period 1990 – 2018

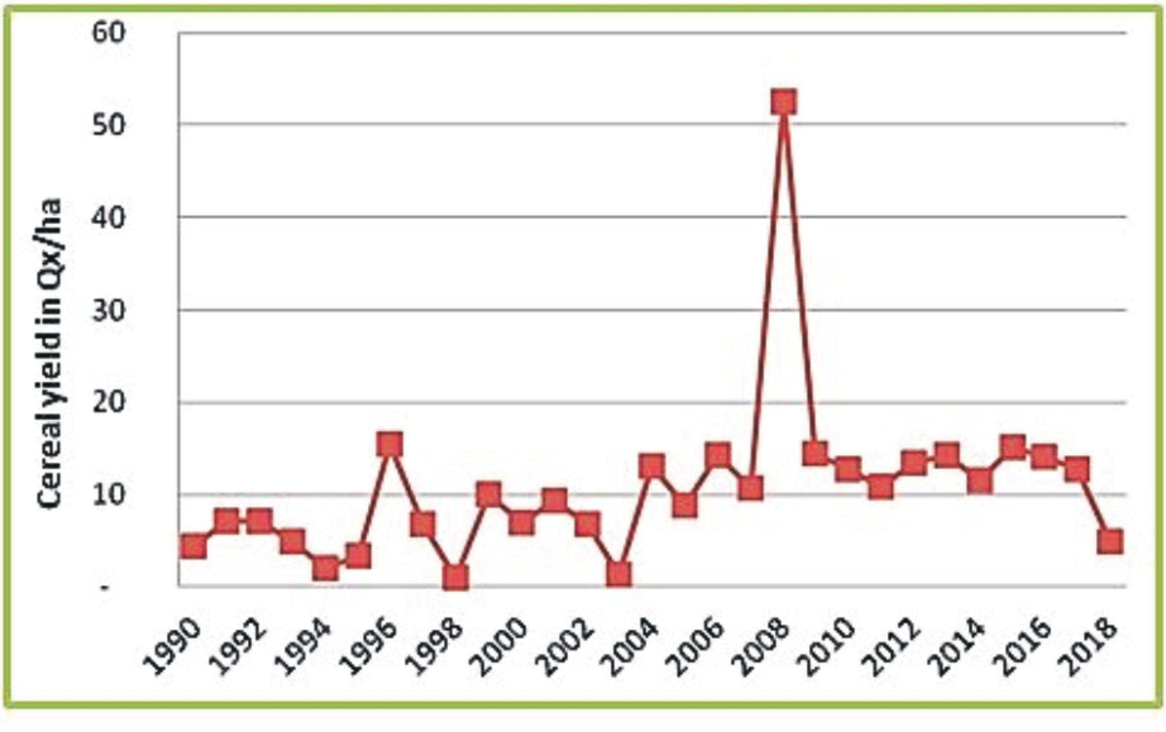

Figure 4. Evolution of cereal yields over the period 1990 – 2018

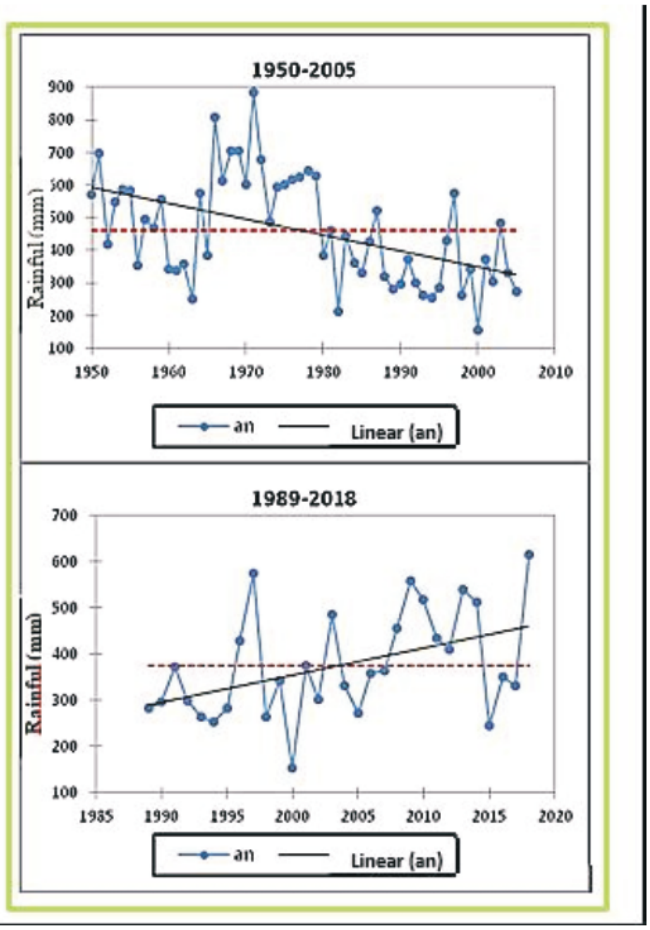

Figure 5. Annual rainfall trend over the period 1951-2005 and 1989-2018

Table 1. Characteristics of the Tiaret station

Station	Latitude	Longitude	Altitude	Study period of Rainfall
Tiaret	34.8529	1.5209	1150 m	1990-2018

Table 2. Results of statistical tests at the annual level

	Tests	1950-2005	1989-2018
M-K test	P-value	0,00	0,02
	Slope of sen	**-5,06**	**6,26**
Pettitt test	Date of rupture	1979	2005
	M before	557,27	331,86
	M after	347,85	426,54
	Dif %	**-38%**	29%

Table 3. Results of statistical tests at the monthly scale during the period 1950-2005

Tests statistiques		S	O	N	D	J	F	M	A	M
M-K test	P-value	0,06	0,70	0,02	0,16	0,22	0,05	0,58	0,00	0,04
	Slope of sen	0,14	-0,06	**-0,68**	-0,35	-0,31	**-0,65**	-0,10	**-0,97**	**-0,60**
Pettitt test	Date (mm/an)	-	-	1979	-	-	1987	-	1979	1979
