Assessing the Impact of Climate Change and Variability on Wetland Maize Production and the Implication on Food Security in the Highlands and Central Plateaus of Rwanda

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Abstract

This paper explores the impact of climate change and variability on wetland maize production in the highlands and central plateaus of Rwanda and its connection to the problem of food insecurity. Data were obtained using different methods and techniques including literature review, analyses of meteorological and maize yield data, field observation, household questionnaire and semi-structured interviews. Research findings revealed abnormal changes in temperature with a mean temperature increase of 0.85 ºC in Bahimba wetland located in the northern highlands and 1.1 ºC in Bishenyi wetland located in the central plateau for the past 30 years. The study revealed also changes in rainfall patterns with a decrease of 114.9 mm and 42.3 mm in Bahimba and Bishenyi respectively. Consequently, due to prolonged droughts in Bishenyi, maize yield per ha was reduced by 41% in 2013 and by 51% in 2014. Likewise, in Bahimba, maize yield was reduced by 17% in 2015. This situation led to food insecurity among maize farmers and other communities in the study areas. It is recommended that improved adaptation measures including watersheds management, new drought resistant and early maturing maize seed varieties, community food reserves, savings and credits groups, improved irrigation infrastructures, diversified income sources and improved maize value chain should be taken to ensure increased maize yields and sustainable food security.

Keywords: climate change and variability, temperature, rainfall, maize farmers, food security, Rwanda

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Introduction

Climate change is a global challenge that is disrupting economies of different countries and affecting lives of local communities and, the trend is likely to increase in the future (Millar et al. 2007). Climate change is already having an impact on agriculture and this situation is leading to reductions in crop production and lower incomes in affected places around the world (FAO 2013a; Rian, 2008). The situation is worse in Sub-Saharan Africa (SSA) where changes in rainfall and temperature patterns are threatening food production across many countries (Arndt et al. 2012). As indicated by Arndt et al. (2012), about 223 million people are currently undernourished in SSA, but the effects of climate change will increase that number up to 355 million people by 2050. In addition, the same impacts will cause a decrease of crop net revenues across the region, especially in the Southern Africa where the loss will reach 90 % in 2100 (Benhin, 2006). Furthermore, climate change will reduce the surface of land suitable for agricultural activities including various types of wetlands in Eastern and Southern part of Africa (Chabala et al. 2015; IIED 2012)

As reported by Rian (2008), climate change poses many risks to agricultural production through the increase of annual average temperatures and that of droughts which have direct effects on water quality and quantity. In addition, it poses other risks such as the high competition for water resources, increased erosion and flooding phenomena from shorter duration rainfalls, etc. (Nabahungu & Visser, 2011). Moreover, climate change has been argued to be responsible for an increased risk of having new pests as well as new crop diseases (Rwanyiziri & Rugema, 2013). This is the case of Maize Streak and Cassava Mosaic viruses in regions characterized by the increase in rainfall patterns, and Sorghum Head Smut (a fungal disease) in regions where rainfall patterns decrease. This change may push local farmers to switch from maize to sorghum in some places where maize becomes less productive (MINAGRI 2009). In the same framework, recent studies have shown that high temperatures are predicted to be causing negative impacts on yields of maize and wheat in the East African region. In many cases, high temperatures increase irrigation water requirements of major crops and that situation leads to the problem of water stress (Böhme et al., 2013; Böhme et al., 2016; Kahsay & Hansen, 2016).

Rwanda has also experienced the effects of climate change and variability through a growing number of disasters in recent decades especially droughts, floods, landslides and windstorms that occurred in 1988, 1989, 2000, 2005-2006, 2010, 2011 and 2014 (MIDIMAR 2015). The average temperature has increased from 19.8 °C in 1971 to 20.7 °C in 2007, making an increase of 0.9 °C in 27 years and the number of days of rainfall has dropped from 148 to 124 from 1971 to 2009 (REMA 2009). As reported by Rwanda Meteorological Agency - RMA (2004), the decrease in number of annual rain days in the country is likely to negatively impact on the growth of crops, including maize, as many of them require a certain quantity of water within a given number of days. The same report revealed an increase of torrential rain resulting in severe floods, landslides and soil erosion in the Northern and Western and drought in the Eastern and Central plateaus of Rwanda. As indicated by Nabahungu & Visser (2011), an increase of dry spells during rainy season contributes to poor performance of crops and therefore, agricultural productivity due to the late set of rainfall and/or early rainfall cessation.

Consequently, these changing climatic conditions are causing poor performance of agriculture including maize production that has been contributing to the exacerbation of the problem of food insecurity and undernutrition throughout the country and the region in general (Beuel et al. 2016; Cairns et al. 2012; Chen & Wong, 2016; Nabahungu & Visser, 2011). Due to seasonal irregularities, farmers were increasingly wary of establishing new optimal times for planting their crops (Mutuyimana, 2015; Nabahungu & Visser, 2011). That has negatively impacted their livelihoods and increased vulnerability to food insecurity (Webber et al. 2014; Nabahungu & Visser, 2011). The agressivity and frequency of climate related hazards in Rwanda and their adverse effects are exacerbated by the country’s topography mainly characterized by a very accidental relief very prone to erosion, landslides and flooding (MIDIMAR 2015). Both the Eastern and some parts of the Southern regions of the country are already constrained with erratic and heavy shorter rainfalls that are responsible for dry spells and prolonged droughts; while in the Northern and Western regions, crops failure is caused by heavy rainfall and floods (Perez et al. 2015; Rwanyiziri & Rugema, 2013; Thornton et al. 2009).

Maize is one of the major crops which have been selected by the Government of Rwanda (GoR) to help in achieving agriculture-market oriented and food sovereignty in the country (Kannan et al. 2010). However, maize production in wetlands has been facing with serious impacts of climate change and variability, including water stress during the extended dry spells that also increases proliferation of crop pests and diseases particularly in lowlands and central plateaus of the country (Nahayo et al. 2017). In highlands, hilly terrain, deforestation and heavy rainfalls cause floods and siltation that damage crops and destroy irrigation infrastructures. According to IPCC (2014), without additional adaptation efforts beyond those in place today, climate change is expected to lead to a high risk of severe and irreversible negative impacts especially on agriculture that will lead to food insecurity and hunger.

