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Impact of climatic factors on the productivity of cereal crops in the region of Meknes (Morocco)

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Abstract

The main objective of this work is to analyze the impact of climate change on the productivity of cereal crops in the region of Meknes. The variables used are: precipitation, temperature, weighted moving average and Nicholson index. Cereals are hard wheat, soft wheat and barley. The period of analysis is from 1984 to 2014. This analysis revealed a great irregularity in the yields of the three types of cereals. Indeed, the analysis of rainfall variability showed the alternation of three major periods, a normal period between 1984 and 1991, then a first dry period 1991 to 2003 and a beginning of a second period from 2011, and finally a wet period ranging from 2008 to 2011.In the precipitation regime characterized by two ruptures during the 2005 and2007. Faced with these conditions, the yields of the three cereal crops Of the region of Meknes have indeed been affected and thus showing their axial dependence of climatic factors.

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Introduction

Agriculture is the great wealth of the region of Meknes. The main agricultural speculation is: viticulture, cereal farming, food legumes. Cereals such as durum wheat, soft wheat and barley are among the most important crops in Meknes. The area occupied by cereals is estimated at 6479 ha (durum wheat), 72411 ha (soft wheat) and 7568 ha (barley).

Previous studies (Saley *and al.*, 2009) suggest that cereal yield correlates significantly with climatic factors (Arifi *and al.*, 1999). The observed or predictable consequences of climate change are manifold (Barakat Handoufe, 1998).

They range from simple meteorological disturbances to irregular changes in soil type; The latter have a decisive impact on cereal production. Other studies (Chebil *and al.*, 2011) have addressed the relationship between the physico-chemical parameters of the Saïs soil and the yield of three types of cereals(Mansouri and Rahouane, 2015). Cereal yields vary greatly from year to year. In years of drought without a period of growth (Fassou *and al.*, 2015) or with a very short growth period, yields are low or absent, whereas in the wet years with a long period of growth they are higher (Salma *and al.*, 2005).

Climate change will reduce the yields of major crops(Balaghi *and al.*, 1995)for the agricultural sector and increase the variability of agricultural production (Balaghi, 1993; Balaghi, 2000).

According to future projections in Morocco, it is reasonable to expect an increase in temperatures and a decrease in precipitation and an increase in their variability. Indeed, the average temperature could increase from 1.1 to 1.6 ° C by 2030, from 2.3 to 2.9 ° C in 2050, and from 3.2 to 4.1 ° C in 2080.

At the level of the whole country, precipitation Could be reduced by 14% in 2030, 13-30% by 2050, and 21-36% by 2080. With 85% of agricultural land that is not irrigated, yields of major crops are the high variability of precipitation and a high frequency of droughts. (Badraoui and Balaghi, 2012).

The main objective of this work is to analyze the impact of climate change on the productivity of the cereal crops in the region of Meknes.

Study area

The region of Meknes covers an area of 178,700 ha (Fig. 1). It is limited to the North by the Province of Sidi Kacem, in the West by the Province of Khémisset, in the South by the Province of El Hajeb and in the East by the Province of Zouagha Moulay Yaakoub (Provincial Directorates of Agriculture, 2014).

The climate of the study area is of the temperate type of the mediterranean understory, undergoing continental influences during the summer and winter season. However, the geographical diversity of this region means that each of its natural areas has particular climatic nuances (Provincial Directorates of Agriculture, 2014). Land use in the Meknes region and crop rotation (crop year 2013-2014) (Table 1).

The occupation of the soilbrings out the followingobsevation, the predominance of cereals with an average of 75 000 Ha or 50% of the UAA (useful agricultural area) of which the common wheat occupies an area of 58,400 ha or 78% of the cereal soil, fruit plantations come second with 31,500 ha (21% of the UAA) with a predominance of olive growing, then pulse legumes with an area of 20,800 ha (14% of the UAA) and a predominance of chickpea and bean, and vegetable crops occupy 6.770 ha (5% of the UAA) with predominance of potato and onion, otherwise forage crops with 8600 ha (6% of the UAA), finally oil crops occupy only 1600ha (1% of the UAA) represented by sunflower.

