**Impacts of Rainfall Variability on the Growth and Production of Rainfed Maize in Uganda. Challenges and Opportunities**

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**Abstract**

The production of maize in Uganda is mainly rainfed, with approximately 63% coverage national harvested area, exposing this major livelihood activity to the variability in the rainfall pattern. With the rising trend in rainfall variation, maize grain yield and quality are likely to decrease due to various biotic and abiotic stresses. The effect of the variations in rainfall pattern is destruction of crops which causes food insecurity and poverty. This is because maize is one of the commonly grown grain crops with about 80% of Uganda’s labor force and is a staple food for over 50% of the population in Uganda. Different studies have examined the effects of climate change on the production of maize and its productivity. However, there is still limited information on the impact of rainfall variability on the growth and production of rainfed maize in Uganda. This review assessed the impacts of rainfall variability on the growth and production of rainfed maize in Uganda looking at challenges and opportunities. Results indicate an increase of 18.1% in the production of maize between 2010 and 2020. The study further shows an increasing trend in maize yield from 2.06 to 3.24 t/ha. With Uganda’s steady population growth rate of 3.5%, it will be difficult to meet the maize demands by its people under the projected rainfall scenarios with an increase of 0.2 mm per day by 2030. This is due to the increasing per capita total maize consumption of 18.98 kg in reference to 2014. Therefore different ways of adapting to the variations in rainfall have been discussed which would help continued increased production of rainfed maize.

**Key words**; Rainfed maize, rainfall, rainfall variability, yields, production

# Introduction

The climate in East Africa is naturally dynamic with high temporal and spatial rainfall variability, some of which is observed from the large scale oscillations in atmospheric and ocean circulation. Within East Africa, Uganda lies along the Equator and experiences high variations in rainfall between 500- 1800 mm according to Figure 1. Uganda experiences bimodal rainfall (Ogwang et al., 2016) with long rains from March to May (MAM) and short rains from September to November (SON). The wet seasons are separated by two distinct dry spells from June to August and then from December to February. According to (Ogwang et al., 2016; Phillips, 2000), ENSO (El Nino Southern Oscillations) has played a significant role in defining the monthly and seasonal patterns of rainfall in the East African region. The current weather variability is mainly manifested as droughts and floods, heat waves and erratic rainfall mainly distributed to the Sea Surface Temperature (SST) (Phillips & Mcintyre, 2000). The amount of rainfall received in various areas of the country in 2010 was more than the long- term average. Its unexpected timing disrupted agriculture and the agro industry leading to damages and losses estimated at 2.8 trillion shillings.

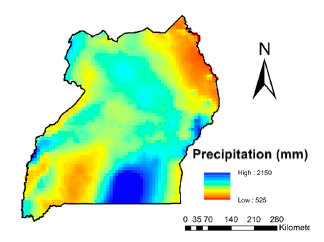


Figure.1 Mean annual precipitation in Uganda (Mccandless, 2013)

This translates to 8% of the country’s GDP (OPM, 2012). The rainfall was not sufficient enough to meet the crop water requirements from 37% to 66% which covered about three seasons in a number of districts (two seasons in 2010 and one season in 2011). The losses in maize alone which was the second to bananas amounted to 181.77 million shillings in 2010 and 94.65 million shillings in 2011. The Uganda National Household Survey of 2005 shows farmers reporting high levels of expected crop yield loss due to drought of which maize had the highest losses above 30% in comparison with other crops of banana, coffee, cassava and sweet potato (UBOS, 2014). The poverty status report (PSR) of 2014 revealed that unreliable rainfall had negative effects on crop production and hence on poverty. This was especially in rural areas with household consumption reducing by around 14% if the main rainy season begins a month or more later or earlier than usual (MAAIF, 2019). This is because most rural farmers depend on rainfed agriculture. This resulted in lower rural incomes and increased poverty.

