

Accepted Manuscript

Climate trends, risks and coping strategies in smallholder farming systems in Uganda

Drake N. Mubiru, Maren Radeny, Florence B. Kyazze, Ahamada Zziwa, James Lwasa, James Kinyangi, Catherine Mungai

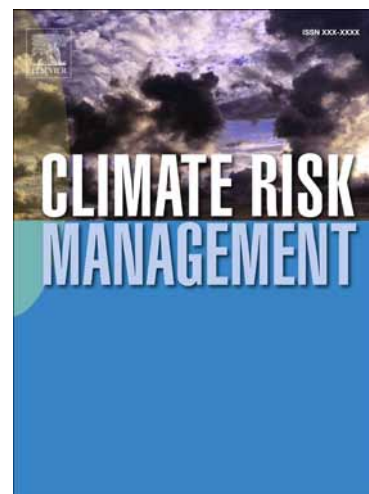
PII: S2212-0963(16)30082-1
DOI: <https://doi.org/10.1016/j.crm.2018.08.004>
Reference: CRM 166

To appear in: *Climate Risk Management*

Received Date: 11 October 2016
Revised Date: 3 August 2018
Accepted Date: 16 August 2018

Please cite this article as: D.N. Mubiru, M. Radeny, F.B. Kyazze, A. Zziwa, J. Lwasa, J. Kinyangi, C. Mungai, Climate trends, risks and coping strategies in smallholder farming systems in Uganda, *Climate Risk Management* (2018), doi: <https://doi.org/10.1016/j.crm.2018.08.004>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.



Climate trends, risks and coping strategies in smallholder farming systems in Uganda

Drake N. Mubiru^a, Maren Radeny^{b,*}, Florence B. Kyazze^c Ahamada Zziwa^d, James Lwasa^a,

James Kinyangi^e and Catherine Mungai^b

^aSoils, Environment and Agro-meteorology Unit, National Agricultural Research Laboratories (NARL) – Kawanda, National Agricultural Research Organization (NARO), Kampala, Uganda.

^bCGIAR Research Program on Climate Change, Agriculture and Food Security Program (CCAFS), International Livestock Research Institute (ILRI), Nairobi, Kenya.

^cDepartment of Extension and Innovation Studies, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.

^dDepartment of Agricultural and Bio-systems Engineering, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.

^eAfrican Development Bank, Avenue Joseph Anoma, 01 BP 1387 Abidjan 01 Côte d'Ivoire.

*Corresponding Author: Maren Radeny, CGIAR Research Program on Climate Change, Agriculture and Food Security Program (CCAFS), International Livestock Research Institute (ILRI). P.O. Box 30709–00100, Nairobi, Kenya.

(Email: m.radeny@cgiar.org)

Abstract

Smallholder farmers in Uganda face a wide range of agricultural production risks. Climate change and variability present new risks and vulnerabilities. Climate related risks such as prolonged dry seasons are becoming more frequent and intense with negative impacts on agricultural livelihoods and food security. This paper examines farmers' perceptions of climate change, climate-related risks affecting crop and livestock production, including climate-risk management and adaptation strategies. Drought, increasing disease and pest incidences, decreasing water sources, lack of pasture, bush fires, hailstorms, changes in crop flowering and fruiting times were the major climate-related risks reported. In order to cope with climate change and climate variability, farmers use a wide range of agricultural technologies and strategies. Mulching, intercropping and planting of food security crops were among the most commonly used practices. Other strategies included water harvesting (mainly for domestic consumption), other soil and water conservation technologies and on-farm diversification. Farmers often use a combination of these technologies and practices to enhance agricultural productivity. Average maximum temperatures increased across the two sites. Trends in average annual rainfall showed mixed results, where a general decline was observed in one district and a relatively stable trend in the other district. Perceived changes in climate included erratic rainfall onset and cessation (which were either early or late), poor seasonal distribution of rainfall and little rainfall. In addition, farmers reported variations in temperatures. Farmers' perception of changing rainfall

characteristics and increasing temperatures were consistent with observed historical climatic trends based on meteorological data.

Keywords

Agriculture; climate risks; livelihoods; vulnerabilities; coping strategies; Uganda

ACCEPTED MANUSCRIPT

1. Introduction

Smallholder farmers across East Africa face a wide range of agricultural production risks, with climate change and variability presenting new risks and vulnerabilities. While the Regional Climate Models (RCMs) agree that the region will become warmer, the degree of warming predicted is quite variable. Rainfall is projected to increase in the region, extending into the Horn of Africa, is robust across RCMs, with 18 of 21 models projecting an increase in the core of this region, east of the Great Lakes (Christensen et al., 2007). Other projections indicate widespread and potentially devastating changes in frequency, intensity, distribution and predictability of rainfall.

The expected impacts of climate change in East Africa include an increase in frequency and severity of droughts leading to water stress and severe water shortages, floods in some areas, increased incidence of pests and diseases, and decline in crop yields with potentially widespread food shortages. Other potential impacts include changes in planting dates for annual crops, occurrence and intensity of crop, livestock and human disease outbreaks, and decline in biodiversity. Already, the impacts of climate change are manifested in East Africa with devastating effects. The severe drought in 2010–2011 in the Greater Horn of Africa, for example, affected nearly nine million people mainly in Somalia, Kenya and Ethiopia (WFP, 2011). The impacts of climate change and variability in East Africa are likely to be compounded by existing

development challenges of high population growth rates, high and increasing poverty levels, low per capita incomes, high levels of inequality and declining GDP growth rates, among others.

In Uganda, a large proportion of the population depends on agriculture for their livelihood. At national level, agriculture contributes up to 25% of the GDP and supports about 72% of the working population (UBOS, 2017). Agricultural production in Uganda is almost entirely rain-fed (GOU 2007, Komutunga and Musiitwa 2001) and therefore marked by seasonality and negatively affected by extreme weather conditions. The farming systems are diverse, ranging from livestock-based systems in semi-arid regions to mixed crop-livestock systems in temperate and humid regions. While the immediate impacts of climate change on overall agricultural production in Uganda are likely to be less severe as compared to other countries in East Africa (van de Steeg et al., 2009), the local impacts are expected to vary by farming system.

Smallholder farmers in Uganda are increasingly facing a wide range of agricultural production risks—climate and non-climate related risks. For instance, low productivity can be attributed to non-climatic factors such as limited use of external inputs or nutrient mining and soil erosion, as well as climate-related droughts, and pests and diseases. In recent years, weather patterns have become more erratic, impacting negatively on soil moisture content leading to either reduced yields or total crop failure (Mubiru et al., 2012; Mubiru et al., 2009). Rainfall patterns are highly variable, both within and between seasons. These changes are closely

associated with climate change and variability. Variable onset and cessation of rainfall makes it difficult for farmers to plan for key activities such as timely planting of crops, leading to frequent crop failures and posing significant threats to food security and livelihoods. Moreover, these problems are compounded by limited provision of precise weather information in Uganda (Anderson and Robinson, 2009), thus making smallholder farming a risky business (Mubiru et al., 2012).

In order to reduce vulnerability to climate variability and change there is need for innovative approaches for managing climate risks while also helping farmers to adapt to climate change. Therefore, it is important to first understand how farmers perceive climate change at the local scale, including historical or observed weather trends. Previous studies have documented that farmers perceive climate to have changed in the last twenty years (Osbaahr et al., 2011; Mubiru et al., 2009). Indeed, farmers in East Africa have developed a number of local coping strategies through indigenous knowledge to improve their resilience and adaptive capacity. Traditional coping strategies do provide important lessons on how local communities can better prepare and adapt to climate change in the long-term. However, local coping strategies are often not documented but rather handed down through oral history and local expertise (Mary and Majule, 2009). Besides, the increasing climate variability, frequency and more severe shocks are likely to surpass traditional coping strategies. Moreover, some of these local coping strategies can only be helpful in the short-term (Boko et al., 2007; Orindi and Murray, 2005). There is a need

therefore to understand, document and strengthen these existing coping strategies. Local coping strategies to shocks such as drought and floods differ among households and communities depending on the farming system or agro-ecological system, resources available and social capacity. Farmers use a wide range of agricultural technologies and strategies to cope with climate variability and adapt to climate change. Moreover, adaptation has the potential to contribute to reductions in negative impacts from changes in climatic conditions as well as other changing socio-economic conditions (Adger et al., 2003).

In rural Uganda, farming communities and households have developed several adaptation options to cope with current climate variability over the years (DanChurchAid, 2010; Anderson and Robinson, 2009). Traditional methods of grain storage, for example, are widely used to cope with periods of hunger and to secure seed for successive crops following severe droughts. However, such methods were less effective during periods of disease and pest attack and sometimes resulted in total losses of food and seed. Thus communities and households are continuously learning to adjust to changing conditions by adapting to new practices to control grain and seed borne pests and diseases. Some of these changes to local practices are marginal rather than transformational in nature. Kristjanson et al. (2012) find little uptake of improved soil, water and land management practices, even when these were often cited to have great potential to contribute to improved food security (see www.actionaid.org; Majaliwa et al., 2009). The capacity of indigenous knowledge and traditional coping practices in adapting to climate

change and variability is likely to be surpassed by the magnitude of changes expected from increased risk exposure.

In order to develop effective strategies for managing and coping with extreme weather and climate variability, farmers need to differentiate climate-related risks from other agricultural production risks. Better understanding of climate-related risks, as well as their impacts on crop and livestock production forms the basis for continuous learning and selection of farmer innovations that are likely to enhance adaptive capacity. This paper examines farmers' perceptions of climate change, climate-related risks affecting crop and livestock production, including climate-risk management and adaptation strategies.

2. Methods

Description of study sites

The paper builds on a previous baseline study carried out by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in 2011 in two rural districts of Rakai and Hoima in Uganda (Fig. 1). The results from the baseline study indicated that farmers were grappling with impacts of climate change, and making changes to their farming activities innovative strategies to deal with the risks were purposely selected (Mubiru and Kristjanson, 2012; Kyazze and Kristjanson, 2011). In addition, the two districts were considered on the premise that they represent diverse agro-ecological, production, social and institutional settings and are representative of East African farming systems (perennial, annual and pastoral).

Majority of households in these districts depend on rain-fed agriculture for their livelihoods, with over 85% of the people engaged in subsistence crop (maize, beans, bananas) and livestock (cattle, goat, sheep, chicken) production. While the overall poverty levels—proportion of individuals estimated to be living below the poverty line—have significantly declined in Uganda over the last five years, poverty incidence in the rural areas remain high at 27.2% (UNHS 2010). In the two districts, poverty levels range from 11.2% in Rakai to 25.3% in Hoima in comparison to the national average of 24.5% (UNHS, 2010).

Rakai District is located in the south-central region of Uganda, west of Lake Victoria and covers an area of 4,909 km² with an estimated population of 252,600 (UBOS, 2017). The rainfall pattern is bimodal, spread over two growing seasons (March–May and September–December). Average annual rainfall ranges from 915 to 1,021 mm, while the temperature ranges from 12.5 to 30°C (GOU, 2004). The district also experiences severe dry spells in the periods June–August and January–February.

Hoima District is located in western Uganda, east of Lake Albert. The altitude ranges from 621 and 1,158 m above sea level and has some of the lowest and hottest areas in the country. The district occupies an area of 5,933 km², with an estimated population of 642,400 (UBOS 2017). In contrast to Rakai, about 38% of the total area is occupied by water bodies (mostly Lake Albert) and 21% is forested. Average annual rainfall is about 1,270 mm with high spatial variability, ranging from about 800 to 1,400 mm (GOU, 2004). Rainfall distribution is bimodal.