Data and methods

The data used are the time series of precipitation, temperature and cerealyields. Theywereprovided by the Provincial Directorate of Agriculture (DPA), the National Office of Drinking Water (ONEP).

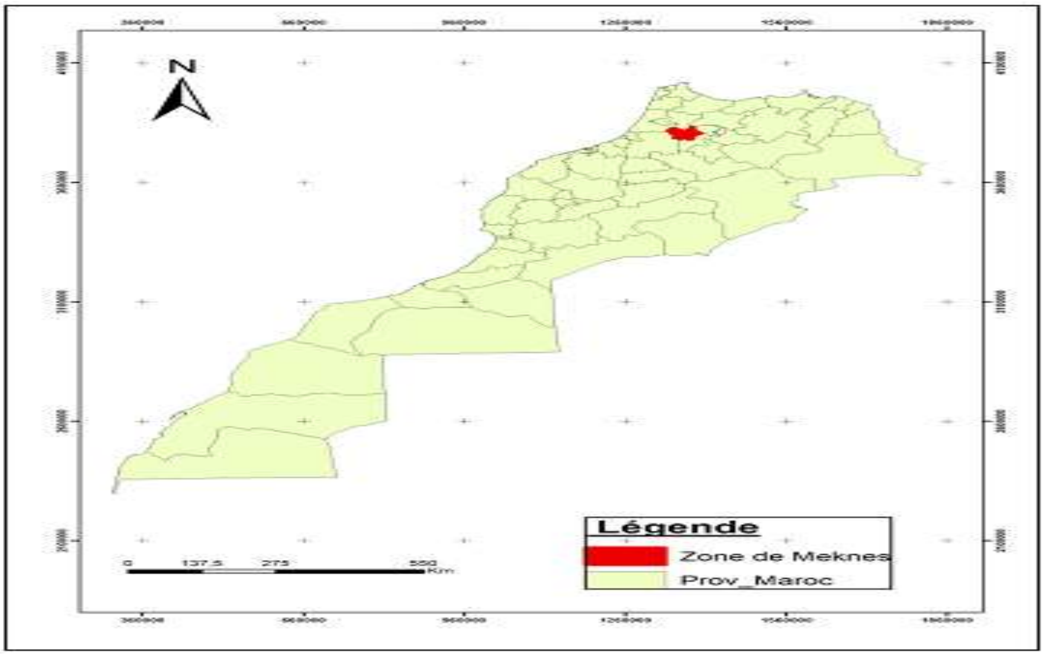

Fig. 1. Location map of the study area.

In this study, the main software used for the hydroclimatic data processing and the generation of the the maticcards are: ArcGis 10, Chronostat 1.1, XLSTAT on 2009.

The Nicholson Index : For the analysis of the hydroclimatic parameters, we calculated the annual rainfall averages and the Nicholson index in order to show the fluctuations of the rainfall regimes.

(Nicholson *and al.*, 1988), (Paturel *and al.*, 1997) defined an index, calculated annually over the period studied, expressed by the following equation

$$Ii = \left(X - \frac{\bar{X}}{\sigma}\right) \quad (1)$$

Ii : Pluviometric indication

$\bar{X}$: Rain height of the year i (en mm),

Xi: Rainy height averages over the period of study (en mm),

σ: Standard deviation of the rainyheight over the period of study.

This equation etermines a centered reduced variable Lamb (Servat *and al.*, 1982 ; Servat *and al.*, 1998). The interannual average of a series corresponds to no worthless indication (index) (0) according to the method of Nicholson.

A normal period is a period during which an identical fluctuation observes on both(all) sides of the X axis. In this case, the annual average is appreciably equal to the average of the total pluviometry. During the wet period, the annual average is superior to the average of the total pluviometry. While, the dry period corresponds to a period or the annual average is lower than the total pluviometric average. (Fossou, 2015).

