# Impact of Climate Variability on Staple Food Crops Production in Northern Togo

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# Impact of climate variability on staple food crops production in Northern Togo

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**Abstract :** This study assesses the impact of climate variability on staple food crops production in the Northern regions of Togo using cereal and climate data over the period of 1972-2013. The linear mixed model and generalized linear mixed model are used. The results indicate that maize is the most vulnerable cereal affected by the inter-seasonal and the intra-seasonal variability of temperature and precipitation compared to sorghum and rice in the study areas. However, encouraging water management in raine-fed agriculture would increase the rice production in the study areas. Policy towards the adoption of new technology to improve maize yields and cope with climatic risks is needed. The investment in rain-fed water management, promoting the use of drought-tolerant seeds and improvement of agro-meteorological information and their integration in farmers' decision making are needed.

*Keywords: Climate variability, Staple food crops, Northern Togo*

## Introduction

Agriculture is the backbone of the economies of many developing countries and highly depends on climatic conditions which are beyond the farmers' control (Egbendewe *et al.*, 2017; Mohammed *et al.*, 2016; Rosenzweig and Parry, 1994). According to IPCC (2014), the concept of climate change refers to the change of climate over time (long-run variability) as a result of human and non-made activities while climate variability refers to the shorter-term variation or seasonal or multi-seasonal of the climate. The pronounced climate change trends have stirred debates around their impacts on staple food crop production (Wossen *et al.*, 2017; IPCC, 2014, Tambo and Abdoulaye, 2013; Deressa *et al.*, 2009). In most of Sub-Saharan African countries, climate change would have negative effects on agricultural production leading to lower farm incomes, an increase of poverty, hunger and malnutrition, particularly in rural areas, with rain-fed agriculture as the main job (Abdulai, 2018;

Lokonon and Mbaye, 2018; Di Falco, 2014; Ahmed *et al*, 2011; Rowhani *et al.*, 2011; Barnet and Mahul, 2007). Rowhani *et al.* (2011) have predicted that maize, sorghum and rice yields may be reduced by about 13%, 8.8% and 7.6%, respectively, as a result of increase of seasonal temperature by 2°C. The effect of climate change on crops production and livestocks continues to attract academic debates (Traore *et al.*, 2013; Parry *et al.*, 2007; Sultan *et al.*, 2005; Philips *et al.*, 1998). For instance, Parry *et al.* (2007) have estimated that there could be up to 50% reduction in crop yields from rain-fed agriculture by 2020 in some African countries as a result of rainfall deficiency.

However, the conclusion about climate change effects on agricultural production may depend on the location of the study (Thomas, 2008). The weather risks have been estimated to be negative and higher in African agricultural production than in other areas in the world (Parry *et al.*, 2007; Mendelsohn and Dinar, 1999; Mendelsohn *et al.*, 1994). For instance, the economic loss due to climate variability is estimated to range between 3.5 and 7.1 billion of dollars in Cameroon (Molua, 2008). Also, Kurukulasuriya and Mendelsohn (2008), using Ricardian model found that the deficits in precipitation and an increase in temperature might lead to a fall in net farm revenues. The results for polar and temperate zones are not the same like those in tropical and dry areas. Even within African countries, the effects of climate variability might be different. It has been projected that, warming could be beneficial for high latitude areas characterized by cold temperature and short growing seasons, while low latitude areas are likely to be harmed by the warming leading to the reduction of the length of growing seasons (Parry *et al.*, 2007; Mendelsohn and Dinar, 1999). For instance, Parry *et al.* (2007) have estimated that crop productivity will increase slightly from mid to high latitudes by considering an increase of mean temperature ranging from 1 to 3°C. Crop yield is estimated to increase up to 20% in the Eastern regions, while it is projected to decrease about 30% in the Southeast, as a result of climate change in the case of Asia (Parry *et al.*, 2007). Yet, climate change impacts on agricultural productivity vary not only by location, but also by products (Thomas, 2008; Rosenzweig and Parry, 1994; Motha and Baier, 2005). For instance, soybeans and non-irrigated maize production is expected to increase in North America, while it is expected to decrease in South and Southeast as a response of increase of temperature and decrease of precipitation (Thomas, 2008). Rosenzweig and Parry (1994) found that climate change will affect mostly cereals production in developing countries than in developed countries, where it is predicted to be beneficial. Using Ricardian approach Gbetibouo and Hansan (2005) found that the increase in temperature in South African field crop positively affects farmers' revenue, while a decrease in precipitation reflects negative effects.

Togo, as part of Sub-Saharan countries would not be exempted from the climate variability phenomenon. Indeed, Togo records a low level of productivity in terms of the ratio of cereal production per capita compared to other neighboring countries

(Burkina Faso and Mali) with similar economic and agricultural characteristics. For instance, the average cereal production per capita in Togo was only 172 kilograms, while it reached 268 kilograms and 400 kilograms in Burkina Faso and Mali, respectively (Mindi and Kougbenya, 2012). Ntagungira (2016) similary has indicated that despite the large size of the Togolese agricultural labor force which is 12 times greater than agricultural labor of Switzerland, the production of cereals per hectare in Togo is six times lower than Switzerland cereals' productivity. The cereals productivity in Togo is about 1.2 tons per hectare compared to average of 1.4 tons per hectare in Sub-Saharan Africa and 5.4 tons per hectare for Organization for Economic Co-operation and Development (OECD) countries (Ntagungira, 2016). The low level of agricultural production led to increased expenditure on food imports during the past fifteen years. For instance, in 2014, Togo's expenditure on food imports reached 185 million US Dollars, while it was only 36 million US Dollars in 2000 (FAO, 2015). In 2015, cereals imports in Togo represent 25% of food imports in Togo (Ntagungira, 2016). What factors could explain this low level of production? The change of temperature and precipitation could be determinants, as the temperature has increased on average about 1.1°C since 1960 at the rate of 0.24°C per decade, with a decrease of precipitation trend on average about 2.4% per decade (Intended Nationally Determined Contribution (INDC), 2015; McSweeney *et al.*, 2010). Unfortunately, very little is known about how inter and intra-seasonal variation and climate shocks have affected staple food crops such as maize, sorghum and rice at the local level in Togo. This study intends to fill this knowledge gap in order to redirect policies towards climate risk management and provide useful information about the crops response to climate change and variability in subsistence agriculture like that in Northern regions of Togo. Specifically, this paper assesses inter and intra-seasonal climate variability on cereal production focusing on maize, sorghum and rice that constitute the staple food crops in the northern region of Togo.

