American Journal of Environment and Sustainable Development
Vol. 5, No. 2, 2020, pp. 24-29
http://www.aiscience.org/journal/ajesd

Implication of Climate Change on Rice Production in Nyanza District of Rwanda

Gustave Nzungize*, Hakizimana Narcisse, Muvunyi Jean Damascene, Lamek Nahayo

Faculty of Environmental Studies, University of Lay Adventists of Kigali (UNILAK), Kigali, Rwanda

Abstract

Climate change, one of the challenges facing the world today, is increasingly affecting people's livelihood in Rwanda like other developing countries. This study aimed to assess the impact of climate change on rice production in Nyanza district, Southern Rwanda. The climate data mainly rainfall and temperature were obtained from Rwanda Meteorological Agency (RMA). The data on rice production were collected from the rice production cooperative in Nyanza district. The employed seven-year (2010-2017) datasets were analyzed by using the Statistical Package for Social Sciences (SPSS), Microsoft excel and Stata. The results indicated that the highest quantity of rice was produced in 2016 (6,254 tons) and 2017 was the year with the lowest rice production (2,809 tons). Regarding rainfall, the highest average was recorded in 2013 and 2016 (126.59-142.56 mm), and these years recorded rice productions of 5,350-6,254 tons, respectively. The temperature manifested a slight change with nearly 2°C between the lowest 20.5°C and the highest 22.44°C. The results indicated that change on average annual rainfall and temperature lead to 64.5% and 4.9% variations on annual rice production, respectively. Thus, rainfall significantly impacts on rice production in Nyanza District. Therefore, rice varieties resisting to climate change, mainly rainfall variability would be productive in this area.

Keywords

Climate Change, Rice Production, Nyanza District, Rwanda

Received: April 12, 2020 / Accepted: May 15, 2020 / Published online: June 9, 2020

1. Introduction

The uncontrollable nature of climatic factors changing over time, especially rainfall and temperature has been causing very strong impact on economic, social and environmental sustainability. Changes in the atmospheric composition due to anthropogenic increase in greenhouse gases lead to changes in the irradiative balance of the earth and consequent alterations in temperature, circulation pattern and weather patterns. Rising temperatures are influencing various systems on the earth, including agriculture [1].

Global warming has a direct effect on crops, food chains and production cycles in terms of marked changes on growth and yield processes. The reports indicated that the rise in temperature since 1980 has led to reduction in yields of staple crops offsetting gains even from improved farm practices, which has several implications for agriculture, crop yields and patterns in the long run [2, 3]. As the world population increases, there is need of increasing food availability to satisfy the rising need. For example world rice production must increase by 1% annually to meet growing demand for food that results from population growth and economic development [4]

The yield of rice, like other crops, depends on many factors including quality of soil (fertility), technology, planting practices, and certainly weather conditions [5]. However, the latter is pertinent, as the climate is likely to change. According to the Intergovernmental Panel on Climate

* Corresponding author
E-mail address: nzungize77@gmail.com (G. Nzungize)

Change (IPCC), global warming is indisputable and global average temperature is anticipated to increase by 2 to 4 Celsius degrees, and precipitation is expected to increase by 6% to 10% by the end of this century [6, 7]. These changes in climatic conditions will affect crop yield and yield variability, thus it is crucial to investigate how sensitive crop yield variability are to whether condition and future climate change.

It has been found that in Rwanda, agriculture is highly susceptible to variation in climate change. The sector feeds more than 90 per cent living in rural areas for their livelihood [8]. Also, this is associated with the fact that agriculture sector contributes to Rwandan economy at 33% of the national Gross Domestic Product (GDP) [9]. However, in Rwanda also, the changing climate started to manifest its impact on agricultural production many years ago. For example, in 2015, the dry season started early than expected, and this greatly led to reduction of agricultural production mainly in the Eastern province [10].

In addition, Rwanda, as well as other developing countries whose agriculture is still rainfed will record great consequences of climate change due to decreasing and/or increasing rainfall record which generate negative effects on the agricultural production [10]. Looking at climate change scenarios, and the growing demand of food, it is important to learn how much crop yield will fluctuate in order to ensure the growing food demand [11]. Therefore, the objective of this study was to analyse the relationship between climate variability, mainly temperature and rainfall and rice production in Nyanza District of the southern Rwanda.