Although Rwanda has designed a comprehensive national climate change policy in order to integrate climate change related matters into all development policies and programmes, local farmers continue to suffer from climate- related hazards. Therefore, there is a need for better understanding of the nature and magnitude of the impacts of climate change and variability in wetland areas as the last options for crop production in Rwanda. The output of this research should inspire agricultural policies for a better adaptation to climate change and variability towards sustainable food security strategies in the country.

Materials and Methods

Study Area Description

The data for this study were collected in the highlands (Rulindo District, Northern Province) and central plateaus of Rwanda (Kamonyi District, Southern Province). In Rulindo District, Bahimba wetland was chosen and in Kamonyi District, Bishenyi wetland was also selected (Figure 1). Bahimba wetland is located in Rulindo District which is mostly characterized by hills among which include Tare, Tumba and Cyungo with an altitude rising to 2,438 m. These hills are interspersed by valleys and swamps that host rivers such as Nyabarongo, Muyanza and Nyabugogo. Low agricultural output/yields, soil acidity, seasonal variability and limited research are challenges that Rulindo district is facing in agriculture sector and therefore, wetland exploitation is one of the major solutions (Rulindo District, 2013). Bishenyi wetland is located in Kamonyi District which is drained by the great river Nyabarongo along the East and North of the

District and Akanyaru River in Northern and Eastern part. There are also a number of small water courses, such as Kayumbu, Bakokwe, Bishenyi, Mukunguri, Nyabuvomo, Bishenyi, Gatimbazi and Ruvubu. Its general relief is made of low-lying plateau. Due to demographic pressure, the District is facing soil erosion and degradation that has led to the decrease of uphill crop production. Therefore, the Government of Rwanda (GoR) decided to exploit several marshes including Rwabashyashya, Kibuza, Bishenyi, Kayumbu, Mpomboli, Kivogo, Kavunja, Akanyaru, Mukunguli, Barama, Ruvubu and Nyabarongo for Maize production (Kamonyi District, 2013).

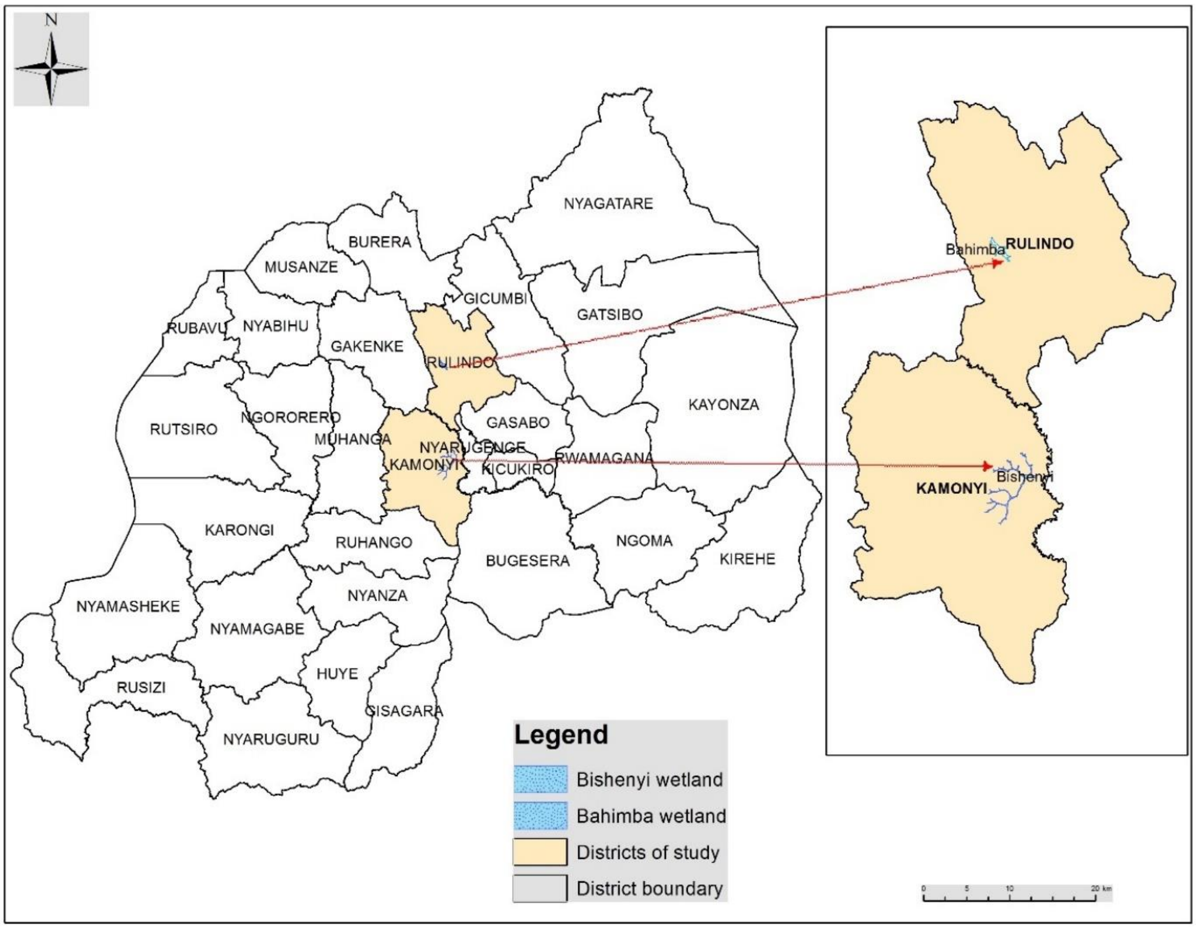

Figure 2**:** Map of Bahimba and Bishenyi Wetlands (Source: CGIS, 2019)

Data Collection

The dataset used consisted of secondary data (existing literature, crop yield and meteorological data) and primary data (maize yield farmers' and key informants' perceptions on the impacts of climate change on wetland maize production) (Alemayehu & Bewket, 2016; Calzadilla et al. 2014; Dawson & Martin, 2015; Kahsay & Hansen, 2016; Sileshi et al. 2010; Verdoodt & Van Ranst, 2006).