Hanning pass filter of order 2 ("weighted moving averages") :This method allows the elimination of seasonal variations in a given time series. The weighted moving average is calculated by the equation below.

$$X(t) = 0{,}06x(t-2) + 0{,}25x(t-1) + 0{,}38x(t) + 0{,}25x(t+1) + 0{,}06x(t+2) \quad (2)$$

With $3 \leq T \leq (V-2)$

Where X (t) is the weighted rainfall total of the term t; X (t-2) and X (t-1) are the observed main rainfall totals of the two terms immediately preceding the term t. X (t + 2) and X (t + 1) are the observed rainfall totals of the two terms immediately following the term t.

The predicted rainfall totals of the first two [X (1), X (2)] and the last two [X (n -1), X (n)] terms of the series are calculated using the following expressions Size of the series):

X(1)= 0,54X(1) + 0,46X(2) (3)

X(2)= 0,25X(1) + 0,5X(2) + 0,25X(3) (4)

X (n-1) = 0,25X (n-2) + 0,5X (n-1) + 0,25X(n) (5)

X(n) = 0,54X(n) + 0,46X (n-1) (6)

To better visualize the periods of rainfall deficit and surplus rainfall, the centered and reduced moving averages are calculated from equation (7).

Y't= (X(t)– m) / σ (7)

Where m is the mean of the series of weighted averages and σ is the standard deviation of the series of weighted moving averages. (Saley, 2009).

Test of Pettitt (1979): The Pettitt test (Soro, 2011; AssEmiAN, 2013) is a modified version of the Man-Whitney test, it has been described by several authors. It verifies the stationarity of the rainfall series. This series is divided into two (2) samples of size m and n, respectively.

The values of the two samples are grouped and ranked in ascending order. The sum of the ranks of the elements of each sub-sample in the total sample is then calculated.

A statistical study is defined from the two sums thus determined, and tested under the null hypothesis that the two sub-samples belong to the same population. This test is based on the calculation of the variable Ut, N defined by equation (8):

$$U_{t,N} = \sum_{i=1}^{t} \sum_{j=t+1}^{N}$$

With Dij = sgn (Xi-Xi) with sgn (X) = 1 if X> 0 and - if X <1

Results and discussion

Evolution of yields

Overall, between 1984 and 2014, there were very significant inter-annual variations in the three types of cereals that could be attributed to climatic hazards(Fig. 2). Throughout the analysis the common wheat presents the best performance followed by durum wheat and finally the barley.

Table 1. Land use in the Meknesregion.

Cultures	Area (in Ha)	Percentage Area%
Cereals	75000	50
Pulse Products	20800	14
Forage crops	8600	6
Oilseedcrops	1600	1
Vegetablecrops	6770	5
Fruit plantations	31500	21
Fallow	3730	3
Total	148 000	100

Meteorological data

The mean maximum temperature (Fig. 3) showed a slight increase of 0.98 ° C during the study period. Indeed, the standard deviations of temperature remain very low between 1984-2014.This shows a small variation of temperature during this period.

The analysis of the precipitation parameter throughout the period of study (1984-2014) shows an increase in mean annual precipitation from one decade to the next with an average of 484,1 mm for the Decade 1984-1993, while the average of the last 10 years is of the order of 587, 8mm (Fig. 4).

In addition, the comparison of variances-types indicates a greater variation of gap-types for the Second Decade. This explains the increase in the occurrence of extreme conditions during this period, in comparison with the first and the last decade.