2. Methods and Material

2.1. Study Area

This study focused on the Nyanza district, one of eight districts of southern province of Rwanda with 671.2 km^2 of the land surface. The district is delimited by neighbouring districts: in North by Ruhango district, in south by Gisagara district and Burundi Republic, in west by Huye and Nyamagabe districts, in East by Bugesera district. The district has ten sectors: Busasamana, Mukingo, Kigoma, Kibirizi, Busoro, Muyira, Ntyazo, Cyabakamyi, Nyagisozi and Rwabicuma [12].

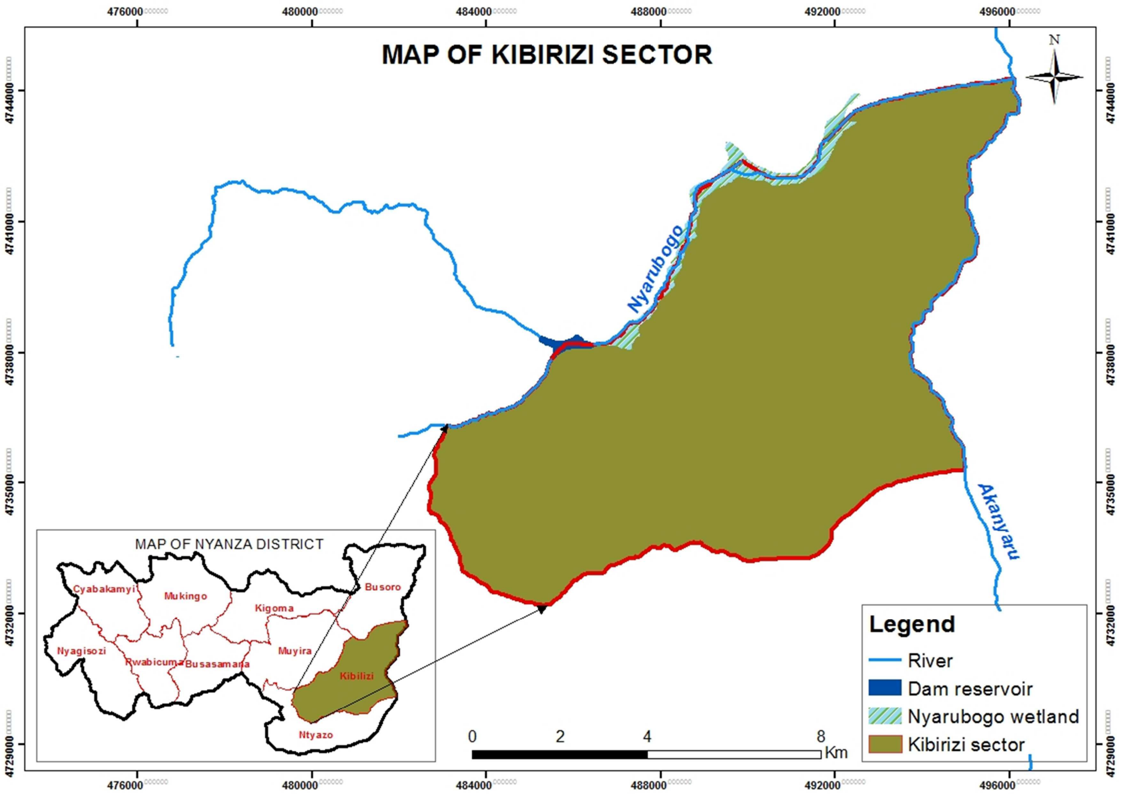

Figure 1. Map of Nyanza district in Rwanda and study area.

The district of Nyanza is inhabited by 323,719 people spread as 482 inhabitants per Km^2 [12]. Nyanza District is situated within a tropical region and has a humid climate. This region experiences alternate season, the rainy season alternates with the dry season. The annual maximum temperature is 24°C, the annual rainfall is 1,400 mm and the main river is Nyarubogo [13].

The district is divided into west and eastern part. The eastern part characterized by low and mid altitude and annual temperatures of around 20°C. This part, commonly known as the Amayaga zone was selected as the concern for this study. The area is known to be a drought- prone area of the country. This part is located in Kibirizi sector of Nyanza district. The authors considered one and largest rice production cooperative in Nyanza district; the Cooperative de Promotion des Riziculteurs (COOPRORIZ) with 1,013 members [13].