Secondary Data

Existing Literature

The literature review consisted of the analysis of relevant climate change and variability-related scientific publications; scientific and technical reports from United Nations Framework Convention on Climate Change (UNFCCC) and International Panel on Climate Change (IPCC); scientific and technical reports from other UN agencies World Meteorological Organization (WMO), Food and Agriculture Organization (FAO), and United Nations Environment Programme (UNEP); and technical reports, policies and strategies from Government of Rwanda ministries and agencies such as Ministry of Disaster Management and Refugee Affairs (MIDIMAR), Ministry of Agriculture (MINIGRI), National Institute of Statistics (NISR), Rwanda Meteorological Agency (RMA), and Rwanda Environment Management Authority (REMA).

Existing Meteorological Data

This study also used climate data for over the past 30 years as recorded by Rwanda Meteorological Agency (RMA) through weather stations in the study areas. The analysis of climate data helped to understand the fluctuation of rainfall and temperature in the study area and therefore, link climate change to performance of maize production in wetlands (Hernandez Nopsa et al. 2014; Rwanyiziri & Rugema, 2013; Thornton et al. 2009). Meteorological data were complemented with Remote Sensing data from World BioClim (Beaumont et al. 2005; Khorozyan et al. 2015).

Data on Maize Yields

The study used maize-yield data as recorded by maize farmers' cooperatives to evaluate the variability in maize seasonal and annual harvests (Kannan et al. 2010). The obtained maize yield was compared to climate trend in order to assess the impact of climate change and variability on maize production (Kannan et al., 2010; Thornton et al., 2009).

Primary Data

Primary data include field observations, interviews and focus group discussions and questionnaires where a semi-structured questionnaire was used during the field survey. In few words, a combination of participatory and rapid assessment techniques was used.

Field Observation

The field observation focusing on the bio-physical status of wetlands' and landscapes' management was conducted in order to get a general picture of the current situation in terms of wetland maize production and management. This phase helped to know and understand local farmers' practices and perceptions towards climate change effects and adaptation (Mutuyimana, 2015; Tenge, 2005).

Questionnaire

A semi-structured questionnaire was given to randomly selected 200 local farmers grouped in cooperatives, meaning 100 farmers were selected for each wetland. It mainly focused on exposure, sensitivity and capacity of maize farmers in wetland regions towards adaptation to the impacts of climate change and variability.

Interviews

Semi-structured interviews were conducted in order to understand maize farmers' and key informants' perceptions on the impacts of climate change and variability on maize yield. It mainly focussed on questions related to rainfall and temperature patterns, various types of climate hazards and their frequencies, level of vulnerability to droughts and floods, and copping strategies (Bizoza & Graaff, 2012; Mutuyimana, 2015; Winter-Nelson & Amegbeto, 1998).

Data Analysis

Maize Yield Data

The current study analysed maize production data to evaluate the relationship between the changes in maize yields and climatic conditions and later on, impacts on food security among local farmers (Cairns et *al*., 2012, Thornton et *al*., 2009). Several methods of data analysis were used. These include statistical analysis of socio-economic data by using SPSS 16 and Microsoft Excel for maize yield and socio-economic analysis. Furthermore, the analysis focused on the information flow in order to understand the status of climate change and variability and its impact on maize yield and food security for local farmers and countrywide (Cairns et al., 2012; Thornton et al. 2009).

Climatic Data

The current study used data merging method to obtain specific data for the areas of study. The Merging method involves combining point measurements from rain gauge networks and satellite estimates. Gauges provide "accurate" point measurements, but limited spatial and temporal coverage whereas coarse resolution satellite data provide only a consistent spatial temporal accuracy (Diak, 2017). Therefore, their integration provides information with higher spatio-temporal resolution and accuracy (Diak, 2017; Porfirio & Ceballos, 2017).

Simple bias Removal

This involves the extraction of rainfall estimate values at rain gauge locations, computation of the difference between satellite and rain gauge values at each station location, and interpolation the differences to each grid point (same as satellite pixel centers). Later on, the interpolated differences were added back to the satellite estimates (Ahmed et al. 2013; Li et al. 2016).

Merging Temperature

Merging temperature data involved combining temperature data from weather stations and satellite/reanalysis to evaluate temperature change at sector levels. The obtained temperature dataset helped to analyze temperature change over the past 30 years at Bahimba wetland (Tumba Sector, Rulindo District) and Bishenyi wetland (Runda Sector, Kamonyi District) as shown by Figure 2.

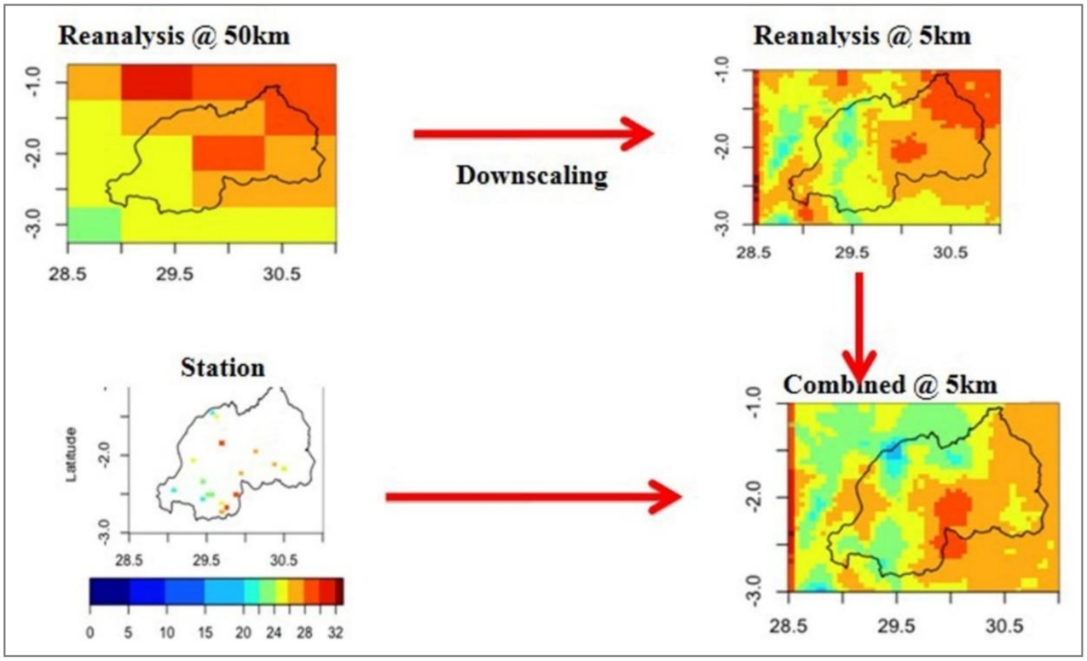

Figure 3: Processing of Temperature Data (Source: RMA, 2018)

