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ESTIMATION OF THE IMPORTANCE OF CLIMATE CHANGE AND ITS FUTURE EFFECT ON THE YIELD OF FOUR LEGUMES IN MOROCCO

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ABSTRACT

The adaptation of agricultural production systems to climate change must take into account the foreseeable impact on crop production based on the knowledge available on the ecophysiology of crops, applied to the simulation of the effects of climate scenarios. Thus, the present work aims to estimate the impact of climate change on the yield of legumes in Morocco. To do this, in this work we applied multiple regression models to estimate the evolution of the yield of four leguminous crops (bean, broad bean, pea and chickpea) during the period 2002-2013. Thus, using HadCM3 model scenarios, an analysis was performed to project the effects of climate change on leguminous crops. The results show that the explanatory variables of yield are the main climatic variables (precipitation and temperature). The results also show that, in the long term, the impact of climate change will be more accentuated in the study region. Indeed, on the basis of the estimation results of this analysis, we carried out a simulation of the impact of climate change on agriculture relative to the projections of a moderate scenario by 2090. According to this simulation 2090 the yield reductions of the four species will be as follows: bean (-55.9%), broad bean (-39%), pea (-25%) and chickpea (-24.9%). Thus, the yields of all four legumes are affected and beans will be the most affected.

Key words: Climate change - simulation - legumes - yield - evolution – Morocco

INTRODUCTION

By the year 2025, the world population will be close to 8.5 billion inhabitants, including 07 billion in Asia, Africa, and Latin America. Among this population 800 million people will suffer from famine and malnutrition[1], the majority of them are in developing countries. This famine is accentuated by other scourges such as diseases, conflicts, the locust invasion, water shortage, drought, and desertification. The latter phenomenon refers to land degradation in arid, semi-arid, and sub-humid areas resulting from factors including climatic variations and human activities.

Contributing to the diversification of cropping systems, pulses also have a range of positive effects on biodiversity at different levels. They stimulate soil microflora and permanent grasslands, which generally contain legumes and usually have rich flora. Legumes generally favor insect populations and consequently insectivorous animals, especially birds. Perennial legumes are refuges for the nesting of certain species of birds,

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for the feeding of insects, birds, and mammals. All of these effects contribute to overall biodiversity at the landscape scale. Grassland legumes, therefore, present a converging bundle of positive effects for the environment, acting as much on climate change, water, and air pollution as on biodiversity, the main ones being those which promote the sustainability of ecosystems. grasslands with low levels of yield and to maintain the diversity of ecosystems at the landscape scale.

In addition, the Leguminosae family is one of the most important botanical families among the dicots. It is the plant family that provides the largest number of species useful to man, whether food, industrial or medicinal. It is characterized by its rhizobial symbiosis, which is an association between plants of the legume family and Rhizobium-type bacteria that reduce atmospheric nitrogen into forms that can be assimilated by plants [2]. Thus, improving soil biodiversity, one of the important properties of legumes is their ability to biologically fix nitrogen. These plants, in symbiosis with certain types of bacteria (e.g. Rhizobium, Bradyrhizobium), are able to convert atmospheric nitrogen into nitrogen compounds that can be used by plants, also improving soil fertility. Similarly, it is estimated that there are hundreds of varieties of pulses including many local species that are not exported or grown around the world. The genetic diversity of these crops is an essential component of soil management and pest management at the farm level, especially at the level of smallholdings.

Furthermore, food production, nutritional security, and climate change are closely linked. Whether in the form of droughts, floods, hurricanes or soil acidification, climate change is destabilizing all links in the food production chain, including prices and the food security of affected farming communities. The repercussions of climate change vary according to regions and cultures. At the global level, they accentuate food insecurity and the risk of undernourishment in the poorest regions. Climate change is also helping to shift the production area of food and non-food crops around the world. If sustainable measures are not taken urgently, climate change will continue to weigh on agricultural ecosystems, especially among particularly vulnerable regions and populations because it does not there is more land available due to the high rural population density[3], [4]. Thus, as indicated by Akotto et al. (2020) [5], in the context of current population growth and with the effects of climate change, it is a question of farmers developing resilience strategies in the face of poverty and food insecurity[6]. As a contribution to the solution, the intensification of production per hectare is therefore necessary. However, several constraints oppose this accentuation, in particular the rise in temperature and the modifications of the rainfall regimes, that is to say, the modifications of the different terms of the water balance (evaporation, drainage, runoff) and all the other climatic factors that govern the functioning of ecosystems.