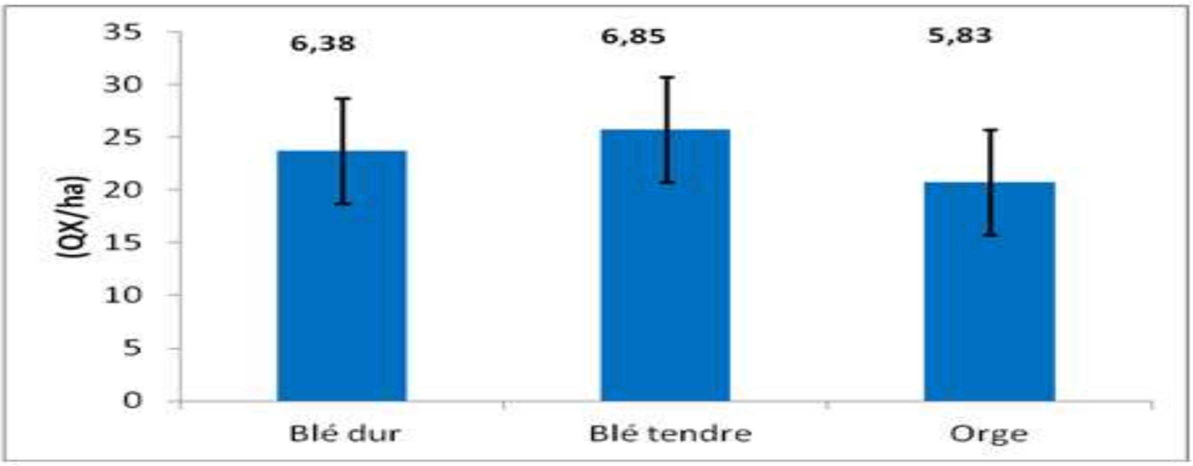

Fig. 2. Average and standard deviation of cerealyield per Meknescropfrom 1984 to 2014.

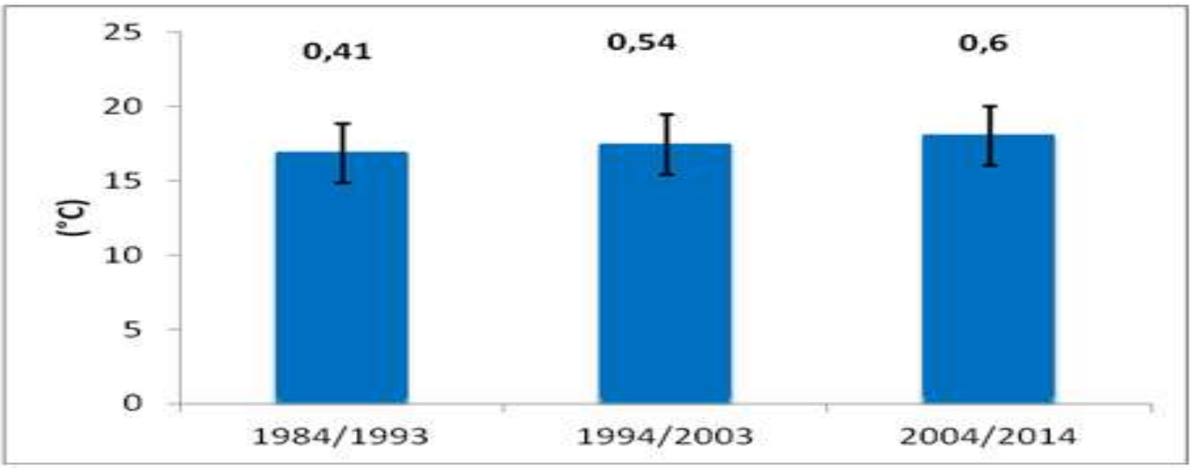

Fig. 3. Change in average maximum temperature in the region of Meknes.

