Applied Studies in Agribusiness and Commerce – APSTRACT
Center-Print Publishing House, Debrecen
DOI: 10.19041/APSTRACT/2015/4/11

THE EFFECTS OF CLIMATE CHANGE ON CEREALS YIELD OF PRODUCTION AND FOOD SECURITY IN GAMBIA

Alieu Loum[1], Csaba Fogarassy[2]

[1] Master student, Faculty of Economics and Social Sciences, FAO Course
[2] Associate professor, Faculty of Economics and Social Sciences, Climate Change Economic Research Centre
Szent István University, 1. Páter Károly Street, 2100 Gödöllő, Hungary
Email: alieu.loum@gmail.com, csaba@fogarassy.hu

Abstract: *Increasingly, empirical evidences are substantiating the effects of climate change on agricultural production is a reality. In the early part of the 20th century many were skeptical about the so-called climate change that is due to global warming. The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate change as follows: "climate change refers to a change in the state of the climate that can be identified by changes in the mean or variability of its properties and that persists for extended periods, typically decades or longer" This study analyses the impact of climate change on cereals production (millet and maize) in the Gambia using a time series data for a period of 46 years (1960 – 2013) at an aggregate level to assess the relationship between climate (temperatures and rainfall,) and non-climate variables fertilizer, area planted respectively and yield. The specific objectives of the research are: (1) How climate change affects the expected cereals (Millet and Maize) output or yield in the Gambia. (2) How the level of output risk within cereals (Millet and Maize) farming is affected? In order to achieve these set objectives, the paper will adopt Just and Pope modified Ricardian production functions for climate change impact assessments (e.g., Chen et al. 2004), the paper will also control for the impacts of regular input factors in the production process. The study used a data set for the Gambia comprising variables relevant for cereals production and climate information from 1960 through 2013. There is strong evidence that climate will affects Maize and Millet; according to the analysis 77% and 44% of the variability in the yield of Maize and Millet respectively is explained by the climate and non-climate variables included in the model. Given the effects of climate variables on cereals production, and increasing climate change vulnerabilities on other food production section, the result of this paper will add voice to the growing call for policy makers to step up funding in research and development in climate change adaptation and mitigation.*

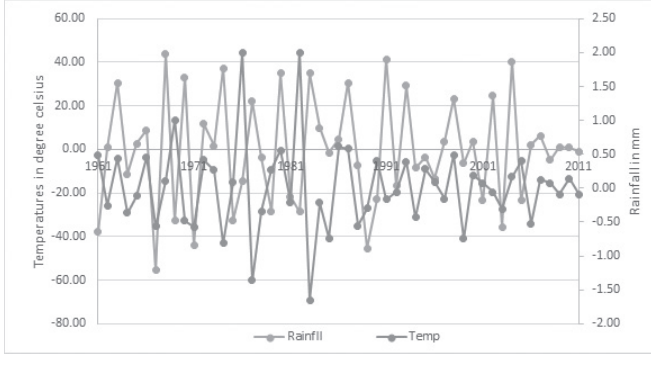
Keywords: *Temperatures, rainfall, fertilizer, Green House gases production and Gambia*
(JEL classification: Q54)

Introduction

Over the past forty years the country has experienced a decline in mean total annual rainfall("Gambia (Vol 7, 2010)," n.d.). Since the mid-1960s, changes in climate observed in The Gambia have been characterized by erratic rainfall patterns; unseasonal rains and torrential rainfall, storms, Intraseasonal drought, cold spells and Climate change has become a household name in 21st century, Increasingly, empirical evidences are substantiating the effects of climate change on agricultural production. In the early part of the 21st century many were skeptical about the so-called climate change that is due to global warming.

The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate change as follows: "climate change refers to a change in the state of the climate that can be identified by changes in the mean or variability of its properties and that persists for an extended period, typically decades or longer "According to previous studies rainfed agriculture produces nearly 90% of sub-Saharan Africa's food and feed (Rosegrant et al., 2002), and is major livelihood activity for 70% of the population (FAO, 2003). The graph below (figure 1) depicts the variability of temperatures and rainfall in the Gambia for the past forty years. The variation is no near the desired condition for farming especially when rainfall is the main source of water for crop production.

Figure 1: The trend of temperatures and rainfall in the Gambia from 1961 to 2011



Source: Self-made according to Climate Research Unit, 2015

Climate change and its inconsistency will poise an imperative short-term and long-term bottlenecks to improvement efforts in the Gambia exclusively crop production and sustenance sanctuary of the rural farmers. In the interim dangerous climate occasions comprising windstorms, rainstorms, droughts and dust storms will become more frequent with increased severity. Land use and land cover change, sea level rise, and coastal erosion present significant long-term challenges. According to (FAO, 2003) Rainfed agriculture employs 80% of labour force more than the sub Saharan Africa average which is 70% of the population and accounts for 25%GDP.

1. Research

1.1. Problem Statement

Droughts is one of the prime problems caused by global climate change in the western Sahel region in general and The Gambia in precise has observed an increased in rate and severity of dry spell events. Direct effects of repetitive tenacious dry spells comprise of ecosystem desiccation by increased salinization in freshwater wetland and loss of productivity in croplands, saltwater encroachment up the river, deforestation, and loss of productivity and biodiversity in woodland ecosystems as a result of wildfires and land use change. More than 97% of croplands in the Gambia are entirely rainfed.