The main rainy season is from August–November and the secondary season is from March–May (GOU, 2004). Temperatures are usually high ranging from 15 to 30°C.

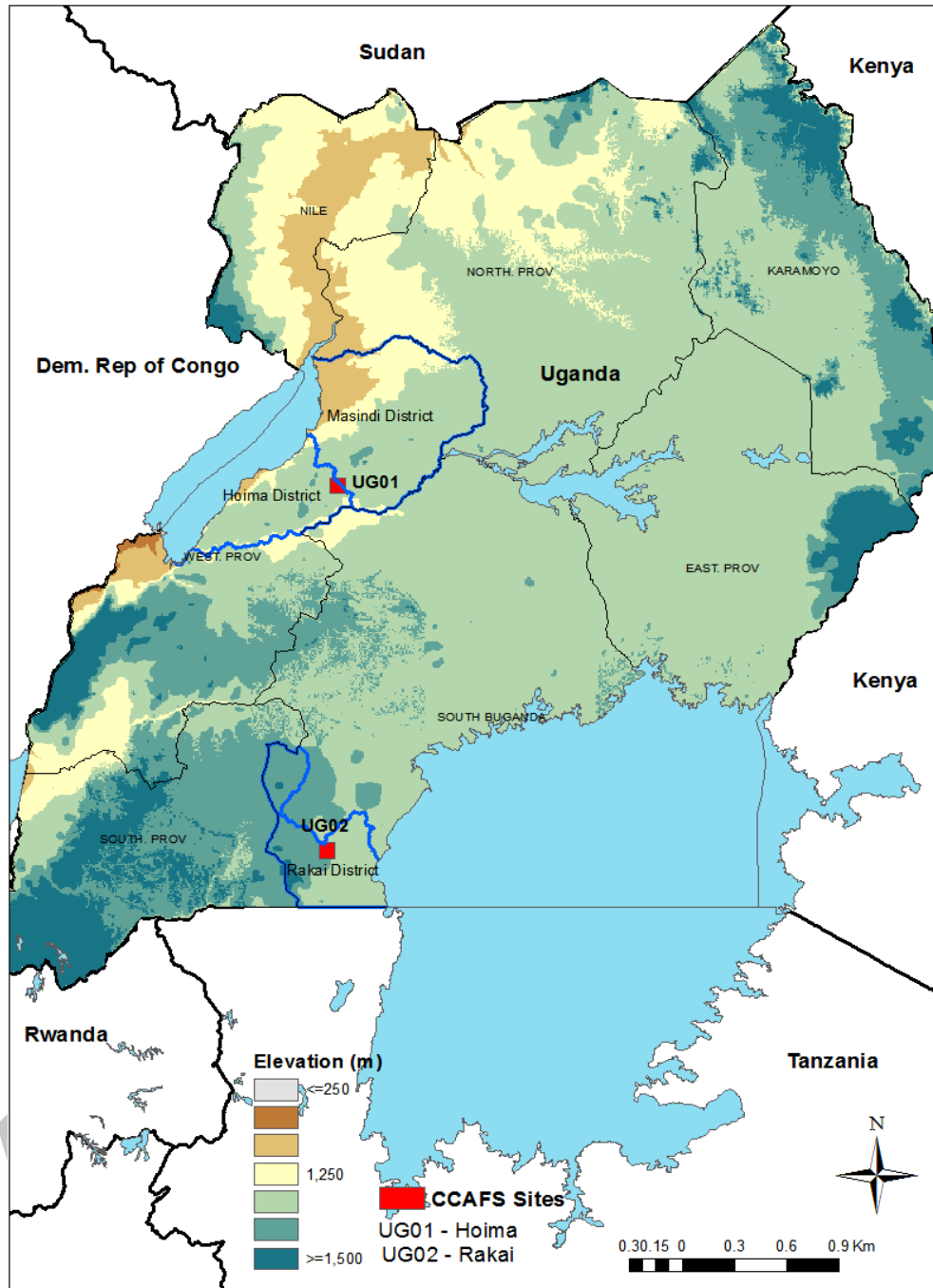


Fig. 1. Map of Uganda showing Hoima and Rakai districts

Data collection and analytical methods

To address the objectives of the study, different methods were used to generate different

but complimentary types of data and information. Primary data were collected through household surveys and with focus group discussions (FGDs), and secondary data were from historical climate datasets over the period 1939–2012. The household surveys were designed to build on initial baseline surveys conducted CCAFS 2010 (Mubiru and Kristjanson, 2012; Kyazze and Kristjanson, 2011). In each district, the household surveys were carried out in three villages, purposively selected to represent the CCAFS blocks. In each village, households were randomly selected from a complete list of all households in the village which had been generated earlier and used in the CCAFS baseline surveys. Data were collected from 120 households in total (60 from each district). The household survey was designed to collect information on demographics, wealth indicators, livelihood, a land-use patterns, farmers' perceptions of climate change, major climate-related risks affecting agricultural production, and scalable innovative strategies for coping with and adapting to climate-related risks.

Historical rainfall and temperature datasets from 1938 to 2012 were obtained from weather stations close to the two sites (Kyotera and Kibanda in Rakai, and Bulindi in Hoima). The FGDs with mixed groups of men and women (42% men and 58% women) were used to triangulate the historical and survey data. The survey data were analyzed in Statistical Package for Social Sciences (SPSS) using descriptive statistics (means and percentages). Qualitative data from the FGDs were presented by matrices, trends, rankings and context/content diagramming techniques. A time-series trend analysis was constructed using the GenStat Discovery Version 3

for daily rainfall and temperature. The trend lines were fitted using linear regression models with the GenStat statistical package.

3. Results and discussion

Demographic and livelihood characteristics

Households had varying demographic characteristics (Table 1). Majority of the respondents were male, with more than three-quarters of the households across the two districts were headed by men. Education levels are relatively low, nearly 80% of the household heads had attained primary level of education, with very few household heads having attained tertiary education. Age of the household head varied from a mean age of 44 years for Rakai and 47 for Hoima. Average family size ranged from seven persons in Hoima to eight persons in Rakai compared to the national average of 4.7 (UBOS, 2014).

Table 1
Demographic characteristics

Demographic characteristics	Hoima	Rakai
<i>Gender of respondent (%)</i>		
Male	56.7	65
Female	43.3	35
<i>Household type (%)</i>		
Male headed	76.7	81.7
Female headed	23.3	18.3
<i>Education level (%)</i>		
None	15.0	13.3
Primary	70.0	48.3

Secondary	10.0	31.7
Tertiary	5.0	6.7
<i>Mean household size</i>		
Persons in household	6.82	8.20
Young dependents (<15 years)	1.93	3.04
People of working age (15 to 64 years)	1.79	1.76
Old dependents (>64 years)	0.37	0.12
Dependency ratio	1.3	1.8
Age of household head (years)	47.0	44.0

The dependency ratio was relatively high, and ranged from 1.3 in Hoima to 1.8 in Rakai. In 2009/2010, the national dependency ratio (young and old) in the population in rural areas was estimated to be 1.26 (UNHS, 2010), translating to 126 dependents for every 100 persons in the working age group. High dependency ratio slows productivity and economic growth, and also increases socioeconomic vulnerability. Table 2 summarizes the household wealth indicators, based on type of housing land ownership, mode of transportation and group membership. Across the two districts, more than three-quarters of the households had iron-roofed houses. However, the proportion of households (48.3%) with houses with walls made of mud and wattle was relatively high in Hoima compared to Rakai where at least 80% of the households had houses with walls made of bricks. Average land size ranged from 4.3 acres in Rakai to 5.4 acres in Hoima, and is comparable to the national average land holdings of 5 acres (Kisamba-Mugerwa, 2001). In both districts, bicycles were the most common mode of transport. Membership to a group is perceived as social capital More households in Rakai than Hoima belonged to a farmer group.

Table 2

Wealth indicators

Wealth indicators	Hoima	Rakai
<i>Type of wall for main house (%)</i>		
Mud and wattle	48.3	16.7
Wood panel	5.0	3.3
Bricks	46.7	80.0
<i>Type of roof for main house (%)</i>		
Grass thatched	21.7	1.7
Iron roofed	78.3	98.3
<i>Mode of transportation to market (%)</i>		
Own bicycle	70.2	53.3
Own motorcycle	10.5	11.7
Hired motorcycle	24.6	40.0
Own truck	7.0	5.0
Walk/Pedestal	54.4	65.0
Group membership (%)	15.0	55.0
Average land owned (acres)	4.3	5.4

Wood et al. (2014) found that house-hold and agricultural production-related assets are negatively related to farm changes. They concluded that farmers with fewer assets may be more vulnerable and therefore more likely to make on-farm changes to mitigate risk. However, they also found that farmers with more assets were more significantly inclined to adopt several practices that require access to capital e.g. labour, improved seed, investment in land management.

Crop and livestock production were the predominant livelihood activities across the two sites.

Table 3 shows land allocation to different crop and livestock enterprises by the farmers, with

similarities in the types of crops grown across the two districts. Significant changes in land use are predicted among the farming communities in East and Central Africa (ECA) due to climate change and other drivers, including increasing populations (van de Steeg et al., 2009). More than half of the land is allocated to crop production compared to livestock production (Fig. 2).

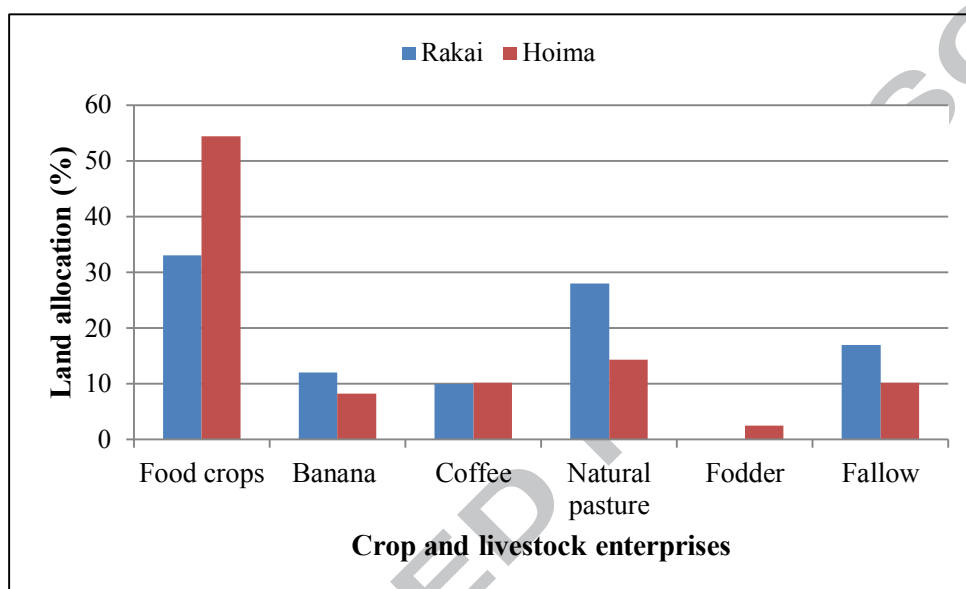


Fig. 2. Land allocation to different enterprises

Banana and coffee were the most important crops in Rakai, allocated the largest acreage of approximately one acre. These two crops are usually intercropped and farmers attach a lot of social and economic value to them. In contrast, maize, potatoes, and coffee were the most important crops in Hoima. These three crops were allocated the largest acreage, attributed to their economic and food security contributions in the site. There was increased allocation of land to seasonal crops such as beans, cassava and sweet potatoes in both sites. Beans and sweet potatoes are early maturing crops whereas cassava is more drought-tolerant and performs well in times of reduced rainfall as has been the case due to climate variability and change. This implies that

farmers are adapting to climate change by spreading the risk through planting early maturing crops e.g. beans and sweet potatoes and drought-tolerant crops like cassava.

