

### Climate change effects on the cereals production in Eastern Province, Rwanda

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#### Abstract

In this paper the analysis of the effects of climate changes on the cereals production have been carried out in Eastern Province of Rwanda in order to sort out the reasons behind the change of cereals production and to help in making their forecasting for future periods. Statistical techniques were applied in order to depict the relationships between temperature, humidity, precipitation, with cereals production during the period 1989-2010, hence correlation and regression analysis were performed using SPSS 13 and Origin pro 8. In addition to those techniques field's surveys and observation were also performed. The results show that cereals production in Eastern Province of Rwanda during this study's period depends less on the precipitation, temperature and humidity either linear or polynomial correlations reveals that dependence. They also revealed that they highly depend on the cultivated area with the linear correlation coefficient of 0.823 and that of polynomial of 0.908 and on the percentage of cultivated area with the linear correlation coefficient of 0.929 and that of polynomial of 0.934. Even though the last two parameters tend to have more impact on the cereals production but they are related to government policies and these recent years government of Rwanda initiated new fields to grow cereals, and due to the land consolidation and crop regionalization policies recently initiated by the government of Rwanda, Eastern province has been favorable for cereals and other crops have been abandoned in the favor of cereals in that area. Hence the increasing of the area used to grow cereals but this increasing of cultivated area has a limit and in the coming years it will be stable or reduced depending on the government decision but it will not continue to increase as the general cultivated area is not increasing, for these reasons climatic factors such temperature, rainfall and humidity should be given priority since they are changing and it is difficult to plan their change as the world is facing a general serious problem of climate change. Another reason to support these factors is the physico-geography of East province of Rwanda which is the poorest region of Rwanda in rainfall with high insolation and dominated by lowlands.

**Keywords:** Cereals production, Eastern Province of Rwanda, Climate change

#### 1. Introduction

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended periods (IPCC, 2001). Climate change is a global issue potentially affecting the vast majority of

organisms and all types of ecosystems (Guo, 2000) and hydrological cycle is intimately linked with changes in atmospheric temperatures and radiation balance (Bates et al., 2008). Climatic conditions affect human well-being both directly, through the physical effects of climatic extremes, and

indirectly, through influences on the levels of pollution in the air, on the agricultural, marine and freshwater systems that provide food and water. It is well known that the average global surface temperature has warmed 0.8°C in the past century and 0.6°C in the past three decades, in large part because of human activities (IPCC, 2001). A recent report produced by the U.S. National Academy of Sciences confirms that the last few decades of the 20<sup>th</sup> century were in fact the warmest in the past 400 years (National Research Council of the National Academies, 2006). The Intergovernmental Panel on Climate Change (IPCC) has projected that if greenhouse gas emissions, the leading cause of climate change, continue to rise, the mean global temperatures will increase 1.4°C~5.8°C by the end of the 21<sup>st</sup> century (IPCC, 2001).

Climate change and agriculture are interrelated processes, both of which take place on a global scale (IPCC, 2007). Global warming is projected to have significant impacts on the conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements (Easterling, et al 2007). These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals.

Climate change induced by increasing greenhouse gases is likely to affect crops differently from region to region. For example, average crop yield is expected to drop down to 50% in Pakistan whereas corn production in Europe is expected to grow up to 25% in optimum hydrologic conditions. Southern Africa could lose more than 30% of its main crop, maize, by 2030. In South Asia losses of many regional staples, such as rice, millet and maize could top 10%, whereas corn production in

Europe is expected to grow up to 25% in optimum hydrologic conditions. More favorable effects on yield tend to depend to a large extent on realization of the potentially beneficial effects of carbon dioxide on crop growth and increase of efficiency in water use. Decrease in potential yields is likely to be caused by shortening of the growing period, decrease in water availability and poor drainage, Lobell et al (2008).

In the long run, the climatic change could affect agriculture in several ways:

- Productivity, in terms of quantity and quality of crops
- Agricultural practices, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers
- environmental effects, in particular in relation of frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, reduction of crop diversity
- Rural space, through the loss and gain of cultivated lands, land speculation, land renunciation, and hydraulic amenities.
- Adaptation, organisms may become more or less competitive, as well as humans may develop urgency to develop more competitive organisms, such as flood resistant or salt resistant varieties of rice.
- Duration of crop growth cycles: An increase in temperature will speed up development. In the case of an annual crop, the duration between sowing and harvesting will shorten (for example, the duration in order to harvest corn could shorten between one and four weeks). The shortening of such a cycle could have an

adverse effect on productivity because senescence would occur sooner.