Regardless of attempts to initiate early-maturing crop diversification and institute sustainable water management practices, crop production is still very impotent to persistent droughts. In The Gambia the topography is predominantly monotonous made up of riverine flats and mangrove swamps divided by tidal creeks and savannah forest with shrub and grass. Twenty per cent of the country is classified as wetlands. The Gambia is situated in the Sahelian zone of the West Coast of Africa and the climate is tropical with a distinct dry and rainfall season. The rainfall season runs between June and October as shown by the table (1) below.

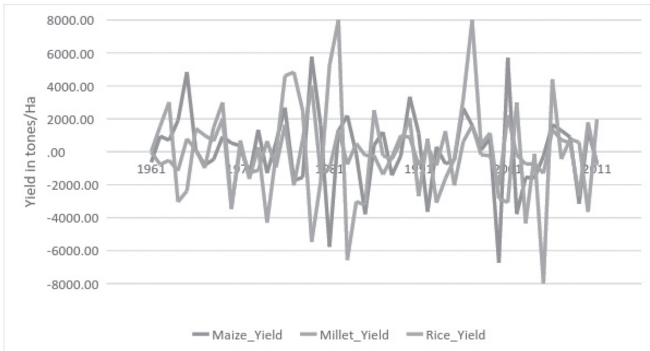
Table 1: Seasonal calendar of the Gambia

The Gambia	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rainy season												
Flood												
Drought												
Sowing/planting					maize	maize, rice, sorghum, millet, groudnuts						
Harvesting	groundnuts								maize	maize, rice, sorghum, millet		groundnuts
Lean season												

Source: Self-made according to the Ministry of Agriculture (MOA), 2015

According (Malanding and Babucarr; 2011), Windstorms are recurrent occurrence in the Gambia, especially at the beginning and about the end of the rainy season. In general, windstorms cause most of the natural disasters especially in the provinces and it account for most damage to properties in rural areas. As forest degradation and land use change strip of the landscape, windstorms could become even more severe, resulting in even greater loss of life and property, the forest which use to serve as wind breaking agent is no more, hence wind move freely in all direction. Floods and storm water runoff are most common in urban areas due to the poor infrastructure and sewage system. Inadequate storm water management systems and lack of compliance to land use zoning regulations have increased the frequency and severity of flooding in urban areas and the resulting loss of human life and property damage they cause. Although catastrophic seasonal floods are rare in the Gambia, the risks of having them are nevertheless present. As extreme weather events become more frequent due to climate change as depicted in figure (1) both temperatures and rainfall has been fluctuating for the past four to five decades. With almost 97% of farmers are depended on rainfall, the consequences of lack of rain and rising temperatures are a threats to the main source of food and income; hence an ultimatum to the entire food chain and food security in the Gambia as a whole.

Figure 2: the changes in the yield of maize, millet and rice from 1961 to 2011.



Source: Self-made according to FAOSTAT, 2015

1.2. General Objective

Given the above situation, the general objective of this study is to intensify the comprehension on the effects of climate change on crop production specifically (Maize and Millet) and food security in the Gambia. The specific objectives of the study are as follows.

1. To determine the effects of temperatures, rainfall and CO_2 on cereals (maize and millet) yield in the Gambia,
2. To use fertilizer and Area planted as non-climate variables in relation to the climate variables
3. To establish a correlation between climatic variables and non-climatic variables and how they affect the yield cereals (maize and millet) in the Gambia

In disparity with several prior studies, which adopt Just and Pope style functions for climate change impact assessments (e.g., Chen et al. 2004), In this study, the rice yield data is regressed on the climate factors to estimate their effects on the cereals yield in the Gambia. We examined the distribution of cereals yield against time by drawing histograms before we selected the Ordinary least squares (OLS) or Quadratic Regression (QR) regression type. We make use of a data set for the Gambia comprising variables relevant for cereals production and climate information from 1960 through 2013.

1.3. Literature review

Farmers generally do not possess any mastery of the exact output as they engage in making their production commitment, that is largely due to the reality that agriculture in as a whole has a long production cycle and is influenced by a large number of endogenous and exogenous precarious factors (Just and Pope 1979; Kumbhakar and Tsionas 2008; Meyer and Yu 2013). The existing climate conditions for instance are crucial sources of unpredictability because factors such as temperature or precipitation are distinguished by inter-annual variability, part of which can be explained by gradual shifts in mean climate conditions caused by global climate change, in contrast another part is constituted by seemingly random variations. Since the precise patterns of the variations are beyond farmers' control and their predictive capabilities, production risk emerges.

The most imminent factors to climate change are; Temperatures, Rainfall and CO_2; all of which are very instrumental in crop production. In the process of adapting to the uncertainty caused by climate change, it is important to have a clear view as to what extent does each of these factors of climate variables poised to cereals production in The Gambia, hence it will serve as yardstick for the relevant authorities in decision making.

Deressa and Hassan (2009) conducted a study regarding the economic influence of climate change on the Ethiopian crop production with the Ricardian method. The research employ county-level survey data and the net crop revenue was regressed on climate (rainfall and temperature), household, and soil variables. The estimation established that, the crop net revenue is slightly affected by climate elements like temperature and precipitation. Their outcomes showed the rather negative effects of the small temperature changes which will occur during the summer and winter time through the net crop revenue. Still they discovered a positive pattern as well, while the crop production could benefit from a small growth in the intensity of rainfall the spring.