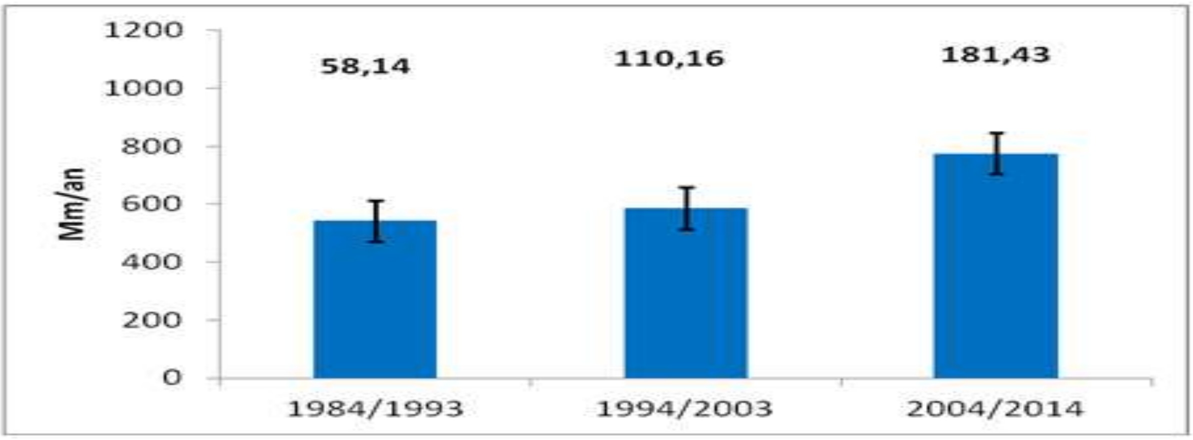

Fig. 4. Variation of the average annual precipitation in the region of Meknes.

Pluviometric indication of Nicholson

The results of the indices of Nicholson as well as the weighted moving average applied to the Meknes region (Fig. 5)allow to identify three major periods, a normal period between 1984 and 1991, then a first dry period 1991 to 2003 and a beginning of a second period from 2011, and finally a wet period ranging from 2008 to 2011.

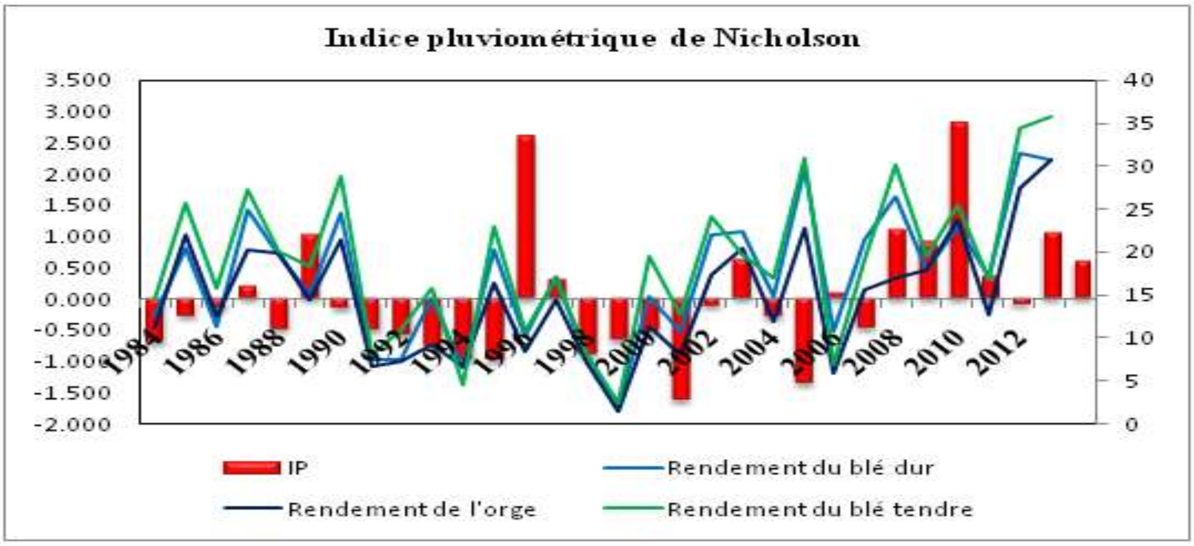

Fig. 5. Nicholson pluviometric index as a function of yield in the region of Meknes.