- Effect of elevated carbon dioxide on crops. Carbon dioxide is essential to plant growth

Controversially, agriculture contributes to greenhouse gas increases through land use in four main ways:

- CO<sub>2</sub> releases linked to deforestation
- Methane releases from rice cultivation
- Methane releases from enteric fermentation in cattle
- Nitrous oxide releases from fertilizer application

Together, these agricultural processes comprise 54% of methane emissions, roughly 80% of nitrous oxide emissions, and virtually all carbon dioxide emissions tied to land use, (IPCC, 2007).

Because of the lack of economic development, and institutional capacity, African countries are likely among the most vulnerable to the impacts of climate change (IPCC, 2001). Climate change impacts have the potential to undermine and even, undo progress made in improving the socio-economic well-being of East African countries where Rwanda is located. The negative impacts associated with climate change are also compounded by many factors, including widespread poverty, human diseases, and high population density, which is estimated to double the demand for food, water, and livestock forage within the next 30 years (Davidson et al., 2003).

Overall Africa has warmed 0.7°C over the 20<sup>th</sup> century and general circulation models project

warming across Africa ranging from 0.2°C to more than 0.5°C per decade (Hulme et al., 2001; IPCC, 2001).

Considering all those issues above and since Rwandan economy highly depends on the agriculture, there is a requirement to analyze the relationship between climate change and cereals production in Eastern Province of Rwanda.

## **2. Materials and methods**

### ***Study area description***

Eastern Province occupies around one third of the total surface of Rwanda i.e. 9,813 km<sup>2</sup>, it is made up by seven districts; Bugesera, Gatsibo, Kayanza, Ngoma, Kirehe, Nyagatare and Rwamanaga. Currently it is the most populated province with 2 600 814 million people, i.e 24.7% of the total Rwandan population MINECOFIN (2012). Eastern Province is bordered in the north by Uganda, in the east by Tanzania and in the south by Burundi. It has fertile agricultural land with the majority of the country's cows (MINITERE, 2004). The Eastern Province is a relatively low-lying and flat region with the climate which is dry and warmer comparing with other Rwandan Provinces, with annual average rainfall of 600 to 1400mm, temperature from 15 to 24°C, evapotranspiration of 1400-1700mm, relative humidity 50-80%, insolation of 6-6.5 hours a day and wind of 4-6 km/hour, (Chemonics International Inc., 2003, MINITERE 2006). There are two dry seasons, a short dry season from January to February and a long dry season from June to September, as well as two wet seasons, one from October to December and another from March to May, (Okoola, 2001). More details for the study area are shown on the Figure 1.

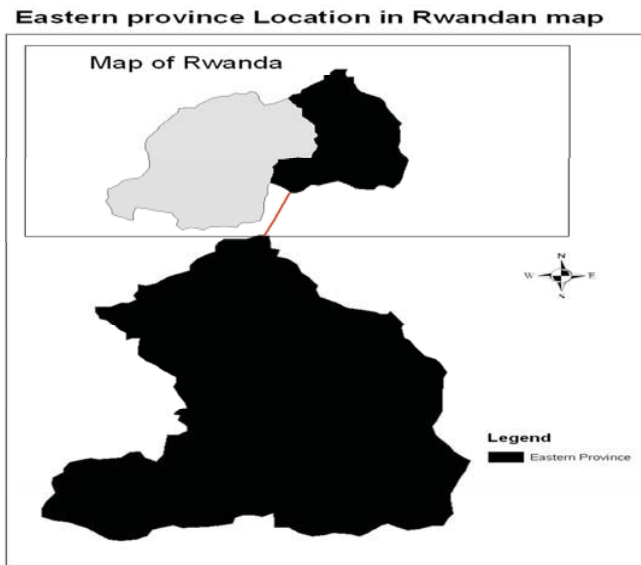


Figure 1. Location of the study area in the map of Rwanda

### 3. Methodology

The precipitation, humidity, temperature data from 1989 to 2010 were collected from Rwanda Meteorology Office while those of cereals production, percentage of cultivated area and cultivated area were collected from the Rwandan Ministry of Agriculture.