The remainder of this paper is organized as follows: section two presents the methodology followed by the results and discussion in section three. Then, section four concludes this paper with policy implications.

## Materials and methods

### *Study areas and source of data*

The agricultural sector in Togo employs 70% of the population and contributes to about 40% of gross domestic product (GDP) and 20% of the value of exports, while irrigation practices are almost non-existent with less than 2% of agricultural land (FAO, 2015; AfDB *et al.*, 2016). Cereal production is the major component of the agriculture sector and contribute about 68.5% of agricultural GDP (FAO, 2015). The sudy focuses on the three Northern regions of Togo (namely Savannah, Kara and Central), where agriculture remains the major source of livelihood and maize, sorghum and rice are the main produced food crops. These regions are characterized by bimodal climate with three agro-ecological zones (Figure 1). Throughout the year, the wet season fleets between April and October, while the dry season lasts from November to March.

The data used in this study come from two sources. The climate data (temperature and precipitation) come from the national meteotological service centre of Togo, while cereal data (maize, sorghum and rice production data) are those from national statistics of crop production (the national agricultural database, information and documentation of Togo-DSID).

### *Temperature data*

The temperature data are available from 1972 to 2013 for Sokodé and Sotouboua synoptic meteorological stations (in Central region) and Mango and Dapaong synoptic weather Stations for Savanah Region. In Kara region, the temperature data come from two synoptic weather stations (Niamtougou and Kara) and one another weather station (Pagouda).

### *Precipitation data*

The precipitation data that are used in this study are sourced from various weather stations (Figure 1). In the Central Region, precipitation data were available for five weather stations: Blitta, Sotouboua, Tchamba, Sokodé and Kpewa-Aledjo (Figure 1). In Kara region, precipitation data were available for six weather stations, notably, Guérin-Kouka, Pagouda, Takpamba, Kara, Niamtougou and Kéran. As for Savannah region, precipitation data were available in Mango, Borgou and Dapaong weather stations (Figure 1).

The average monthly temperature (T) and average monthly value of precipitation (P) are based on the cereal growing season in the Northern regions of Togo (from April to October). We consider that off-seasonal rainfall and temperature would not affect cereal production. The monthly average of temperature and average monthly value of precipitation capture inter-seasonal variability. The observed spatial climate data from existing meteorological stations in each region were used (Figure 1). The seasonal coefficient of variation of temperature and precipitation, captures the intra-seasonal variability of temperature and precipitation and taken as the seasonal ratio of standard deviation to the mean of temperature and precipitation, respectively.

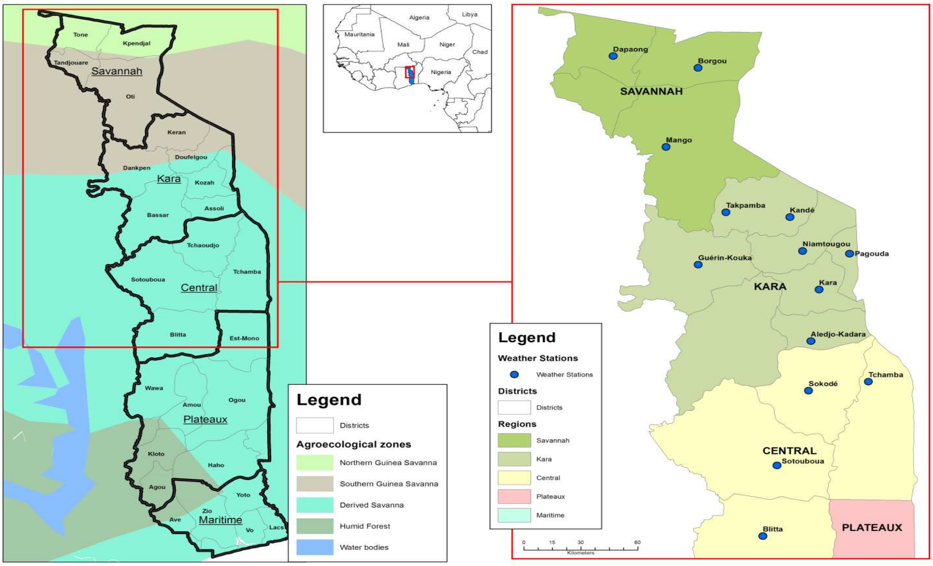


*Figure 1 - Agroecological zones and Weather Stations in Northern Togo*
*Source*: Author, using WorldClim-Global Climate data

## *Flood events*

The drought and flood events, known as extreme natural events that often occurs in developing countries could affect crops yields throughout the growing seasons. In case of Togo, most of natural extreme event that have been occurred are flood events (McSweeney *et al*., 2010). For instance, McSweeney *et al*., (2010) have mentioned that, more than 60 flood events have been observed in Togo since independence in 1960. The rare cases of drought have been observed in 1970 and 1971 while this study use the data from 1972 to 2013. For these reasons, the flood events only would be used. The flood event is measured as a dummy variable. If during the growing season, the flood event occurs in the region, then we score "1" and "0" otherwise. It is assumed to affect negatively crop yields.