Table 3

Land allocation to crop and livestock enterprises

Agricultural enterprise	Mean acreage per household	
	Rakai	Hoima
<i>Crops</i>		
Bananas	1.2	0.8
Beans	0.7	0.7
Maize	0.7	1.1
Cassava	0.4	0.8
Sweet Potatoes	0.5	0.7
Potatoes	0.7	1.2
Coffee	1.0	1.0
Groundnuts	0.3	0.8
<i>Livestock</i>		
Natural pasture	2.8	1.4
Fodder	-	0.25
Fallow	1.7	1.0

Cassava, maize, sweet potatoes and sorghum are important crops in ECA, closely followed by rice, banana (or plantain), potatoes and beans (van de Steeg et al., 2009). Each of these crops is affected differently by climate variability and will be affected differently by climate change. In Uganda, maize, cassava and sweet potatoes are grown in areas that are projected to experience moderate losses due to climate change by 2050. In order to prevent these losses there is need to

introduce alternative crop varieties and crop substitution, as well as a change in livestock feeding practices.

Livestock production is also an important source of livelihood. Cattle, goats, pigs and poultry were among the livestock species kept by the household (Table 4), with no differences observed in average livestock holdings across the two sites.

Table 4

Average livestock holdings per household

Type of livestock	Average number of livestock per household	
	Rakai	Hoima
Cattle	3	5
Goats	4	3
Pigs	3	2
Chickens	10	10

Farmers' perceptions and knowledge of climate change

Global weather and climate patterns have changed and will continue to change. How are these changes perceived, interpreted and expressed by local farmers in Uganda? Are farmers' perceptions of climate change at the local scale consistent with historical or observed trends in rainfall and temperature patterns? In this section explores farmers' perceptions of climate change and the major climate-related risks over the past 30 years and how these perceptions relate to the observed trends in rainfall and temperature.

Respondents were asked whether they had noted any changes in weather patterns over

the last 5 to 30 years. Majority of the respondents reported changes in the weather patterns. Farmers' perceptions of rainfall onset and cessation, amount and distribution of rainfall, and temperature across the two districts are shown in Figs. 3 to 7. Perceived changes in weather patterns included erratic rainfall onset and cessation, which was described as either early or late; poor rainfall seasonal distribution; and little rainfall. Majority of the respondents (55%) across the two sites reported late onset of rain. On average, 40% reported variable onset of rain (oscillating from early, normal or late). Overall, less than 10% of the farmers reported early and normal onset of rains. Okonya et al. (2013) found that farmer perception of climate change was influenced by the agro-ecological zone, with the proportion of households reporting late onset of rains (47%) nearly equal to those reporting early onset across six agro-ecological zones in Uganda. The six agro-ecological zones included the Northern farming system, South Western Highlands, Western Rangelands, Lake Albert Crescent, East Savannah and Lake Victoria Crescent. Farmers' perceptions of rainfall cessation were categorized as early, normal and late. There were, however, mixed perceptions of rainfall cessation across the two sites. Majority of respondents (81.6%) in Rakai reported early rainfall cessation compared to 35% in Hoima. In contrast, majority of the respondents (41.7%) in Hoima reported late cessation relative to 15.3% in Rakai. Late onset of rainfall coupled with early cessation, as reported by majority of the respondent in Rakai leads to a shorter growing season. This coupled with the increasing mid-season droughts (Table 5), increases the risks in smallholder farming.

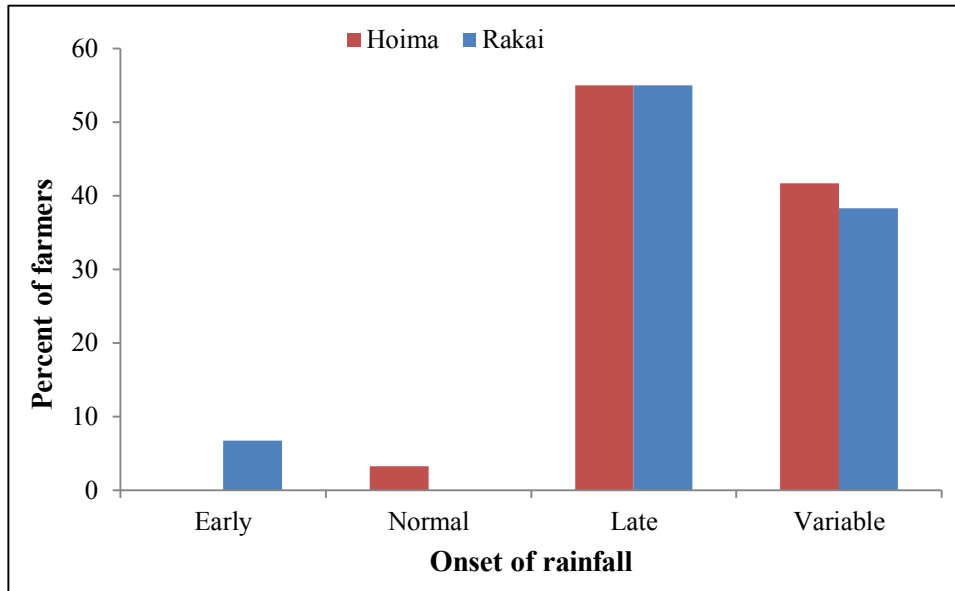


Fig. 3. Rainfall onset

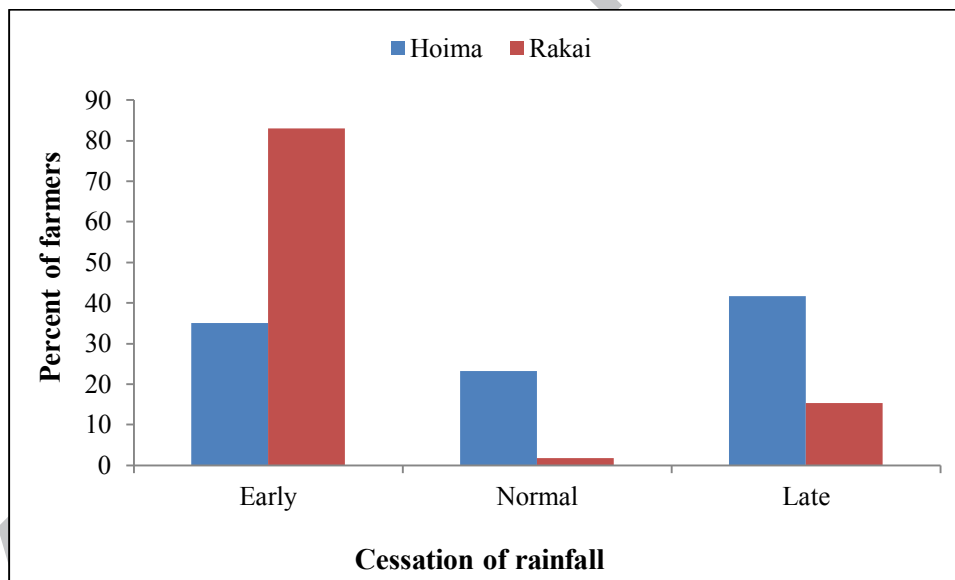


Fig. 4. Rainfall cessation

Farmers' perceptions of seasonal distribution of rainfall were divided into five categories: normal, more in first season, more in second season, mid-season droughts, and variable (Fig. 5).

Majority of respondents, on average 45% reported variable distribution of rainfall, that is, either

normal, more in first or second season. This was followed by mid-season droughts, averaging 24.2%. A smaller proportion reported a normal rainfall pattern.

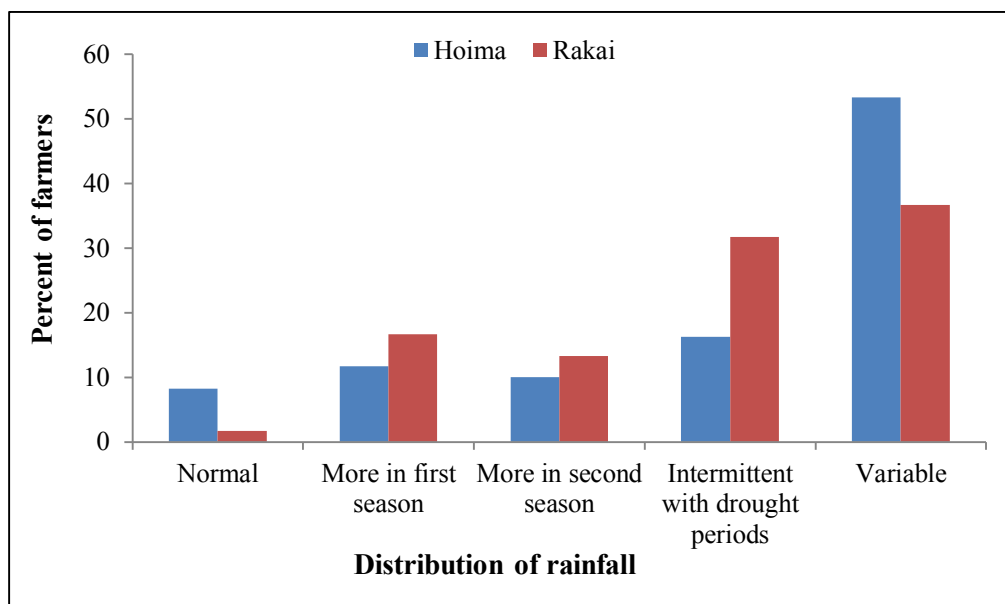


Fig. 5. Seasonal distribution of rainfall

The onset and cessation of rainfall also influences perceived characterization of the amount of rainfall received. Over 85% of the respondents across the two sites reported changes in the rainfall amount that is either, less, high or variable (Fig. 6). There were, however, differences in the perceived changes across the sites. While majority of respondents in Hoima (51.7%) reported that the rainfall was variable, in Rakai the majority of respondents (56.7%) reported that the rainfall amount was less. Apparently, from the farmers' perceptions, the two sites receive quite different amounts of rainfall, with Hoima receiving relatively more rainfall than Rakai. As mentioned previously, Rakai is characterized by low rainfall and low agricultural potential.

Changes in precipitation—onset or cessation, intensity, length of rainy and growing seasons— affect crop production depending on their timing and magnitude. Production uncertainty associated with between and within-season rainfall variability remains a fundamental production constraint (van de Steeg, 2009).