As a first step in developing any project aimed at reducing the constraints that hinder the increase in agricultural production, it is first necessary to predict and quantify these changes and their consequences [7]. Thus, the objective of this work is to estimate the

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effect of climate change on the yield of cultivated legumes in the case of Had Kourt (Rabat_Salé-Kenitra region, Morocco) and more precisely the expected losses in crop yield. legumes according to HadCM3 model projections for 2030, 2050, and 2090. It is therefore a simulation of climate, climate change, and the impact of these climatic variations on legume yields in the region of Had Kourt, Morocco.

MATERIAL AND METHODS:

Study site:

Had Kourt, a city in Morocco, is located in the region of Rabat-Salé-Kénitra (Fig. 1). Had Kourt takes its name from a mountain "JabalKourt" located about 5 km from the city. The topography of its CCA action zone can be divided into two large agro-climatic zones, namely an area of marly hills with an average slope of less than 15% and a plains area with deep and fertile soils. As for the relief we find A mountain area: occupying 45% of the area. The plain: occupies 20% of the area. The valleys or basins: occupy 15% of the area. 10% Hills and 10% Trays.

Figure 1: Geographical location of Had Kourt

Superficial resources

The area is crossed to the southeast by OuedOuergha, whose tributaries build the hydrographic network. The most important from East to West are Rdat and Tnine:

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- OuedOuergha: flowing from the East to the South with many Rif tributaries (Joumoua, Drader, Aoudiar, Hamdallah)
- OuedRdat and Ettine flow in the middle of the area by draining water from the hills of Ouezzane and Arabia.
- Ouedsebou: constitutes the outlet of OuedsRdat, Ettine, and Tnine.
- OuedMda: flowing to the north of the area and overflows its bed in the rainy period.

Underground resources

The area is poorly endowed with aquifer reserves and underground water resources appear precarious and insufficient for the population living there. Indeed, the most important water table is located in the Ouezzane thrust, mainly contained in the sandstone formations.

Framework and methodology of the study and data sources:

- **Legumes in the Had Kourt region (2015/2016 data):**

Legumes occupy an area of 10.000 ha with: 6,500 ha for chickpeas, 2.500 ha for the faba bean, 500 ha for beans, 500 ha for peas (Regional directorate of the national office of agricultural advice Rabat SaléKénitra). Figure 2 illustrates the evolution of legumes in the Head Kourt CCA area of action over ten years.