## *Model specification*

Empirically, studies have been conducted to assess the potential impact of climatic conditions on agricultural production (Rowhani *et al*., 2011; Lobell and Burke, 2010). If a vector of inputs X is used to produce an output (non-empty assumption of production function), then the technology form of production function could be specified as:

$$Y = f(X_1, X_2, X_3, \dots, X_n) \quad (1)$$

Following Rowhani *et al.* (2011), the linear mixed model is used to assess the effects of climate variability on maize, sorghum and rice production in the Northern regions of Togo. The general form of the Linear Mixed Model (LMM) applied in this study is given as:

$$Y_{ij} = X_{ij}\beta + Z_{ij}\gamma_i + \varepsilon_{ij} \quad (2)$$

Where is the response variable (yields) for the jth observation in region i (i=1,2,3); is the matrix of potential covariates variables that could affect cereals yields; is a vector of fixed effects regression coefficients, Z is the covariate matrix for the random effect and is the vector of the residuals. Temporal trend or first auroregressive serial correlation is often used to capture the yield variability due to non-climatic and development factors (Kim and Chavas, 2003; Rowhani *et al.*, 2011). The yield technology functional form can be expressed as follows:

$$Y_{ij} = \delta_0 + \delta_1 T_{i,j} + \delta_2 P_{i,j} + \delta_3 T^2 + \delta_4 {P_{i,j}}^2 + \delta_5 CV_{T-i,j} + \delta_6 CV_{P-i,j} + \delta_7 FLO_{ij} + \alpha_i + \varepsilon_{i,j} \quad (3)$$

Y is the yield, measured as production per area harvested. i represents the region; i=1, 2, 3 (Central=1, Kara=2, Savannah=3), j is the observed yield in the region i. T and P, are the mean monthly temperature and precipitation, respectively. T2 and P2 are the square of mean monthly temperature and precipitation, respectively. CVT and CVP denote the coefficients of variation of temperature and precipitation respectively. FLO denotes a dummy variable capturing the extreme natural events. $\delta$ n are the model parameters (n=0,1,2,…,7); is the random intercept term and ε is an error term. We assume that the error term is independent and normally distributed within the region. To account for regional heterogeineity in the climate and other factors, the generalized linear model which accounts for fixed effects is also used (equation 4).

$$Y_j = \delta_0 + \delta_1 T_j + \delta_2 P_j + \delta_3 T^2 + \delta_4 {P_j}^2 + \delta_5 CV_{T-j} + \delta_6 CV_{P-j} + \delta_7 DUM_{CENT\,j} + \delta_8 DUM_{KAR\,j} +$$
$$\delta_9 DUM\_SAV_j + \delta_{10} FLO_j + \delta_{11} Trd_j + \varepsilon_j \quad (4)$$

In the above equation, DUM_CENT, DUM_KAR and DUM_SAV are dummy variables, for Central, Kara and Savannah regions, respectively, which capture the specific effect for each region due to its own climate and topological characteristics.

The Kara region is purposely chosen as reference given the geographical position of these regions. The yield vary over time and this changing may due to the technological development. In order to capture the aggregate effects of yield variability over years, the time trend ($\boldsymbol{Trd_j}$) was used (Farmer and Lafond, 2016; Rowhani *et al.*, 2011; Kim and Chavas, 2003; Fan, 1991; Hansen and Hill, 1991).

### *Descriptive statistics*

The data show that the mean annual temperature fluctuates between 27°C and 30°C in the Savannah region, while it is between 26°C and 28°C in Kara and Central regions (Figure 2). It is much higher in Savannah region over the period of study, followed by Kara and Central region which constitutes a transition zone between the Northern regions and Southern regions charactirized by two wet seasons and two dry seasons.

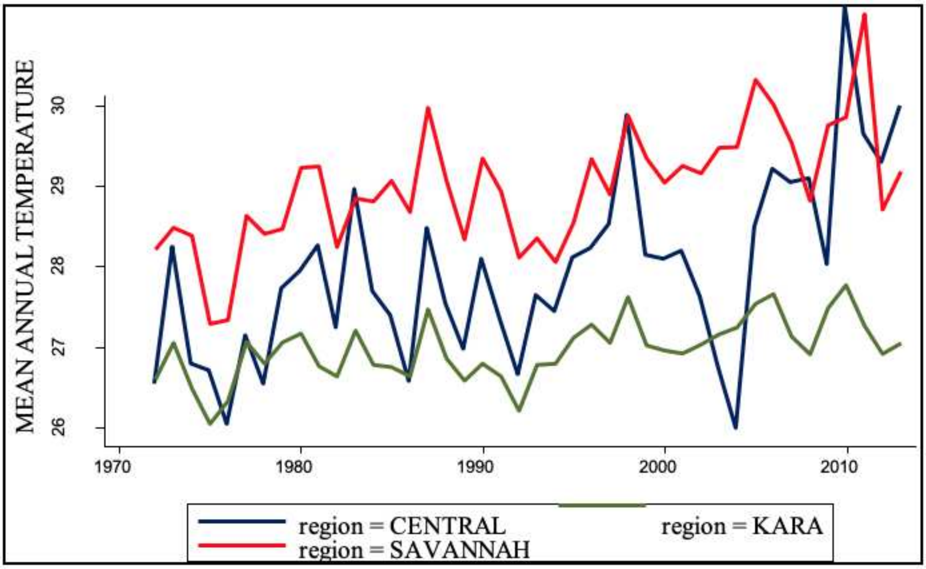


*Figure 2 - Mean Annual Temperature in °C in the Northern region of Togo (1972-2013)*

The mean seasonal temperature was, on average about 26°C in Central and Kara regions and 28°C in the Savannah region (Figure 3). In the Central region, the variability of the mean seasonal temperature is more observed over the past fifteen years. The deviation from the mean of temperature seems to to be more accentuated in Kara and Savannah regions over the periode of study.

