Climate Change Impact on Rainfall: How will Threaten Wheat Yield?

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ABSTRACT. Climate change has a significant impact on the environmental condition of the agricultural region. Meknes has an agrarian economy and wheat production is of paramount importance. As most arable area are under rainfed system, Meknes is one of the sensitive regions to rainfall variability and consequently to climate change. Therefore, the use of changes in rainfall is vital for detecting the influence of climate system on agricultural productivity. This article identifies rainfall temporal variability and its impact on wheat yields. We used monthly rainfall records for three decades and wheat yields records of fifteen years. Rainfall variability is assessed utilizing the precipitation concentration index and the variation coefficient. The association between wheat yields and cumulative rainfall amounts of different scales was calculated based on a regression model.
The analysis shown moderate seasonal and irregular annual rainfall distribution. Yields fluctuated from 210 to 4500 Kg/ha with 52% of coefficient of variation. The correlation results shows that wheat yields are strongly correlated with rainfall of the period January to March. This investigation concluded that climate change is altering wheat yield and it is crucial to adept the necessary adaptation to challenge the risk.
Keywords: Climate change, wheat yield, rainfall variability, precipitation concentration index.

1. Introduction

Climate change is considered to be a world-wide phenomenon. The effect that it will have on agriculture is the biggest concerns. Morocco is especially notable for its vulnerability to climate change [1], climate is characterized by long periods of drought and a strong interannual variability in rainfall amount and distribution [2-4]. In the past few decades Moroccan agriculture have been suffering from severe water resources deficits [5-7].

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Various studies has reported varied effect of climate variations on agricultural production [1, 8-10]. In Morocco, cereals represents the main crop and are of great importance to national food security; the main part of the diet comes directly or indirectly from cereals [11]. Compared to other countries in the Mediterranean Basin, Production levels are generally poor [12]; the most due to direct exposure to nature. The heaviest bills are those of cereals, which represent almost 36% of imports in 2014 [13].

In earlier studies, Jarlan [14] has mentioned that the development of cereals is related to local environmental conditions, among which water availability are the most decisive. This discovery is consistent with previous works [15-17] and indicate the need for local specific studies.
Rainfall furnish the water which contributes to the transportation of the nutrients for plants development. In consideration of this essential role, deficiency of water supply, especially during critical developmental stages has negative effects on efficient plants growth, resulting enormous yield reductions.

Meknes is among the provinces that contribute most to national wheat production. Considering that 97% of total cultivated area is non-irrigated, this makes the agricultural system in the region vulnerable to dry spells and uneven distribution of the rainfall. What might straightly influencing the livelihood of the inhabitants.
Our ongoing study analyses rainfall variability at annual, seasonal and monthly scales and evaluate the correlation between rainfall and the yields of wheat, then it could be used in developing risk reducing strategies.

2. Material and methods

2.1. Study area

The domain of study was Meknes province north-west of Morocco (Figure 1). It is situated between longitude 33°88 N and latitudes 5°53 S. It has an area of 1692 km2. Characterized by a semi continental climate of Mediterranean type, with cool winters and rainy and hot summers and dry. The temperatures means range from 3 °C in cool season and 34 °C in hot season. The average annual rainfall ranges from 450 to 600 mm.

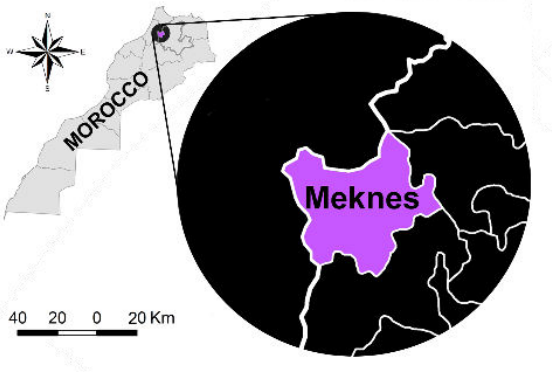

Fig.1. Location of Meknes in Morocco

2.2. Data and analysis

A rainfall data recorded over three decades (from 1985 to 2016) and crop yield records of soft wheat and hard wheat from 1995 to 2015 were provided by DPA; Provincial Department of Agriculture in Meknes. The mean and Coefficient of Variation (CV), Standard Deviation (SD) of monthly, seasonal and annual rainfall are computed by using

Excel software. The Precipitation Concentration Index (PCI, [18, 19]), was calculated on an annual scale, seasonal scale for winter (DJF), spring (MAM), autumn (SON), and on supra-seasonal scale for wet season (ONDJFM) by means of the following equation:

$$PCI = [CV * Pi]^2 + 1/n$$

Where Pi is the monthly precipitation in month i, CV is variance.

