https://dx.doi.org/10.22161/ijaers.4.1.32 ISSN: 2349-6495(P) | 2456-1908(O)

Impact of Climate Change on the Production of Wheat and Rice in India

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Abstract*— *India is a world agricultural power, the share of agriculture in GDP is 17.8%, agricultural employment represents 54.87% of total employment and the country is considered the second largest producer wheat and rice. But this advantage is facing several obstacles because India is likely to be severely affected by climate change. India is one of the country's most vulnerable to disasters around the world and many of its 1.2 billion people live in areas vulnerable to hazards such as floods, cyclones and droughts.

In this work, we propose a model that highlights the impacts of climate changes (changes in temperatures and precipitations) on the production of wheat and rice. The results confirm the hypothesis according which the impact of climate changes in India are Important.

***Keywords*—Climate Change, Precipitation, Temperature, Impact, Wheat, Rice, India**

JEL: Q15, Q54

I. INTRODUCTION

In developing countries, agriculture provides employment to 60% of their population and represents approximately 30% of their gross domestic product (GDP), it is a central part of the livelihood of 40% of the world population and occupies 40% of total land (90% of farms in the world have a size of less than 2 hectares). In many countries, economic health is closely linked to wealth or poverty of the farming communities. But the current vulnerability to climate change and extreme events is a major threat to agricultural systems.

By 2100, in South Asia, the decline in wheat and rice yields is important for a temperature increase of 2.5°C. The net cereal production in South Asian countries should drop within 4 to 10% by the end of this century. Changes in cereal production potential indicate an increasing strain in many developing Asian countries.

India is a world agricultural power, the share of agriculture in GDP is 17.8%, agricultural employment represents 54.87% of total employment and the country is considered the second largest producer wheat and rice. But this advantage is facing several obstacles because India is likely to be severely affected by climate change. India is one of the countries most vulnerable to disasters around the world and many of its 1.2 billion people live in areas vulnerable to hazards such as floods, cyclones and droughts.

All aspects of food security are potentially affected by climate change, including access to food, land use, and price stability. The increase in temperature between 1°C to 4°C result in a reduction of 5 to 30% of cereal production.

In our study, we tried analyzing the impacts of climate variability (temperature and precipitation) on the yield of wheat and rice in India and how will evolve their production? At the first section, we will pass the main studies related to this subject, the second section will be devoted to the empirical estimation and finally the main results are past in the third section.

II. EMPIRICAL LITERATURE REVIEW

In the agricultural sector, Guiteras (2009) evaluated the medium term (2010 to 2039) that climate change will reduce crop in India between 4.5 and 9%, depending on the degree of warming. Agriculture accounts for 17.8% of GDP in India, the only impact on this sector would decrease GDP by 1 to 1.8%. This could significantly slow the pace of poverty reduction in India; recent estimates show than an agricultural GDP point in less decreases the consumption of the poorest of 4 to 6%.

The frequency and intensity of droughts inter and intra-seasonal and floods can have a significant impact on agricultural production and therefore food security. A strong linear decrease in the yield of wheat was noted when the temperature increase in January. For each degree increase in the average temperature, the grain yield decreased to 428 kg/ha.

Malli et al (2006) reported than an increase of 2°C in average air temperature could decrease rice yield of about 0.75 t / ha in high-yield areas and about 0,06 t/ha in coastal areas with low yields. In addition, a temperature increase of 0.5°C winter may reduce the duration of the wheat harvest seven days and reduce the yield of 0.45 t/ha.

An increase in winter temperature of 0.5°C will result in a 10% reduction in wheat production in areas with high yield of Punjab, Haryana and Uttar Pradesh. The reduction will be smaller in eastern India compared to all other regions.

Kaur Hundal and (2002b) studied the impact of climate changes on the productivity of wheat, rice and maize in Punjab. If all other climate variables remain constant, the increase in temperature of 1.2 to 3 reduced wheat grain yield by 8.1 to 25.7%, the rice from 5.4 to 25.1%, the maize from 10.4 to 21.4%.

Chatterjeea observed that the increase in temperature reduced the yield of maize and sorghum from current conditions. The temperature increase of 1°C to 2°C decreased potential yields of sorghum 7 to 12%, on average. Sahoo (1999) made of maize simulation studies on climate change in irrigated and rainfed conditions. The increase in temperature decreases the yield under both conditions.

According Saseendran et al (1999), the experiments of temperature sensitivity, showed that for positive change in temperature to 5°C, there is a continuous decline in performance. For each increase of one degree, the efficiency drop is about 6%.

III. Methodology and Data

2.1. Model specification

The model is based on an approach in terms of production function. Production of wheat (*wheat*) and rice (*Rice*) depend of on five factors of production: arable land (*Arable*), the irrigated area (*Irrig*), temperature (*Temp*), precipitation (*Prec*) and employment agricultural (*Empl*).

$$Wheat = f(Arable, Irrig, Temp, Prec, Empl) \quad (1)$$

$$Rice = f(Arable, Irrig, Temp, Prec, Empl) \quad (2)$$

According to the functions (1) and (2) our model is written:

$$Wheat = \alpha + \beta Arable + \gamma Irrig + \delta Temp + \varphi Prec + \theta Empl \quad (3)$$

$$Rice = \alpha + \beta Arable + \gamma Irrig + \delta Temp + \varphi Prec + \theta Empl \quad (4)$$

To study the impact of climate change on wheat and rice, we use equations (3) and (4) equations that describe the relationship between the production of wheat and rice and arable land, irrigated area, temperature, rainfall and agricultural employment.