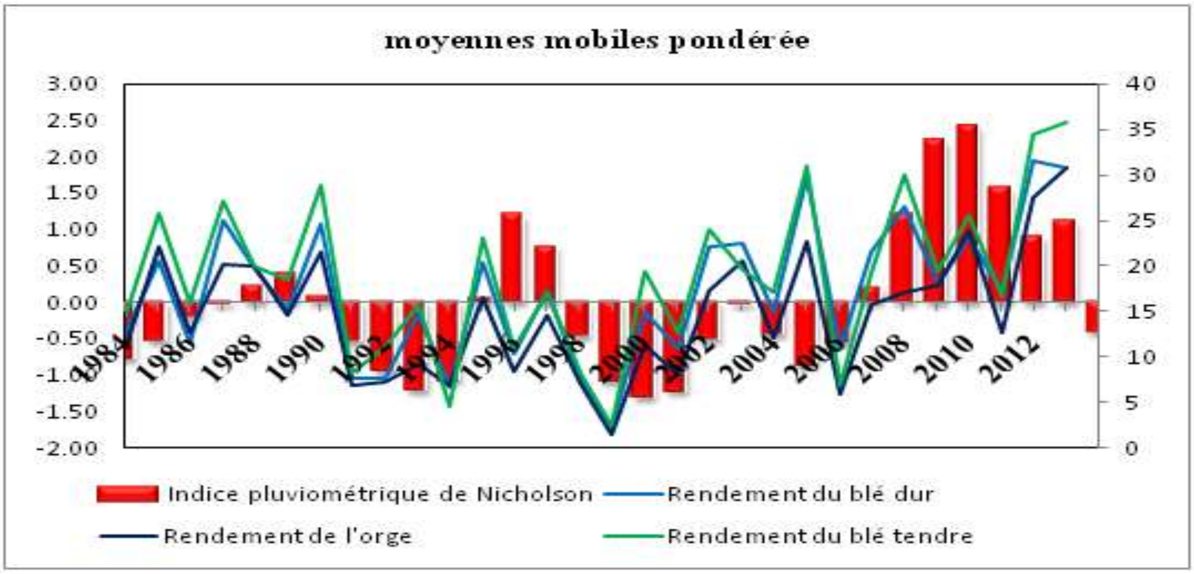

Fig. 6. Rain index moving averages weighted according to performance in the region of Meknes.

The curves of variation in cereal yields reflect well the great rainfall variability. (Fig.6) This correlation is demonstrated by both the Nicholson indices and the weighted moving averages.

We note however that despite a low rainfall index we have a satisfactory return, this is the case for the year 2012/13.

Test of Pettitt (1979)

On the time series of annual precipitation, the Pettitt test shows the 99% confidence level in year (X) and precipitation (Y) as breakpoints in the series indicating a change in mean precipitation. (Fig. 7) illustrates the case of this series.

The rupture is here translated by a sudden change in the rate of evolution of the curve.

Principal Component Analysis (PCA)

We made an ACP under XLSTAT to highlight of possible correlation between the various parameters to know the yield(efficiency) on the durum wheat, the common wheat and the barley, the temperature, the humidity and the haste in the region of going Meknes 1984 until 2014 (Fig. 8).