Considerable research works have been carried out on the effects of climate/rainfall on agricultural production but few works have been specific on the effects of rainfall variation on rainfed maize production. In a study by (Mccandless, 2013) found out that maize production for the sole growing season in Sanzara experienced an 8-10% decrease while Kayonza and Katenga experienced 0-2% increase by 2050. In this study an ecophysiological crop model “Decision Support System for Agrotechnology Transfer” was used to understand how predicted changes in temperature and precipitation influenced crop growth and yield for the years 2010, 2030 and 2050. Another study by Bagamba et al., (2012) while assessing climate change impacts and adaptation strategies for small holder agricultural systems in Uganda discovered that 70-97% of the households would be adversely affected by climate change. A trade off analysis model was used in this research in the three regions of central, Masaka and Southwest in Uganda. Mibulo & Kiggundu, (2018) carried out a study to evaluate the FAO AquaCrop model for simulating rainfed maize growth and yields in Uganda. In this study the FAO AquaCrop model was evaluated for its predictability potential of maize yields and growth. The model was using maize growth and yield data collected during the seasons, September to December 2014, March to July 2015 and September to December 2015. This research revealed that higher rainfall amounts of approximately 590 mm received between the months of September and December 2015 gave much higher yields of maize of approximately 4.56 t/ha. This was compared to 302 mm that received between March and July 2015 which gave quite less yield of 3.83 tons per hectare. The rainfall received for September to December was high and evenly distributed. According to the policy brief by AATF/ WEMA/NARO (2009), Uganda had a potential of producing up to 7.5 million metric tons if the area under cultivation was well utilized. However, there were number of constraints one of which was the erratic rainfall patterns and drought stress during some seasons. This kept Uganda’s maize yield production very low that resulted in high unit costs and hence very low returns. Maize yield levels were low in Uganda between 1.0 to 1.8 MT/ha regardless of the size of the farm (MAFAP/ NARO, 2012).

In another study by Nimusiima et al., (2018), the impacts of climate change scenarios on maize yield in the cattle corridor of Central Uganda were predicted. Under this study crop- environment resource synthesis (CERES) simulation model was used to examine the relationship between maize yield and the changes in weather and climate. Two future temporal scales that is, near future (2021-2050) and mid-century (2051-2081) and seasons, one beginning March and the other from September were used. The overall future maize yield was projected to reduce by 5-50% in the near future and by 10-60% in the mid-century climate period compared to the base climate period of 1980-2010. They however suggested that early planting in both seasons may potentially alleviate these yield reductions by 5%. Nimusiima et al., (2018) continue to indicate mean annual precipitation increasing with an ensemble of the models predicting precipitation between -20 to +46% by the 2090s in comparison to the 1970-1999 average. These projected anomalities would lead to lower yields in many crops mainly through reduced growing season length, increased water stress and increased attack of pests and diseases (Adhikari et al., 2015). Mubiru et al., 2012 discovered that the variability in rainfall onset dates across Uganda was greater than the variability in withdrawal dates. This was in a study of characterizing agrometeorological climate risks and uncertainties; crop production in Uganda. They also discovered that even when rains start late, withdrawal was timely and this made the growing season shorter. They spotted out that during the March- May rainy season, the number of rainy days was decreasing yet this was the critical crop growing period. This meant that crops grown in that season were prone to climate risks. According to Chabala et al., (2015), assessment of variations in the yield of maize due to the changes in rainfall and temperature in the three agro ecologic zones of Zambia was done. It indicated increased yields with increase in rainfall in some districts under study while in other districts it was opposite. The yields were higher in agro ecological zone 11 (800 to 1000 mm of rainfall per annum) with yield production of 61,599 MT with a standard deviation 36,760 MT. A study by Nahayo et al., (2018) indicated a reduction in maize production from 57,695 to 20,967 MT while accessing the effect of changes in rainfall on rainfed crop production in Rwanda. Sixty seven percent of the farmers who grow maize in Bugosera district in Rwanda were affected by delays in rainfall and heavy rainfall that lasted for a very short period of time. Approximately 59% of the maize was lost due to floods because it was planted in the lowland areas (Byishimo, 2017). Bugosera is a lowland district 1100-1780 m above sea level receiving between 800-1600 mm of rainfall. As a result of the variability in rainfall, farmers no longer followed their normal farming calendar and instead had opted for other strategies to mitigate the negative effects on their livelihoods. According to Ayman et al., (2018), different yield attributes such as stem length, ear height, number of kernels/ row, grain weight, grain yield, biomass yield and harvest index were adversely affected by shortage of rainfall (drought stress). A different study by(Sabagh et al., 2018) found that under well irrigated conditions all the yield attributes mentioned before significantly increased in comparison to drought stress. The ARCH model study estimates showed that a shift in rainfall and temperature from the long term mean had significant effect on the yield. The study still showed that exponential increase in rainfall had a detrimental effect on the yield of crops in Uganda (Mwaura & Okoboi, 2014). In Kenya, the arid and semi-arid counties were facing a challenge of rainfall variability which had greatly affected maize yields and thus food security (Omoyo etal., 2015).