Each month is represented by its first letter e.g. ONDJFMAM = October November December January February March April May.

According to Oliver's classification:

A PCI values of less than 10 represent a uniform precipitation distribution; PCI values from 11 to 15 denote a moderate precipitation concentration; values from 16 to 20 denote irregular distribution and values above 20 indicates a strong irregularity (i.e., high precipitation concentration).

To evaluate the relationship between rainfall and wheat yields we used the correlation analysis. The calculation of the correlation coefficient is performed using Equation (1), in which rainfall represents the independent variable (X) and wheat yield represents the dependent variable (Y).

$$r = \frac{\Sigma (x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma (x - \bar{x})^2 \ (y - \bar{y})^2}} \qquad (1)$$

Where ẍ and ȳ are the mean of the matrix X and the matrix Y respectively.

3. Result and discussion

3.1. Rainfall pattern

The trend of the total annual rainfall (mm) from 1984-2015 in Meknes province is as shown in the Figure 2. The annual rainfall volume was variable from year to year and ranges from 284 mm to 876 mm. In seasons 2008-2009, 2009-2010 and 2012-2013 the annual rainfall amounts surpass 800 mm and fall below 300 mm in 1994-1995.

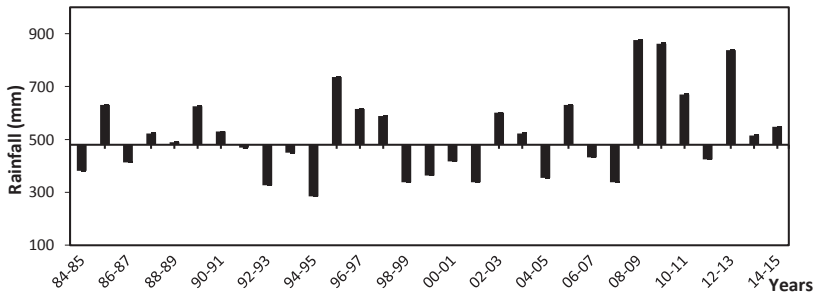

Fig.2. Annual rainfall compared with the median

From Table 1 one can learn that growing season account 93% of total annual rainfall where more than 46% occurs in winter-season and approximately 20% in the ending of autumn and 20% at the beginning of spring.

Table 1: Statistics for rainfall of multiple time scales from 1984 to 2016

	Annual	Growing Season	Supra-Season	Autumn	Winter	Spring
Mean	520	486	405	145	221	142
Coefficient of Variation	31	30	38	50	51	42
PCI (%)	17	15	12	13	11	13
Total %	100	93	76	28	41	28

3.2. Wheat yield trends

Historical records of soft and hard wheat yield from 1995 to 2015 as represented in Figure 3, show that, in general, the yield is low and variable in time. The coefficient of variation was very high, showed 52% for soft wheat and 53% for hard wheat. The highest observed yield was approximately 4500 kg/ha for both hard and soft wheat, registered in season 2014-2015, while the lowest yields were 210 kg/ha for hard wheat and 240 kg/ha for soft wheat obtained in season 1999-2000, it was a very dry year. Such variation has often exposed poor farmers to migration to cities.

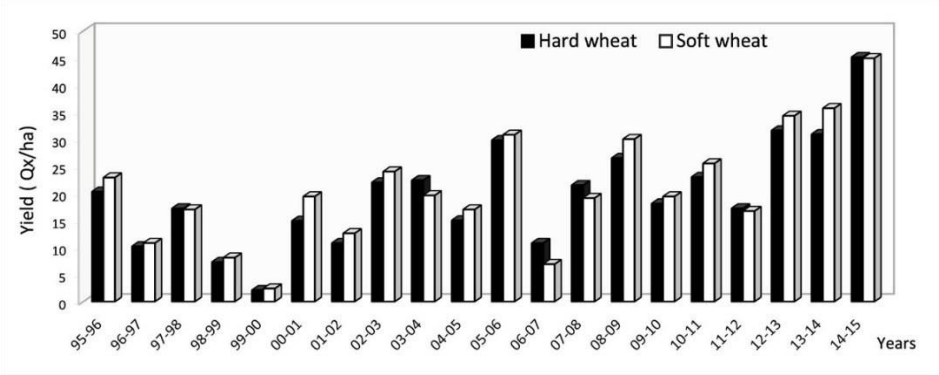

Fig.3. Variation of yield of hard wheat and soft wheat of Meknes from 1995 to 2015