The evaluation of the effect of climate impact on the dynamics of long and short term will be done with an ECM (error correction model) or VAR (Vector Autoregressive). For each crop, the goal is to know its impulse response function following a climate shock. The data to use in the empirical analysis are from the World Bank database, the Indian government and the NOAA, these data are annual and cover the period which runs from 1980 to 2013.

Table.1: Variables of model

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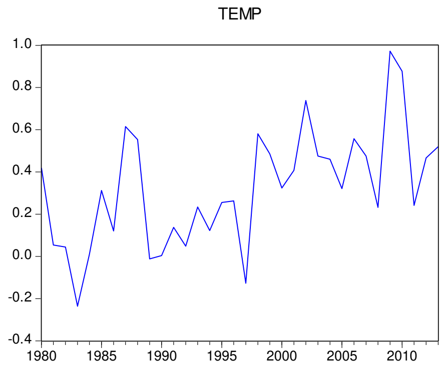

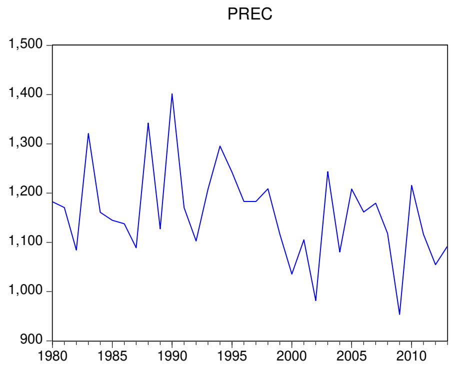

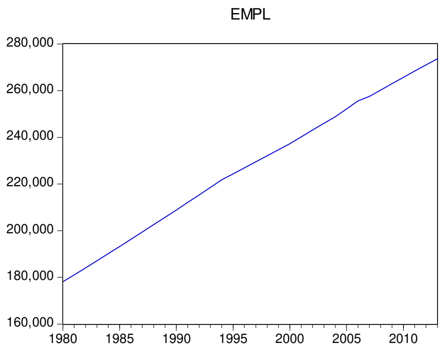

IV. ESTIMATE

4.1. Impulse response function

The ECM methodology provides the ability to analyze the short-term dynamic relationships between variables in the model through the study of the dynamic response following a unitary shock suffered by the series.

In general, the analysis of a shock is a measure the impact of the variation of a share (innovation, shock pulse) on variables. For example from the model of wheat estimated for India:

$$Wheat = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$
$$Arable = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$
$$Irrig = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$
$$Temp = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$
$$Prec = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$
$$Empl = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$

A change at a given time of ϵ_{1t} has an immediate impact on $wheat_t$ then $Arable_{t+1}$, $Irrig_{t+1}$, $Temp_{t+1}$, $Prec_{t+1}$ and $Empl_{t+1}$ for example if there is a shock in t ϵ_{1t} at 1, we have the following impact:

At time t:

$$\begin{bmatrix} \Delta Wheat_t \\ \Delta Arable_t \\ \Delta Irrig_t \\ \Delta Temp_t \\ \Delta Prec_t \\ \Delta Empl_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

At time t+1:

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$$\begin{bmatrix} \Delta Wheat_{t+1} \\ \Delta Arable_{t+1} \\ \Delta Irrig_{t+1} \\ \Delta Temp_{t+1} \\ \Delta \Pr ec_{t+1} \\ \Delta Empl_{t+1} \end{bmatrix} = \begin{bmatrix} \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \beta \\ \beta \\ \beta \\ \beta \\ \beta \\ \beta \end{bmatrix}$$

At time t+2 :

$$\begin{bmatrix} \Delta Wheat_{t+2} \\ \Delta Arable_{t+2} \\ \Delta Irrig_{t+2} \\ \Delta Temp_{t+2} \\ \Delta \Pr ec_{t+2} \\ \Delta Empl_{t+2} \end{bmatrix} = \begin{bmatrix} \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \\ \beta & \gamma & \delta & \varphi & \theta \end{bmatrix} \begin{bmatrix} \beta \\ \beta \\ \beta \\ \beta \\ \beta \\ \beta \end{bmatrix} = \begin{bmatrix} \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \\ \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \\ \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \\ \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \\ \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \\ \beta^2 + \gamma\beta + \delta\beta + \varphi\beta + \theta\beta \end{bmatrix}$$

Etc.…

The various values thus calculated are the impulse response function.

The analysis of impulse response functions in the following figures reveal than the variation in rainfall positively affect wheat production while the temperature variation is negative and that this effect is prolonged in time. Both effects cannot be neutralized.

Recent increases in climate variability may affect yield in India causing great variability in wheat and rice yields. Even cultures middle latitudes might suffer at very high temperatures in the absence of adaptation.