Merging Rainfall

Merging rainfall data involved combining rainfall data from both weather stations (gauges) and satellite to obtain rainfall datasets for climate monitoring at small scale (Diak, 2017; Porfirio & Ceballos, 2017). The obtained rainfall dataset over past 30 years helped to analyze rainfall fluctuation in the study areas (see Figure 3).

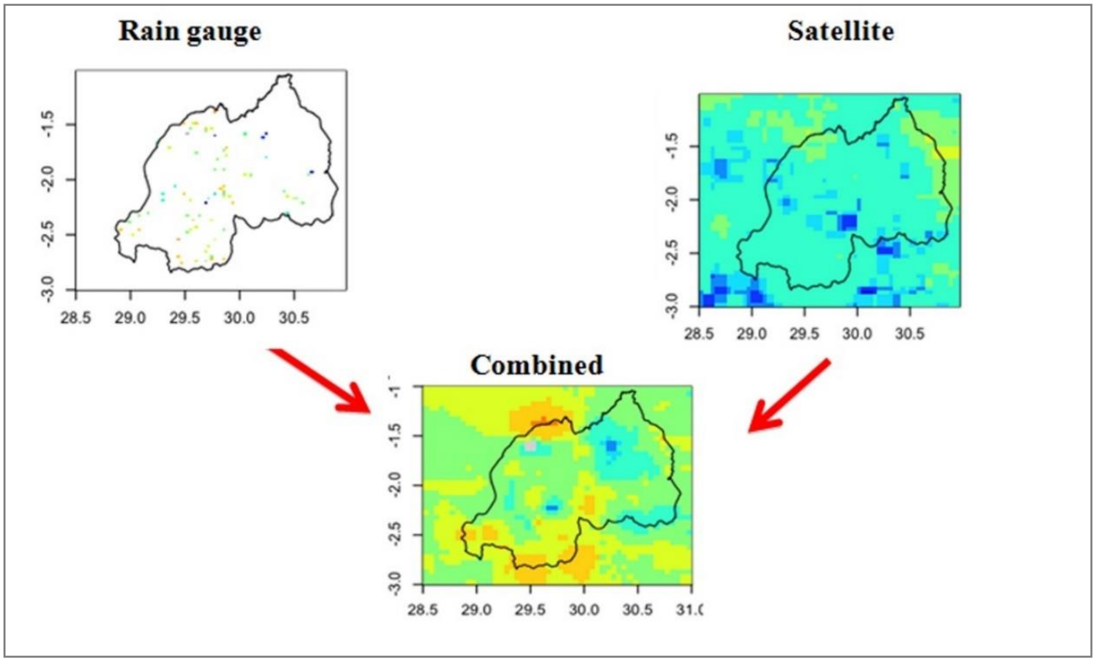

Figure 4: Processing of Rainfall Data (Source: RMA, 2018)

Results

The findings of this research are presented in a logical sequence according to which, the trends of major variables (temperature and rainfall) of climate change and variability were analyzed over the last 30 years; the evolution of maize yield was assessed and later on, impacts of climatic conditions on maize yield were also investigated.

Temperature Change for Bahimba and Bishenyi Wetlands

Rwanda is located in the equatorial region and would therefore be characterized by a very humid climate. However, its geomorphology with an altitude varying from 900 m in Bugarama plain in the South-west to 4,507 m at Karisimbi volcano in the North-west has resulted into a tropical temperate climate with an average temperature of 20^{o}C (REMA, 2009). The Western highlands of the Congo-Nile divide and the Northern mountains where Bahimba wetland is located are characterized by a low mean annual temperature (15^{o}C ≤ Mean ≤ 17^{o}C) as highlighted by figure 4. Bahimba wetland is located in the central plateus of the Country which are characteraize by medium temperature (16^{o}C ≤ Mean ≤ 19^{o}C).