2.2. Data Collection and Analysis

This study employed types of data namely the time series data (secondary data) which include data on rice production and climate variables (rainfall and temperature). Secondary data were collected and used to provide in-depth analysis of climate change impact on rice yield. A set of secondary data on rice was collected from the Cooperative de Promotion des Riziculteurs (COOPRORIZ). The data on climate variables (rainfall and temperatures) were collected from Rwanda Meteorology Agency. These climate and rice production-related data were subdivided into two phases. The first phase covered the months of March, April and May (MAM) and the last phase was for September, October, November and December (SOND).

Finally, after data collection, the rainfall and temperature (minimum and maximum) data were analyzed in comparison with the production of rice by using the Statistical Package for Social Sciences.

3. Results

3.1. Temperature and Rainfall Record

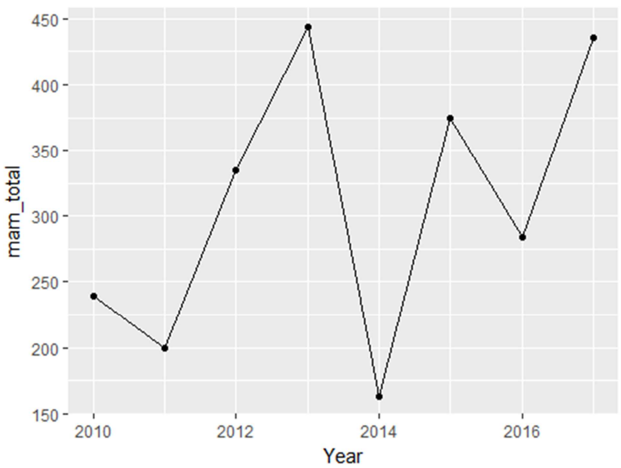

Figure 2. MAM rainfall trend.

The results in Figure 2 indicated that the average rainfall in March, April and May (MAM) was lower in 2010 and began to increase from 2011 up to 2013. However, the results demonstrated a mixture of rainfall trends in the years between 2014 and 2017.

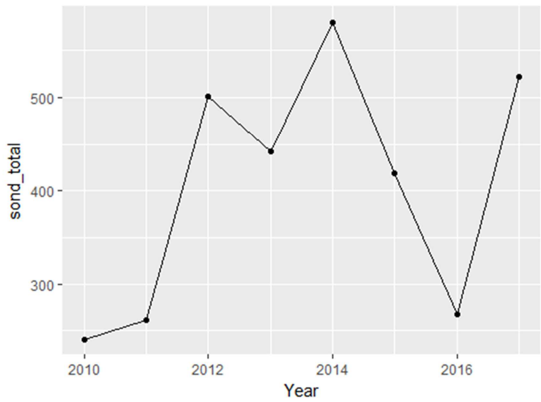

Figure 3. SOND rainfall trend.

The results on the rainfall of September, October, November and December (SOND), as shown in Figure 3 revealed a decreasing record of rainfall between 2010 and 2011. The same Figure revealed a considerable decrease rainfall between 2014 and 2016.

For the temperature, the study analyzed the minimum and maximum to see temperature trends as the normal range for rice growing season is between 20°C and 27°C whereas the minimum temperature for rice should not go below 15°C since the germination cannot take place below this threshold [14].

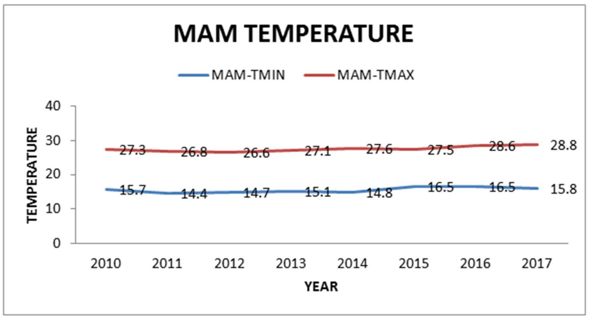

Figure 4. MAM temperature.

According to the results in Figure 4, during the MAM period, the minimum temperature across the study was low in 2011 while the highest record was registered in 2016 and 2017 at 16.5°C, respectively. In addition, Figure 4 demonstrated that the maximum temperature in the same period was low in 2012 and high in 2017.