Mendelshon (1996) focused more on the 1960-2000 time interval in case of the effects of climate change on agriculture. The research uses a cross-sectional model, experimental (crop simulation) model, and response functions for temperature, precipitation, and carbon-dioxide. The study concluded that temperature and precipitation move the global agricultural GDP between a -0.05% and 0.9% change interval. When carbon fertilization is incorporated in the prototype, historic climate change swells the world's agriculture production from 2% to 4%. So as an empirical result he discovered that climate change impacts differ between geographical locations. The outcome recommend that the positive upshot is greater in the mid to high latitude countries while is smaller in the low latitude countries. Most developing countries unfortunately are on the developing countries are located in the low latitudes while developed countries on the mid to high latitudes.

During the examination of the Japanese rice production Horie (1995) concluded – with using the SIMRIW rice crop simulation model – that, the growing CO_2 levels in a warmer atmosphere result in higher rice yields and yield stability. Still it is only valid for the northern and north-central part of Japan because in the case of the south-central and south-western parts of the country the same pattern causes a 30% loss in the rice yields.

Also with a simulation model Basak (2009) has studied climate change effects on rice production in Bangladesh. His tool was mainly developed for Boro where the 58% of the total rice production of the country took place in 2008. Therefore it meant a good example for the examination of the impacts of climate change in the future rice production in Bangladesh. The study uses soil and hydrologic characteristics of the locations, classical crop management Practices, accustomed production interval and climate data in 2008 was employed in the assessments and temperature and CO_2 levels are controlled in the simulation model called DSSAT (Decision Support System for Agrotechnology Transfer). The outcome of the research indicate that rice production varies for two reason geographically and climatically.

Mathauda et al. (2000) analysed the impact of temperature variation on the yield of rice in Punjab, India; the CERES RICE simulation model from1970 to 1990. The study designated the weather scenario to 5 different conditions which are normal weather, slight warm (0.5°C increase in temperature), moderate warm (1°C increase), greater warm (1.5°C increase), and extreme warm (2°C increase) in the simulation model. The research outcome was an increase in temperatures will decrease rice yield up to 3.2% during the slight warm period, 4.9% during the moderate warm period, 8.2% during greater warm and 8.4% during the extreme warm condition juxtapose to normal conditions. Temperatures increase according to the research outcome will have negative impacts on rice production as well as biomass, crop duration and straw yield.

Later on the Ricardian method – besides five AOGCM experimental model – came up again during the research of Seo (2005) who studied the effects of climate change on Sri Lankan agriculture. The research analysed the net revenue per hectare of the four most important crops (rice, coconut, rubber, and tea) in the country. The studies concentrated majorly on rainfall on crop production. The research output illustrates how an increase in precipitation on both the Ricardian method and five AOGCM experimental models. The benefit to the four tested crops ranges from 11 % to 122 % of the current net revenue of the crops in the model. The effects of increase in temperatures are projected to be detrimental to the nation and the loss extent from18 % to50 % of the contemporary agricultural productivity.

Most of the studies on climate change have concluded that the impact will be more sevier on developing countries than developed countries according to (Mendelsohn and Dinar 1999) in their research they employed three different models Ricardian method, agro-economic model, and agro-ecological zone analysis for investigating climate change impacts in India and Braizil. Non-environmental variables such as farm performance, land value or net income, was regressed on a set of environmental variables, traditional economic inputs (land and labour), and reinforce systems such as infrastructure in the models. The research highlighted the significance of farmers' adaptation to new techniques as their environment change, the argue farmers will judicious decision to serve their best interest. According to the output of the three different models used in the studies an increase in temperature will eventually reduce the yield of most crops especially those grown on clod areas such as wheat.

Using simulation modelling, Mendelshon (2005) studied the effects of climate change on South East Asia by adopting three AOGCMS models to project the state of agriculture in 2100. As indicated by the outcome of the PCM model will increase agriculture revenue up to $35billions per annum with a 6% benefit. The other two models; the CCSR scenario and the CCC scenario are likely to make net revenues decline about $60 billion per year, 11% loss and $219 billion, 39% loss to Southeast Asian agriculture.

Maddison (2000) explored the elements of agricultural land prices in England and Wales using a hedonic price equation. He recognized that indeed soil quality and climate factors do influence farm-land earnings. Suitable climatic factors such as the number of frost days during winter, temperature and good grade soil were found to be beneficial to agriculture because the cost to farmer is reduced as tilling becomes easier. High elevations and relative humidity on the other hand appeared detrimental because of the tendency of diseases. Specifically, higher summer temperatures and altitude caused a reduction in farmland prices by £883.78 per degree Celsius and £3.68 per meter respectively. Winter temperatures on the other hand increased farmland revenue by about £485.45 for every degree Celsius rise.

According to the findings of (Mano and Nhemachena, 2006) on small scale farmers in Zimbabwe, increase in temperature affect net farm revenue negatively while an intense in precipitation has definite impact on net farm income. The findings also indicated that rainfed farms will be more affected than irrigated farms.

In a similar study by (Gbetibouo and Hassan, 2005) indicates that marginal changes in temperatures is more sensitive compared to a marginal change in precipitation on field crops production in South Africa. Although rising temperatures seems to affect net revenue positively, while reduction in rainfall negatively affect net farm revenue. This was remotely far from the studies of (Deressa, 2007): according to his findings climate variables have significant effects on farmer's net revenue after analyzing net revenue on climate, soil variables and household among Ethiopian farmers. Although the effects are uniform in all seasons, rising temperature and declining precipitation as a whole have negative and serious impact on the Ethiopian agriculture.