## Maize production trends

The demand of cereals globally is estimated at 2.1 billion MT and will for the first time show a major shift in favor of maize with demand estimated at 852 (45%) million MT by 2020. This is in comparison with 760 (30%) million MT for wheat and 503 (32%) million MT for rice (IFPRI 2008; Wei et al., 2016; Kassie et al., 2014. This reflects a substantial growth of 72% for maize in developing countries. Maize occupies about 40% of the entire cropland and is a key source of livelihood for more than 50% of the population in the Sub Saharan Africa (Adhikari et al., 2015).

In Uganda, maize is one of the most and highly grown crops in terms of area planted and volume produced after bananas and cassava (UBOS, 2015). Maize is cultivated on about 1 million ha of land which represents about 46% of the area under cereal production across all agro ecological zones in Uganda (UBOS, 2014; Angelucci et al., 2014). Maize is grown by small scale farmers all over Uganda for household food and income security. It has become a known non-traditional export crop and also an industrial crop for the animal feeds industry. The yields in maize have drastically increased over the last 15 years and the production was seen to increase from 1.1 million MT in 2000 to 2.7 million MT in 2013 when it was ranked third in production after banana and cassava (UBOS, 2014). The production of maize in 2014 was 2.9 million MT with low yield levels between 2.2 to 2.5 t/ha as compared to the potential yield of 5 t/ha (MAAIF, 2019). Of the 2.9 million MT, 134,903 MT were exported which generated an income of US$43.567 million for the country. The target of the agriculture sector is to produce 10 million MT of maize with an expected export income of US$ 105 million for the country by 2020. Maize production for 2019 was 2.8 million MT (MAAIF, 2019). Despite the contributions of agriculture to Gross Domestic Product, the yield of maize in Uganda is still low from 2.2 to 2.5 metric tons per hectare. This is in comparison with the global average of 5 metric tons per hectare mainly due to the erratic distribution of rainfall across the crop seasons (MAAIF, 2019; Adhikari et al., 2015; Rockström & Barron, 2014). The growing of maize depends on the availability of water (approximately 450 to 600 millimeters of water per season) and most of Uganda’s agriculture is rainfed. As a result maize production is affected by rainfall shocks such as droughts and floods.

## Gender roles in maize production

Globally, women represent 43% of the workforce in agriclture while in most developing countries 60-80% of women spend their working hours in food production through agriculture (FAO, 2019; Nabikolo, 2014). In Uganda, women provide the largest labor force (over 70%) in agricultural production yet they have less control (less than 20%) over the outputs and resources (MAAIF, 2019). Although women farmers are more into agriculture, they are more vulnerable to rainfall variability and extremes due to their limited entitlements and assets. They have restricted access to the social and natural resources required for adaptation to rainfall variability and resilience building. This means women have less decision making on how to utilize the land to overcome the challenges of rainfall variability such as installation of affordable irrigation system. They are also not able to acquire credit to install the irrigation system and cannot easily access extension services that would help boost their agriculture. Their vulnerability also stems from their illetracy, minimum mobility due to the reproductive roles and having fewer opportunities outside the house.