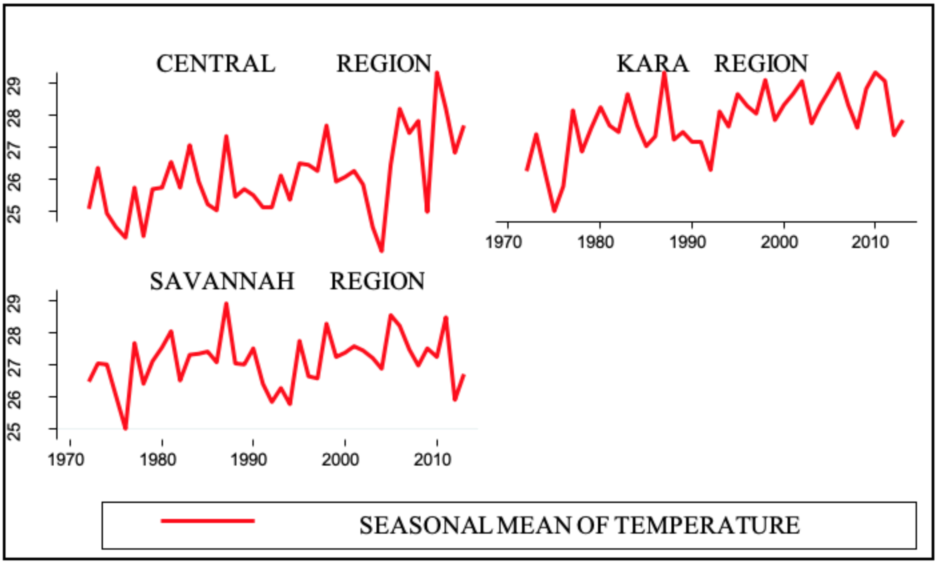


*Figure 3 - Seasonal Mean of Temperature in °C in the Northern region of Togo*

The minimum and maximum of the mean seasonal temperature was, on average, about 25°C and 29°C, respectively. The average annual precipitation in the Northern regions of Togo fluctuates between 769 mm and 1641 mm (Figure 4). It is much higher in Kara region, while Savannah region seems to be less rainy region.

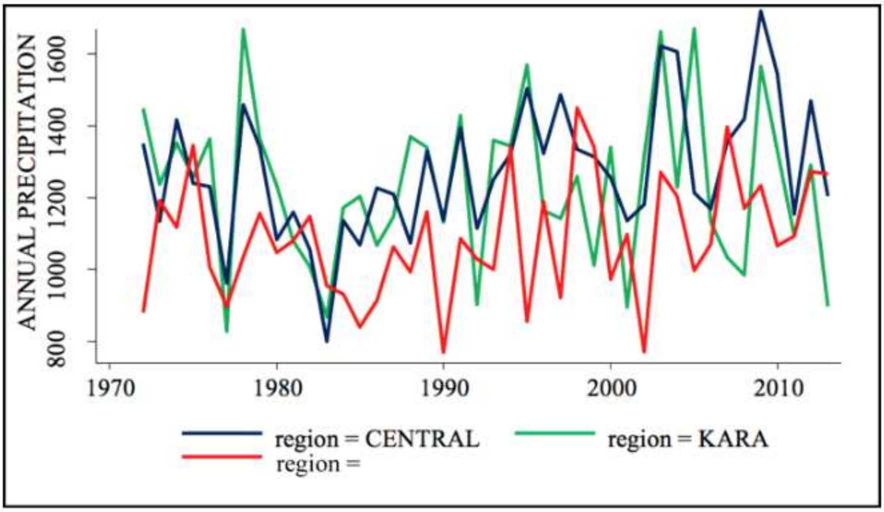


*Figure 4 - Annual precipitation in mm in the Northern regions of Togo (1972-2013)*

The average annual precipitation in Central region waves between the average amount of rainfall in Kara and Savannah regions. The average monthly seasonal precipitation in the Northern regions falls between 105 mm (Savannah region) and 227 mm (in Kara region) as shown in Figure 5.

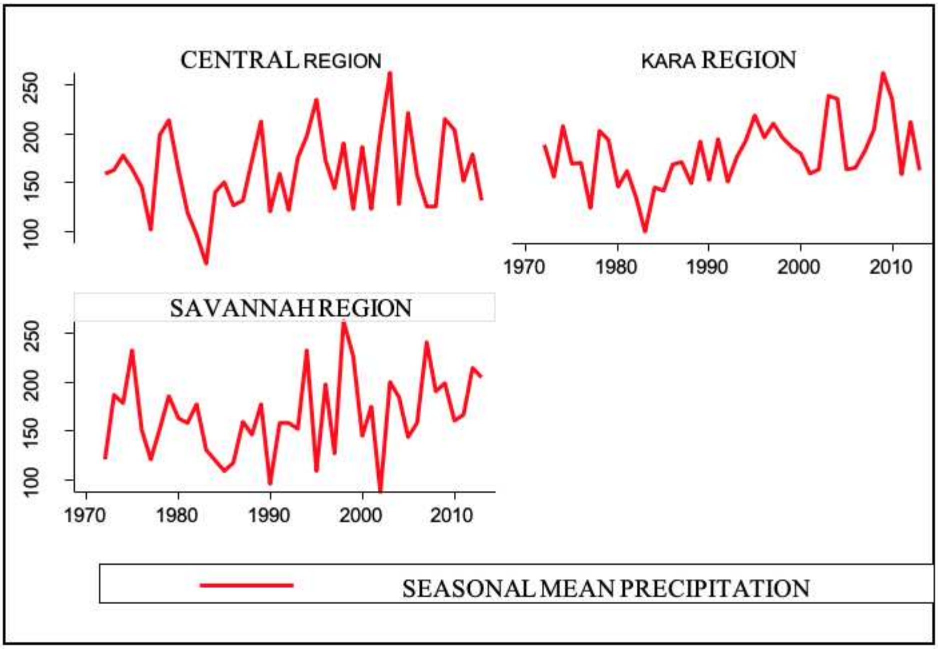


*Figure 5 - Seasonal average precipitation in the Northern region of Togo*

The seasonal monthly average precipitation was about 129 mm and 120 mm, respectively, for Central and Kara regions. Between April and October, the mean monthly precipitation was, on average, about 142 mm, while it seems to be similar in Kara and Central regions (172 mm and 171mm for Kara and Central regions, respectively). The maximum monthly mean precipitation since 1972 reached on average only 216 mm and 186 mm respectively for Central and Savannah regions.

### *Cereal yields in the Northern regions of Togo*

Maize, sorghum and rice production data as well as the harvested areas were available from 1971 to 2014 for Central, Kara and Savannah regions. The yield is calculated as the ratio of production per harvested area for each selected crop. Only the data from 1972 to 2013 are used in this study, since precipitation and temperature data are available only for the period of 1972-2013. The data show that, maize, sorghum and rice production in the Northern Regions of Togo represent on average 30%, 85% and 69% of national production respectively (Table 1).