In (Kurukulasuriya and Mendelsohn 2007), conducted a research on the effect of climate change among 11 African countries cropland based, they regressed net farm revenue against water, soil, climate and economics variables; according to the findings a decline in precipitation and an increase in temperatures will also have negative effects on net income. These two variables may not be the only climate variables but in the study of climate change the have been widely used to forecast the future agriculture globally. The study concluded that the impact cannot be generalized within the African continent, since different geopolitical zones have different climate features and climate scenarios.

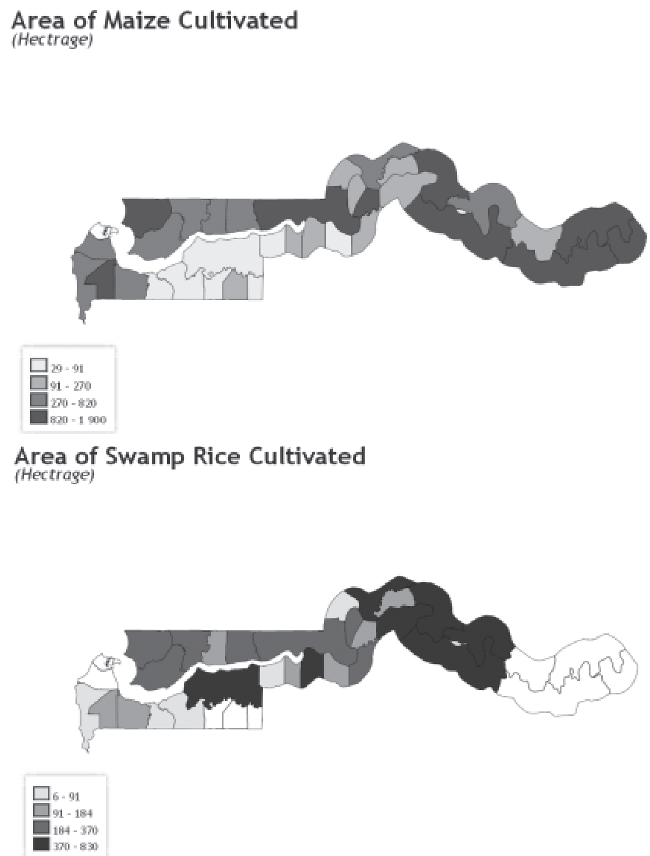
Mendelsohn et al, 2007 Using the data from (Kurukulasuriya and Mendelsohn 2007) established that African agriculture is vulnerable to the threats posed by the effects of climate change specially those countries with searing climate are likely to suffer considerable loss in the productivity as compared with cooler climate. According to the analysis it was estimated that Burkina Faso and Niger will suffer a loss of 19.9 percent and 30.5 percent productivity, respectively; while Ethiopia and South Africa will entail a loss of 1.3 percent and 3 percent of their productivity respectively.

2. Methods

2.1. Study Area and source of data

The Gambia is an agrarian country and more than half of its inhabitants are directly or indirectly involved in crop production. In Figure (3) below are portrayals of areas where Maize, millet and rice are mostly grown. The pattern of millet is almost the same with that of maize. The Upper River Region (URR), Central River Region (CRR), North Bank Region (NBR) and West Coast Region (WCR) are the major maize and millet while Central River Region and Lower River Region (LRR) and the North bank region are the major rice producers. Since we import more than 75% of the rice we eat we will dwell more on millet and maize for this paper.

Figure 3: Maps showing growing areas for Maize, Millet and Rice in the Gambia



Source: FAO, 2013

The most common farming system in the Gambia is subsistence farming: on average every farmer is engage with two or more cereals crop including the main cash crop groundnut (*Arachis hypogaea). Due to the poor soil conditions, farming is getting more expensive year by year due to the high cost of chemical fertilizer as well as pesticides. Priority is given to groundnut for it is the main cash crop of the country and have multiple usage.*

2.2. Climate Data

The meteorological data used for the climate analysis in this study were recorded at the meteorological stations by the Climate Research Unit (CRU) of the University of East Anglia in collaboration with IPCC and UCAR database system. The database contained long-term (from 1960 to 2006) the additional seven years (2007 to 2013) were estimated using a moving average; for the daily rainfall and temperatures. Daily temperature was averaged over the rainy season to represent the seasonal temperatures.

2.3. Quadratic Regression Model

$$Y=\alpha-\beta x1+\beta x12+\beta x2-\beta x22+\beta x3-\beta x22+\beta x4+\beta x5+e \qquad eq1$$

Hypothesis
H0 = β1=β2=β3=β4=β5=0 (None of the independent variable is significant)
HA= β1≠β2 (at least one of the independent variable is not equal to zero hence is significant)

The above model is aim at predicting the effects of climate change on cereals production (maize and Millet) in the Gambia in a nonlinear format. The Y in the model; is representing the dependent variable or the predicted variable which is the yield of cereals, α is the constant, as for x1, x2, x3, x4, and x5, denotes the independent variables i.e. Temperature, rainfall, CO_2, fertilizer and Area planted respectively and *x12,x22and x32 are denoting the squared root of Rainfall and* CO_2 while β is denoting the slope of each of the independent variables and e is representing the error terms which usually represent those variables that affect the dependent variable but are not included in the model.