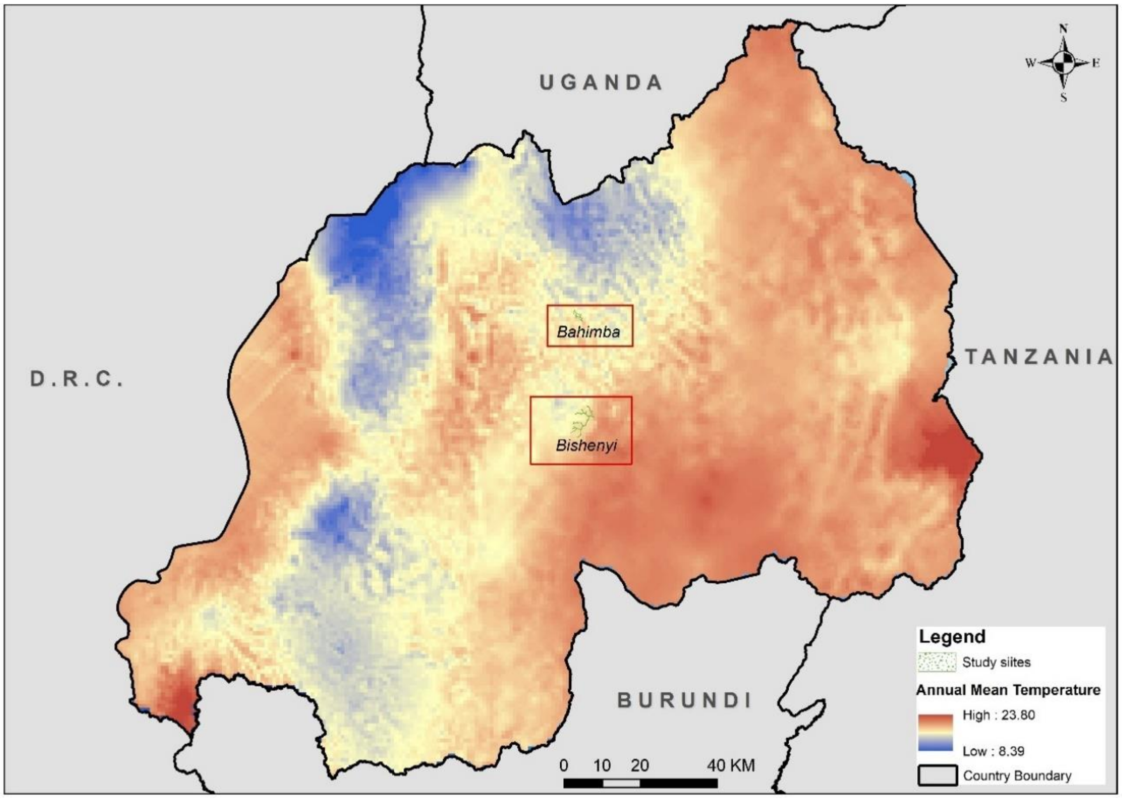

Figure 5: Annual Mean Temperature in Rwanda (Source: RMA, 2018)

There is an increase of mean temperature in both Bahimba and Bishenyi wetlands between 1981 and 2014 as highlighted in Figure 5. For Bishenyi wetland, the temperature increased from 17.6°C to 18.46°C making an increase of 1.1°C while temperature in Bahimba wetland increased by 0.85°C (from 17.70°C to 18.49°C).

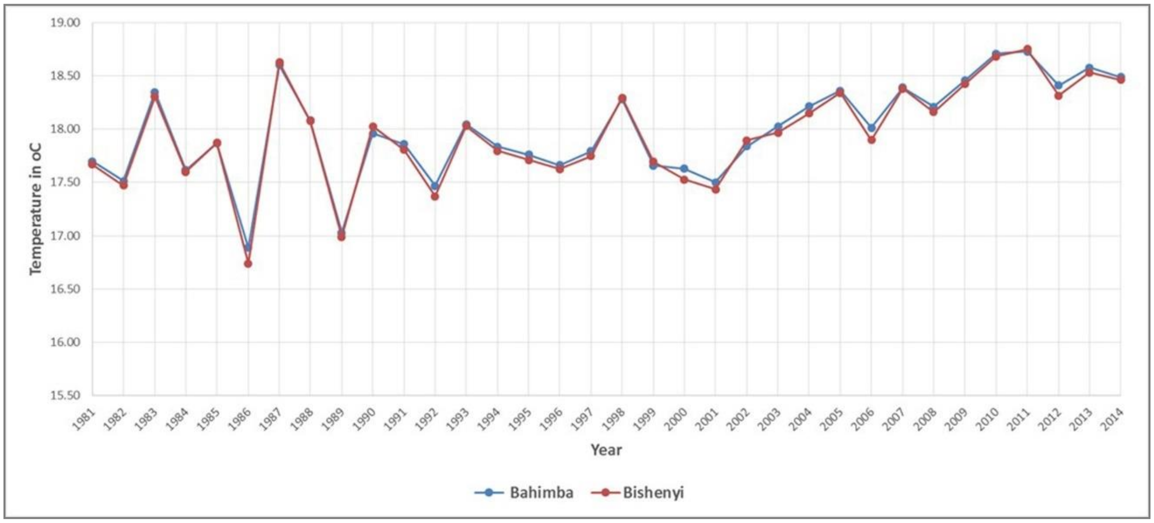

Figure 6: Trend of Temperature for Bahimba and Bishenyi Wetlands (1981 – 2014) (Source: RMA, 2015)

Rainfall Change for Bahimba and Bishenyi Wetlands

The location of the Country in the equatorial region has resulted in a humid climate all over the year with an average annual average rainfall of approximately 1,250 mm. Bahimba wetland located in the northern highlands of the country receives more rain than Bishenyi welands which is located in the central plateaus (Figure 6). The higher amount of rainfall in Bahimba wetlands has been associated with floods that caused more crop losses compared to Bishenyi.

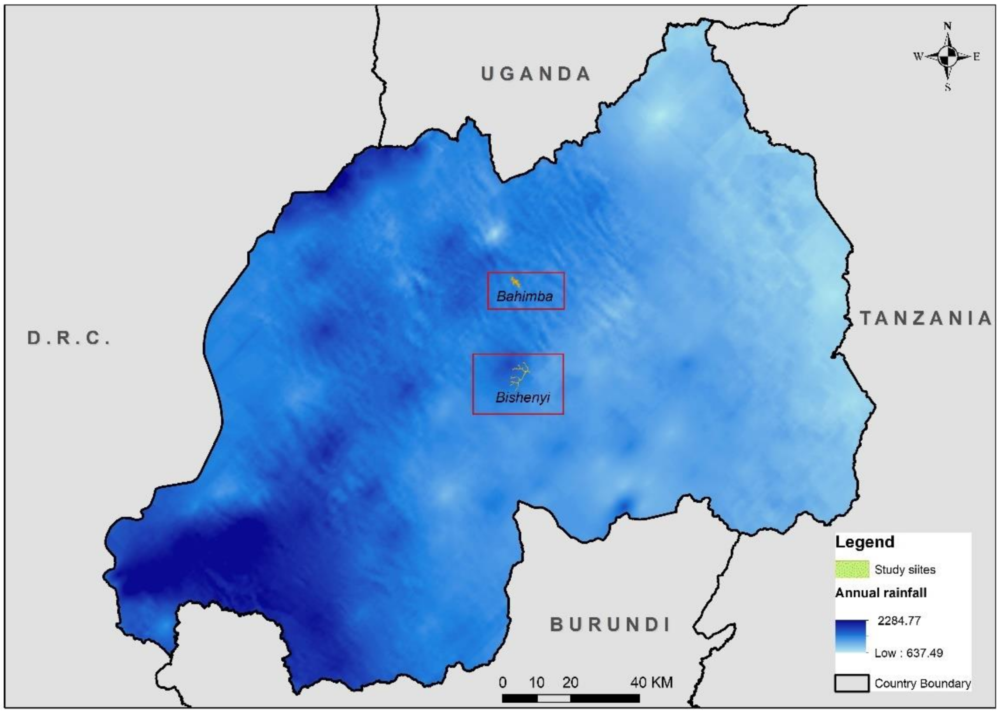

Figure 7: Annual Rainfall in Rwanda (Source: RMA, 2017)