The extremes temperatures changes in short-term can be critical, especially if they coincide with development milestones. Only a few days of extreme temperatures (over 32 ° C) at the flowering stage of many crops can significantly reduce performance. (Wheeler et al. 2000).

Temperatures have a strong influence on the growth and yield of rice. The air temperature is a major factor in areas where, because of the latitude or altitude, or both, nighttime temperatures may fall below acceptable limits. Low temperatures, eg from 14 to 18 ° C during floral initiation, meiosis and pollen development have negative effects on culture.

Crop response to changes in growth conditions may be non-linear and subject to combinations of stressors that affect their growth, their development and potential output. In the short term high temperatures can affect the enzymatic reactions and gene expression. In the longer term, they will impact on carbon assimilation and therefore the growth rate and the potential return. The impact of high temperatures on the final yield may depend on the stage of crop development.

The impact of changes in rainfall on the production of rice is positive and also extends in time, while the temperature has a negative impact. Beyond the seventh period these two effects have even a small positive impact on rice production.

Changes in rainfall in India are partly due to the expected weakening of the dynamics of the monsoon circulation (decrease Indian monsoon precipitation) compared to the increase in atmospheric moisture content associated with warming (increase Indian monsoon precipitation (Meehl et al 2006).

However, changes in seasonal rainfall may be more relevant to agriculture than the average annual variations. In India, climate models generally predict a decline in dry-season of rainfall and an increase during the remainder of the year, the monsoon season, but still with a big gap between the models (Christensen et al 2004).

The rainfall is not the only influence on water availability. The increasing demand for evaporation because of higher temperatures and longer growing seasons could increase the need for irrigation of crops worldwide between 5 and 20% or more, for 2070 and 2080, but with large regional variations irrigation needs in Southeast Asia that could increase by 15% (Döll. P 2002).

In recent years we observed heavy rainfall and shorter monsoons in semi-arid regions. In 2009 parts of Maharashtra, Karnataka and Andhra Pradesh received heavy rainfall between September and October, thus causing flooding and major crop losses.

The rain does not allow groundwater to recharge enough because they need moderate rainfall. Rising temperatures increase the water needs of crops and dry soils. The

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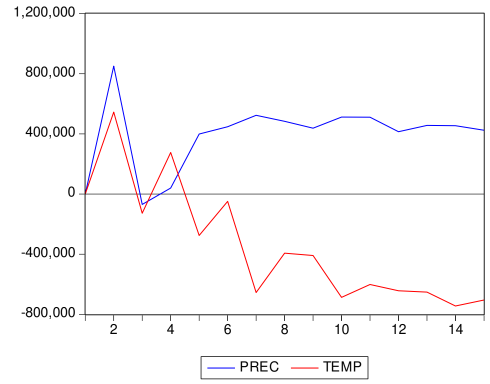
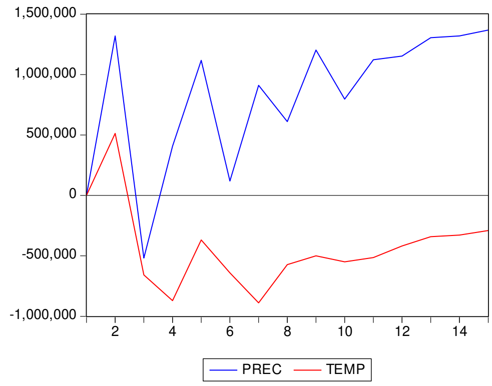
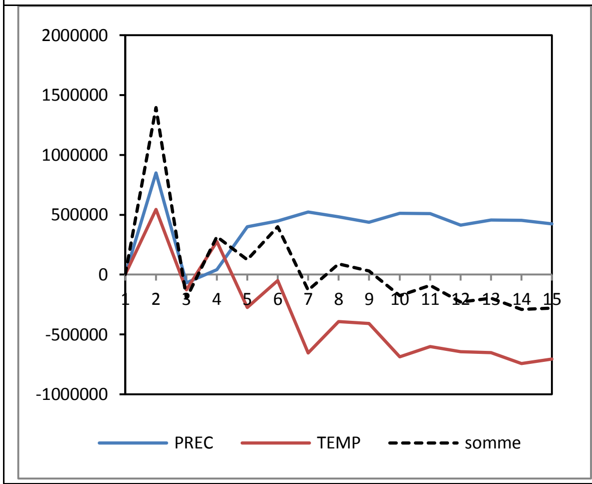
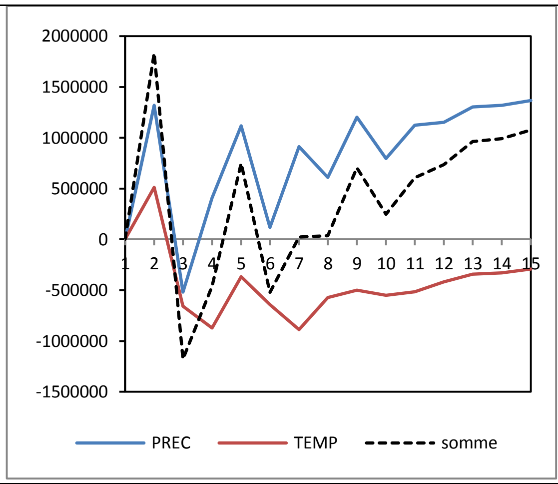
climate change projections indicate that even if farmers come adapt them cultural in arid zone, stress and the growing demand for the resulting water would decrease agricultural productivity and seriously endanger their livelihoods.