*Table 1 - The cereal production in the Northern region of Togo over the period 1972-2013*

| Crops | Min | Mean | Max | Standard Deviation | Percentage of National Production (%) |
|---|---|---|---|---|---|
| | (Metric tons per hectare) | | | | |
| **Central Region** | | | | | |
| Maize | 0.589 | 2.759 | 11.8 | 3.002 | 18 |
| Sorghum | 0.488 | 0.833 | 1.538 | 0.196 | 27 |
| Rice | 0.252 | 1.621 | 3.140 | 0.700 | 30 |
| **Kara region** | | | | | |
| Maize | 0.300 | 1.111 | 2.3 | 0.393 | 5 |
| Sorghum | 0.434 | 0.726 | 1.209 | 0.167 | 22 |
| Rice | 0.122 | 1.411 | 4.5 | 0.745 | 9 |
| **Savannah region** | | | | | |
| Maize | 0.352 | 1.217 | 2.8 | 0.5146 | 7 |
| Sorghum | 0.303 | 0.776 | 1.435 | 0.294 | 36 |
| Rice | 0.195 | 1.903 | 4.272 | 1.134 | 30 |

Savannah Region is likely to produce more sorghum and rice (36% and 30%, respectively of national production), while in the Central Region, there is a diversification of maize, sorghum and rice cultivation that represent on average about 18%, 27% and 30% respectively of national production. Kara region has lower production level in terms of percentage of national production compared to other regions for the selected staple food crops (5%; 22% and 9% of national production respectively for maize, sorghum and rice).

### *Maize production*

On average, maize production reached 60,054 tons per year in Central region; 17,960 tons in Kara region and 23,816 tons in Savannah region that represents on average 18%, 5% and 7%, respectively, of national production (Table 1). The minimum of maize yield was 0.6 tons per hectare in the central region, while it was on average 0.3 tons per hectare and 0.4 tons per hectare, respectively, in Kara and Savannah regions. Maize yield reached its maximum of 11.8 tons per hectare, 2.3 tons per hectare and 2.8 tons per hectare in Central, Kara and Savannah regions respectively (Table 1).

### *Sorghum production*

The data show that sorghum is the most cultivated crop in the Northern regions. Sorghum production represents on average 85% of national production (Table 1). It is more cultivated in Savannah and Central regions (36% and 27% of national production, respectively). On average, sorghum yield represents on average 0.8 tons per hectare in the Central Region, while it represents 0.72 tons per hectare and 0.78 tons per hectare on average in Kara and Savannah regions, respectively. The minimum yield of sorghum has reached 0.3 tons per hectare with a maximum yield of 1.5 tons per hectare.

### *Rice production*

Rice is a major staple food crop as a direct consequence of urbanization and the dispersion of its production to the mean over 1972 to 2013 is on average 60% and 53% in Savannah and Kara regions, respectively and 43% in the central region (Table 1). The rice yield in Kara region reached a maximum of 4.5 tons per hectare compared to 3.1 tons per hectare and 4.3 tons per hectare in Central and Savannah regions, respectively. The average rice yield from 1972 to 2013 in Savannah was 1.9 tons per hectare compared to 1.6 tons per hectare and 1.4 tons per hectare, in Kara and Central regions, respectively.

## Results and discussion

The results using Linear Mixed Model (LMM) indicate that inter seasonal temperature and precipitation have significant impact on maize yields (Table 2). Seasonal mean temperature is positive and significant at 10%, while temperature square is significantly and negatively related to maize yield. It emplies that there is non-linear relationship between the seasonal average temperature and maize yield. Seasonal mean of precipitation is significant at 1% level and positively related to the maize yields. This result is not surprising since maize needs sufficient water during the planting period as well as the flowering period. Also, there is a significant and negative relationship between maize yield and precipitation square. It means that beyond the seasonal monthly average (129 mm, 120 mm and 105mm for Central and Kara region, respectively), precipitation could affect negatively maize yield in study areas. At a certain level, the amount of precipitation along the rainy season might yield a negative impact on crop development. The coefficient of variation of precipitation that captures intra seasonal variability of precipitation is significant at 1% and negatively related to maize yields. Also, the intra-seasonal variability of temperature and precipitation show a considerable effect on maize yield. Increasing intra-seasonal variability of precipitation by 1 unit could reduce maize yield on average by 0.906 metric tons per hectare. Increasing intra-seasonal variability of temperature by 1 could reduce maize yield on average by 8.51 metric tons per hectare. The results show also an important variability within regions. The maize yield variability between regions was relatively low (less than 2 grams per hectare), while its variability within regions was, on average, 11.18 metric tons per hectare as is indicated by variance between and within the regions (Table 2). The model has positive autoregressive serial correlation (0.985), implying that the maize yield would be somehow influenced by non-climatic factors such as change of maize variety or agricultural policies that would be implemented in the study areas over the period of study. The results showed that maize yield has been negatively affected by flood events that mostly occured in Kara and Savannah region as indicated by (McSweeney *et al.*, 2010; Yendoukoa, 2008). This result would inform policymakers' decisions towards risks preparedness and management in order to reduce the potential loss of crop yields in the Northern regions of Togo.

*Table 2 - Impact of Climate variables and shocks on Maize yield in the Northern regions of Togo*

| Maize Yields | LMM | | GLM | |
|---|---|---|---|---|
| | Estimates | Std. Error | Estimates | Std. Error |
| Temperature | 4.136* | 2.345 | 0.438 | 6.05 |
| Precipitation | 0.013*** | 0.004 | 0.031 | 0.050 |
| Coefficient of Variation of Temperature | -8.505*** | 0.803 | 8.023 | 11.75 |
| Coefficient of variation of precipitation | -0.906*** | 0.054 | -1.614 | 1.582 |
| Precipitation square | -4e-05*** | 0.1e-04 | -0.8e-04 | 1.5e-04 |
| Temperature square | -0.074* | 0.043 | -0.002 | 0.111 |
| Flood events | -0.465*** | 0.154 | -0.330* | 0.087 |
| Time trend | | | -0.091*** | 0.016 |
| Dummy Central | | | 1.566*** | 0.239 |
| Dummy Savannah | | | -0.159 | 0.432 |
| Intercept | -55.708* | 30.094 | -12.158 | 81.35 |