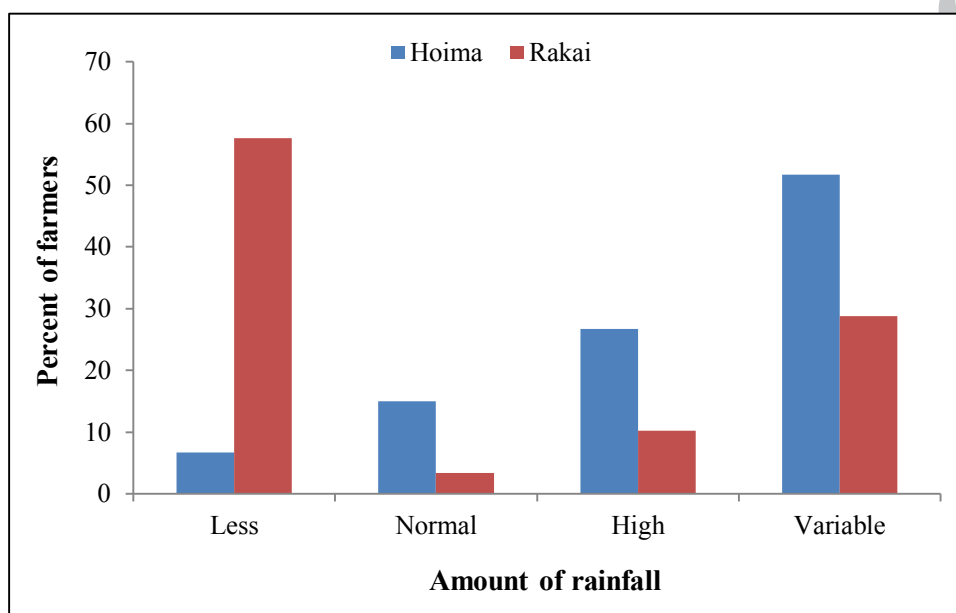


Fig. 6. Rainfall amount

Similarly, farmers reported variations in temperatures. Farmers' perceptions of changes in temperature were grouped into four categories: lower, moderate, higher, and variable (Fig. 7). A clear difference in perception across the two sites is evident, with majority of respondents in Rakai (78.3%) reporting an increase in temperature. In Hoima, the proportion of respondents (43.3%) reporting moderate and higher temperatures was equal. These findings on perceived changes in temperature are consistent with those of Okonya et al. (2013) where majority of the farmers (39%) across six agro-ecological zones in Uganda reported an increase in temperature

over the last 10 years. However, while perceptions in temperature changes across the two sites slightly differ, average maximum temperature at both sites is 30°C (GOU, 2004). The differences in perceptions of temperature changes across the two sites could be explained by the differences between evaporation and rainfall during the dry months. In Rakai, evaporation exceeds rainfall by a factor of six during the dry months, whereas in Hoima it is by a factor of only five (GOU, 2004).

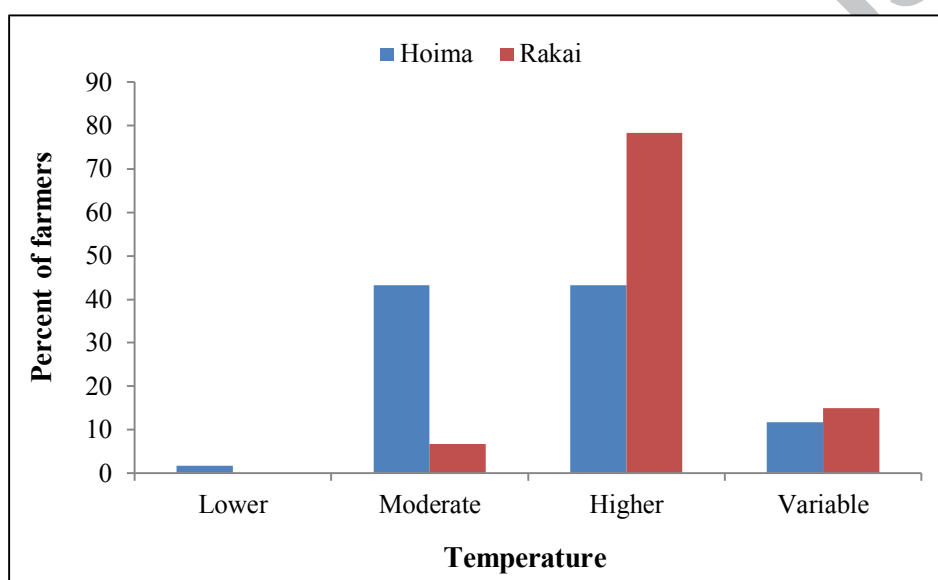


Fig. 7. Changes in temperature

Rainfall and temperature trends

As discussed previously, historical rainfall and temperature data were analyzed, including variability in Rakai and Hoima over the period 1938–2012. Average monthly rainfall data shows that both districts experience a bi-modal distribution within the year (Figs. 8 and 9). Peak rainfall seasons are between March–May and August–November in Hoima. Rakai has similar rainfall patterns to Hoima, although with a slight difference, where peak rainfall seasons are between

March–May and October–December. January, February and December are fairly dry months in Hoima. February, June, July and August are also fairly dry months in Rakai. The sharp peak in the March–May rainy season at both sites means that rains are more likely to come and disappear quickly during the first season. The distribution of rainfall is more even in the second season, and the length of the growing period seems to be longer in the second season across the two sites as well.

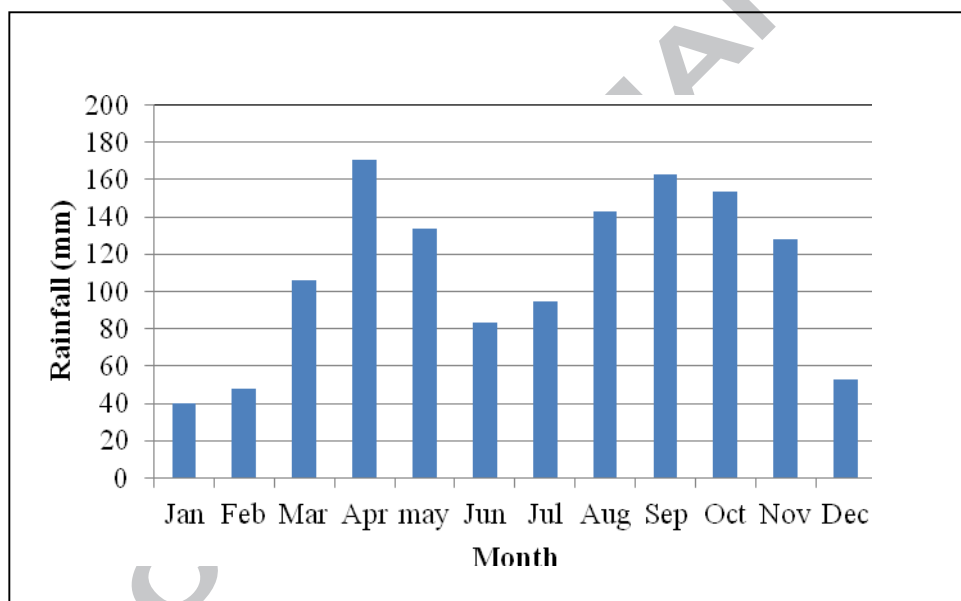


Fig. 8. Distribution of average monthly rainfall from 1938–2012 at Bulindi in Hoima District

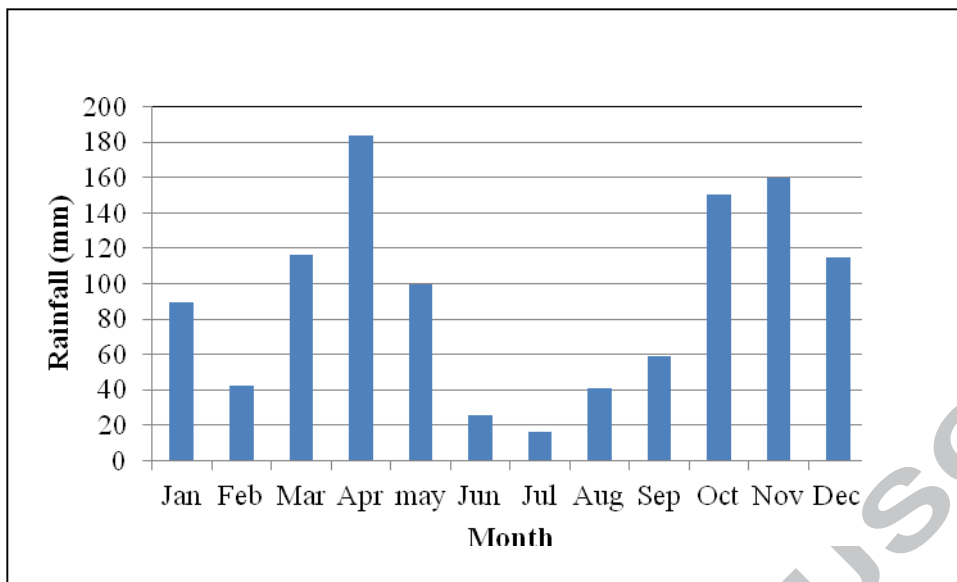


Fig. 9. Distribution of average monthly rainfall from 1998–2007 at Kyotera in Rakai District

Trends in average annual rainfall are shown in Figs. 10 and 11. Fig. 10 shows a general declining trend in annual rainfall at Bulindi in Hoima. The results for Kyotera in Rakai show a relatively stable average annual rainfall trend (Fig. 11). Total monthly rainfall over the years reveals a declining trend in monthly rainfall for all the months except January, March and August at Bulindi in Hoima District (Fig. 12). At Kyotera in Rakai, all the months with the exception of June, July, November and December reveal a declining trend in monthly rainfall (Fig. 13).

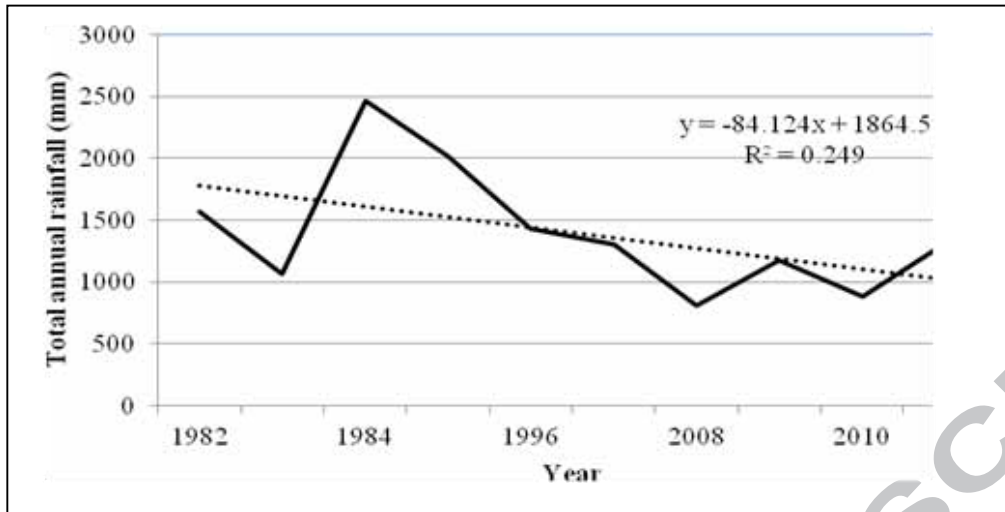


Fig. 10. Average total annual rainfall trend at Bulindi in Hoima District

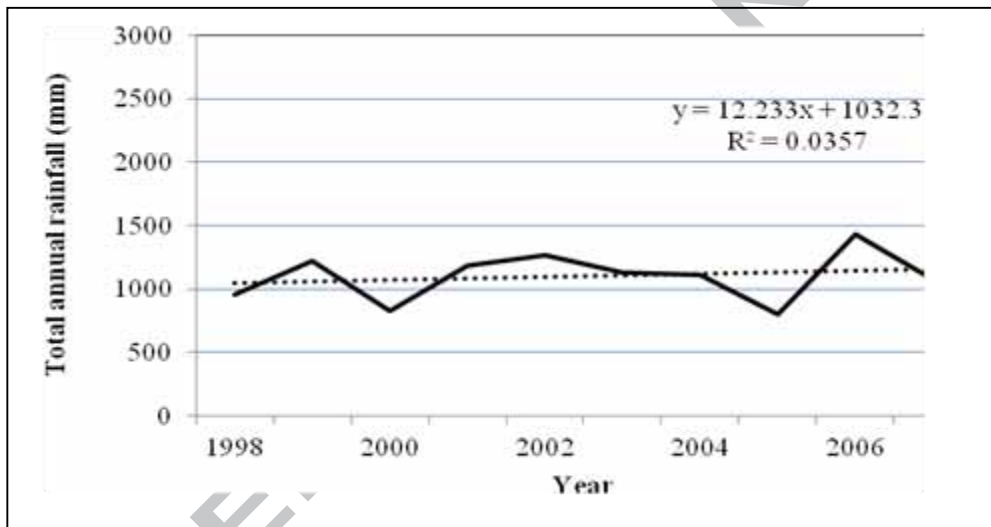


Fig. 11. Average total annual rainfall trend at Kyotera in Rakai District

At Bulindi, the number of rainy days shows a decreasing trend for the months of February, May, June, August and October (Fig. 14), while the others either have a stable trend (July) or an increasing trend. At Kyotera, there was a decreasing trend in the number of rainy days for all months except June, July and November (Fig. 15).