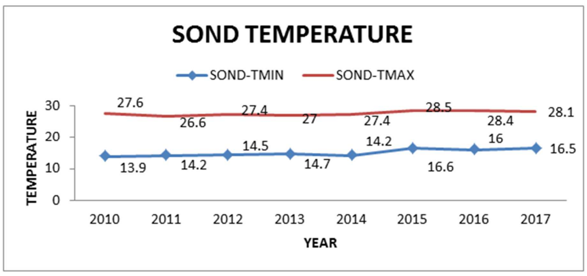

Figure 5. SOND temperature.

The results in Figure 5 indicated that during the SOND period, both minimum and maximum temperature records were fluctuating. For the minimum temperature, the lowest record of 13.9°C was registered in 2010 and then kept on increasing until 2017. However, the maximum temperature indicated that the years of 2011 and 2016 recorded the lowest and highest temperature records of 26.6°C and 28.5°C, respectively (Figure 5).

3.2. Rice Production Record

After analyzing trends of climate factors, the authors analyzed the rice production within the studied period and compared the rice production variations vis a vis annual rainfall and temperature averages.

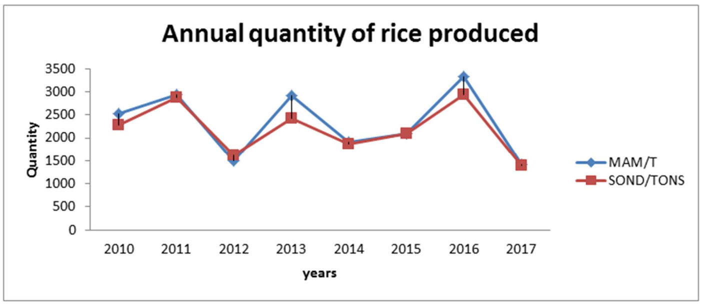

Figure 6. Annual quantities of rice produced.

The results (Figure 6) on the rice produced annually in Nyanza district indicated that during MAM period, there has been an increasing record of rice production than that of SOND period. However, the results showed that during the period of MAM 2012, the rice yield was lower than that of SOND period. The highest production of 6,254t was recorded in 2016 while the lowest production was 2,809t in 2017.

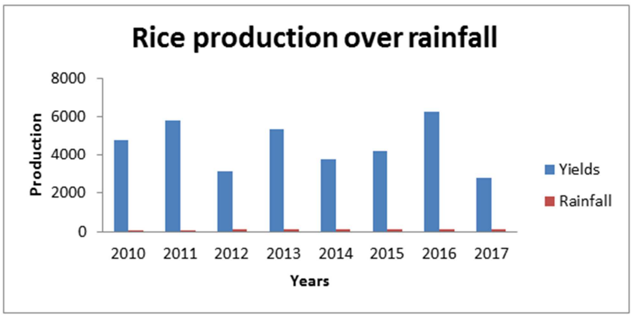

Figure 7. Rice production over rainfall.

As previously reported [15], rainfall and temperature are very critical factors for the growth of food crops like rice. During the rainfall period (Figure 7), the highest rainfall average was recorded in 2013 and 2016 (126.59-142.56 mm) with 5,350-6,254 tons of rice produced over both years, respectively. This shows that food production in Rwanda fluctuates from year to year due to frequent variations in the magnitude of rains during and between growing seasons.

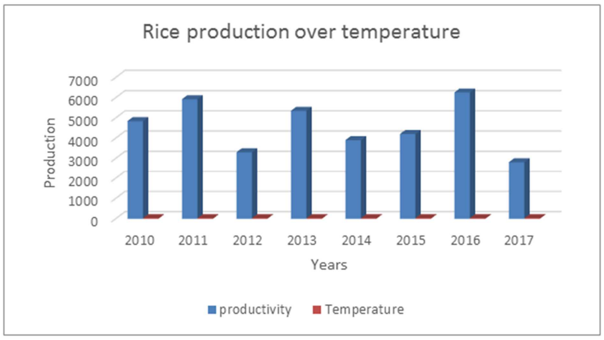

Figure 8. Rice production over temperature.

As stated above, temperature plays a big role in crop growth and production. However, the results of this study (Figure 8) indicated that temperature didn't have significant changes on rice yield. The record varied between 20°C and 22°C and despite those slight changes in temperature, rice production kept changing from year to year (Figure 8).