*Table 2 - continued*

| Maize Yields | LMM | | GLM | |
|---|---|---|---|---|
| | Estimates | Std. Error | Estimates | Std. Error |
| Between regions variability | 1.96e-12 | | -0.164 | 0.291 |
| Within regions variability | 11.180 | | | |
| Auto regressive serial correlation AR(1) | 0.985 | | | |
| Scale parameter (Deviance / Residual df) | | | 0.918 | |
| Akaike Information Criterion (AIC) | | | 2.835 | |

*** p<0.01, ** p<0.05; * p<0.10

The results from the Generalized Linear Model (GLM) gives information on the relationship between maize yield and different climatic variables and highlights the best fit of maize production in different regions taken as dummy variables (Table 2). The regional dummy variables shed light on the specific effect for each region due to its own climatic and topological characteristics. It lets us know which region is a better fit in the production of maize. Kara region, which is located between Central and Savannah regions, is purposely taken as reference. The results from GLM show that the coefficient of dummy variable (Central region) is positive and significant at 1%, while the coefficient of dummy variable for Savannah region is not significant (Table 2). It means that, Central region fits better in maize production compared to Kara region. This result was confirmed by the Central region share of national production of maize compared to the Kara region (18% of national production of maize in the Central region against 5% and 7% for Kara and Savannah regions, respectively). It is important to note that, the Central region is the transition zone characterized by one rainy season toward bimodal climate observed in the Southern regions. The non-climatic effects such as the impacts of technological change shows a negative relationship with maize yield over time. It could be explained by the farming practices that have been adopted by farmers in the study areas. Research on the adoption of technology among maize farmers as well as its impact on farm level revenue in the study areas would shed light on this result.

The results of the impact of climate variability on sorghum production in the Northern Regions show that the inter-seasonal monthly precipitation is significant at 5% level and negatively related to sorghum yield (Table 3).

*Table 3 - Impact of Climate variables and shocks on Sorghum yield in Northern Togo*

| Sorghum Yields | LMM | | GLM | |
|---|---|---|---|---|
| | Estimates | Std. Error | Estimates | Std. Error |
| Temperature | -0.170 | 0.885 | -3.064* | 1.812 |
| Precipitation | -0.006** | 0.003 | 0.007 | 0.012 |
| Coefficient of Variation of Temperature | 0.282 | 2.289 | 2.744 | 2.620 |
| Coefficient of variation of precipitation | -0.495*** | 0.411 | -0.420 | 0.403 |
| Precipitation square | 2.3e-05** | 4e-05 | -1.8e-05 | 3.9e-05 |
| Temperature square | 0.0036 | 0.016 | 0.057* | 0.033 |
| Flood events | 0.002 | 0.047 | 0.038 | 0.051 |
| Time trend | | | 0.011*** | 0.002 |
| Dummy Central | | | 0.127** | 0.059 |
| Dummy Savannah | | | 0.002 | 0.131 |
| Intercept | 3.209 | 12.085 | 39.256 | 24.326 |
| Between region variability | 1.25e-19 | | | |
| Within region variability | 0.049 | | | |
| Auto regressive serial correlation AR(1) | 0.587 | | | |
| Scale parameter (Deviance/ Residual df) | | | 0.038 | |
| Akaike Information Criterion (AIC) | | | -0.345 | |

*** p<0.01, ** p<0.05; * p<0.10

A positive relationship between seasonal mean of precipitation and sorghum yield was expected. The negative relationship would be dependent on the crop location and climate characteristics of that location (Mishra *et al.*, 2008) and wether it is intense or frequent rainfall (Guan *et al.*, 2015). Similar results are found in the literature. It is an example of Kukal and Irmak (2018) in the case study of the US Great Plains, Lambert (2014) in the case of Kansas, as well as the work by Maccarthy and Vlek (2012) in the case of semi-arid region of Ghana. The within regional variability of observed sorghum yield that was measured by the variance of error term was about 0.0499 metric tons per hectares on average. Under GLM, seasonal mean temperature

has negative and significant effect on sorghum yields. It implies that an increase of seasonal temperature by 1°C would result to the decreasing of sorghum yield by 3.062 metric tons per hectare. The regional endowment effects on sorghum yield is captured by regional dummy variable. We conclude that Central Region is likely to be the better fit region in sorghum production compared to Kara region. This result is also confirmed by the rank of Central Region in terms of the proportion of national production (27% of national sorghum production in central region compared to 22% for Kara region). The results also show that there is a positive relationship between the change due to technological change and the sorghum yield in the Northern regions (Table 3). This result can be explained by the impact of the project of changing sorghum varieties that have been launched by the Institute of Togolese Agronomic Research (ITRA) in the Northern part of Togo. Encouraging farmers in the adoption of such technology could increase their revenue and reduce their vulnerability.
The result from the LMM for rice data is given in Table 4.

*Table 4 - Impact of Climate variables and shocks on Rice yield in Northern Togo*

| Rice Yields | LMM | | GLM | |
|---|---|---|---|---|
| | Estimates | Std. Error | Estimates | Std. Error |
| Temperature | -15.276*** | 0.703 | -8.758*** | 2.284 |
| Precipitation | 0.032 | 0.020 | 0.022 | 0.019 |
| Coefficient of Variation of Temperature | 8.044* | 4.362 | 5.453 | 3.687 |
| Coefficient of variation of precipitation | -1.668* | 0.941 | -1.249** | 0.554 |
| Precipitation square | -7.67e-05 | 7.05e-05 | -4.99e-05 | 5.7e-05 |
| Temperature square | 0.286*** | 0.013 | 0.161*** | 0.043 |
| Flood events | 0.198*** | 0.086 | 0.185*** | 0.067 |
| Time trend | | | 0.021*** | 0.003 |
| Dummy Central | | | 0.089 | 0.092 |
| Dummy Savannah | | | 0.471** | 0.192 |
| Intercept | 201.66*** | 9.713 | 116.11*** | 29.85 |
| Between region variability | 1.23e-20 | | | |
| Within region variability | 0.611 | | | |
| Autoregressive serial correlation AR (1) | 0.659 | | | |

*Table 4 - continued*

| Rice Yields | LMM | | GLM | |
|---|---|---|---|---|
| | Estimates | Std. Error | Estimates | Std. Error |
| Scale parameter | 0.561 | | 0.401 | |
| Scale parameter (Deviance/ Residual df) | | | 0.444 | |
| Akaike Information Criterion (AIC) | | | 2.008 | |

*** p<0.01, ** p<0.05; * p<0.10

Inter-seasonal variation of temperature is significant at 1% level and negatively related to rice yields, while intra-seasonal temperature and precipitation were significant and affect differently the rice yield. For instance, rice yields would increased as a result of an increase in intra-seasonal variability of temperature while intra-seasonal variation of precipitation would negatively affect rice production in the study areas. The intra-seasonal variability of temperature have shown to not reduce rice yields in the study areas. However, an increased of variability of seasonal precipitation by 1 unit from one season to another would reduced rice yield by about 1.668 metric tons per hectare in all regions.