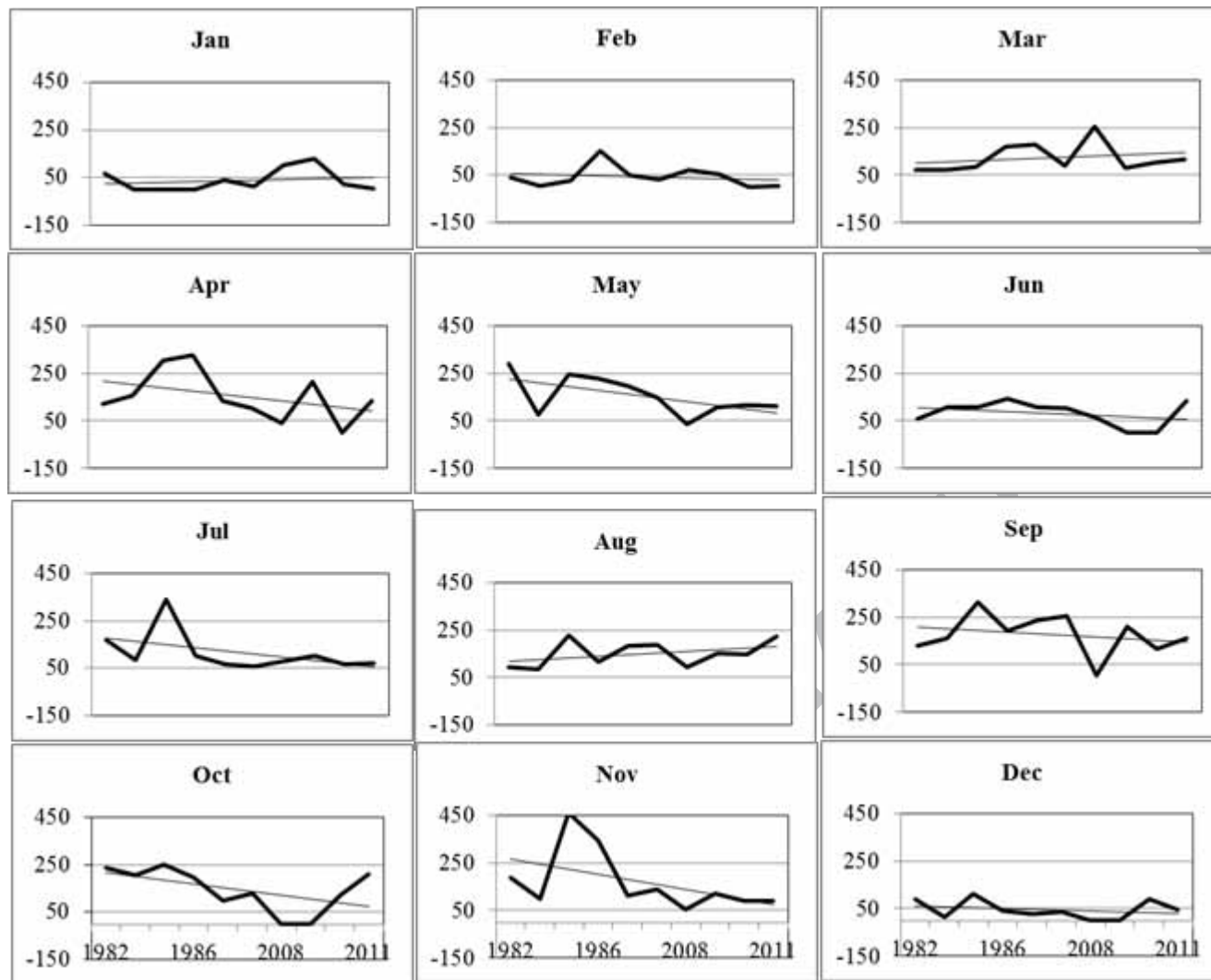


Fig. 12. Trend in monthly rainfall amount from 1982-2011 at Bulindi in Hoima District

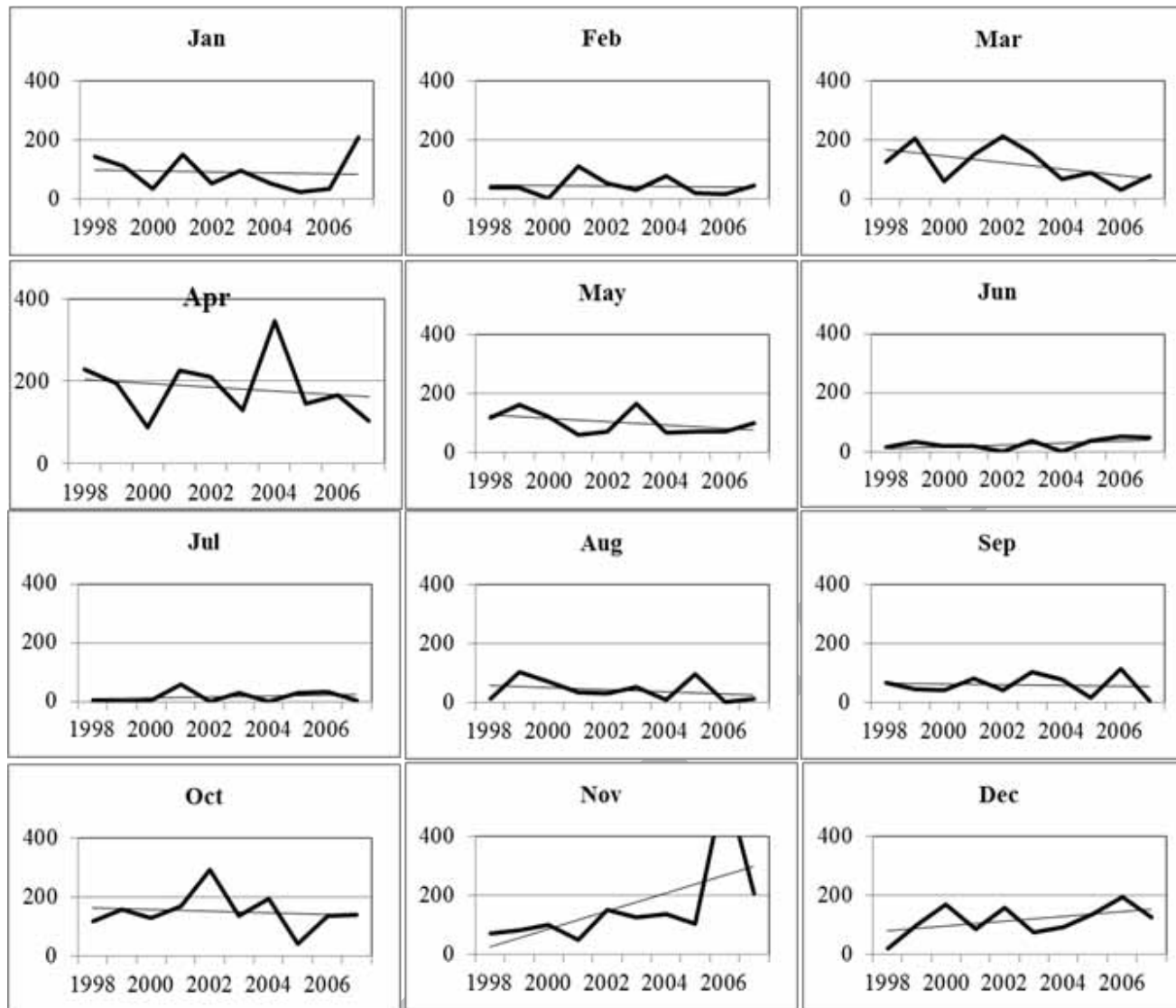


Fig. 13. Trend in monthly rainfall amount from 1998-2007 at Kyotera, Rakai District

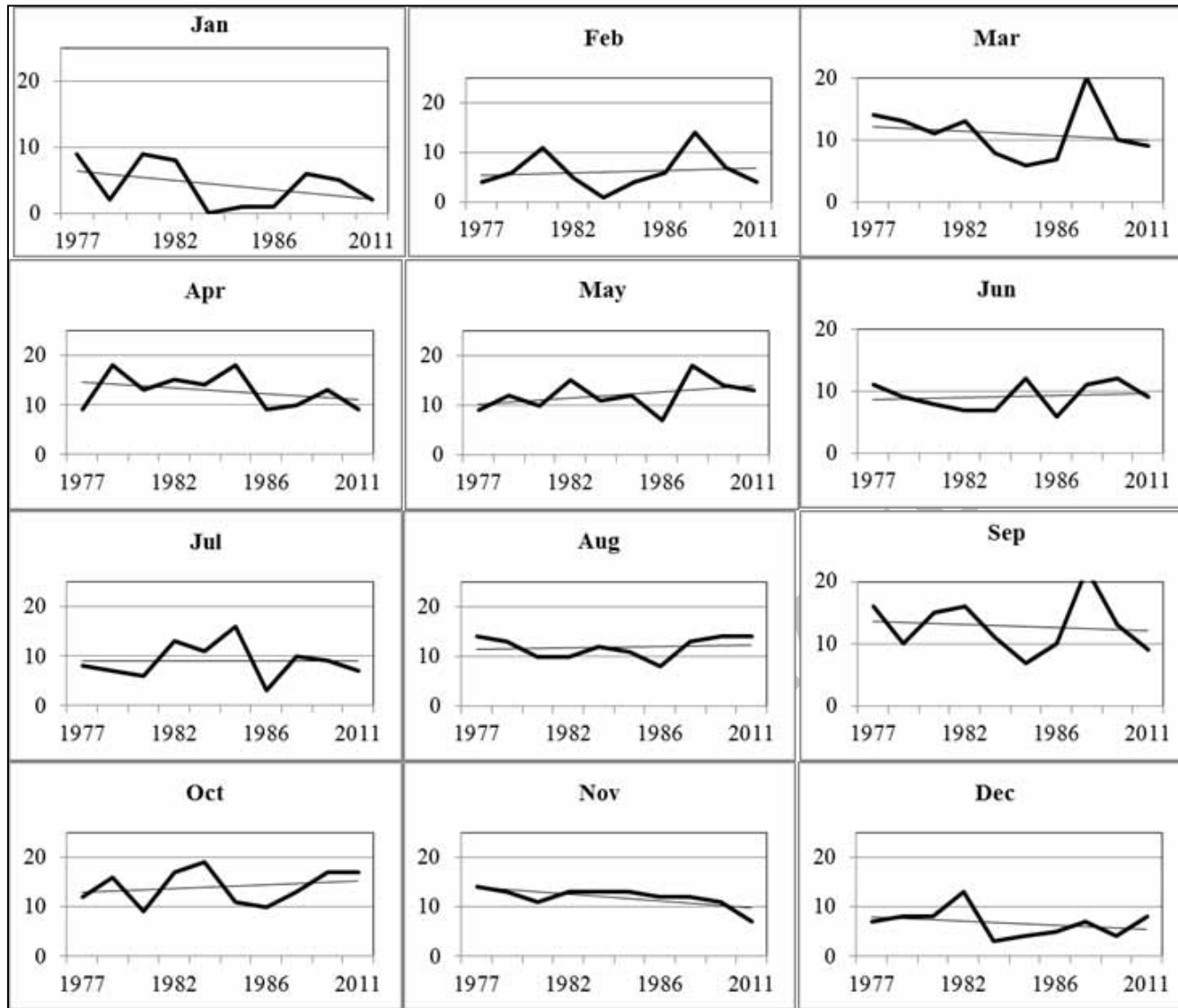


Fig. 14. Trends in number of rainy days from 1977-2011 at Bulindi in Hoima District