Table.2: Response of wheat and rice has a shock (precipitation and temperatures)

Wheat	Rice
	

Source : A. Ghazouani, et al

Table.3: Response of wheat and rice has a shock (rainfall + temperatures)

Wheat	Rice
	

Source : A. Ghazouani, et al

4.2. variance decomposition

The objective of the variance decomposition of the forecast error is calculated for each of the innovations contributing to the variance of the error. By a mathematical technique, we can write the variance of the forecast error at horizon h depending on the variance of the error assigned to each variable, and just bring each of these variances to the total variance for its relative weight in percentage.

if we take our model estimate for India, we interest for example at the two variables $wheat_{1t}$ and $temp_{2t}$, the variance of the forecast error for $wheat_{1t+h}$ can be written:

$$\sigma^2_{Wheat1}(h) = \sigma^2_{\varepsilon 1}\left[m^2_{11}(0) + m^2_{11}(1) + \ldots + m^2_{11}(h-1)\right] + \sigma^2_{\varepsilon 2}\left[m^2_{22}(0) + m^2_{22}(1) + \ldots + m^2_{22}(h-1)\right]$$

m_{ii} are the terms of the matrix M.

On the horizon h, the decomposition in percentage of the variance of innovations $wheat_{1t}$ on $wheat_{1t}$, is given by:

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$$\frac{\sigma_{\varepsilon 1}^{2}\left[m_{11}^{2}(0)+m_{11}^{2}(1)+\ldots+m_{11}^{2}(h-1)\right]}{\sigma_{Wheat1}^{2}(h)}$$

And the decomposition in percentage of the variance of $wheat_{1t}$ innovations on $Temp_{2t}$ is given by:

$$\frac{\sigma_{\varepsilon 2}^{2}\left[m_{22}^{2}(0)+m_{22}^{2}(1)+\ldots+m_{22}^{2}(h-1)\right]}{\sigma_{Wheat1}^{2}(h)}$$

Interpretation of the results is important:

- If a shock on ε_{1t} does not affect the variance of the $temp_{2t}$ error whatever the forecasting horizon, then $Temp_{2t}$ can be considered as exogenous because $Temp_{2t}$ evolves independently ε_{1t}.
- If a shock on ε_{1t} strongly affects (see totally) the variance of the $temp_{2t}$ error, $Temp_{2t}$ can be considered endogenous.

In practice, the results are not as marked but show the contribution of each variable in the variance of the error.

The variance decomposition of the forecast error, allow evaluate for a several time horizons, the relative importance of different shocks on the fluctuations of the dependent variables of the model. In our case, we use this decomposition to measure the relative magnitude of impact of changes in precipitation and temperature on the fluctuation in the production of wheat and rice. The variance decomposition of the forecast error allows determine which way and in which direction the impact of a shock has more importance.

Table.4: Variance decomposition of wheat

Period	WHEAT	ARABLE	EMPL	IRRIG	PREC	TEMP
1	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	88.85405	0.905167	0.576558	4.078792	3.959658	1.625773
3	81.82434	1.646682	4.525393	8.126985	2.710677	1.165920
4	82.52718	2.268504	4.335284	7.252169	2.357592	1.259269
5	71.15187	2.189242	9.165400	14.23808	2.136685	1.118724
6	63.85082	3.213237	9.071292	21.11194	1.925816	0.826900
7	59.09907	2.810198	10.33362	24.44280	2.000323	1.313991
8	55.10106	2.733481	10.84962	28.14551	1.912726	1.257601
9	50.32072	3.425101	12.21826	31.06147	1.770272	1.204178
10	46.82947	3.407491	12.99142	33.66386	1.704657	1.403104
11	44.52337	3.514225	13.54647	35.26784	1.668790	1.479301
12	41.94629	3.735877	14.39414	36.81714	1.559957	1.546596
13	39.99340	3.984294	14.87834	38.05367	1.490958	1.599333
14	38.30170	4.106055	15.44182	39.01509	1.433464	1.701876
15	36.89287	4.276616	15.86217	39.84281	1.371451	1.754091