3.3. Variability of rainfall and distribution

The rainfall variability resulted by coefficients of variation of seasonal and annual rainfall have shown that there existed a moderate variability, except for Autumn and Winter season where rainfall variability is high. Standard Deviation shows 72mm for Autumn and 112mm for winter, such values can lead to a success or failure of the crops. Additionally, on yearly basis, the computed PCI annual value of 17% indicates that, rainfall distribution over months is erratic. Generally dry years have recorded a high values (PCI ranges from 15 to 25). Nonetheless, the PCI value for season indicates moderate rainfall concentration (PCI<13).

Monthly average rainfall in Meknes is a clear seasonal cycle. Generally most of the precipitation occurs between November and January. This situation often fills the soil profile of the coarse-textured soil. A preview of the monthly rainfall trend over the period of two decades shows that monthly rainfall amount tend to decline in February after reaching its peak in December and January.

In respect to distribution, Figure 4 show that rainfall in the month of February and March are very erratic; the variation coefficient showed respectively 78% and 87%. This

might present dangers of water stress and dry spells which has a proven effect on yield since it coincide with production phase.

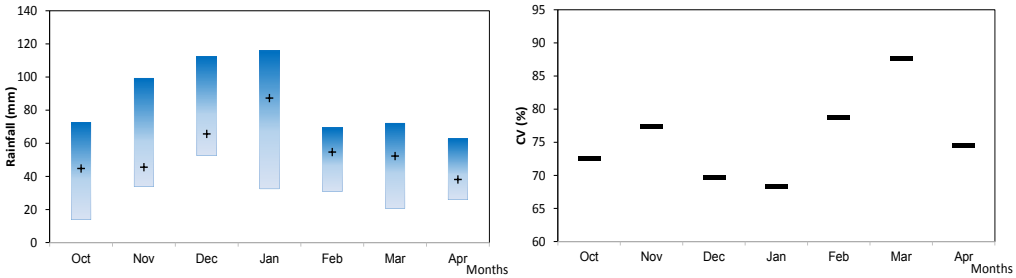

Fig.4. Box plot and coefficient of variation of monthly rainfall (Oct to Apr) from 1995 to 2016.

3.4. Relationship between rainfall and wheat yield

The Table 2 shows the relationship between rainfall of different period and wheat yield. Whereby all results, for seasons and inter-seasons are positive and significant.
For spring the correlation coefficient value was low. It showed 0.18; unfortunately, because the most rainfall of this season (March to May) coincides with wheat maturation. While a moderate amount of rainfall benefits wheat grain development, however, waterlogged soils during grain fill contribute to high disease pressure and can reduce wheat yields and test weight.

In contrast, a strong correlation were illustrated between wheat yield and rainfall at the other intervals; the correlation coefficients range from 0.52 to 0.76. Thus revealing that the beginning and the middle of growth period is the most sensitive stages of growth to rainfall. Owing to the fact that the water supply from rainfall during this period will affect the root yield, the survival and fertilization of ears and consequently of the grains. The highest value of correlation was 0.73 obtained between wheat yield and rainfall of January to March (JFM).

These results reveal on the one hand the importance of rainfall volume of the period January to March, on the other hand the damaging effect of mid-spring rains. Both factors independently influencing annual yield of soft and hard wheat.

Table 2: Coefficients of determination showing the relationship between wheat yield and rainfall at different time scales.

Crop/Time	Annual	Grow season	Supra-season	Autumn (SON)	Winter (DJF)	Spring (MAM)	*Inter-season*			
							ONDJ	JFMA	JFM	FMA
Wheat	0,66	0,72	0,76	0,57	0,52	0,18	0,62	0,64	0,73	0,53

4. Conclusion

The study quantifies the impact of climate change on wheat production by assessing the rainfall variability and its relationship with wheat yields in Meknes province of Morocco. It revealed moderate seasonal and irregular annual rainfall concentration. When the estimated correlation between wheat yield and rainfall at different scale showed a significant effect of the precipitation. The yield variability showed a higher relationship with precipitation at

small period (January to march). Seen the degree of rainfall variation of month in this period, wheat cropping would be more risky.
Having these results, without considering changes in practices of water-conservation, irrigation schemes, varieties and other, wheat yield might be in big trouble.

5. References

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