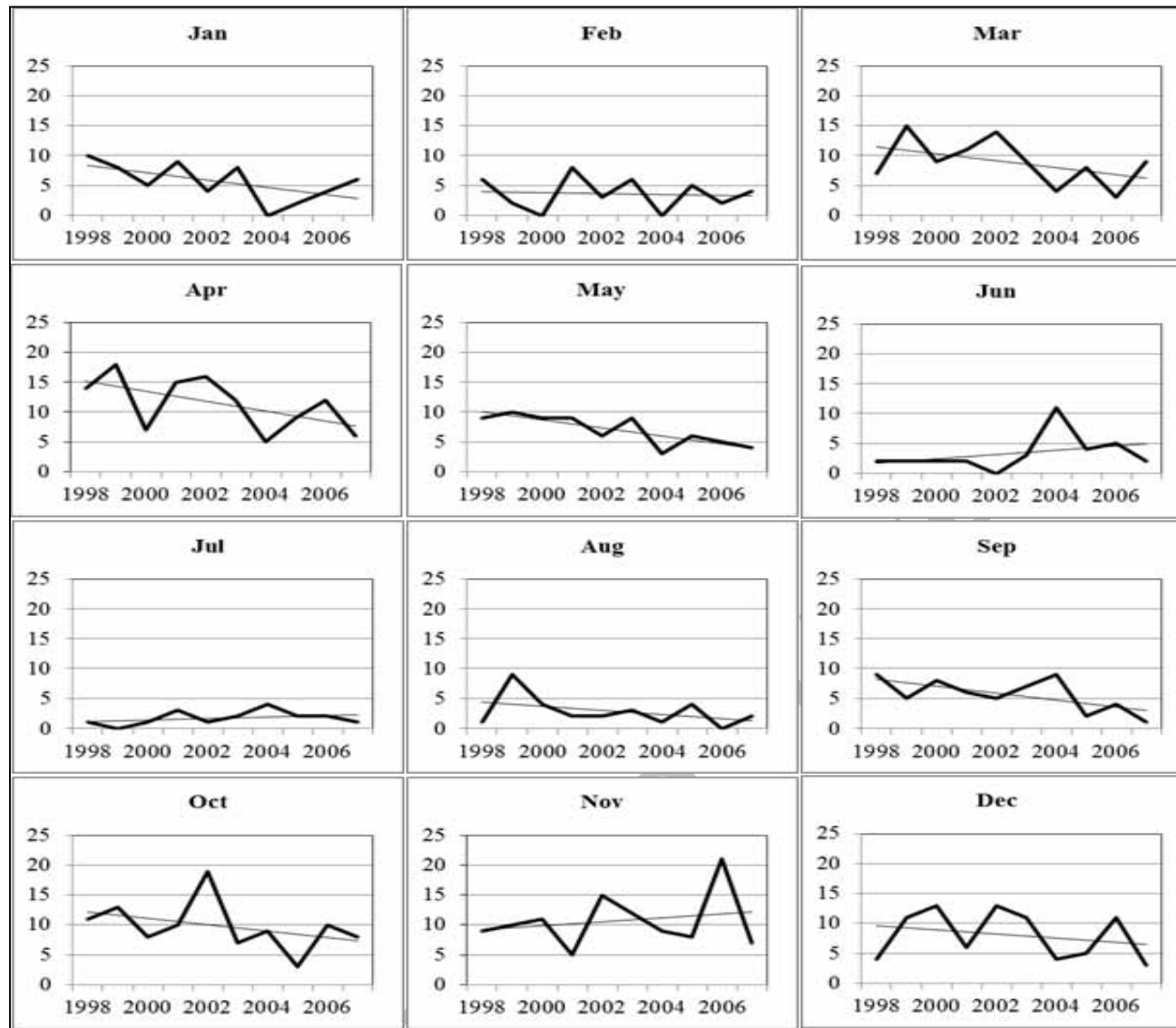


Fig. 15. Trends in number of rainy days from 1998-2007 at Kyotera in Rakai District

Jennings and Magrath (2009) observed that within recognizable seasons, unusual and unseasonable events are occurring more frequently. For example, heavy rains occurring in dry seasons, dry spell in rainy seasons and storms at unusual times. The changes in monthly rainfall and rainy days have significant impact on farm level activities across the entire value chain, ranging from pre-production, production, post-harvest and marketing. During the production stage the changes are more pronounced if these spikes of moisture stress occur at the critical biological stages.

Trends in average annual maximum and minimum temperatures from 2007–2012 are shown in Figs. 16 and 17. There has been an increase in the average maximum temperatures across the two sites. Although Rakai is located in the dry-lands (commonly referred to as the cattle corridor) the mean maximum temperature on average is 2.7°C lower than in Hoima. As earlier stated, due to its geographical location, Hoima is one of the hottest areas in Uganda. Between 2007 and 2012, the average maximum temperature increased by 0.8°C in Hoima and by 0.5°C in Rakai. The increase in temperatures is consistent with historical trends in mean temperature for East Africa. During the last century, Africa as a continent has had a decadal warming of about 0.05°C with slightly larger warming in the June-November seasons than in December-May (Hulme et al., 2001).

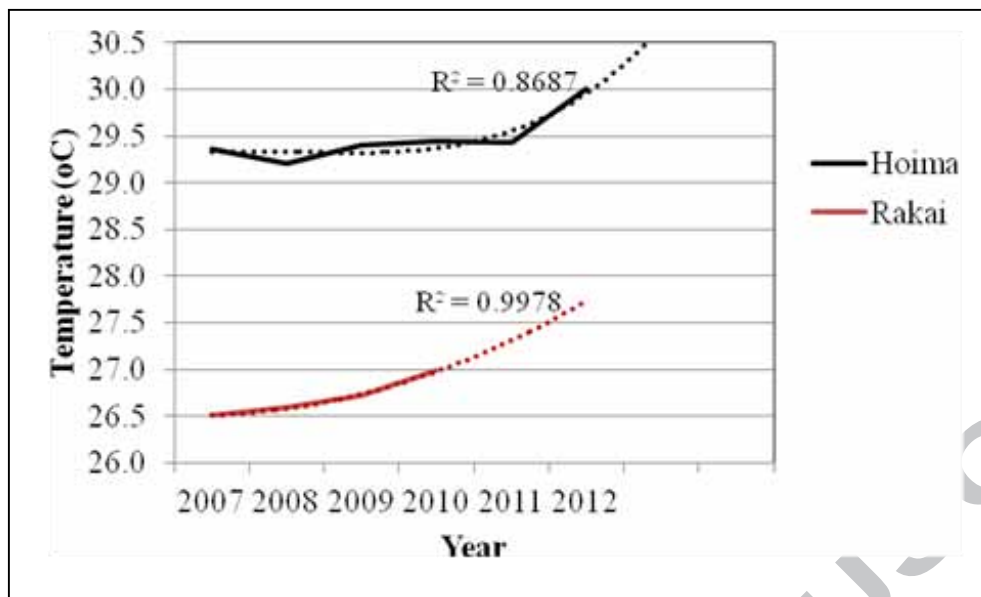


Fig. 16. Trends in average annual maximum temperatures at Hoima (Bulindi) and Rakai (Kyotera) from 2007-2012

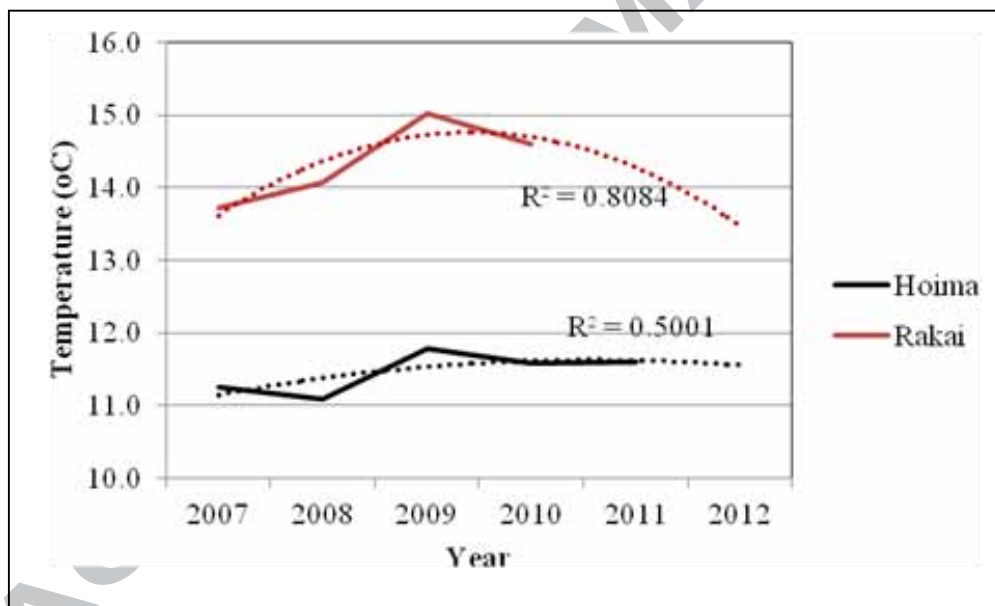


Fig. 17. Trends in average annual minimum temperatures in Hoima (Bulindi) and Rakai (Kyotera) from 2007-2012

While the average maximum temperatures at both sites show a quadratic increasing trend, the average minimum temperatures show quadratic declining trends. Although Hoima had higher

average maximum temperature, it had a lower average minimum temperature. Other studies have reported that the global mean temperature has increased in a linear trend of 0.74°C over the last 100 years (Schneider et al. 2007). Increase in temperature may influence the length of the growing season, especially in temperate regions. Higher temperatures also increase the atmospheric demand for moisture, or potential evapotranspiration (PET). In areas where average annual maximum temperature will increase from under 30°C to over 30°C, rice and maize yields and other staple crop yields will suffer (Ziervogel and Ericksen 2010). Grazing resources, food safety and disease transmission patterns are also likely to be affected.