	Med. Before (mm)	-	-	78,27	-	-	65,80	-	79,54	65,28
	Med. After (mm)	-	-	31,01	-	-	35,12	-	33,43	37,05
	Differance %	-	-	**-60%**	-	-	**-46,63%**	-	**-58%**	**-43%**

Table 4. Results of statistical tests at the monthly level during the period 1989-2018

Tests statistiques		S	O	N	D	J	F	M	A	M
M-K test	P-value	0,34	0,16	0,03	0,72	0,09	0,04	0,02	0,40	0,59
	Slope of sen (mm/an)	0,31	0,65	**1,25**	0,13	1,00	**0,87**	**1,81**	0,48	-0,14
Pettitt test	Date (mm/an)	-	-	2005	-	-	2005	2008	-	-
	Med. Before (mm)	-	-	32,49	-	-	35,47	33,41	-	-
	Med. After (mm)	-	-	47,86	-	-	55,89	57,05	-	-

Table 5. Correlation between rainfall and cereal production

P-value	Correlation coefficient (R)
0,008	0.62

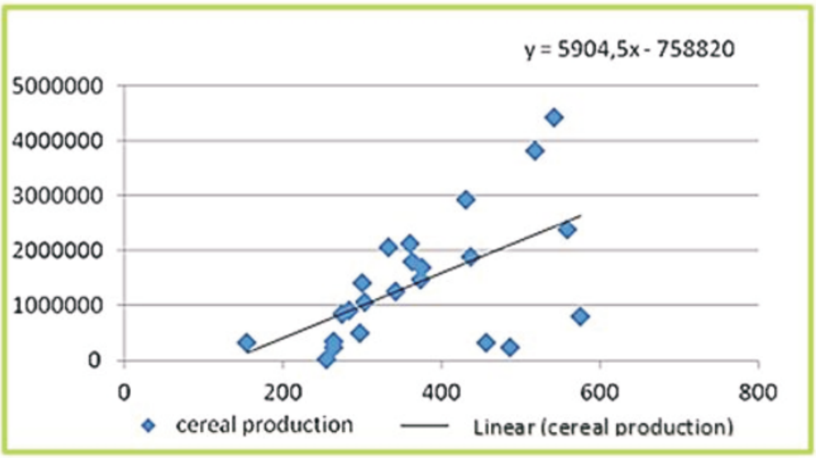

Figure 6. Relationship between cereal production and rainfall

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Rec. on 01.06.2022 & Acc. on 10.06.2022

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