Source : A. Ghazouani, and al

Table.5: Variance decomposition of Rice

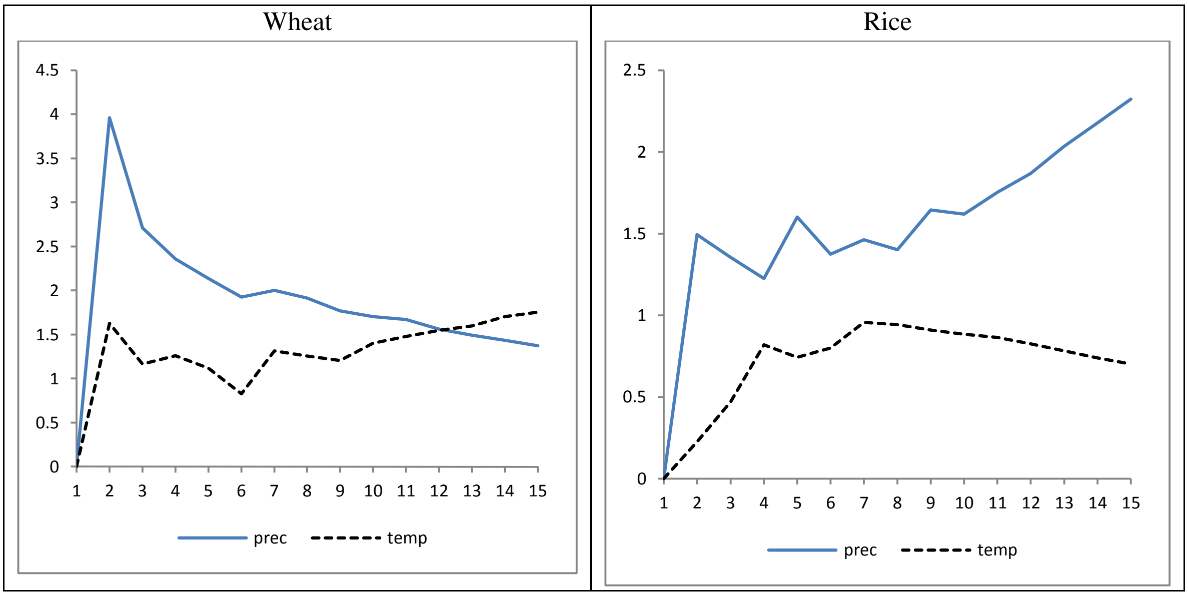
Period	RICE	ARABLE	EMPL	IRRIG	PREC	TEMP
1	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	84.86334	7.640466	1.998442	3.779426	1.492785	0.225536
3	81.75912	6.705364	5.290681	4.421835	1.353808	0.469190
4	76.59566	10.03468	5.348529	5.978026	1.224735	0.818367
5	73.91863	9.945693	6.092966	7.698230	1.601061	0.743426
6	71.28126	11.29017	6.094942	9.161585	1.373253	0.798793

https://dx.doi.org/10.22161/ijaers.4.1.32 *ISSN: 2349-6495(P) | 2456-1908(O)*

7	69.30065	11.52490	6.239556	10.51826	1.461320	0.955321
8	68.13045	12.04743	6.234020	11.24428	1.401879	0.941939
9	66.46767	12.48004	6.695692	11.80341	1.643780	0.909406
10	66.07303	12.44789	6.769702	12.20617	1.619360	0.883858
11	65.07207	12.71728	6.853968	12.74133	1.752018	0.863325
12	64.68753	12.57137	7.142455	12.90591	1.868481	0.824263
13	64.05070	12.69860	7.331352	13.10331	2.035313	0.780724
14	63.77337	12.53246	7.517197	13.26073	2.176810	0.739433
15	63.41238	12.48989	7.678230	13.39415	2.323592	0.701751

Source : A. Ghazouani, and al

Table.6: Evolution of the share of rainfall and temperature variation in wheat and rice



Source : A. Ghazouani, and al

Tables 4 and 5 shows that wheat production is influenced by temperature variation: the impact on temperatures contributes at 1.62% in explaining the variance of wheat production to a horizon of 2 year and 1.75% in 15 years, the influence of this shock becomes important as we move away from the moment of its occurrence.

The result confirms the negative impact of rising temperatures on wheat production. It should be stressed that the relative share of shock fluctuations in rice production gradually increases over time from 0.22% to 0.95% and then decreased to 0.70%. The temperature will have little impact on rice production as opposed to the production of wheat (Wheat poor resistance to water stress).

The relative share of the variation in rainfall fluctuations in the production of wheat fell by 3.95% to 1.37% after 15 years and its share in the production of rice increases from 1.49% to 2.32% in 15 years. This result confirms the importance of precipitation in rice production in India. The variability of rainfall during the growing period is extremely important.

4.3. Discussion

Climate changes have a negative overall impact on Indian agriculture. The two main crops (wheat and rice) will see their yields decline in the first half of the XXI century. Rising temperatures would affect grain quality and shorten the duration of crop growth. But agriculture will be affected primarily by higher droughts and water shortages.

Increasing droughts and climate variability would increase the likelihood of crop failures and the problems of desertification could be severe due to the more random nature of rainfall and rising temperatures due to climate change, which would also lead to an increase the use of fertilizers and pesticides, which has serious consequences on the quality of water and soil.

Farmers are exposed to significant economic and social risks posed by the evolution of the agricultural potential of the India. Increasing in the likelihood of reduced their crop yields will be a constraint to improving their living standards. Crop losses and increased drought resulting could harm farmers´ capacity to adapt to these impacts and lead to rural exodus to other more favorable agricultural areas to urban centers or in full growth.

https://dx.doi.org/10.22161/ijaers.4.1.32 *ISSN: 2349-6495(P) | 2456-1908(O)*

The issue of food security and the potential impact of the entry of the India on the market of international agricultural products is an important issue, because of the loss of arable land, rising water shortages and rising extreme weather events. India will see its capacity to produce cereals decrease, which will lead the country to the import huge quantities of cereals.