Overall, the farmers' perceptions of changing rainfall patterns and increasing temperatures across the two sites are consistent with the observed historical trends from historical climate data. The declining trends of monthly rainfall amounts and rainy days are manifested in the farmers' perceptions of abnormal rainfall onset, amount and cessation, and the increasing mid-season droughts. These findings are also consistent with a similar study in Tanzania (Mary and Majule, 2009), where the local perceptions by farmers of changes in temperature and increasing rainfall variability were closely related with empirical analysis of rainfall and temperature trends using meteorological data.

Climate-related risks and impacts on crop and livestock production

Farmers in Hoima and Rakai have experienced major climate-related risks, that threaten current and future agricultural production. The various risks and their level of importance or prevalence are summarized in Figs. 18 and 19 (proportion of households reporting the risk). In Hoima, the five most important climate-related risks included drought, disease and pest epidemics

(for crops and livestock), hailstorms, lack of pasture and bush fires. Similarly, drought, disease and pest epidemics were emerged among the five most important risks reported for Rakai. Other climate-related risks in Rakai included decreasing water sources, lack of pasture and changes in crop flowering and fruiting times.

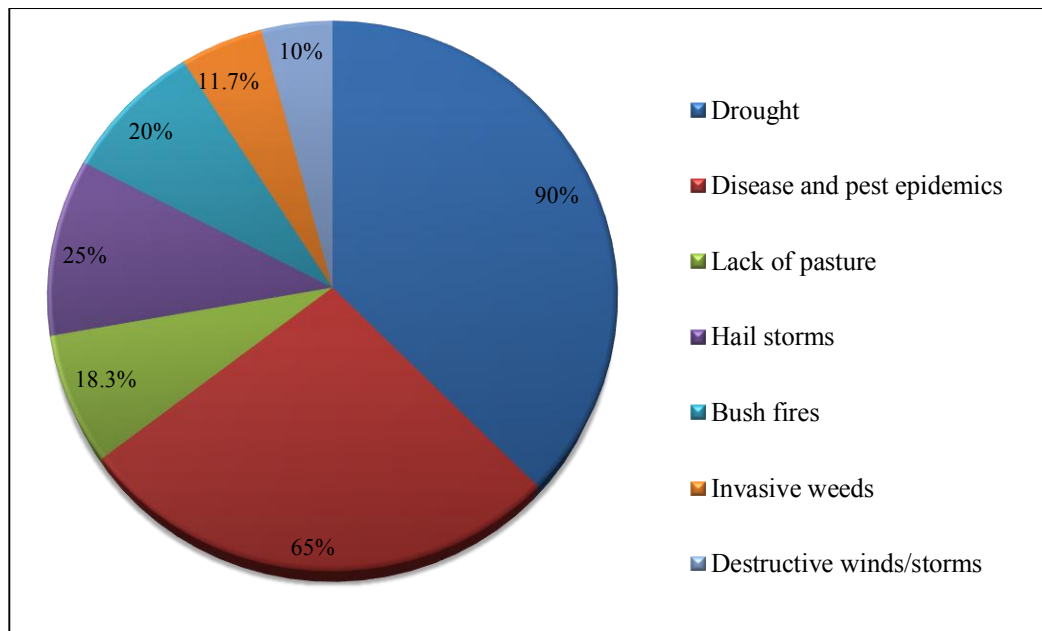


Fig. 8. Climate-related risks in Hoima District

Drought, diseases and pests were the most severe climate-related risks in both sites, with 90% of the respondents reporting drought in both site. Disease and pests were reported by 65% of the respondents in Hoima, and 56.7% in Rakai. Drought hazard and vulnerability are present risks in Africa and are likely to be the most damaging of all impacts of climate change (Downing et al., 1997). However, one should not underestimate the potential of the lesser important climate related-risks (e.g. lightening, floods and invasive weeds) to escalate into more pronounced and severe risks, if not addressed early enough. The potential devastating impacts of climate-related risks on crop and livestock production implies that urgent practical action is required to reduce the large-scale risks and their adverse impacts.

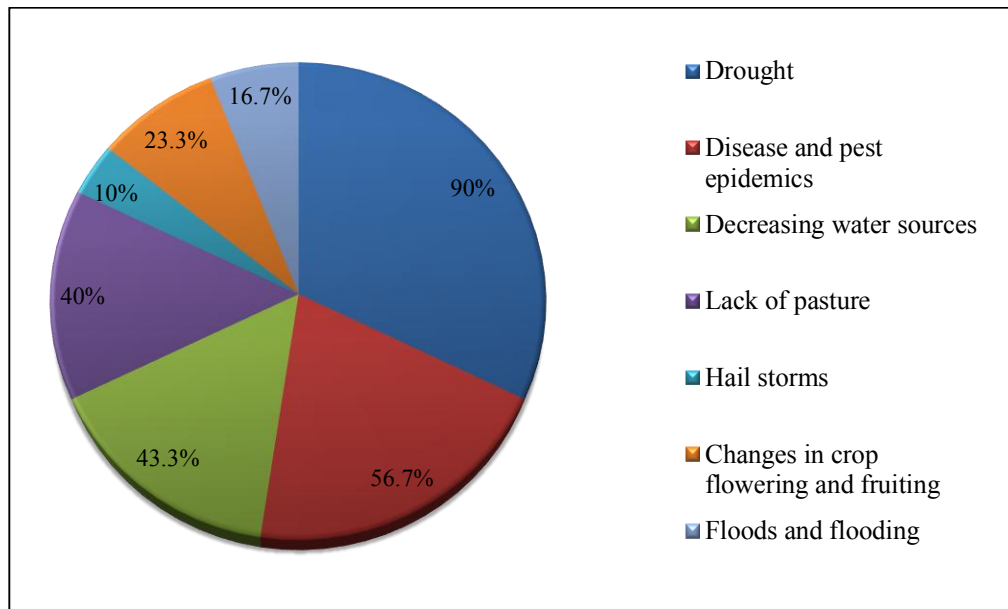


Fig. 9. Climate-related risks in Rakai District

The adverse effects that may result from the different risks are presented in Table 5. Crop failure and damage, pest infestation and disease prevalence were the most severe climate related impacts on crop production reported. Crop failure had the greatest impact on crop production among farmers in Rakai (reported by 93.3%) and Hoima (76.3%). Other impacts of climate change such as crop damage, pest infestation and disease prevalence were each reported by more than 45% of respondents in both districts. Similarly, the impacts of climate change on livestock production included lack of feeds, water shortage, low milk production, and vector prevalence. Over 80% of the farmers in Rakai reported lack of feeds as one of the major impacts of climate change on livestock production compared to 78% in Hoima. Disease prevalence was also commonly reported across the two sites (Table 5).

Table 5

Major impacts of climate-related risks on crop and livestock production

Impact on crop and livestock production	Proportion of respondents (%)	
	Rakai	Hoima
<i>Crop production</i>		
Crop failure	93.3	76.3
Crop damage	45.0	45.8
Pest infestation	48.3	55.9
Disease prevalence	46.7	61.0
<i>Livestock production</i>		
Lack of feeds	85.2	78.0
Water shortage	66.7	34.1
Low milk production	24.1	43.9
Small grazing areas	35.2	19.5
Disease prevalence	48.1	48.8
Vector Prevalence	9.3	7.3

Other impacts of climate related risks from the focus group discussions included i) Drying of water sources leading to reducing number of water source points and reduced water infiltration capacities resulting from soil hardening in dry conditions. Households walk for long distances and take more time to access water, and in some cases, households buy water for domestic use; ii) Poor or low crop yields due to water stress from extended droughts, variable rainfall onset periods and uncertainties in planting time. Farmers have encountered reduction in yields of major crops like maize, beans, groundnuts, coffee, and bananas. Rampant food insecurity, consequently leading to malnutrition; iii) Increased poverty levels and loss of assets (houses, and animal deaths from hailstorm) leading to poor living standards, low education levels and ill-health; and iv) Emergence of new diseases and pests for some crop varieties. These include small snails that are common in

mulched banana plantations, they also attack beans and eat away flowers and leaves; cassava disease; coffee wilt disease; and banana bacterial wilt.

Climate risk management and adaptation strategies

As discussed previously, farming communities and households in rural Uganda have developed several adaptation options to cope with current climate variability. Specifically, the different technologies and strategies used by farmers in Hoima and Rakai districts based on their own innovations or through advice from other sources are summarized in Table 6. These include soil moisture conservation, soil fertility enhancement, on-farm diversification, improved inputs and management, local innovations and food storage. While some of the technologies were widely used, others were only practiced by a few of the farmers. Mulching, intercropping and planting of food security crops, for example, were among the most popular and widely used technologies. Notably, these three practices have been in existence for a long time and still feature as important practices. Rainwater harvesting, using plastic water tanks or Ferro-cement cisterns, for domestic consumption is among the fast-growing local innovations in these sites. This is not to underestimate the importance of other technologies such as soil bunds, manure, and storage facilities among others. Often, farmers use these technologies in combination to enhance agricultural production.

Farmers also use soil moisture conservation techniques. Mulching, for example, enhances conservation of soil moisture, controls soil erosion and enhances water catchment. Incentives for adopting soil fertility practices included increased crop yields, improved soil fertility, and enhanced plant germination potential and growth rates. The differences in utilization of soil fertility enhancement technologies between Hoima and Rakai are attributed to differences in

livelihood activities. Rakai, for example, has a higher livestock population compared to Hoima. Consequently, 18.3% of the respondents from Rakai reported availability of materials on the farm for soil fertility enhancement compared to only 1.7% in Hoima (data not presented). Trends in fertilizer use across the two sites are similar to the national trends in Uganda, where fertilizer use is very minimal due to various factors including high costs and lack of knowledge on fertilizer use. On average, only 1 kg of nutrients is used per hectare per year (FAOSTAT, 2002; GOU, 2006). However, at the current level of degradation of most Ugandan soils, 200 kg of nutrients is required per hectare per year (GOU, 2006).

Table 6

Farm-level climate change adaptation technologies and strategies

Adaptation technologies and practices	Proportion of farmers (%)	
	Rakai	Hoima
<i>Soil moisture conservation</i>		
Mulching	89.1	54.8
Use of cover crops	1.8	21.4
Agro-forestry	40.0	11.9
Soil bunds	45.5	7.1
Irrigation	10.9	4.8
<i>Soil fertility enhancement</i>		
Use of backyard manure	55.4	36.7
Use of compost manure	51.8	12.2
Use of inorganic fertilizer	39.3	10.2
Use of green manure	10.7	2.0
<i>On-farm diversification</i>		
Intercropping	85.2	79.2
Integration of livestock and crops	22.2	34.0
Use of new crop varieties e.g. <i>Fhia</i> in banana	38.9	28.3
Planting of fruit trees e.g. mangoes	29.6	15.1
<i>Use of improved inputs and management</i>		
Improved seed	48.1	35.7
Proper spacing	63.0	42.9
Timely planting	66.7	78.6
Timely weeding	61.1	66.7
Post-harvest handling	40.7	33.3
<i>Food storage</i>		
Planting of food security crops	78.8	72.5
Use of storage facilities	56.7	21.6
<i>Local innovations</i>		
Kitchen gardens	25.0	66.7

Rain water harvesting for domestic use	89.6	44.4
Rain water harvesting for agricultural production	2.1	11.1
Organic pesticides	6.2	7.4
Micro irrigation	8.3	-
Non-conventional organic fertilizers e.g. urine	12.5	-

According to (Kandlinkar and Risbey, 2000), crop diversification is one of the important adaptation options in agriculture. Crop diversification is a risk management strategy (acts as insurance) against rainfall variability as different crops are affected differently (Mary and Majule, 2009; Bradshaw et al., 2004). The uptake of crop diversification as a risk management and adaptation strategy across the sites has been enhanced due to their efficiency on limited land holdings, improvement of soil fertility and boosting crop yields, among other benefits.