The flood events positively affected rice yield, while one would expect the negative effects. Indeed, the Northern regions of Togo are water-limited regions compared to the other regions. The cultivated rice comes from lowland and therefore, the flood event in water-limited region could be an opportunity to store water for later use, hence, their positive effects on rice yield. This result was found by Asada *et al.* (2005) in the case study of Bangladesh and Sim *et al.* (2012) in the case of Cambodia. The best way in this case, is to promote irrigation practices to increase rice yields through rain-fed water management as was the success story in the case of the West and Eastern Asia, in Egypt, Singapore, Viet Nam, Brazil (Abdullah and Rahman, 2015; Johnston *et al.*, 2012). However, both negative and positive effects of floods events on crop yield were also found by Kang *et al.* (2009). The results from Linear Mixed Model for rice could be compared to those from GLM (Table 4). The results from the both models are similar regarding the signs of different covariates. The coefficient on the dummy variable for Savannah region is significantly and positively related to rice yield, indicating that Savannah region is in a better position in rice production compared to Kara region. This is true when referring to the proportion of national rice production of each region. The proportion of rice production in Savannah regions was, on average, about 30% of national rice production over the period of 1972-2013, against 9% for Kara region.

## Conclusion and policy implications

The frequency of climatic risks is increasing as a result of climate change and variability. There is a need to assess their impacts on each agricultural sub-sector in order to redirect policies toward food security. This paper assessed the impacts of climate variability on staple food crops production focusing on maize, sorghum and rice. Linear Mixed Model (LMM) was used to assess the impacts of climate variability on cereal production at the local level. In oder to capture the regional heterogeneity due to non-climatic factors such as soil characteristics, the economic position of the region as well as the impact of technological change on crop production, the GLM was used for the purpose. The historical data for the period of 1972 to 2013, of the Northern regions of Togo (Central, Kara and Savannah) was used. These data come from two sources: the data on cereal production and harvested areas come from the national statistics of crop production, while weather data (temperature and precipitation) comes from the national meteorological service centre of Togo.

The regional heterogeneity of climate has been shown to be determinant of the food crops production in the study areas. Inter and intra-seasonal variations of temperature and precipitation have diverse effects on cereal yields in the Northern regions of Togo. For example, the intra-seasonal temperature has negatively affected maize, while the intra-seasonal variablility of precipitation () would reduce the yield of the three major food crops in the study areas. As for the inter-seasonal variability of precipitation, it has affected negatively the sorghum yield. The rice yield would be reduced by an increase of inter-seasonal variability of temperature. The flood events have affected negatively maize yield, while positively associated to rice yields. Maize seems to be at risk under climate variabilities. There is a need for research on maize variety that can be more productive and more resistant given the regional heterogeneity in climate. In the particular case of rice, there is a need for investment in setting irrigation facilities and increase productivity. Being water-limited regions; policy may target investment in water management in rain-fed agriculture in the Northern regions of Togo. It may also target on the promotion of use of drought-tolerant seeds in order to reduce the predicted harmful effects of climate change and variability on food crops. In addition, improvements in agro-meteorological information forecast and advertisement and its integration in farmers' decisions and crop selection for cultivation are needed. This can help farmers adapt to climate change and variability and improve crop yield and reduce vulnerability and poverty.

## *References*

Abdulai A., 2018. Simon brand memorial Address: the challenges and adaptation to climate change by farmers in Sub-Saharan Africa. Agrekon. DOI: 10.1080/03031853.2018.1440246

Abdullah H.M., Rahman M.M., 2015. Initiating rainwater harvest technology for climate change induced drought resilent agriculture: Scope and challenges in Bangladesh. Journal of Agriculture and Environment for International Development, 109(2): 189-208

AfDB, OECD, UNDP, 2016. African Economic Outlook (2016): Cities and Structural transformation. 15th Edition, African Economic Outlook. DOI: http://dx.doi.org/10.1787/aeo-2016-en

Ahmed A., Diffenbaugh N., Hertel T., Lobell D., Ramankutty N., Rios A., Rohwani P., 2011. Climate volatility and poverty vulnerability in Tanzania. Global Environmental Change, 21: 46-55

Asada H., Matsumoto J., Rahman R., 2005. Impact of recent severe floods on rice production in Bangladesh. Geographical Review of Japan, 78(12): 783-793

Barnett B., Mahul O., 2007. Weather Index Insurance for agriculture and rural areas in lower-income countries. American Journal of Agricultural Economics Association, 89(5): 1241-1247

Deressa T, Hassan R, Ringler C, Alemu T, Yusuf M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Bassin of Ethiopia. Global Environmental Change 19: 248-255

Di Falco S., 2014. Adaptation to climate change in Sub-Saharan agriculture: assessing the evidence and rethinking the divers. European Review of Agricultural Economics, 41(1): 405-430

Egbendewe A.Y.G., Lokonon O.K.B., Atewemba C., Coulibaly N., 2017. Can intra-regional food trade increase food availability in the context of global climatic change in West Africa? Climate change, https://doi.org/10.1007/s10584-017-2083-0

Fan S., 1991. Effects of technological change and institutional reform on production growth in Chenese agriculture. Amercican Journal of Agricultural Economics 73(2):266-275

FAO, 2015. FAO Statistical Pokectbook: World food and Agriculture. Food and Agriculture Organization, Rome.