# Materials and methods

## Data collection

Uganda is located in East Africa and currently has a population of approximately 41.6 million people (UBOS, 2014). Uganda is a humid equatorial country with mean annual precipitation between 800 mm and 1500 mm (USAID, 2015; USAID, 2010) . Precipitation in the South is bi-modal (March- May and September- November) and is uni-modal in the North (April- October). The secondary rainfall data was collected from the weather station at the National Crops Resources Research Institute– Namulonge (NaCRRI). Meteorological data from Namulonge is recorded on a daily basis and is then kept on record at the Department of Meteorology in Kampala. It is from here that it is entered and archived using climate- computing format. The data was analyzed focusing on mean annual variability for the time series 2010 to 2020. Data on maize production, yield, exports and consumption was derived from the Uganda Bureau of Statistics National Statistical Abstracts (UBOS, 2014; 2019; 2020), the annual agricultural surveys and Ministry of Agriculture Animal Industry and Fisheries reports (MAAIF, 2019; UBOS, 2020). All the data obtained was parameterized, compared and averaged to acquire a reliable and representative data package. The data was then analyzed using Microsoft Excel 10.

## Study area

Namulonge is located in Busukuma parish, Kyadondo county in Wakiso district in Uganda. Namulonge is located just a few kilometers from the equator in Uganda, on Latitude 0o 5’ North and longitude 32o61’ E. Namulonge lies at an altitude between 900-1340 m above sea level. The topography is characterized by flat- topped hills dissected by broad valleys that are occupied with swamps. This location exposes Namulonge to an equatorial climate characterized by comprehensive sunshine associated with high temperatures and high rainfall. The average rainfall received throughout the year is around 1170 mm and it is bi modal in nature with two wet seasons (March to May and September to November). The dry spells occur between January to February and July to August. Maximum temperatures occur in February while minimums occur in July. Namulonge village has 424 households and total populations of 1743 people of which 835 are female and 908 are male. Namulonge village practices small scale agriculture and is also an agricultural research area at the National Crops Resources Research Institute. The area is rural in nature and a number of the residents are employees of the institute. Agricultural practices at Namulonge are therefore highly influenced by the institute. The agricultural practices are also highly influenced by rainfall availability since it is mostly rainfed.

# Results

## Rainfall variation

The annual rainfall patterns for the selected study area for the study period 2010 to 2020 are presented in Graph 1 below. The graph shows that there was variation in the amounts of rainfall between 2010 and 2020 with a sharp decrease in the rainfall in 2013 and a steady increase between 2014 and 2018. The minimum amount of rainfall of 1033 mm was received in 2013 while 2018 received the maximum amounts of 1375mm. There was quite a high standard deviation of 96.1034 mm in the amounts of rainfall received. The variations in the amounts of rainfall depicted in the graph show the extent to which the onset and cessation, intensity, frequency and amount of rains are affected (Mkonda et al., 2018). This has a significant impact on the farming calendar for most farmers thus affecting the whole process of agricultural production.

Figure. 2 Annual rainfall pattern for the time period 2010 to 2020 (USAID, 2020&Nsubuga, 2018)

## Maize production and yields

The yields in maize had an increasing trend from 2.3 T/ha in 2010 to 3.6 T/ha in 2016 and later declined 2.87 T/ha in 2020 according to Figure 1. The poor spread of rainfall throughout the study period has a damaging impact on maize crop yields. Maize yields in Uganda are relatively low compared to the global average of 5 MT/ ha (MAAIF, 2019). This is attributed to the erratic rainfall and increasing temperatures in addition to limited input of fertilizers and improved seeds. Table 1 shows that there has been an increase of 18.1% in maize production from 2010 to 2020 though the production is still low compared to the increasing population in Uganda.