In order to supplement the collected secondary data, a guided interview was conducted with

people in charge of environmental management and those in charge of agriculture in the Eastern Province. Also there have been observation and visit of cereals corps's fields in the study area. GIS (arcmap) has been used to produce the study area map; SPSS and ORIGIN PRO 8.0 were used to determine the relationship between cereals production and other parameters and to produce the required figures.

### 4. Results

#### *Correlation between cereals production and other parameters*

Table 1. Correlations between cereals production and other parameters

Parameters	Linear correlation	Polynomial correlation
Temperature	0.205	0.462
Precipitation	0.013	0.052
Humidity	0.02	0.175
% of cultivated area	0.929	0.934
Cultivated area	0.823	0.908

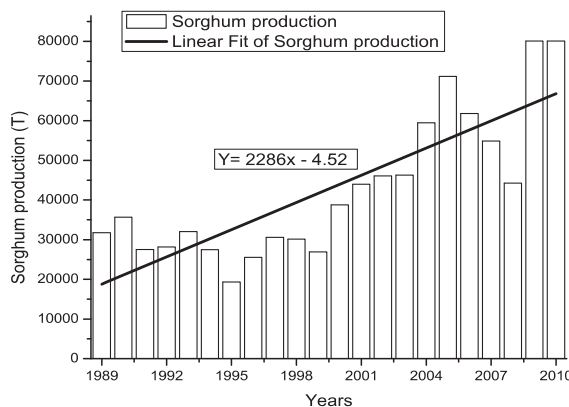
Table 1 shows that cereals production in Eastern Province of Rwanda highly depends on cultivated area with the linear correlation coefficient of 0.823 and that of polynomial of 0.908 and on the percentage of cultivated area with the linear correlation coefficient of 0.929 and that of polynomial of 0.934 and less on the precipitation, temperature and humidity either linear or polynomial correlations before or after forecasting reveals that dependence. The first two parameters tend to have more impact on the cereals production but they are related to government policies and these recent years government of Rwanda was initiating new fields to grow cereals, also due to the land consolidation and crop regionalization policies recently initiated by the government of Rwanda, East province has been

favorable for cereals and other crops have been abandoned in the favor of cereals in that area. Hence the increasing of the area used to grow cereals but this increasing of cultivated area has a limit and in the coming years it will be stable or reduced depending on the government decision but it will not continue to increase as the general cultivated area is not increasing, for these reasons other factors such temperature, rainfall and humidity should be given priority since they are changing and it is difficult to plan their change as the world is facing a general serious problem of climate change. Another reason to support these factors is the physico-geography of East province of Rwanda which is the poorest region of Rwanda in rainfall with high insolation and dominated by lowlands.

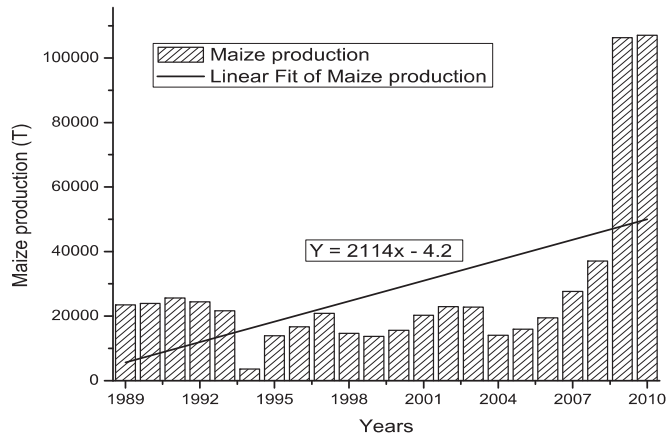
**Statistical description and trends for cereals production**

Figure 2 shows that there is an increasing long term trend for sorghum production from 1989 to 2010. From 1989 to 1999 the variation of production was not high and it was either

decreasing or increasing, from 2000 to 2005, the production was increasing at a remarkable rate while it was decreasing during the period 2006-2008 and increased again in the period 2009-2010.