2.4 Log-Regression Model

The Log-Regression method involves the transformation of both the dependent and the independent variables data into log form. When data is transformed into log form any measurement made by the data will be in the form of percentage and hence changes expected to the dependent variable are also expressed in term of percentages. It is important to understand that when we use log scale for the predictor, we are saying that a given percentage change in the predictor has the same impact on the response. That is to say every time we increase the predictor, we expect the same change on an average in the respond. Below is the Log-Regression model:

$$lnY=\alpha-ln\beta x1+ln\beta x2+ln\beta x3+ln\beta x4+ln\beta x5+e \qquad eq2$$

Hypothesis
H0 = β1=β2=β3=β4=β5=0 (None of the independent variable is significant)
HA= β1≠β2 (at least one of the independent variable is not equal to zero hence is significant)

The model is aim at predicting the effects of climate change on cereals production (maize and Millet) in the Gambia in logarithm form. The lnY in the model; is representing the dependent variable or the predicted variable which is the yield of cereals, α is the constant, as for lnx1, lnx2, lnx3, ln x4, and ln x5, denotes the independent variables i.e. Temperature, rainfall, Co_2*, fertilizer and Area planted respectively. The symbol β is denoting the slope of each of the independent variables and e is representing the error terms which usually represent those variables that affect the dependent variable but are not included in the model.*

2.5. Theoretical Assumptions

1. ***Temperature:*** Temperatures are said to have negative effects on cereals yield that's if temperatures increase the yield of cereals will reduce significantly. According Basak (2009) who conducted a research on rice production in Bangladesh, a fall in minimum temperature will reduce rice yield while an increase in maximum may causes damages to rice crops. In Deressa and Hassan (2009) studies on the economic effects of climate change on crop production in Ethiopia employing Regression modelling, concluded that a proportional increase in temperature during summer and winter will have negative effects.
2. ***Rainfall:*** Cereals required high volume of water hence consistent rainfall will have positive effects on cereals yield. According to Deressa and Hassan (2009) and (Basak et al 2009) increase in rainfall will increase the yield of cereals. Although they also indicated that high rainfall will only have negative effects if the cereals plant is to face flooding for a long period of time, thereby it will reduce the yield of most cereals plant.
3. ***CO_2*** which one of the most fundamental elements that plants required for their growth has positive effects in cereals production an increase in CO_2 concentration will increase the rate at which photosynthesis occur which will boost the yield of cereals plants. Horie et al (1995) studied the effects of an increase CO_2 level and maximum temperature on Japanese rice and concluded that an intensify CO_2 levels in a high temperature aerospace will considerably increase rice yields and yield steadiness in northern and north-central Japan. It is worth mentioning that despite CO_2 being very crucial to plant growth; higher concentration of CO_2 on the atmosphere will increase Temperatures as well as transpiration and evaporation thereby serving as agent for the depletion of the ozone layer.

3. Result and discussion

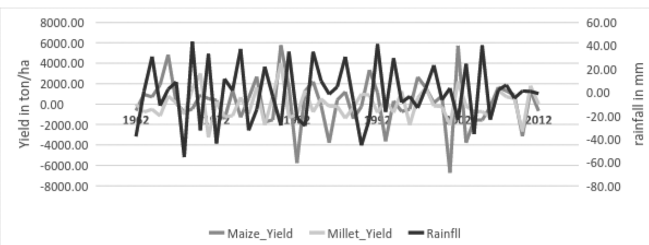
3.1. Observed trend of climate in the Gambia

*The climate is "Sudano-Sahelian, with a short rainy season from June to October and a long dry season from November to May. Mean annual rainfall varies from 900mm in the South West to about 500mm in the North East. Variably cloudy, humid and warm atmospheric conditions combined with scattered to widespread thunderstorms sometimes with strong winds, accompanied by moderate or heavy rains has prevail over the years. Normal temperatures across the country vary between 27°*C and 28°C. In the meantime, extreme temperatures varied between 32°C and 34°C over the entire country, whilst minimum temperatures fluctuated between 21°C and 24°C with high average relative humidity across the country mostly above 70% demonstrating an increased level of moisture in atmosphere. With high temperatures the condition is ideal for rainfall occurrences.

3.2. Cereals yield and climate variability

Regular rainfall is an ideal condition for a successful farming season, over the past five decades (1962 to 2012), crop yield has been fluctuating just as temperatures and rainfall as shown in the figures (4 and 5) respectively. This is due to mere fact farmers are unable to give a good prediction about the climate pattern in the country. Most cereals are usually pre sown refer to table (1) gambia seasonal calendar, hence a small amount of rain could trigger their seeds to germinate and in most cases the gap between the first and the real raining season is huge, therefore both the cereals and grasses that germinate might eventually die due lack of water and crop stress.

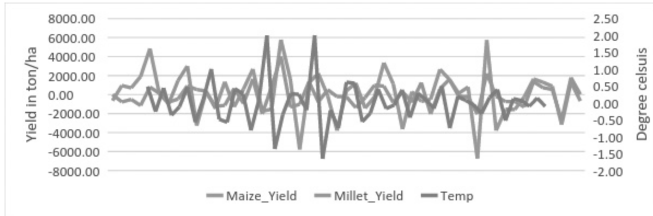
Figure 4: the trend of cereals yields (maize and millet) and rainfall from 1962 to 2012



Source: Self-made according to FAO, Climate Research Unit (CRU), 2015

Rainfall is the bedrock of agriculture in the Gambia; the fluctuation of rain during the raining season means a huge economic and livelihood lost. An agriculture that is 97% reliant on rain could be easy brought to standstill, hence rural farmers mostly are very prone to poverty and food insecurity. The river Gambia could be a big source for irrigation along its banks from Central River Region to the Upper River Region with approximately 8000ha of irrigable land suitable for continuous or year round production which is yet to be exploited. Although, it is doable, but, it requires huge financial muscle to be fully operational and sustained for the future. There are many development projects designed for land development; but in many cases the visibility studies that set the tone and direction and intervention areas is done without proper consultation of the indigenous people.