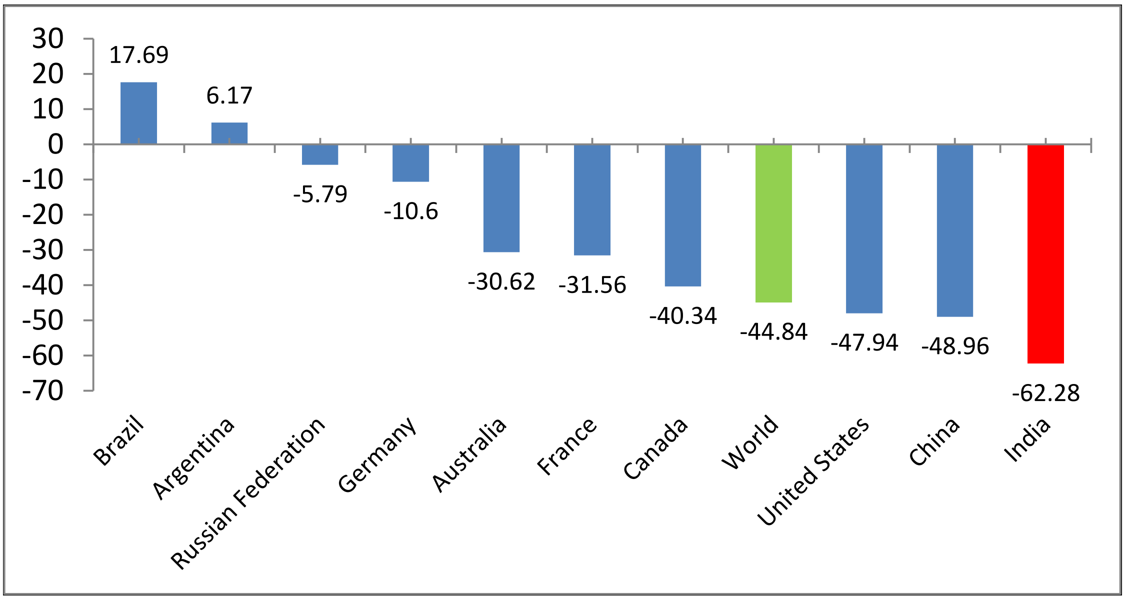


Fig.1: Evolution of arable land between 1962 and 2012 (in %)

Source : A. Ghazouani, et al

To feed its population with 17.83% of the 7.3 billion people on the planet (WDI 2016) and in strong growth, India must focus either on a import agricultural model or to increase production by adapting to climatic hazards. In 2006, adverse weather conditions (drought and increased temperatures) have affected most of the countries. India under the effect of rising temperatures has seen its wheat production reduced, what pushed the country to import 6079555 tons of wheat (a record) either 1,291,789,000 US dollars (wheat stocks fell 1.138 million tons) (FAO).

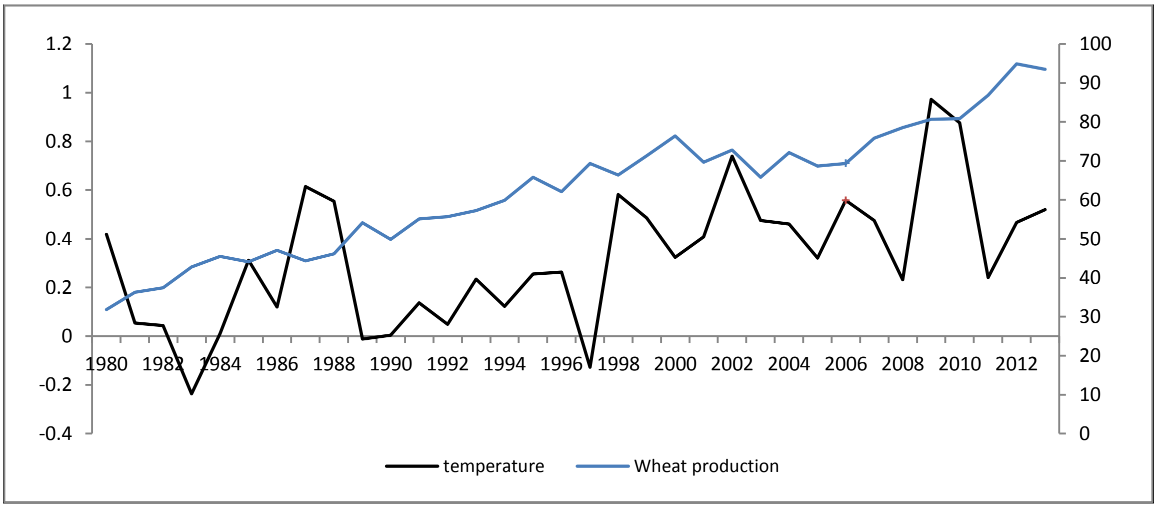


Fig.2: Change in temperature (° C) and wheat production (in millions)