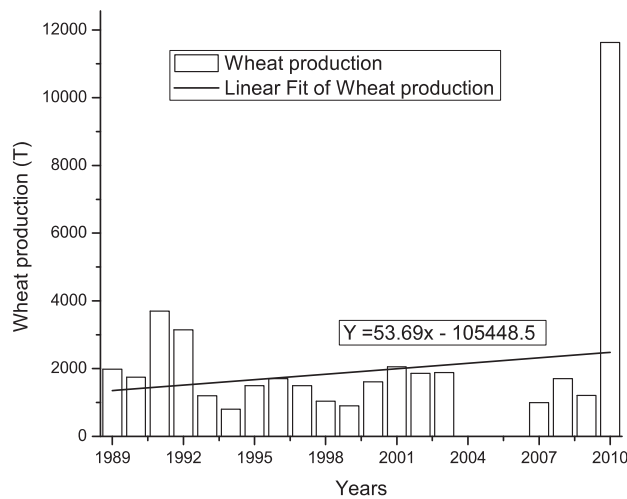
**Figure 2. Variation of sorghum production and its trend line from 1989 to 2010**



**Figure 3. Variation of maize production and its trend line from 1989 to 2010**

Based on Figure 3, it is easily depicted that maize production was slowly changing from 1989 to 2008 except the year 1994 where it decreased dramatically due to the war and genocide which

took place at that time and it was highly increasing in the period 2009-2010 due to the favorable policies. It is noticed also that the general trend for maize production is increasing.



**Figure 4. Variation of wheat production and its trend line from 1989 to 2010**

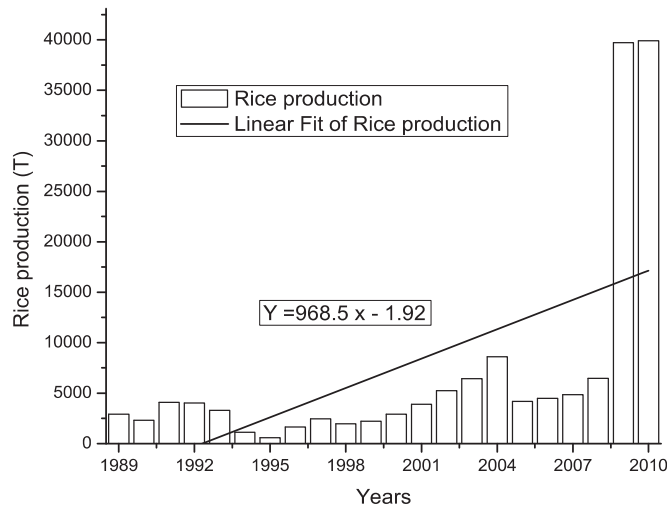
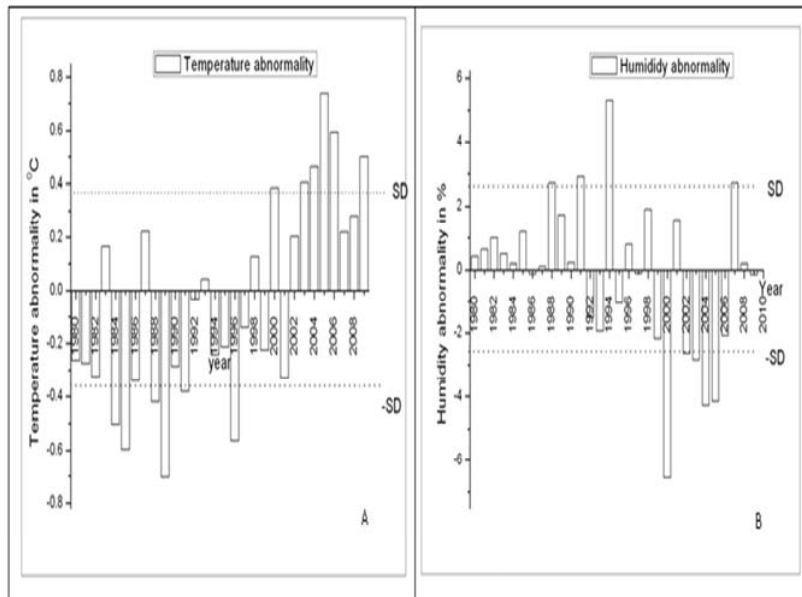