The analysis indicates abnormal rainfall fluctuations where decreases of 114.9 mm (from 992.2 mm to 877.3 mm) and 42.3 mm (from 909.4 mm to 867.1mm) occurred in Bahimba and Bishenyi respectively between 1981 and 2014 (Figure 7). The decrease in rainfall in both wetlands is also associated with seasonal variabilities that have led to extreme climatic conditions such as droughts and floods. For example, extended dry spells were observed especially in Bishenyi wetland in 2013 and 2014 and in Bahimba in 2015. The farming season A (2015-2016) in Bahimba wetland was characterized by early cessation of rainy season which had with no doubt a big impact on both the crop yield and welfare of neighboring population.

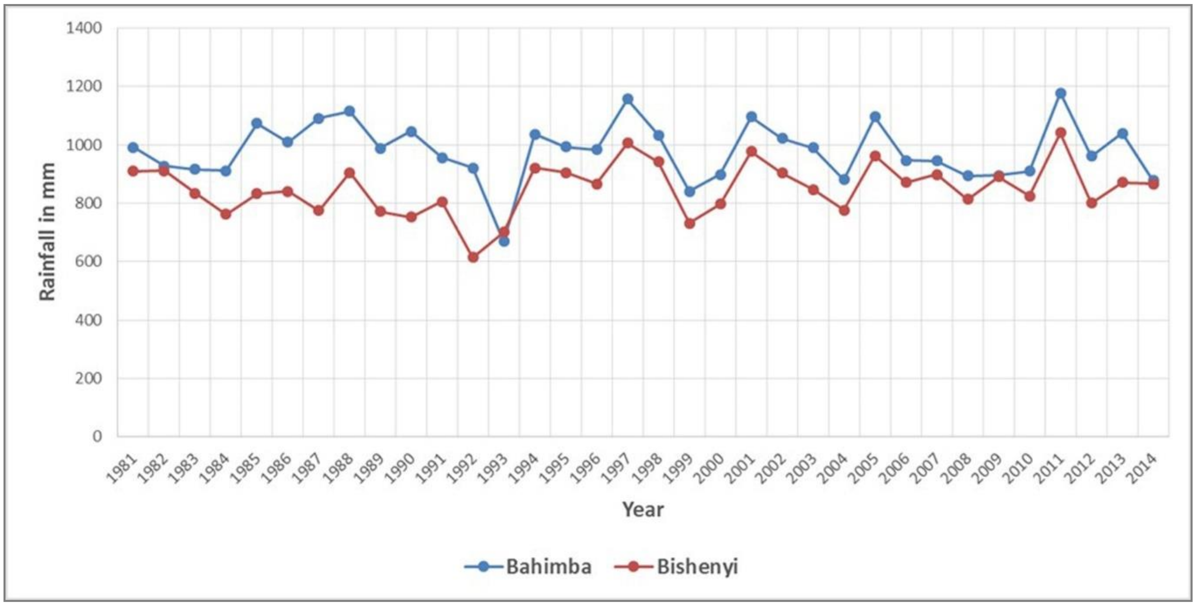

Figure 8: Trend of Rainfall in Bishenyi and Bahimba Wetlands (1981 – 2014) (Source: RMA, 2015)

Seasonal Variability

The country has four seasons: short rainy season (September-December), short dry season (January-February), long rainy season (March-May) and long dry season (June-August) as highlighted by Figure 8. Rwanda has also experienced effects of seasonal variability resulting in a growing number of disasters in recent decades, especially droughts in the central plateaus and the eastern lowlands and, floods and landslides in the Northern and Western highlands that occurred in 1988, 1989, 2000, 2005-2006, 2010, 2011 and 2014 (MIDIMAR 2015).

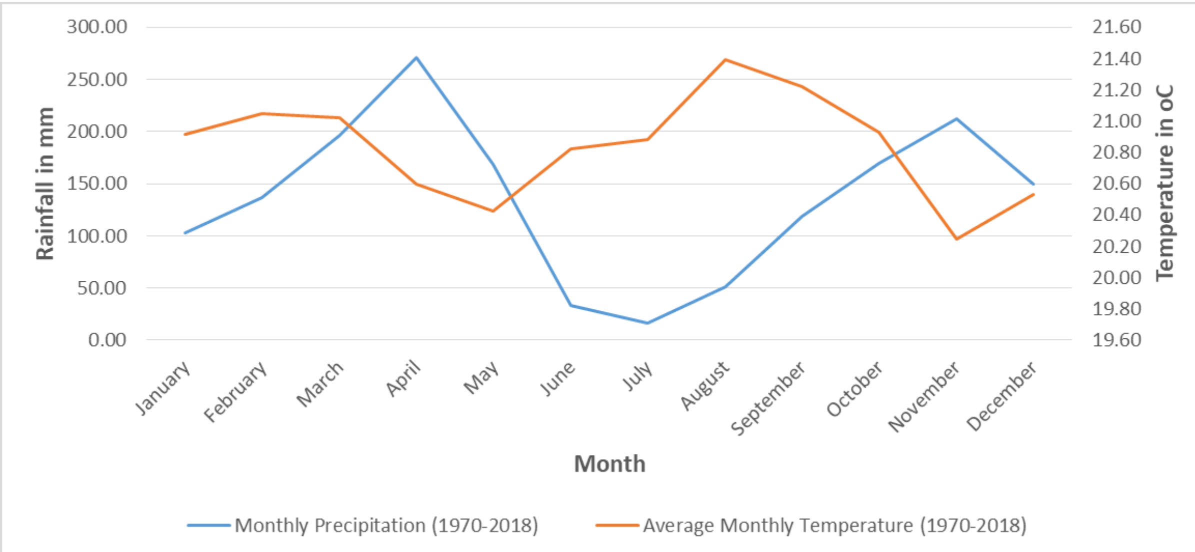

Figure 9: Trends of Monthly Rainfall and Average Temperature in Rwanda between 1970 and 2018 (Source: RMA, 2018)