Figure 5: the trend of cereals yields (maize and millet) and temperatures from 1962 to 2012



Source: Self-made according to FAO, Climate Research Unit (CRU), 2015

International consultants, are usually hired by most international developments agencies of the United Nations and private funded NGOs. In many cases these consultants and expert have limited knowledge about the socio-demographic patterns of the country, hence rely heavily on the official version of the situation on the ground.

3.3. Log Multi-Linear Regression Model

It is important to understand that when we use log scale in regression analysis the unit of measurement for the predictors changes from their actual unit to percentages. Thus in table 2, the results indicate that 44% of the variability in millet yield is explained by the independent variables; all in all, both the F-statistic and the Probability test conformed to the fact that the model is reliable. Individual predictors are all significant at the 95% confidence interval although entire model is fit for the purpose of explaining the variation in millet yield, but it can only explain 44% which mean more variables could also account for the low or variation of millet yield in the Gambia over the past five decades.

Dependent Variable: Millet Yield, R-squared 44%: significant level P-value < 0.05** Table 2: Results of a quadratic regression model for maize production in the Gambia.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.29103	0.447178	23.01326	0.0000
Temperature	0.259098	0.065637	3.947416	0.0003**
Rainfall	-0.228980	0.094074	-2.434041	0.0189**
CO_2	-0.412209	0.076910	-5.359649	0.0000**
Millet Area	0.143521	0.031773	4.517101	0.0000**
Fertilizer	0.023952	0.019199	1.247567	0.2185

Source: Self-made, 2015

Although almost all the independent variables are significant except fertilizer; holding all other factors constant, each variable will affect millet yield. Temperatures will positively affect millet yield especially during maturity period until it is finally dehusk; during this period the millet crop require good exposure to sunlight with normal temperatures as this is very essential to postharvest handling. According to the FAO (2003), almost 20% to 40% of crop losses is incurred during postharvest period, consequently it contradicts to earlier studies on rice by both Dressa and Hassan (2009), Mathauda et al. (2000) (Basak et al 2009) and Horie et.al (1995) that temperatures will have negative effects on the yield of rice. Rainfall will negatively affect the yield of millet for the simple fact the Gambia raining season start from June to October as shown in table (1) above and millet is an early maturing crop approximately three months it is ready for harvesting; if the rain continues pouring till October, the millet will not dry properly and eventually some will develop fungal disease and some might start to germinate on the millet plant itself. Therefore, rainfall is a prerequisite to crop production but too much of rain or irregular raining season can cause either delayed or damage millet plants, hence yield of millet will reduce during these periods.

3.4. Quadratic Regression Model

Yield of Maize is the dependent variable and the rest are the independent variables or the predictors. The impacts of climate factors on maize yield is depicted in Table 3, which shows the models is statistically significant in general which means that the climate variables are able to explain some of the variation in maize yield of production in the Gambia. The R-square shows that 77% of the difference on maize yield is described by climate variability.

Dependent Variable: Maize Yield, significant level P-value < 0.05**
R-squared 0.77829 F-statistic 18.4299 Prob(F-statistic) 0.000000
Table 3: results of a quadratic regression model for maize production in the Gambia.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.26506	12.53503	-1.058239	0.2960
Temperature	1.527299	0.593229	2.574553	**0.0137****
Rainfall	-1.532830	0.714510	-2.145289	**0.0378****
CO_2	5.517022	3.772533	1.462418	0.1511
Fertilizer	0.096077	0.039419	2.437325	**0.0191****
LAGMYIELD	0.528496	0.103769	5.093024	**0.0000****
Maize area	0.049234	0.067345	0.731075	0.4688
Sq. Rainfall	4.93E-05	2.37E-05	2.076057	**0.0440****
Sq-CO_2	-0.432385	0.283039	-1.527651	` 0.1341

Source: Self-made,2015

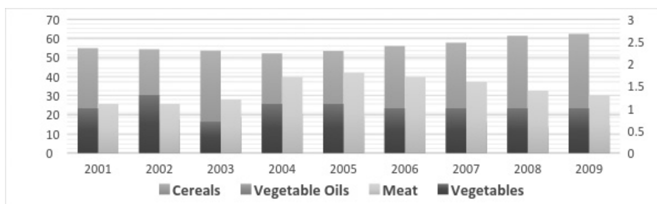
Individually only temperatures, rainfall and area planted are significant at 0.05 significance level; as depicted by both the P-values and the T-test, thus we reject the Ho and accept the alternate *(Hypothesis H0 = β1=β2=β3=β4=β5=0 (None of the independent variable is significant) HA= β1≠β2 (at least one of the independent variable is not equal to zero hence is significant)). The results indicated most of the predictors will increase or decrease yield the equivalent of its coefficient along the curve, hence the marginal changes will not be constant as in the case of linear model. This is because every movement along the curve is independent of its original position. In a quadratic regression model interpreting individual variables will not give any meaning to us, therefore the most important elements are the test for overall significance which help in identifying whether the correlation between the predicted variable and the predicting variables is strong.*

As revealed by most research the effects of climate change will be felt by every part of the world but the magnitudes or the extent to which it affects people differ depending on the their geographical and resources available to cope with these changes. The changing socioeconomics conditions can also play a crucial part on the magnitudes of the effects, according to (Thapa and Joshi, 2010) on the Nepal agriculture; they examined the relationship between net farm revenue and climate variables; regressing climate variables and net farm revenue independently in one model and the other model including socioeconomic variables, the findings shows that low precipitation and high temperatures affects net farm income positively during the fall and spring which are peak harvest season.