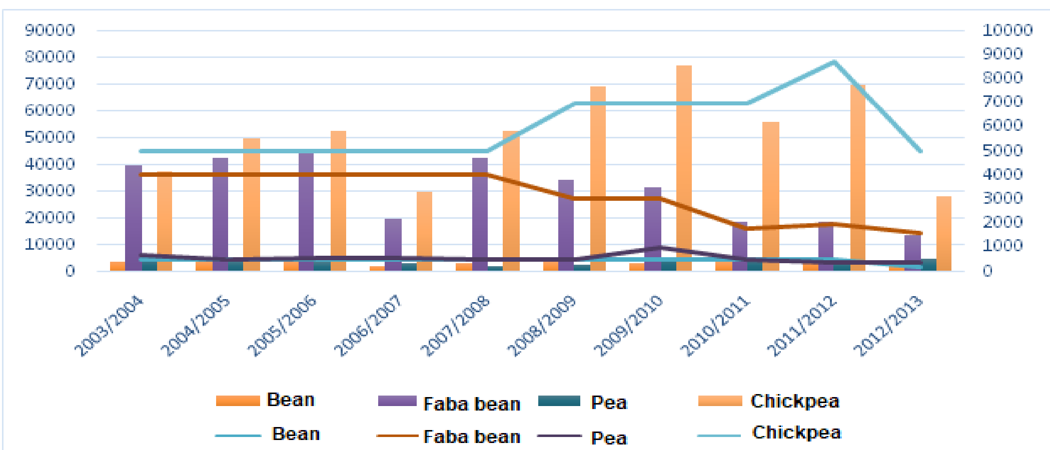

Figure 2: Evolution of production (in tonnes) and areas (in hectares) of legumes in Rabat SaléKénitra

In this study, we exploited the meteorological data (Rain and Temperatures) measured by the classic and automatic climatological stations of the Experimental Domain of the studied area, namely the rain and temperature values recorded during the period covering the years 2002-03 to 2012. -13 from the Had Kourt station and the rainfall and temperatures for the period (2002-2013). The estimate of climate change in the region

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and the correlation between this evolution and those of the main cereals and legumes have been evaluated.

The correlation of the evolution of climatic parameters. The production, as well as the yield of legumes, vary according to the seasons. This variation is mainly due to climatic fluctuations. The future evolution of the climate was determined through the daily outputs of the A2 and B2 scenarios of the HadCM3 model (Hadley Center Coupled Model, version 3) for the period 2010 – 2090. It should be remembered that the A2 scenario describes a very heterogeneous characterized by high population growth, low economic development, and slow technological progress. While the B2 scenario describes a world characterized by intermediate levels of demographic and economic growth, emphasizing local action to ensure economic, social, and environmental sustainability.

Specification of the used model:

We adopted the semi-logarithmic functional form to estimate the variation in leguminous yields (Bean, Pea, chickpea, and Faba bean) in Morocco over a period from 2002 to 2013. According to certain authors[8], [9], this form is the most adapted for this type of analysis. Our econometric model is as follows:

$$\mathbf{Log Y_t = \beta_0 + \beta_1 ARE + \beta_2 ARE^2 + \beta_3 PRE + \beta_4 PRE^2 + \beta_5 TEM + \beta_6 TEM^2 + \beta_7 PROD + \beta_8 PROD^2 + \varepsilon_t} \text{..............................} \mathbf{1}$$

Where:

Y_t: Yield of legumes (beans, broad beans, peas or chickpeas) for year t.

β_0: Constant.

ARE: The area per crop

PRE: Annual precipitation in mm

TEM: Annual temperature in ° C

PROD: Annual production in q

ε_t: An errorterm

RESULTS AND DISCUSSIONS

The results of the estimation of the model by the Ordinary Least Squares (OLS) method are summarized in Table 1. The coefficients of R^2 determinations obtained are of the order of 0.99; 0.98, 0.98, and 0.97 respectively for beans, broad beans, peas, and chickpeas and they indicate that the models explain a large variability in yield. With regard to the Fischer test, the calculated values are lower than the critical values for the four crops (〖F〗 _(3 6) ^ 0.05) = 4.76, At the 5% threshold, we accept the hypothesis of l equality of

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variances. The values obtained from the Durbin Watson (DW) error autocorrelation test range from 1.27 to 1.35, indicating the absence of a first-order autocorrelation problem.