Figure 5. Variation of rice production and its trend line from 1989 to 2010

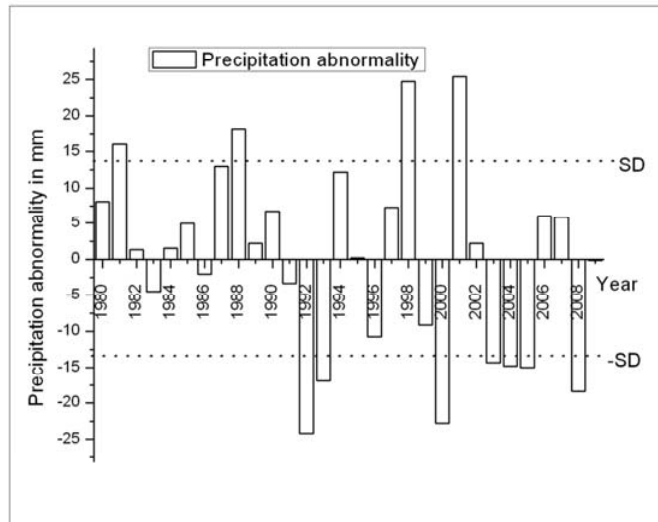
Comparing with other types of cereals, wheat production from 1989 to 2010 was low and its variation was also at small rate except the year 2010 where the production was highly increased. The general trend is also increasing but with a smaller increasing rate as shown on the figure 4.

Rice production followed almost the same pattern as maize and its variation was low from 1989 to 2008 except for the period 2009-2010 where it increased dramatically. The trend line was also increasing as for other cereals as presented on the figure 5.

**Climatic abnormalities**







**Figure 7. Precipitation anomaly**

The variability of air temperature was marked by the increase of temperature from 2000 and higher values were attained in 2000, 2003, 2004, 2005, and 2009 and the year 2005 being the hottest one. However, the lower temperatures were observed before the year 2000 where the lowest temperature was in year of 1989 as shown on the figure 6.A, for the humidity it has inverse proportion of temperature i.e. the higher the temperature corresponds to lower values of humidity and hence lowest values of humidity were remarked

from the year 2000 as presented on the figure 6.B. The analysis of rainfalls variability for the period from 1980 to 2009 indicates that from 1992 up to 2008 was the driest since 1980. In fact, the study area was marked by pluviometric deficits during five years (1992, 1993, 2000, 2003, 2004, 2005 and 2008) out of which 2 were very remarkable (1992 and 2000). The pluviometric excesses were remarked in the years 1981, 1988, 1998 and 2001 as shown on the figure 7.

***Some current effects of floods in Eastern Province***

As Figure 8 shows, in Rwamagana District of Eastern Province, trees, crops and many houses were damaged by heavy rainfall and floods in 2011 where more than 100 families needed help as reported by the mayor of that District. In the same Eastern Province, in December 2011, Rice farmers in Nyagatare District were on Thursday December 1st, 2011, left in shock after a heavy downpour destroyed rice fields at Cyabayaga rice scheme.

According to the president of the cooperative that runs the rice scheme, Elijah Mboneza, floods destroyed 65 hectares of rice as shown on the and Figure 9 , “It’s a shock. Heavy rains started in the afternoon hours. We later received reports from Cooperative members that about 65 hectares of rice had been destroyed. These floods effects tend to be cyclical and frequent every year during the raining seasons while during the dry seasons eastern Province has a serious lack of water.





**Figure 8. Land degraded in Rwamagana District due to floods in 2012**



**Figure 9. Bananas destroyed by floods in Rwamagana in 2011**

## 5. Conclusion

The results show that cereals production in Eastern Province of Rwanda highly depends on cultivated area with the linear correlation coefficient of 0.823 and that of polynomial of 0.908 and on the percentage of cultivated area with the linear correlation coefficient of 0.929 and that of polynomial of 0.934 and less on the precipitation, temperature and humidity either linear or polynomial reveals that dependence. Even though the first two parameters tend to have more impact on the cereals production but they are related to government policies and these recent years government of Rwanda was initiating new fields to grow cereals, also due to the land consolidation and crop regionalization policies recently initiated by the government of Rwanda, East province has been favorable for cereals and other crops have been abandoned in the favor of cereals in that area. Hence the increasing of the area used to grow cereals but this increasing of cultivated area has a limit and in the coming years it will be stable or reduced depending on the

government decision but it will not continue to increase as the general cultivated area is not increasing, for these reasons other factors such temperature, rainfall and humidity should be given priority since they are changing and it is difficult to plan their change as the world is facing a general serious problem of climate change. Another reason to support these factors is the physico-geography of East province of Rwanda which is the poorest region of Rwanda in rainfall with high insolation and dominated by lowlands. The results also showed that the general trend for all cereals is increasing and will continue to increase with increasing cultivated area, percentage of cultivated area, suitable climatic conditions and favorable policies.

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