4. Research summary

Cereals production is very crucial for the attainment of food security which is highly emphasizes in the National Agricultural and food policy (figure 6) below by 2009 60% of the total food supply was cereals, thus environmental factors plays a vital role in the determining the performance of cereals (maize and millet) production which is the core of food security in the Gambia; as cereals are the staple food of the country. The main environmental factors related the crop productions are rainfall, temperatures and carbon dioxide (CO_2) concentration which are believed to have significant effects on crop yield.

Figure 6: Food group shares in total food supply (%) in the Gambia from 2001 to 2009.

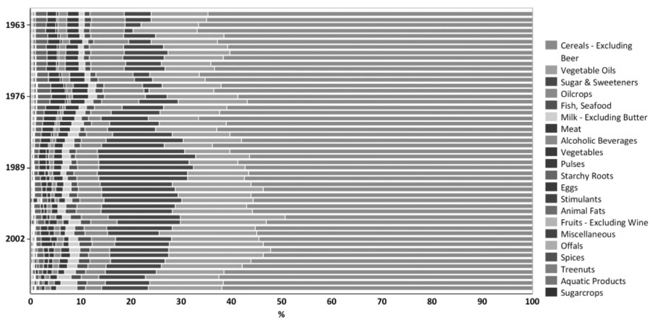


Source: Self-made according to FAOSTAT, 2015

The study endeavours to analyse the consequences of climate change on cereals yields of production in the Gambia's. Secondary data for climate change and cereals yield are used to estimate the effects; a modified production function is employed to highlight the effect of climate change in cereals yield of production from 1960 to 2013. A regression model was used to approximate the impacts of both climatic and non-climatic factors on cereals production particular attention was given to maize and millet which is grown nationwide. The non-climatic variables in the model are fertilizer and area planted, accordingly the purpose of their inclusion into to the model was based on their significance on cereals plant and their relationship with the climatic variables example; temperature precipitation and CO_2.

Climate change if not immediately addressed, looms to unbutton years of development endeavor in a near distance period time. A significant portion of development investments in the Gambia are in activities affected by climate risks, since most sectors are susceptible to climate change. The achievement of self-sufficiency in food by the year 2016 as enshrine in the vision 2016 Gambia Government blue print will only be a realistic if the irrigable area is fully functional. Many times governments have to divert resources meant for development projects to serve as first aid for people subsist up with effects of utmost weather and climate events. With increased frequency of occurrence of utmost weather and climate events, poverty has progressively shot up and development efforts have continuously been frustrated. The MDGs whose chief objective was to eradicate poverty were continuously frustrated by climate change and variability.

Figure 7: Depicting share of food products in daily diet, % in the Gambia from 1963 to 2014



Source: FAO, 2014

The General objective of this research was to intensify the knowledge on the results of climate change on crop production specifically (Maize and Millet) and food security in the Gambia. As highlighted in table (2) and (3) climate change indeed will have impacts on cereals production in the Gambia and thus food security. According to the data 77% of the variation in maize yield could be explained by both climate and non-climate variables, whereas only 44% of the variation in millet yield could be explained by climate and non-climate variables. Cereals are an important tool in the reduction of food insecurity in the Gambia; cereals constitute almost 60% of food products in daily diet in the Gambia as depicted in the figure (7) above.

The Gambia like any developing country need massive investments in infrastructure and agricultural production. If these are pursued using customary technologies and carbon potencies, these much-needed investments will increase the presence of greenhouse gases and, eventually, more climate change. Therefore, the multi-million-dollar question, is not just how do we make development further pliable to climate change but rather how to pursue development and success without inducing "treacherous" climate change. Developing countries should strive to slip to lower-carbon path without hampering development, the financial muscle of a country will dictate the applicability of the above and will rely on the extent of financial and technical assistance from developed countries; off course, the Gambia is in the forefront among the developing countries who will need such fiscal and high-tech assistance to help in combatting climate change.

4.1. Adaptation and Mitigation

An impact relates a particular change in a process caused by its exposure to climate change, which may be concluded as to be damaging or useful (Schneider et al 2007). The outcomes of climate change both direct as well as incidental are particular to divergent socio-geographic regions; livelihood groups and areas. In sectoral terms, agriculture, social amenities infrastructure, and the environment are the most affected. Incidentally, climate change eventually leads to malnutrition as a result of food insecurity, health problems and conflicts due to resource insufficiency and ignominy, and finally the decision to migrate.

Since it is evident that we cannot reverse our climate, the only way coexist with these rapid changes in climate change is to look for channels that will help in minimizing it effects on both agriculture and society as a whole by means of adaptation and mitigation.

Adaptation is a powerful means of minimizing the effects of climate change on the variability of cereals yield; it should be quickly established that adaptation cannot eliminate climate change as a whole but if no adaptation measures are put in practice, the effect of climate change will be more serious. Hence, adaptation involves the act of reducing the risk of adverse consequences from expected crop response to the projected climate change. Therefore, adaptation activities can be used as a mechanism to increase the resistance and elasticity of ecosystem to climate change.

(Fuhrer and Gregory, 2014) in their studies remark that another adaptation practices that relates to biotic and abiotic stresses is crop breeding. Rising temperatures and variation in humidity affects the diversity and responsiveness of agricultural pest and diseases. Therefore, in the context of this study adaptation will be use modern agricultural techniques, adapting planting dates, diversification of crops planted and mixed cropping adopt early maturing and drought-resistant crops use irrigation- from close by rivers especially the Central River Region (CRR)and Upper River Region (URR), planting trees as shade for and windbreak seedlings closely planted as Insurance strategy increase use of inorganic fertilizers and improved soil moisture contents and finally Livestock rearing to diversify.