Source : A. Ghazouani, and al

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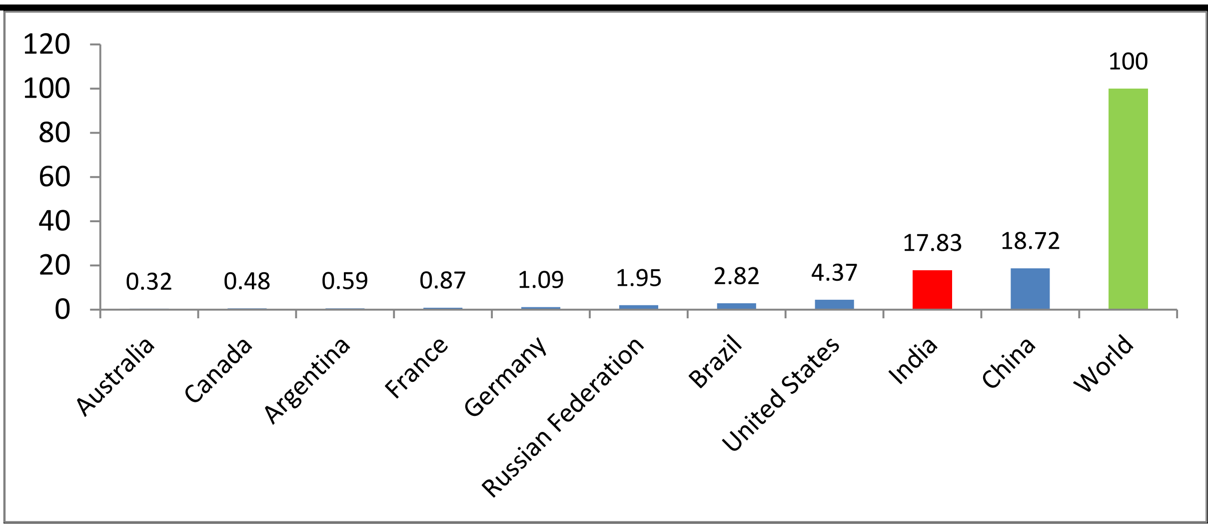

Fig.3: Part of the Indian population in the world population in 2015 (in %)

Source : A. Ghazouani, and al

The dependence of India for some agricultural products has a negative impact on world agriculture, especially in South America and Africa, and represents a great danger to food security due to the instability of commodity prices.

The consequences would be a significant increase in prices on international markets and a growing threat to political stability and food security in the world. Climate changes will accentuate these trends by increasing soil loss by amplifying the desertification, drought or flooding and increasing water deficits.

Disruptions in global agricultural products markets could essentially come coping strategies than will take India to respond to the food crisis. The ability to produce grains needed to feed more than one billion people remain adequate, but push the use of land and water resources to their maximum would not be rational.

V. CONCLUSION

The rate of climatic changes involves changes in the yield of agricultural crops in each region. Now it seems as wheat and rice produced in India have joined this disturbing list of crop punished by global warming, there is a link between the increase in average temperatures in India and lower production of wheat and rice.

The high temperatures recorded in recent years in the main belt of wheat and rice in India have a negative effect on the performance of these cultures and these temperatures are expected to increase in the coming decades because of climate changes.

Farmers should start thinking seriously about change the varieties of wheat and rice cultivated to more heat tolerant varieties, to avoid production losses caused by temperature.

Currently in India, 213 million people suffer from food insecurity and over 100 million expense of the national food aid which uses large quantities of wheat and rice. This highlights that the wheat varieties will grow in the coming decades to ensure production.

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Annex

1. ADF test of Dickey-Fuller

variables	Test for unit root in level	Test for unit root in 1st difference
Wheat	-0.018	**-9.283**
Rice	-0.726	**-10.524**
Arable	0.654	**-6.482**
Irrig	-1.510	**-5.330**
Temp	**-3.683**	-
Prec	**-5.855**	-
Empl	-2.898	**-3.704**

https://dx.doi.org/10.22161/ijaers.4.1.32 ISSN: 2349-6495(P) | 2456-1908(O)

2. Numbre of lags

Wheat		Rice	
Lag	AIC	Lag	AIC
0	101.1483	0	102.2997
1	88.40714	1	89.98189
2	87.95041*	2	89.82065*

3. Cointégration test of Johansen

$$Wheat = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.849957	145.6383	95.75366	0.0000
At most 1 *	0.637427	86.83650	69.81889	0.0012
At most 2 *	0.551496	55.38609	47.85613	0.0084
At most 3 *	0.440507	30.52910	29.79707	0.0411
At most 4	0.271343	12.52662	15.49471	0.1334
At most 5	0.083811	2.713502	3.841466	0.0995

$$Rice = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.851267	155.1993	95.75366	0.0000
At most 1 *	0.704021	96.12561	69.81889	0.0001
At most 2 *	0.533233	58.38409	47.85613	0.0038
At most 3 *	0.442986	34.76438	29.79707	0.0123
At most 4 *	0.314649	16.62429	15.49471	0.0337
At most 5 *	0.146529	4.911757	3.841466	0.0267