Maize Farmers' Perceptions about Climate Change and Variability

Maize farmers in Bahimba and Bishenyi wetlands have been experiencing climate change and variability. Results from maize farmers' survey, interviews and group discussion revealed that there have been climate change and seasonal variability since 1981 which were manifested by different indicators especially erratic rainfall, delay of rainy season, prolonged drought, dry up of rivers, warmer weather and high temperature, heavy rains, outflow of rivers and floods. Erratic rainfall, delay of rainy season, prolonged drought, dry up of rivers, warmer weather and high temperature have been experienced by the majority (>80%) of maize farmers in both Bahimba and Bishenyi (Figure 9).

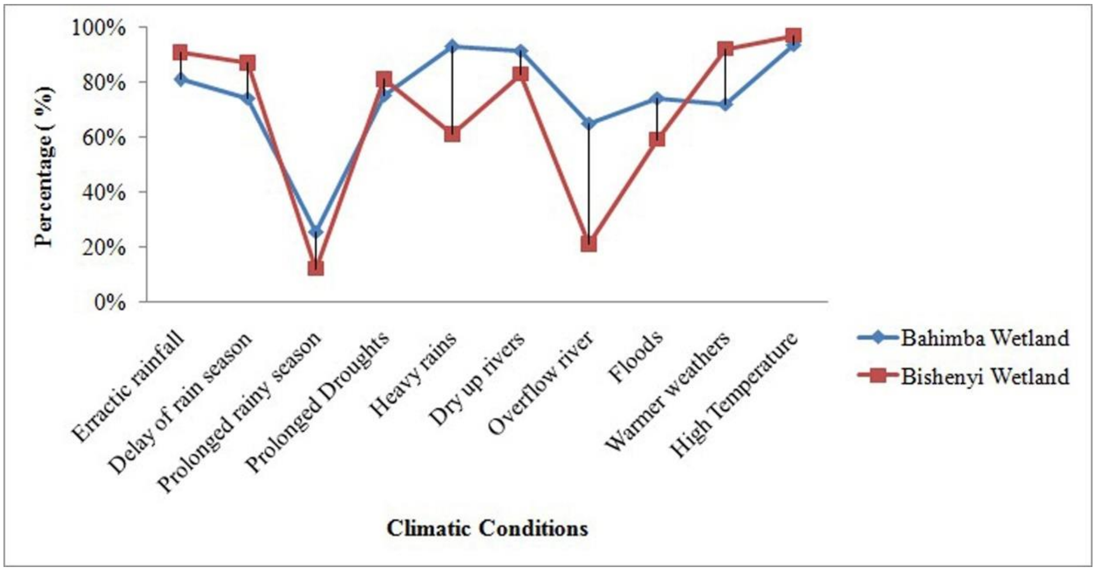

Figure 10: Farmers' Views on Climatic Conditions in Bahimba and Bishenyi Wetlands (Source: Field Work, May 2016)

Impacts of Climate Change and Variability on Maize Production

Analysis of maize yields data for the past 5 years showed an overall reduction (Table 1). For the season A (2014/2015), farmers in Bahimba had experienced poor germination due to early cessation of rainfall and had to redo seeding that had caused a reduction of maize yields by 17% in 2015. In Bishenyi wetland, maize yield per hectare had reduced by 41 % in 2013 and 51% in 2014 due to extended dry spells. On the hand, the maize yields in Bishenyi wetland increased by 77% due to favorable climate conditions in 2012 while for Bahimba it increased by 10%, 27% and 7% in 2012, 2013 and 2016 respectively.

Table 1: Trend of Maize Yields (in tons/ha) in the Last Five Years (2011-2015) in Bahimba and Bishenyi wetlands

Year	Bahimba Wetland	Bishenyi Wetland
2011	1.17	1.58
2012	1.29	2.59
2013	1.64	1.54
2014	1.75	1.65
2015	1.46	2.41

Source: Field Work (May 2016)

Effects of Climate Change and Variability on Food Security

According to maize farmers from both wetlands, the abnormal changes in temperature and rainfall patterns have led to poor harvests and therefore, food insecurity not only for maize farmers but the entire community surrounding the surveyed wetlands. Results revealed that when maize harvests were reduced, food security was adversely affected within households. The majority of farmers in both Bahimba and Bishenyi wetlands had a reduced quality and quantity of meals per day. The same food insecurity was justified by an increased food prices at markets and rate of robbery of food and livestock in the community (Table 2). For Bishenyi maize farmers, the situation of food security is a bit better due to the fact that Bishenyi wetland is located nearby the City of Kigali where farmers can get more off-farm activities.

Table 2: Indicators of Food Insecurity among Maize Farmers

Effects	Farmers in Bahimba (%)	Farmers in Bishenyi (%)
Reduced Number of Meals per Day	95	52
Reduced Quantity of Meals	97	96
Poor Quality of Meals	81	82
Increased Family Conflicts due to Food Shortage	14	16
Increased Cases of Malnutrition	20	61
High Robbery of Food and Livestock	72	19
Rural Exodus	7	65
High Prices of Food at Markets	97	65

Source: Field Work (May 2016)

Discussion

Temperature Change for Bahimba and Bishenyi Wetlands

The current study found that in Bishenyi wetland, the temperature increased by 1.1°C while temperature in Bahimba wetland increased by 0.85°C (Figure 4). The increase in mean annual temperature in Bishenyi wetland is due to its location in central plateaus which is characterized by higher temperature than the Northern highlands of Rwanda (MIDIMAR 2015). Indeed, the central plateaus of Rwanda are characterized by more droughts frequencies than the Northern highlands (Bizoza & Graaff, 2012). These mean temperature increases confirm climate change and variability in Bahimba and Bishenyi wetlands as compared to the Global mean temperature increase (0.850C between 1980 and 2012) as indicated by IPCC (2014). Therefore, Bahimba and Bishenyi wetlands have been affected by climate change and its adverse impacts on maize yield and food security over the last 30 years (Nabahungu & Visser 2011; Rwanyiziri & Rugema, 2013). The increase in temperature puts the study areas and the whole country in an alarming situation of climate change as the mean temperature has increased by +0.85°C (IPCC, 2014 & De Groote et al. 2016).