Adaptation strategies should be used to build the normal development strategies by balancing competing objectives. The transformation to a sustainable energy future i.e. energy efficiency and low-carbon technologies accelerating innovation and advanced technologies integrating policy transcending the tensions between climate and development in the Gambia.

Mitigation on the other hand is composed of measures that dwell mostly on the legal aspect and policy implementation. These policies should play a balancing role of the consequences between socio economic development, technological advancement, population growth and governance with the climate change. Mitigation in essence is the use of available resources without compromising their effects on our agricultural production. Controlling emissions and concentration of greenhouse gases is an integral part in any mitigation strategies that policy maker might come up with. Finally, the introduction new varieties and the use of advance technology will play a key role in minimizing the impact of climate change on cereals production in the Gambia.

Climate Change is a problem of immense proportions and is a threat to the majority of development efforts in the Gambia and its livelihood. The process of development itself has a huge impact on vulnerability to climate change (both positive and negative). Therefore, there is the need to climate-proof all development processes and plans this include both government and the private sector climate-proof policies are important and therefore must constitute the basis of climate smart policies for development in the Gambia.

4.2. Limitation of the study

The study has some shortcomings ensuing most specially from the scope of the climate indicators considered. The variables used to represent climate change in these studies are part and parcel a whole lot of other elements that affect cereals production, beside temperatures, rainfall and carbon dioxide. This include environmental indicators such as soil type, magnitude, daily sunlight, humidity and radiation rate all of which greatly affects cereals yield. Secondly the fertilizer used in this study does not represent the total amount since most farmers buy fertilizer from Senegal which is usually cheaper, hence it is not accounted for, thus it is to be regarded as suboptimal data, which do not give full representation of fertilizer as far as the it effects on cereals yield is concerned. It was difficult to collect data on fertilizer used hence the study could only rely on the government import.

Finally, the research is basically based on inherent assumption of the regression analysis method. That yield is fixed through the period, thus yield changes from period to period and the omission of yield variation will exaggerate the effect climate variable on cereals production. Above all the Ordinary least squares (OLS) regression analysis challenges researchers to work hard not to be biased by considering variation of econometric testing. Lack of finance to travel back to the Gambia to collect firsthand information has resulted in the dependence of secondary data as a source of information, which make the research to be biased towards quantitative rather than qualitative research.

4.3. Recommendation for future research

The study has aroused many questions requiring further investigations. Firstly, there is an immediate need to conduct research on other agricultural related activities such as livestock in the Gambia in other to arrest the whole picture on the performance of these segments in relation to climate change issues. Secondly, the impact of other climate predictors such as solar radiation, light length, humidity, socio-economic and sea level, should also be considered in any further research on cereals production in the Gambia. Research should also be able to highlight regional variation in terms of magnitude of climate change effects to enable the usage of a better strategy to minimize the damages that arises due the climate change in different regions and for different crops.

5. Conclusion

Generally, the effects of periodic rainfall and temperature variability on cereals yield is greater than that of the long-term Changes in climatic variables. The important distinctive amongst rainfall and crop production is the rainfall distribution which is connected to the number of dry days throughout the rainy season. The significant escalation of the number of dry days during the rainy season over the period 1960–2013 and its impact on yield makes it one of the most important specification of climate change in the Gambia. An average total rainfall in the Senegambia regions is not necessarily synonymous with good rainy season or with good crop production. In our study which is based on an analysis of empirical data or secondary data, it appears that the effects of declining soil fertility, postharvest handlings are as important as those of climate variability and change.

Nevertheless, disentangling the effects of climate and soil fertility is not straightforward, and results depend on the spatial scale of analysis which will require further studies and analysis on the subject. It is unanimously agreed by all researchers that excessive rainfall and high temperatures during extreme climatic conditions will have adverse impact on the yield of cereals. A marginal increase or decrease in both rainfall and temperatures may negatively affect cereals productivity. Carbon dioxide which is a fundamental element for plant growth has positive effects on crop yield and simultaneously it serves as the mother of all climate change activities. There are strong evidence suggesting that the agriculture sector in the gambia as a whole is vulnerable to climate change. An examination of historical data from 1960 to 2013 on climate change and crop production especially maize and millet has provided supporting evidencing that the impact of climate change on crop production in the Gambia could affect the food chain system which will have multiplier effect to the socio economic development. The knowledge of this potential impact can contribute in reducing the level of crop damages and environmental losses in the future.

With the increasing uncertainties of the impact of climate change is the key to maintain economic growth and productivity, especially in the agricultural sector. Sequel to this, effective measures need to be taken to avoid the worst possible climate change impacts in the future. In general, all stakeholders in cereals production should undertakes different mitigation and adaptation strategies to help minimize the effects of changes in climate provided they have proper information about it potential impact. Overall, the study adds to existing body of knowledge of climate change in the Gambia, by modifying the production function to capture variables such as area planted and fertilizer in cereals production. The modified framework could be used in future research in assessing the direct and indirect effects of climate change in other crops in the agricultural sector. Finally, the findings of this study could be a takeoff point in a drive to measure the future impact of climate change on agriculture in order to sustain agriculture as the backbone of the Gambia's economy. The reality of climate change cannot be sideline anymore, all plans and policies should be climate-proof inclusive.

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