4. Error Correction Model Estimation

$$Wheat = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$

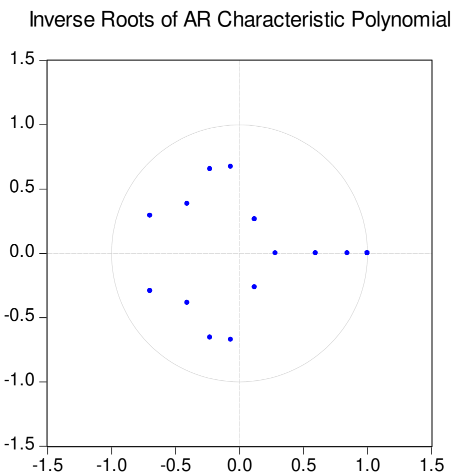
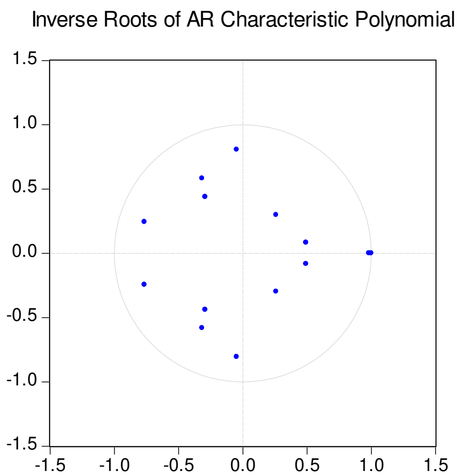
Error Correction:	D(WHEAT)	D(ARABLE)	D(IRRIG)	D(TEMP)	D(PREC)	D(EMPL)
CointEq1	0.417648	0.000112	-8.32E-06	-3.71E-09	-2.76E-05	4.43E-05
D(WHEAT(-1))	-0.841967	-4.74E-05	2.56E-05	7.15E-09	1.60E-05	-4.41E-05
D(WHEAT (-2))	-0.224920	-4.33E-05	1.07E-05	-3.50E-09	7.18E-06	-2.08E-05
D(ARABLE(-1))	-2749.290	-0.366259	0.121740	0.000122	0.125416	0.273462
D(ARABLE(-2))	-334.7578	-0.540905	-0.203833	-4.58E-05	0.053560	-0.134382
D(EMPL(-1))	-2015.450	0.203169	0.136744	0.000225	0.010976	0.188704
D(EMPL(-2))	-2605.469	-0.550247	0.184378	-0.000290	0.186865	0.080325
D(IRRIG(-1))	1196.130	-0.203838	0.962256	0.000250	0.031202	-0.374203
D(IRRIG(-2))	-8335.462	-0.770053	-0.038211	-0.000151	0.196494	-0.098131
D(PREC(-1))	-14548.77	-4.988456	0.830398	-8.34E-05	0.735279	-2.566790
D(PREC(-2))	2093.555	-2.930282	0.314172	-0.000478	0.203133	-1.767130
D(TEMP(-1))	-1040993.	-305.3002	347.5503	-0.357706	97.75004	-324.4331
D(TEMP(-2))	695066.7	-323.6313	420.0647	-0.358488	55.19606	-170.2822
C	22575204	1588.719	-975.3327	0.140040	-770.7516	2637.829

$$Rice = \beta Arable_{t-n} + \gamma Irrig_{t-n} + \delta Temp_{t-n} + \varphi Prec_{t-n} + \theta Empl_{t-n} + \epsilon_{1t}$$

https://dx.doi.org/10.22161/ijaers.4.1.32 ISSN: 2349-6495(P) | 2456-1908(O)

Error Correction:	D(RICE)	D(ARABLE)	D(IRRIG)	D(TEMP)	D(PREC)	D(EMPL)
CointEq1	-0.163131	-2.81E-05	-1.42E-05	-2.69E-10	6.24E-08	-1.47E-05
D(RICE (-1))	-0.500531	5.24E-05	1.98E-05	7.68E-10	-5.20E-06	1.40E-05
D(RICE (-2))	-0.038986	4.42E-05	6.35E-06	3.62E-11	-4.41E-06	7.58E-06
D(ARABLE(-1))	2466.303	-0.681494	-0.080097	0.000125	0.073053	0.048397
D(ARABLE(-2))	-5826.234	-0.169265	-0.332440	-8.14E-05	-0.077365	0.005810
D(EMPL(-1))	-7885.488	-0.644570	-0.271776	0.000203	0.059304	-0.085945
D(EMPL(-2))	5852.881	-0.622615	-0.023772	-0.000272	0.095653	-0.105798
D(IRRIG(-1))	-9392.390	-0.546688	0.831769	0.000223	0.023559	-0.430383
D(IRRIG(-2))	3549.326	0.325066	-0.150354	-0.000164	-0.051757	0.232884
D(PREC(-1))	33319.68	2.451201	0.809987	-0.000322	-0.635834	0.950228
D(PREC(-2))	5940.840	-0.217706	0.449852	-0.000478	-0.253436	-0.254478
D(TEMP(-1))	6175657.	326.1507	521.3690	-0.364060	35.93394	-19.17139
D(TEMP(-2))	127092.6	65.70183	313.3612	-0.343541	-22.46302	-64.46394
C	14240647	3249.630	951.0643	0.182850	-405.5759	3565.152

5. Dynamic stability of model

Wheat	Rice
	

Changes in temperatures and precipitation in India between 1980 and 2013