Poor post-harvest handling of agricultural produce is a major constraint in Uganda, often resulting in substantial loss of produce during harvesting, processing, and storage. Poor post-harvest handling also affects the quality of farm produce. In addition, the available marketing schemes do not offer farmers reasonable revenue for their produce. Due to post-harvest handling constraints farmers often sell their produce just right after harvesting when the supply is much higher than the demand. As a result, the prices are usually low and exploitative, whereas if they could afford to wait for a couple of months the prices could even go up three to five times (Mubiru et al., 2009). With increasing changes in climatic conditions and climate variability there is need to minimize the post-harvest losses. Incentives for adoption of food storage technologies included the ability of farmers to store the crops for a longer period, ability to sell at a later date and obtain better prices which improved household incomes, and also increased food security.

The local innovative adaptation strategies included kitchen gardens especially for vegetable growing, rainwater harvesting, micro-irrigation and use of organic pesticide

concoctions. The water harvesting techniques were adopted because they offer households clean water for domestic use. Factors that impeded uptake and use of the various techniques discussed above were cross-cutting and included high costs associated with implementation of the technologies, labour requirements and intensity associated with adoption, lack of capital and inputs to implement the technologies in accordance with the scientific recommendations, inadequate technical know-how of using the technologies and rainfall uncertainty.

4. Conclusions

Climate change and variability presents new risks and vulnerabilities to smallholder farmers in Uganda. This paper examined farmers' perceptions of climate change, climate-related risks affecting crop and livestock production, including climate-risk management and adaptation strategies. Perceived changes in climatic conditions by the farmers included erratic rainfall onset and cessation, which were either early or late, poor rainfall seasonal distribution and little rainfall. Farmers also reported variations in temperatures. Results from the historical climate data showed that average maximum and minimum temperatures have increased steadily over the years across the two research sites.

Annual rainfall patterns have also changed, with average monthly rainfall and the number of rainy days showed a decreasing trend, especially during the critical months of crop growth (April - June and September – November). Although the changes in rainfall patterns were weak as explained by the correlation coefficients, there was a lot of variability. Rainfall intensity has become more variable and erratic impacting negatively on soil moisture content and availability, leading to either reduced crop yields or total crop failure. Rainfall patterns within and between seasons are highly variable. The erratic onset and cessation of rains makes it difficult for farmers to plan for their cropping activities. Heavy rains were occurring in dry seasons, dry spells in rainy

seasons, and storms at unusual times as indicated by the average monthly rainfall. Rising temperature and increasing rainfall variability are resulting in decreased crop and livestock productivity with negative effects on food security. The observed historical trends from meteorological data were consistent with the farmers' perceptions of changing rainfall characteristics and increasing temperatures. Understanding farmers' perceptions of climate change and how climate-related risks impact smallholder crop and livestock production is important for designing climate change adaptation strategies and formulation of policy recommendations.

Drought, disease and pest epidemics and hailstorms were the major climate-related risks. These risks caused decline in water resources, reduction of pasture productivity, bush fires, crop failure and physiological changes in crop flowering and fruiting times. Drought and associated diseases and pests were the most severe climate-related risks. Farmers are using indigenous traditional innovations and modern technologies to cope with climate risks. These include mulching, intercropping, use of manure and improved crop varieties, some of which have been in existence for a long time. Other local innovations for coping with climate-related risks included establishment of kitchen gardens, rain water harvesting for domestic and agricultural use, and use of organic pesticides. Often, farmers use a combination of these technologies and strategies to cope with climate change and variability and to enhance agricultural productivity.

The results clearly highlight the need for climate-smart agriculture focusing on early maturing, drought tolerant and water efficient crops and crop varieties; pastures and fodder varieties; and soil and water management technologies; and livestock management options and strategies that can improve adaptive capacity and explore mitigation co-benefits, as well as sustainable productivity. Research and farm development initiatives should foster integration of crops and livestock that exploit synergies of indigenous traditional practices and modern

technologies and innovations. Efforts to improve climate information services should be strengthened to improving planning and farm investment decisions, including establishing effective information flow networks to inform farm-level decision making taking into account the already existing communication channels or structures.

ACCEPTED MANUSCRIPT

Declarations of interest
None

Acknowledgements

The study was financially supported by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) East Africa Program. We acknowledge the participation of farmers in Hoima and Rakai districts in Uganda.

5. References

- ActionAid. 2008. The time is NOW: Lessons from farmers adapting to climate change. (Available from <http://www.actionaid.org>).
- Adger WN, Huq S, Brown K, Conway D, Hulme M. 2003. Adaptation to climate change in the developing world. *Progress in Development Studies* 3:179–195.
- Anderson IM, Robinson WI. 2009. Uganda 10th European Development Fund Karamoja Livelihoods Programme (KALIP): Technical Reference Guide. Delegation of the European Commission to the Republic of Uganda; Food and Agriculture Organization; Republic of Uganda.
- Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R, Yanda P. 2007. Africa. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*, Cambridge University Press, Cambridge UK. p 433–467.
- Bradshaw B, Dolan H, Smit B. 2004. Farm-level adaptation to climate variability and change: crop diversification in the Canadian Prairies. *Climatic Change* 67:119–141.
- Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon WT, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P. 2007. Regional Climate Projections. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, eds. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. p 847–940.
- DanChurchAid. 2010. Climate change and adaptation strategies in the Karamoja sub region. DanChurchAid, Kampala, Uganda.
- Downing TE, Ringius L, Hulme M, Waughray D. 1997. *Adapting to climate change in Africa.* Kluwer Academic Publisher. Belgium.
- FAOSTAT. 2002. Fertilizers. (Available from <http://faostat.fao.org/default.aspx>)
- GOU [Government of Uganda]. 2007. Climate change: Uganda National Adaptation Programmes of Action. Environmental Alert/ GEF/ UNEP/ MWE, Kampala, Uganda
- GOU [Government of Uganda]. 2006. *Uganda fertilizer strategy.* Ministry of Agriculture Animal Industry and Fisheries, Entebbe, Uganda.

- GOU [Government of Uganda]. 2004. *Increasing incomes through exports: a plan for zonal agricultural production, agro-processing and marketing for Uganda*. Ministry of Agriculture Animal Industry and Fisheries, Entebbe, Uganda.
- Hulme M, Doherty RM, Ngara T, New MG, Lister D. 2001. African climate change: 1900–2100. *Climate Research* 17(2):145–168.
- Jennings S, Magrath J. 2009. What happened to the seasons? Oxfam GB Research Report. Available from: http://www.oxfam.org.uk/resources/policy/climate_change/.
- Jost C. 2011. Climate Change, Agriculture and Food Security Challenge Program Uganda site characterization. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.
- Kandlinkar M, Risbey J. 2000. Agricultural impacts of climate change: If adaptation is the answer, what is the question? *Climatic Change* 45:529–539.
- NEMA [National Environment Management Authority]. 2008. State of the environment report for Uganda 2008. NEMA, Kampala, Uganda.
- Kisamba-Mugerwa W. 2001. Social background. In: Mukiibi JK, eds. *Agriculture in Uganda*. Volume I. General Information. ACT/ NARO/ Fountain Publishers, Kampala, Uganda. p. 186–199.
- Komutunga ET, Musiitwa F. 2001. Climate. In: Mukiibi JK, eds. *Agriculture in Uganda*. Volume 1, General Information. ACT/ NARO Fountain Publishers, Kampala, Uganda. p. 21–32.
- Kristjanson P, Neufeldt H, Gassner A, Mango J, Kyazze FB, Desta S, Sayula G, Thiede B, Förch W, Thornton PK, Coe R. 2012. Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security* 4:381–397
- Kyazze FB, Kristjanson P. 2011. Summary of baseline household survey results: Rakai district, south central Uganda. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. (Available from <http://ccafs.cgiar.org/resources/baseline-surveys>).
- Majaliwa M, Nkonya E, Place F, Pender J, Lubega P. 2009. Case studies of sustainable land management approaches to mitigate and reduce vulnerability to climate change in sub Saharan Africa: the case study of Uganda. IFPRI and MUIENR
- Mary AL, Majule AE. 2009. Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology* 3(8):206–218.

- Mubiru DN, Agona A, Komutunga E. 2009. Micro-level analysis of seasonal trends, farmers' perception of climate change and adaptation strategies in eastern Uganda. Paper presented at: International Conference on Seasonality; 2009 Jul 08–10; Brighton, UK. Brighton: Institute of Development Studies, University of Sussex; 2009. (Available from: <http://www.event.future-agricultures.org>).
- Mubiru DN, Komutunga E, Agona A, Apok A, Ngara T. 2012. Characterizing agrometeorological climate risks and uncertainties: crop production in Uganda. *South African Journal of Science* 108(3/4), Art. #470, 11 pages. <http://dx.doi.org/10.4102/sajs.v108i3/4.470>.
- Mubiru DN, Kristjanson P. 2012. Summary of baseline household survey results: Hoima district, west central Uganda. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. (Available from <http://ccafs.cgiar.org/resources/baseline-surveys>).
- Okonya JS, Syndikus K, Kroschel J. 2013. Farmers' perception of and coping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *Journal of Agricultural Science*. 5 (8):252–262.
- Orindi VA, Murray LA. 2005. Adapting to climate change in East Africa: a strategic approach. Gatekeeper Series 117: International Institute for Environment and Development (IIED). (Available from <http://pubs.iied.org/pdfs/9544IIED.pdf>).
- Osbahe H, Dorward P, Stern R, Copper S. 2011. Supporting agricultural innovation in Uganda to respond to climate risk: linking climate change and variability with farmer perceptions. *Experimental Agriculture* Vol I. pp. 293-316. <https://doi.org/10.1017/s0014479710000785> published online: 25 March 2011.
- Schneider SH, Semenov S, Patwardhan A, Burton I, Magadza CHD, Oppenheimer M, Pittock AB, Rahman A, Smith JB, Suarez A, Yamin F. 2007: Assessing key vulnerabilities and the risk from climate change. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. Cambridge University Press, Cambridge, UK. p 779–810.
- UBOS [Uganda Bureau of Statistic]. 2017. *Statistical abstract*. UBOS, Kampala, Uganda.
- UBOS [Uganda Bureau of Statistic]. 2014. National population and housing census 2014. UBOS, Kampala, Uganda.
- UNHS [Uganda National Household Survey 2009/10]. 2010. Socio-economic module. Uganda Bureau of Statistics (UBOS), Kampala, Uganda

van de Steeg JA, Herrero M, Kinyangi J, Thornton PK, Rao KPC, Stern R, Cooper P. 2009. The influence of climate variability and climate change on the agricultural sector in East and Central Africa-sensitizing the ASARECA strategic plan to climate change. Research Report 22. ILRI (International Livestock Research Institute, Nairobi, Kenya, ICRISAT (International Crop Research Institute for the Semi-Arid Tropics), Nairobi, Kenya, and ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe, Uganda.

[WFP] World Food Program. 2011. Building resilience: Bridging food security, climate change adaptation and disaster risk reduction. An overview of workshop case studies. World Food Programme Office for Climate Change and Disaster Risk Reduction. (Available from <http://www.wfp.org>)

Ziervogel G, Ericksen PJ. 2010. Adapting to climate change to sustain food security. *Wiley Interdisciplinary Reviews: Climate Change* 1(4):525–540.