Rainfall Change for Bahimba and Bishenyi Wetlands

The current study showed a rainfall variation with decreases of 114.9 mm (from 992.2 mm to 877.3 mm) and 42.3 mm (from 909.4 mm to 867.1mm) that occurred in Bahimba and Bishenyi respectively between 1981 and 2014 (Figure 5). The differences in rainfall in the two wetlands are associated with their locations (MIDIMAR 2015). Bahimba wetland is located in the Northern part of Rwanda which receives rainfall almost through the whole year while Bishenyi is located in the central plateaus which have been experiencing rain shortage and seasonal variability over years as highlighted by Figure 5 (MIDIMAR 2015, Nabahungu & Visser, 2011; Rwanyiziri & Rugema, 2013).

In conformity with RMA (2010) and Rwanyiziri & Rugema (2013), the fluctuation characterized by an overall decrease in the country has resulted in poor performance of agriculture and therefore, food insecurity in Rwanda. In addition, the fact that rain shortage is associated with seasonal irregularities, heavy rains and associated extreme events such as floods and landslides, are also among big challenges that farmers in the study area especially Bahimba wetland, the country and the whole region, have been facing (Ballantine et al. 2017; Beuel et al. 2016; Chen & Wong, 2016; Leauthaud et al. 2013; Nabahungu & Visser, 2011; Namaalwa et al. 2013).

Maize Farmers' Perceptions about Climate Change and Variability

Apart from poor rainfall and increase in temperature, maize farmers from both wetlands had also faced challenges of extended dry spells and floods events (Figure 9). Group discussion with farmers, key informants and agronomists converged their views on the reduction of maize yields as a consequence of late sets of rainy seasons, erratic rainfall, floods, droughts, water shortage and increased warmer weathers (MINAGRI 2009; Mutuyimana, 2015, Nabahungu & Visser, 2011). The same seasonal irregularities were associated with pests and crop diseases mainly maize streak virus, cornstalk borer, leaf blight, rust and worms, among others (MIDIMAR, 2015). The findings of this study showed that famers in Bishenyi are more vulnerable to erratic rainfall and droughts while farmers in Bahimba are more vulnerable to heavy rains and floods. These disparities are due to the fact that Bahimba is located in highlands part of Rwanda where heavier rainfall and floods are more frequent than in central plateaus of the country where Bishenyi wetland is located. As a result of abnormal changes in rainfall maize harvests and food security were adversely affected.

Effects of Climate Change and Variability on Maize production

During the past 5 years, maize yield in both areas has been characterized by instability with some years of increase and decrease as highlighted by Table 1. The instability in maize yield was due to seasonal variability which were characterized by early cessation of rain like the case of Bahimba in season A (2014/2015). Dry spells have also been the cause of decrease of maize yield in Bishenyi wetland in 2013. However, maize yield has increased whenever climatic conditions have been favorable. The findings of this study reflected MIDIMAR (2015) that suggested a decrease of crop yield in various areas of Rwanda due to seasonal irregularities. In fact, seasonal irregularities are associated with extreme events which have direct and indirect impacts on crop yield (FAO 2013b; MIDIMAR 2015; MINAGRI 2009; Mutuyimana, 2015; Nahayo et al. 2017; Rwanyiziri & Rugema, 2013). The situation could be aggravated and lead to poor performance of agriculture and therefore, food insecurity not only among local farmers but also in the whole country (Leauthaud et al. 2013; Nhamo et al. 2014; Rwanyiziri & Rugema, 2013; Webber et al. 2014).

Impacts of Climate Change and Variability on Food Security

Despite the advance in agricultural intensification technologies, climate change and variability have been considered as the main causes of food insecurity all over the World (UNFCCC 2007). The research findings of current study also confirmed the same hypothesis. In fact, maize farmers in Bahimba and Bishenyi wetlands have been facing food insecurity characterized mainly by reduced number of meals per day, reduced quantity of meals, poor quality of meals, increased family conflicts due to food shortage, increased cases of malnutrition, high robbery of food and livestock, rural exodus and high prices of food at markets (Table 2). Indicators of food insecurity were the same as suggested by Musumari et al. (2015). Food insecurity in Sub Saharan Africa, has always been associated with increase of prices, insufficiency of food and low proteins which is mostly manifested by an increase of malnourished people especially vulnerable groups such as children, HIV positive people and women (Ashley, 2016; Musumari et al. 2015; Paul et al. 2017; Pritchard, 2013).

Conclusion

The evaluation of climatic variables using merged station satellite data revealed a steady increase in mean temperature for both Bahimba and Bishenyi wetlands between 1981 and 2014. The same analysis showed a decline in the amount of annual rainfall for both Bahimba and Bishenyi wetlands. The instabilities in rainfall and temperature patterns have been also mentioned by the local maize farmers, who mainly depended on rain-fed agriculture, as the main cause of decline of maize yield in both Bahimba and Bishenyi wetlands. Seasonal variability characterized especially by variation in rainfall patterns has been reversing the time for planting, germination and crop growth until ripening. High temperatures were considered favorable to higher proliferation of diseases and pests.

Despite the advance in agriculture technologies in the study sites, the current study showed a decline in maize yield which was mostly attributed to extreme weather conditions, especially erratic rains and dry spells. The decline of maize yield in the study area was associated with food insecurity characterized mainly by poor quality, small quantity of food and therefore, malnutrition.

Even though other factors such as adequate fertilizer, improved seeds, timely planting and weeding, and pesticides can be equally dependable for a good harvest, it has been found that seasonal stability is a key factor. Therefore, increased support on adaptation and resilience strategies including watersheds management, new drought resistant and early maturing maize varieties, community food reserves, savings and credits groups, improved irrigation infrastructures, diversified income sources and improved maize value chain are vital for sustainable maize production and for improved food security.

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