Table.1 Variations in the area harvested, production and yields for maize in Uganda between 2010 and 2020

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Area harvested (‘000 ha) | Production (million MT) | Yield (T/ ha) |
| 2020 | 1100 | 2.80 | 2.87 |
| 2019 | 0951 | 2.75 | 3.01 |
| 2018 | 1042 | 2.77 | 3.00 |
| 2017 | 1011 | 2.63 | 3.13 |
| 2016 | 0961 | 2.41 | 3.60 |
| 2015 | 1125 | 2.81 | 2.87 |
| 2014 | 1103 | 2.76 | 3.24 |
| 2013 | 1101 | 2.75 | 2.65 |
| 2012 | 1094 | 2.73 | 2.06 |
| 2011 | 1063 | 2.55 | 2.23 |
| 2010 | 1032 | 2.37 | 2.30 |

**Source; (UBOS, 2014 & 2020)**

Figure 2. Maize production and yields in Uganda (UBOS, 2014 & 2020)

## Effect of rainfall variation on maize production

According to Figure 3 below, we noticed that maize production varied in response to rainfall changes. There was a small change in the production of maize except in 2014 where there was a sharp decline in the production. The trend in maize production was generally seen to increase between 2010 and 2020. These findings are in line with (Mibulo & Kiggundu, 2018) who revealed that higher rainfall amounts gave much higher yields of maize of approximately 4.56 t/ha. This was in a study to evaluate the FAO AquaCrop model for simulating rainfed maize growth and yields in Uganda. In this study the FAO AquaCrop model was evaluated for its predictability potential of maize yields and growth. The highest production of maize was in 2015 with annual rainfall of 1274 mm. The changes in the maize production are mainly due to the effect of either early or late rainfall. The changes in the production of maize could also be attributed to variations in temperature, low yielding varieties, and poor farming methods. A number of studies apart from (Mibulo & Kiggundu, 2018) have been found to be in line with this study though some other literature opposes. For example Chabala et al., (2015) while assessing variations in the yield of maize due to the changes in rainfall and temperature in the three agro ecologic zones of Zambia. It indicated increased yields with increase in rainfall in some districts under study while in other districts it was opposite. The yields were higher in agro ecological zone 11 (800 to 1000 mm of rainfall per annum) with yield production of 61,599 MT with a standard deviation 36,760 MT. A study by Nahayo et al., (2018) indicated a reduction in maize production from 57,695 to 20,967 MT while accessing the effect of changes in rainfall on rainfed crop production in Rwanda.

Figure 3. Relationship between rainfall variation and maize production in Uganda for the years 2010-2020 (USAID, 2020& UBOS, 2020)

## Adaptation of rainfed maize to rainfall variability

Due to the adverse effects of rainfall variability on maize production as explained in different studies above, farmers have overtime developed copying strategies to shield them against uncertainties induced by year to year variations in rainfall (Cooper et al., 2017). A number of copying strategies have been reported by farmers one of which is encroachment on swamp areas to grow the crop in case of increase incidences of drought conditions and moisture stress (Bagamba et al., 2012).

Although different drought tolerant varieties have been developed, future climate scenarios call for more resistant varieties than the present types. Earlier maturing genotypes are better adapted to the environment where the period of favorable rain water is short and the risk of water stress is relatively high. Studies indicate that compared with local varieties, drought tolerant maize can increase yields by 15% and also reduces probability of crop failure by 30% (Wheeler, 2013). According to (Doso et al., 2018), shifting planting dates of maize would help farmers adapt to the rainfall variability. Delaying to plant for about 5- 8 weeks would be essential under future climate scenario since projections suggest increased rainfall ahead. This enables growth under favorable climatic conditions because heavy rains affect the yield. Moreover, the prevailing cropping pattern is more focused on ensuring that crops survive without due consideration of the growth stage when a crop requires sufficient water for optimal yields. Intercropping may also be used with maize which helps the maize to use water from the different soil layers by the other different crop (Adiku et al., 2001).