Farmer J.D., Lafond F., 2016. How predicable is technological progress? Research Policy 45: 647-665

Gbetibouo A., Hassan R., 2005. Measuring the economic impact of climate change on major South African field crops: a Ricardian approach. Global and Planetary change. 47:143-152

Guan K., Sultan B., Biasulti M., Baron C., Lobell D.B., 2015. What aspects of future rainfall changes matter for crop yield in West Africa. Geophysical Research Letters, 42: 8001-8010. DOI:10.1002/2015GL063877

Hansen G.S., Hill C.W.L., 1991. Are institutional investors myopic? A time series study of four technology-driven industries. Strategic Management Journal, 12:1-16

Intended Nationally Determined Contribution-INDC 2015. Intended Nationally Determined Contribution (INDC) within the framework of the United Nation Framework Convention on Climate Change (UNFCCC). Republic of Togo.

IPCC, 2014. Climate change impacts, adaptations and vulnerability, contribution of working group 2 to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Johnston R. Hoanh C., Lacombe G., Lefroy R., Pavelic P., Fry C., 2012. Improving water use in rainfed agriculture in the Greater Mekong Sub region. Summary report Colmbo, Sri Lanka. doi:105337/2012

Kang Y., Khan S., Ma X., 2009. Climate change impacts on yield, crop water productivity and food security: a review. Progress in natural Science, 19: 1665-1674

Kim K., and Chavas JP., 2003. Technological change and risk management: an application to the economics of corn production. Agricultural Economics 29: 125-142

Kukal M.S., Irmak S., 2018. Climate-driven crop yield and yield variability and climate change impacts on U.S. Great Plains agricultural production. Scientific Reports, 8: 3450. DOI:101038/s41598-018-21848-2

Kurukulasuriya, P., Mendelsohn, R., 2008. A Ricardian analysis of the impact of climate change on African cropland. African Journal of Agricultural and Resource Economics 2, 1 1-23

Lamber D.K., 2014. Historical impacts of precipitation and temperature on farm production in Kansas. Journal of Agriculture and Applied Economics, 46(4): 439-456

Lobell D., Burke M., 2010. On the use of statistical models to predict crop yield response to climate change. Agricultural and forest meteorology, 150: 1443-1452

Lokonon B., Mbaye A., 2018. Climate change and adoption of sustainable land management practices in Niger Basin of Benin. Natural Resources Forum, 42:42-53

Maccarthy D.S., Vlek P.L.G., 2012. Impact of climate change on sorghum production under nutrient and crop residue management in semi-arid Region of Ghana: A modelling perspective. African Crop Science Journal, 20(2): 243-259

McSweeney C., New M., Lizcano G., Lu X., 2010. The UNDP Climate Change Country Profiles Improving the Accessibility of observed and projected Climate Information for Studies of Climate Change in Developing Countries Bulletin of the American Meteorological Society. 91: 157-166

Mendelsohn R., Dinar A., 1999. Climate Change, Agriculture and Developing Countries: Does Adaptation Matter? World Bank Research Observer. 14(2): 277-293

Mendelsohn R., Nordhaus D., Shaw D., 1994. The impact of global warming on agriculture: a Ricardian analysis. American economic Review. 84(4): 753-771

Mindi L., Kougbenya L., 2012. Rendement de l'agriculture: l'excédent céréalier au Togo. African Development Bank, Revue Economique Mensuelle, No.4, Oct. 2012

Mishra A., Hansen J.W., Dingkuhn M., Baron C., Traoré S.B., Ndiaye O., Ward N.M., 2008. Sorghum yield prediction from seasonal rainfall forcasts in Burkina Faso. Agriculture and Forest Meteorology 148: 1798-1814

Mohammed A.M., Tena T., Singh P., Molla A., 2016. Modelling climate change impact on chickpea production and adaptation options in the semi-arid North-Eastern Ethiopia. Journal of Agriculture and Environment for International Development, 110(2): 377-395

Molua E., 2008. Turning up the heat on African agriculture: the impact of climate change on Cameroon's agriculture. AfJARE, 2(1): 45-64

Motha R., Baier W., 2005. Impact of present and future climate change and climate variability on agriculture in temperate regions: North America. Journal of Climate Change, 70: 137-164

Ntagungira C., 2016. Food trade deficit poses a major challenge for Togo. African Development Bank. Available at: https://www.afdb.org/en/blogs/measuring-the-pulse-of-economic-transformation-in-west-africa/post/food-trade-deficit-poses-a-major-challenge-for-togo-15886/. Access in April 2018

Parry L., Rosenzweig C., Iglesias A., Livermore M., Fischer G., 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global environmental Change. 14: 53-67

Philips J., Cane M., Rosenzweig C., 1998. ENSO, seasonal rainfall patterns and simulated maize yield variability in Zimbabwe. Agricultural and Forest Meteorology, 90: 39-50

Rosenzweig C., Parry M., 1994. Potential impacts of climate change on world food supply; Nature; 367: 133-138

Rowhani P., Lobell D., Linderman M., Ramankutty N., 2011. Climate variability and crop production in Tanzania. Journal of Agricultural and Forest

Meteorology, 151: 449-460

Sim K., Sou S., Sam C., Chou P., Neang M., 2012. The impact of climate change on rice production in Cambodia. NGO Forum on Cambodia. DOI: 10.13140/2.1.3464.5122

Sultan B., Baron C., Dingkuhn M., Sarr B., Janicot S., 2005. Agricultural impacts of large-scale variability of West African Monson. Agricultural and Forest Meteorology, 128: 93-110

Tambo J., Abdoulaye T., 2013. Smallholder farmers' perceptions of adaptations to climate change in the Nigerian Savanna. Regional Environmental Change 13(2): 375-388

Thomas R., 2008. Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. Journal of Agriculture, Ecosystem and Environment; 126: 36-45

Traore B., Corbeels M., Wijk M., Rufino M., Giller K., 2013. Effects of climate variability and climate change on crop production in southern Mali. European Journal of Agronomy, 49: 115-125

Wossen T., Abdoulaye T., Alene A, Feleke S., Menkir A., Manyong V., 2107. Measuring the impacts of adaptation strategies to drought stress: The cases of drought tolerant maize varieties. Journal of Environmental Management, 203: 106-113

Yendoukoa L., 2008. Lutte antiérosive et contraintes socio-économiques dans la région des Savannes du Nord Togo. Sécheresse, 19(2): 103-114