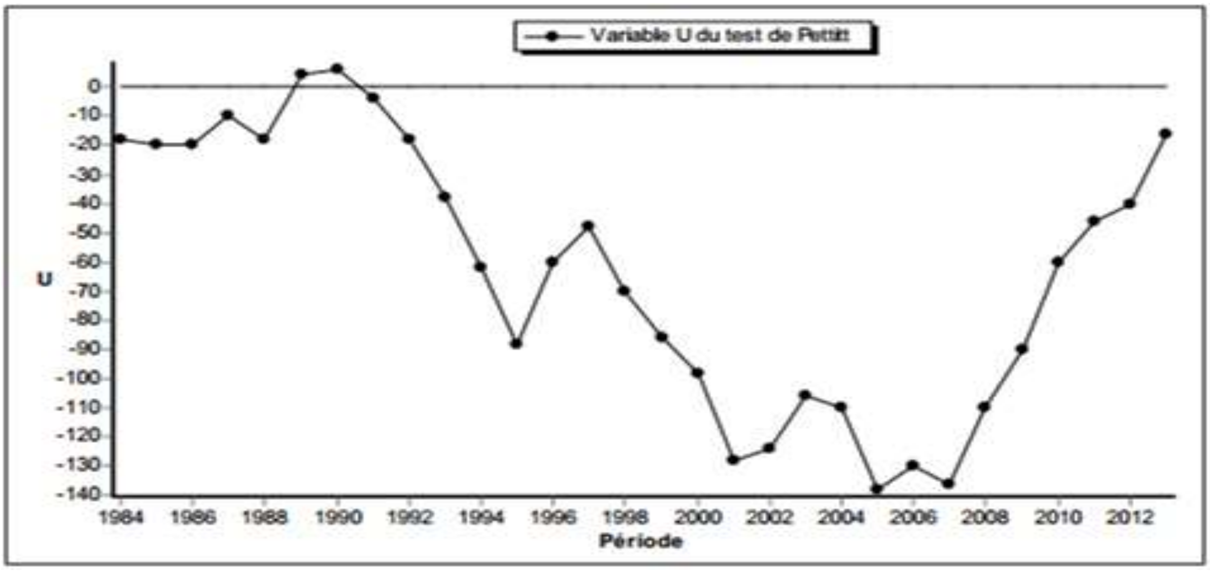

Fig. 7. Pettitt test (1979) in the region of Meknes.

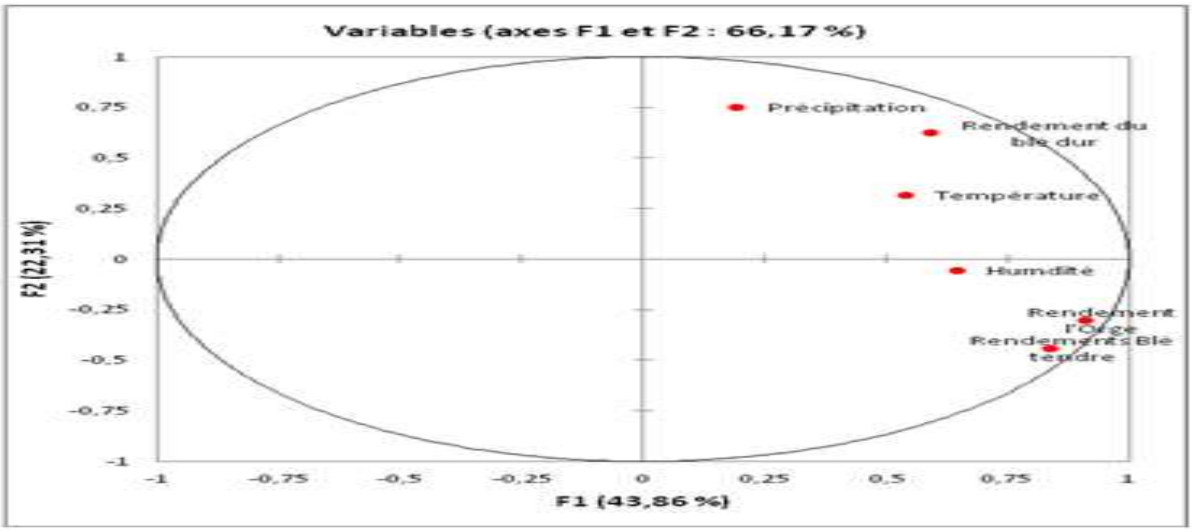

Fig. 8. Principal Component Analysis (PCA) graph in the Meknesregionfrom 1984 to 2014.

Based on the analysis of the correlation circle (Fig. 8), the yield of common wheat and barley is correlated positively with moisture, while that of durum wheat Negatively correlated with temperature.

Conclusion

The various parameters that we analyzed in order to reach our objective of studying the impact of climate change on the cereal sector in the Meknes region made it clear that this region is confronted both with the problem of rainfall irregularity and temperature rise the two major factors of global warming. Together these factors have affected the yields of the three cereal crops.

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