Table 1: Estimation results for the four leguminous crops

Variables	Bean	Faba bean	pea	chickpea
Constant	12,4107	0,5970	6,2136	3,9437
	(0.5314)	(0,0004)	(9,2976)	(7,889)
ARE	-0,0249	-0,0023	0,0126	-0,0015
	(0,0001)	(0,0002)	(0,0009)	(0,0001)
PRE	3,87E-05	0,00037	0,0002	0,0006
	(0,0290)	(1,77E-05)	(0,0006)	(0,0004)
PRE* PRE	1.5E-05	1.4E-07	4E-08	3.6E-07
	(0,00084)	(3.1E-10)	3.6E-07	1.6E-07
TEM	0,0045	0,43651	-0,0094	0,2510
	(0,0290)	(0,3258)	(0,5122)	(0,4352)
TEM* TEM	2E-05	0,19054	8.8E-05	0,0630
	(0,000084)	(0,10615)	(0,26235)	(0,1894)
PROD	0,0019	0,0002	0,00207	0,00018
	(1,81E-05)	(0,0002)	(0,0002)	(1,39E-05)
R2	0,999	0,981	0,977	0,974
F	1.000	1.029	1.023	1.024
Dw	2,609	1,620	1,740	1,681
The Chow test	1,342	1,306	1,272	1,314

The Chow test of model stability shows that the three estimated models, using the two sub-periods (2003–2007 and 2008–2012) to perform this test, are stable over the study period. Indeed, the calculated statistics (calculated F) for the models corresponding to the four crops are lower than the tabulated value F_8.7 ^ 0.05 = 2.47. This confirms that the model is stable for the four estimated models. The results also show a significant relationship for the four crops at the 10% threshold between the dependent variables and the explanatory variable (precipitation P), which confirms that precipitation positively

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affects the yield of legumes given the need for rainfall for this sector. The results also show a significant relationship for the four crops at the 10% threshold between the dependent variables and the explanatory variable (precipitation P), which confirms that precipitation positively affects the legume yield given the need for rainfall for this sector. It can also be noted that the second-order coefficients of the precipitation variables are negative, which implies the non-linearity of the climatic variables and the fact that the yield is a concave function of the precipitation. We also notice a somewhat significant relationship between the dependent variable and the explanatory variable (temperature T), which confirms that the temperature negatively affects the yield of peas. The second-order coefficients of the temperature variables are negative, confirming that temperature negatively affects pea yield. Otherwise, in periods when there is a frequency of drought, the production of legumes will decrease and the yield will be minimal given the massive need for rainfall for this sector. It can be concluded that these negative coefficients result in the fact that the climatic variables (precipitation and temperature) are non-linear and that the yield has a concave relationship with the precipitation and the temperature. The area has a negative effect, which explains why the areas of small farms characterizing the region contribute to a decrease in cereal yield. This confirms that the larger the area, the greater the yield of the cereal sector. In areas that are most vulnerable to the impacts of climate change, perhaps a solution for seasonal crops. Rainfed production in the country contributes to the food security of many family farms and the possibility of growing irrigated production under climatic constraints could reinforce the idea that irrigated agriculture will be an essential part of the future of agriculture. Technological progress also consists in selecting varieties through the genetic improvement of the legume, which is one of the most important factors that gradually led to the modernization of legumes in Morocco. Even more, and especially with the advent of new varieties, the adoption of other technical advances has been encouraged, in particular nitrogen fertilization, chemical weeding, chemical disease control, the use of certified seeds, and irrigation. The yields of the new varieties of legumes are three to four times higher than those of the old varieties.

Simulation:

As indicated previously, we were based on the projections of the HadCM3 model (MARHP, 2007) stipulate an increase in temperature of 0.8 ° C and a decrease of 5% in precipitation by 2030 in the study region (Had Kourt region) (Fig. 3-5).

Projections for the future are now based on a larger panel of models. The future simulations made by the software on the basis of the A2 and B2 scenarios predict for the end of the 21st century, a warming in all seasons.