3.3. Correlation and Regression Analysis of the Relationship between Annual Rainfall, Temperature and Rice

Table 1. Regression on the relationship between rice yield and average rainfall.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.803[a]	.645	-.0070	.005644

a: Predictors: (Constant), total annual rainfall (mm)

Table 2. Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients		T	Sig
	*B**	*Std. Error*	*Beta*		
(Constant) total annual rainfall	.548	.086		7.843	.000
	.0426	.01	-.145	-4.38	.000610

a: Dependent variable: annual rice production (Mt/ha)

The equation for the linear regression is of the form: annual quantity of rice produced: 0.548+0.0426 (average annual rainfall).

The constant term is indicative of the fact that the annual quantity of rice produced would be 0.548 metric tons per hectare if the average annual rainfall was 0 mm. The slope of the line (.0426) also shows that an increase in the average annual rainfall by 1 mm will lead to a 4.26% increase or decrease in the annual quantity of rice produced. Thus, there is an association between average annual rainfall and rice production. The regression from Table 1 reported an R squared of 0.645. This means that a variation in average annual rainfall can account for 64.5% of the variations in the annual quantity of rice produced over the period.

Implicitly, about 35.5% of the variations in the quantity of rice produced annually cannot be explained by variation in average annual rainfall. These variations can be associated with other factors that affect rice productions (like farming in waterlogged areas, irrigation, fertilizer application, improved seeds, farming practices, etc.) which could have effects on annual rice produced per hectare. The correlation coefficient is 0.803. This means that there is a strong relationship between rainfall and rice production.

Table 3. Regression on the relationship between rice yield and average temperature.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.158[a]	.049	-.065	.04060

a: Predictors: (Constant), total annual temperature (°C)

Table 4. Coefficients[a].

Model	Unstandardized Coefficients	Standardized Coefficients		T	Sig
	*B**	*Std. Error*	*Beta*		
(Constant) total annual temperature	2.042	2.602	-.158	.790	.540
	.046	.079		-.553	.581

a: Dependent variable: annual rice production (Mt/ha)

The equation for the linear regression is of the form: annual quantity of rice produced: annual rice produced: 2.042-0.046 (average annual temperature).

The constant term is indicative of the fact that, the annual quantity of rice produced will be 2.042 metric tons per hectare if the average annual temperature becomes 0°C. The slope of the line (-0.046) also showed that an increase in the average annual temperature by 1°C will reduce the annual quantity of rice produced by .046 metric tons per hectare. Thus, there is a slight negative relationship between average annual temperature and rice production.

From Table 3, the regression reported an R squared of 0.049. This means that the average annual temperature is can account for 4.9% of the variations in the annual quantity of rice produced. About 95.1% of the variations in the quantity of rice produced annually cannot be accounted for by the average annual temperature. The correlation coefficient is 0.158. This means that there is a weak relationship between temperature and rice production.

Table 5. Overall analysis.

ANOVA				
	df	*SS*	*MS*	*F*
Regression	2	81076.75449	40538.3772	5.985031
Residual	5	33866.47159	6773.29432	
Total	7	61163.2692		

The test of hypothesis indicated that climate change has no impact on rice production in Nyanza district.* Degree of freedom from numerator: 2, Degree of freedom from denominator: 5, Level of significance is 0.05. Therefore, Fisher table is 5.78614 and the Fisher calculated is 5.985031.

4. Discussion

Basing on the findings of previous studies [16, 17, 18], there is possibility of harvesting increased rice production when at the same time keeping abreast with climate change especially rainfall. The increasing and decreasing rainfall must be observed as a guiding principle. Otherwise, failure will subsist. Rainfall is one of the inevitable factors of success in rice production. It can be concluded that rainfall has a significant effect on increasing or decreasing of rice production. Similarly, this study also found that temperature has no real impact on increasing or decreasing rice production (Tables 3 and 4).

It is reported that temperature rise extends the growing season and the farmable area; it causes earlier maturity of grain and opens up for the growing/farming of new crops. While the temperature rise is beneficial to the crops, the extra heat also affects weeds. Weeds, pests, and insects tend to get better living conditions under higher temperatures [4, 8]. The increase in temperature also increases evapotranspiration, which has a negative impact on crop yields. During the growth cycle of the plant, water is needed at the initial stages of production, but not during the final stages. Low levels of precipitation have a negative effect on the germination of the seeds. Dry conditions, frequency and severity of dust storms all result in decreased production of major grains [4, 8].