Farmers’ yields can be improved by applying external inputs for example irrigation. This can help reduce water losses drastically using advanced irrigation systems such as drip and sprinkler. These allow water to be delivered precisely when and where it is needed. It also enables availability of water at critical stages of maize development under water stress (Amikuzuno, 2013; Doso et al., 2018). There was an observed difference in yields and gross margins under irrigation and rain-fed agriculture for maize in Tanzania. Results showed that both yield and gross margin were quite higher under irrigation than rainfed. It is seen from Table 3 below that irrigated maize yielded more (2,550 kg/ha) than rainfed maize (1,100 kg/ha).

**Table 3. Crop yields and gross margin differences between rainfed and irrigated systems in Tanzania**

|  |  |  |  |
| --- | --- | --- | --- |
| **Crop/system** | **Yields (kg/ha)** | **Break-even yield (kg/ha)** | **Gross margin(US$/ha)** |
| Maize (rainfed) | 1100 | 0728 | 058 |
| Maize (irrigated) | 2550 | 1185 | 205 |

**Source:** (FAO, 1997) **Irrigation technology transfer in support of food**

However, successful adoption of irrigation requires increased financing, enhanced coordination of government and non-government agencies to develop and disseminate the technologies (Mwaura & Katunze, 2014).

Diversification of agriculture can help farmers expand into new or existing market opportunities so as to increase income or decrease income variability. This helps in case maize crop fails due to variations in the rainfall. Thus farmers can rely on production of alternative crops or activities adopted under the diversification scheme. For this case, this may mean switching from maize to crops that are more tolerant to the effects of rainfall variability such as millet and sorghum.

There should be a shift in the growing areas of maize under projected harsh conditions of drought and floods. Maize growing in the country can be concentrated around the semi-deciduous rain forest zones. Much as rainfall may be predicted to reduce under projected climate change scenarios, this zone will be less affected than all the other zones (Doso et al., 2018).

The ministry of Agriculture, Animal Industry and Fisheries through the Agriculture Sector Strategic Plan 2015/16- 2019/20 has identified and instituted the necessary affirmative actions. These actions ensure that both men and women participate and benefit equally from development initiatives across all sub sectors (MAAIF, 2019). The ministry is facilitating training in joint decision making and planning of the household agriculture. This encourages women to take up leadership positions in farmer groups and cooperatives. It also promotes gender equity in ownership, access and control over production resources such as land, agricultural equipment and labor. It is also promoting utilization of the women fund and other funds targeting women by profiling and supporting women undertake agricultural enterprises. This will help ease access to irrigation facility especially in dry spells and also help women access maize crop varieties that are more tolerant to drought.

The ministry of Agriculture, Animal Industry and Fisheries in collaboration with the Ministry of Water and Environment has established a climate change unit that will increase partnerships and resource mobilization initiatives. This will support implementation of climate smart agriculture through collaborations with available initiatives including funds targeting the promotion of climate conservation activities (MAAIF, 2019).

# Conclusion

A review on the impact of rainfall variability on rainfed maize has been done in this paper. Although the trend for maize production is seen to increase with increasing rainfall in this study, a number of studies show that variation in rainfall has negatively affected maize production. Maize production in Uganda is seen to increase for example from 2.37 million MT in 2010 to 2.8 million MT in 2020, but the yield is still low (2.2 to 2.5 MT/ha) as compared to the global average (5 MT/ha). In this study the average production of maize was 2.6 million MT. This low production is mainly due to the erratic rainfall patterns, water and heat stress on maize plants not forgetting other factors like pests and diseases that cause considerable destruction on the crop. With the reduction in yields, there will be increased food insecurity and reduced incomes since maize is a staple for 50% of the country’s population. As a result of the effect of the erratic changes in rainfall on maize yield, many farmers have adopted to various adaptation measures as discussed in the paper.

**Conflicts of interest**

The authors declare that there was no conflict of interest

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