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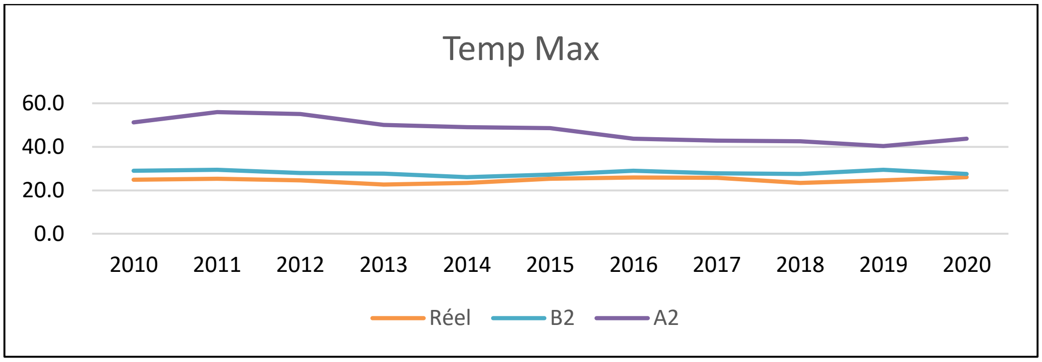

Figure 3: Trend in annual maximum temperatures predicted by the model at Had Kourt (2010 - 2020)

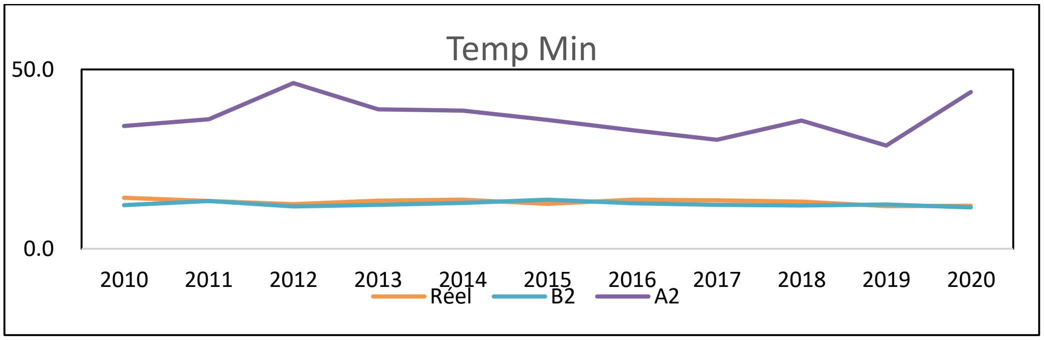

Figure 4: Trend in annual minimum temperatures predicted by the model at Had Kourt (2010-2020)

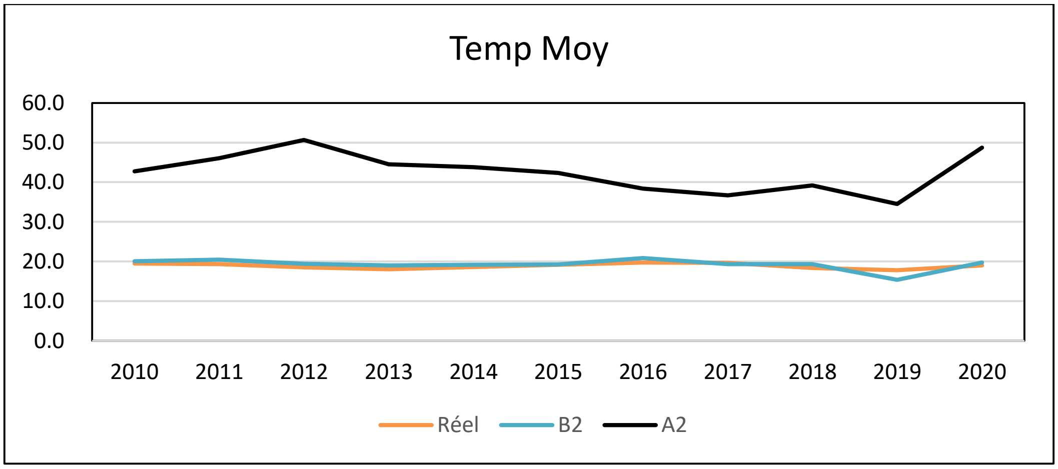

Figure 5: Trend in mean annual temperatures predicted by the model at Had Kourt (2010-2020)