Rainfall also plays a major role in determining the overall relationship between crop production and other factors such as soil, water, and technology. This observation formed the basis for recommending that a lot more efforts must be done to improve crop production within the major season because of less rainfall variability compared to the minor season. This strategy can help increase crop production, food security, and availability even as production in the minor season reduces. Analysis of rainfall distribution and crop production could be done using several models for a relatively high-humid agro-ecological area.

Based on the results of this study, it was indicated that rainfall variability in both seasons plays a major role in rice production at Kibilizi sector where agriculture is generally rainfed. Thus, as long as agriculture development extends in Rwanda and for other most parts of the world, the absence of mitigating measures and government decisions in handling the problem of climate change leads to a huge decrease in agricultural production, it is good to ensure appropriate adaptation policies.

5. Conclusion

This study aimed to identify the relationship between climate change and rice production in Nyanza district of Southern Rwanda. The results indicated that increasing rice production is possible when at the same time keeping abreast of climate change especially the rainfall. However, the temperature on the other side was found to have no significant impact on the increase or decrease of rice production over the study area. Therefore, the results suggest conducting more research on rice resistant varieties to rainfall variability; invest in capacity building for the vulnerable population both in terms of designing adaptation measures as well as enhancing their knowledge and understanding of policies and politics of climate change. Finally, vulnerability analysis for all cooperatives producing rice to identify the effect of climate change on agriculture and the other sectors of the economy are suggested.

Acknowledgements

The authors greatly thank the Rwanda Meteorology Agency and COOPRORIZ Nyarubogo for the provision of data which led to completing this study.

References

[1] Bazzaz, F. A, Fakhri A, Sombroek, Wim G. (1996). Global climate change and crop production: Food and Agriculture Organization of the United Nations; Chichester; New York: Wiley

[2] FAO. 2018. “The status of food security in the world.” Rom, Italy

[3] IPCC, (1995). Climate change: a glossary by the Intergovernmental Panel on Climate Change. Available at: www.ipcc.ch/pdf/glossary/ipcc-glossary.pdf.

[4] Chang &Derados (2006). Impact of climate change on rice and adaptation strategies, report submitted to the Economic and Planning Unit (EPU), Prime Minister’s Department, Putrajaya, Malaysia

[5] Hazall, (1984). The economic impacts of climate change on rice production in Malaysia. International Journal of Agricultural Research, 6, 67-74.

[6] Boo, K (2004a), Response of global warming on regional climate change over Korea: An experiment with the MM5 model, Geophys. Res. Lett., 31 (21), L21206,

[7] Michel at all, (2007). Global climate changes and rice food security. IRC Report, 24-31.

[8] Mc. Carthy et al, (2001). The potential of non-granary areas as a national source of rice production, proceeding at the Rice National Conference, Sunway Carnival Convention, 10-12 December.

[9] FAO. 2014. “Adapting to Climate Change through Land and Water Management in Eastern Africa.” Rome, Italy.

[10] L. NAHAYO, (2018). Rainfall variability and its impact on rainfed crop production in Rwanda.

[11] Man Keen Kim (1999). Simulated impact of climate change on rice production in Peninsular Malaysia. Proceedings at National Conference on Climate change, University of Putra Malaysia, 41-49.

[12] NISR. 2012. EICV3 District Profile South - Nyanza. 2010/11 Integrated Household Living Conditions Survey (EICV3). National Institute of Statistics of Rwanda. Kigali, Rwanda.

[13] Nyanza District (2018): District development Strategy 2018-2024

[14] Zhang T, Huang Y, Yang X (2013) Climate warming over the past three decades has shortened rice growth duration in China and cultivar shifts have further accelerated the process for late rice. Glob chang biol 19: 563-570.

[15] S. Ceccareli, et al. (2010). Plant breeding and climate changes, Journal of Agricultural Science 148, 627-638

[16] Warner et al. 2015. “Climate Change Profile: Rwanda

[17] Popova Z, K. M. (2005). "CERES model application for increasing preparedness to climate variability in agricultural planning-risk analyses." Phys Chem Earth 30 (117): 24.

[18] Kang, Y., S. Khan, et al. (2009). "Climate change impacts on crop yield, crop water productivity and food security-A review." Progress in Natural Science 19 (12): 1665-1674.