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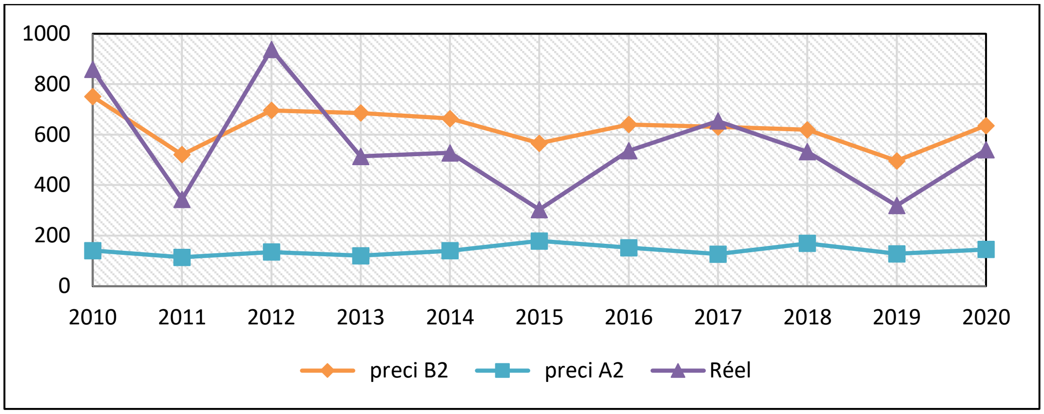

Figure 6: Forecast annual precipitation trends for the period 2010 – 2020

The two climate scenarios A2 and B2 predict a decrease in annual precipitation in the future as shown by the trend lines. The decrease in precipitation is obviously greater according to the pessimistic scenario A2.

For temperatures (T max and T min), according to the climate scenario model B2, there will be an increase in temperature. The study area will get warmer in the future. For future yields under scenario B2, the study area will become more arid in the future which will have direct and negative effects on legume yields. This is consistent with the results obtained.

In order to be able to estimate the impact of climate change on legume yields, we calculated the percentage change in yield obtained by the model, using the average climatic data of the analysis period (Y1) and those based on on the scenarios of the HadCM3 model up to 2030 (Y0). The formula iswritten as follows:

$\Delta Y = \frac{(Y1-Y0)}{Y0}$*100……………………………...2

The results of the variation, in percentage by crop type, are shown in Table 2.

Table 2: Predicted yield losses of leguminous crops according to the projections of the HadCM3 model for 2030, 2050 and 2090

Plant	**2030**	**2050**	**2090**
beans	-44,2%	-29,4%	-55,9%
Favabeans	-21,9%	-17,1%	-39,8%
Pea	-11,9%	-10,11%	-25,4%
Chickpea	-8,6%	-8,5%	-24,9%

From these projections, the results of the calculation of the percentage losses show that the bean is the crop that will be most affected by the increase in temperatures and the

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decrease in precipitation by 2030 as indicated by the projections of the HadCM3 model. Had Kourt could see legume yield losses of around 44.2%; 21.9%; 11.9% and 8.6%.

At the dawn of the year 2090, the Had Kourt region could record losses in legume yields of around 55.9%, 39.8%, 25.4% and 24.9% respectively for beans, fava beans, peas and Chickpea.

These losses will surely affect the income of farmers in the Had Kourt region, who are generally specialized in cereals and pulses, and who may induce them to switch to other crops less vulnerable to climate change. This will have repercussions on the national production of pulses, and consequently, on the food security of Morocco taking into account the importance of these agricultural products in the food balance of the country.

CONCLUSION

The Choa in the light of the results observed, we note the non-correlation of rainfall with the yield of legumes for most of the cases we have noticed for this city studied a decrease in the yield of legumes, there is a decrease between 8% and 40% of legume yield over the next 9 years. To ensure an always satisfactory production, Moroccan agriculture must take into account all its changes in the climate and must adapt to these conditions, for example by bringing forward the sowing periods of legumes to avoid periods of drought, or the use of irrigation to fill water shortages. Thus, helping the food security of the country and also to estimate the impact of climate change on the productivity of the legume in the region of Had kourt.

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