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# Perceived and Actual Rainfall Trends and Variability in Eastern Uganda: Implications for Community Preparedness and Response

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## Abstract

This study assessed the extent of rainfall trends and variability in Eastern Uganda and implications for community preparedness and response. Regional and national climate studies have been generalized over large scales and thus are insufficient in capturing variability at local level where management actions occur. This study used both observational rainfall data for the period 1971 to 2010 and primary data on communities' perceptions of changes in rainfall. The study was conducted in three distinct agro-ecologies covering highland, low land and floodplains. Trends analysis was done using Regression method, while Coefficient of Variation and ANOVA techniques were used to analyze variability. Rainfall satisfaction index was used to assess farmers' perceptions. The results show statistically significant increasing trends ($P \leq 0.05$) in annual and seasonal rainfall for highland areas, and negative, but non-significant trends for low lying areas. Analysis of Variance shows significant within and between season variations for L. Victoria and less significant variations for Mt. Elgon and SE L. Kyoga agro-ecologies. However, Mt. Elgon exhibits a very high coefficient of variation for ASON (CV > 30%), indicating high rainfall variability. Over 90% of the interviewed farming communities perceived change in rainfall pattern, dating as far back as 10 to 15 years. The rainfall subjective index of 0.19 was obtained, which indicates that the rainfall situation for the base year of this study was undesirable. Adaptation to the observed variability may include; development of early warning systems based on a combination of meteorological data and communities' knowledge, adoption of crops adapted to water logging or stress conditions for the different seasons and agro-ecologies, and local institutional preparedness to anticipate and manage the climate variability induced risks.

**Key words**: Rainfall Variability, Rainfall Trends, Farmers' Perceptions, Eastern Uganda.

## 1. Introduction

Evidence is emerging that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). Boko *et al.* (2007) predict that Africa is likely to warm across all seasons during this century with annual mean surface air temperatures expected to increase between 3°C and 4°C by 2099, roughly 1.5 times average global temperatures. Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5 - 20% from December to February, and decrease rainfall by 5-10% from June to August by 2050 (Hulme *et al.*, 2001; IPCC, 2007). Analyses from General Circulation Models (GCM's) indicate an upward trend in rainfall under global warming over much of Burundi, Kenya, Rwanda, southern Somali and Uganda (Schreck & Semazzi, 2004; van de Steeg *et al.*, 2009).

Studies conducted in Uganda indicate a general lack of scientific consensus on the trend and distribution of annual and seasonal rainfall. McSweeney *et al.* (2008) report an annual rainfall decrease of 3.5% since the 1960s, with annual rainfall due to decline further. McSweeney *et al.* (2008) further suggest that rains during the March to May rainy season are falling by 4.7% per decade. However, Government of Uganda (GOU 2007) indicates that the wetter areas of Uganda, around the Lake Victoria basin and the east and northwest are tending to become wetter, indicating an increase in rainfall in these areas. Temperature and rainfall simulations by Goulden (2008) indicate high percentage increases in rainfall for historically dry seasons for many parts of Uganda. In their study of localized precipitation around Kibale National Park in mid Western Uganda, Stampone *et al.* (2011) found that patterns in annual time series do not reflect the direction and magnitude of seasonal trends nor the spatial variability in intra-annual rainfall.

On the seasonal scale, GOU (2007) reports increasing erratic onset and cessation of rainfall seasons across the country in recent years; coupled with increasing frequency of droughts. It has also been observed that falls are heavier and more violent. Non-governmental organizations working in Uganda also report that farmers recognize an increasingly erratic rainfall pattern in the first March to May rainy season, causing drought and crop failure, but also more intense rainfall, especially in the second rains at the end of the year, causing flooding and erosion (Oxfam, 2008). The spatial variability has been attributed to the complex topography and existence of large inland water bodies (Bamanya, 2007), La Niña and El Niño phenomena, with La Niña years tending to bring significant drying and El Niño years heavy rains (GOU, 2009).

Despite these evidences in general trends of rainfall withnin the region and Uganda, this information may not be relied upon to make policy and management decisions, due to generalization over large scales. General Circulation Model scenarios are insufficiently precise in terms of spatial resolution or scale of assessment and fail to reasonably differentiate spatiality (Thornton, *et al*., 2008). Local level studies conducted in Uganda have been based on the magnitudes of monthly and seasonal rainfall (Kigobe *et al*., 2011; Komutunga & Musiitwa, 2001) and the occurrence of dry and wet spells (Bamanya, 2007, Osbahr *et al*., 2011), with limited focus on the variability of rainfall within the year and seasons. Yet according to Mukiibi (2001), the magnitude of rainfall is less critical to farmers' production than distribution through a season. While, Stampone *et al*. (2011) assessed variability in areas around Kibale National Park, a tropical rain forest, results obtained from this area cannot be easily generalized over other areas in Uganda due to contextual and environmental differences. In addition, the lack of consensus by previous studies in Uganda calls for location-specific analysis to understand where variability is highest in order to support local level decision making on adaptation.

This study addressed this information gap by providing empirical evidence of the extent of annual and seasonal rainfall variability in the context of Eastern Uganda for the 40-year period from 1971 to 2010. The region comprises of three distinct agro-ecological zones, ranging from low land to highland, and semi arid to sub humid. Clarity on variability by region and specific agro-ecology is essential to support vulnerable communities to adapt their food systems to emerging climate variability realities. It was hypothesized that there is no significant variation in the pattern of seasonal and inter-annual rainfall pattern in the three agro-ecologies of Eastern Uganda.

## 2. Study Area and Relevance to Sub-Saharan Africa

Uganda lies in East Africa, astride the equator with its area lying between latitude $4^0$12'N and $1^0$29'S and longitude $29^0$34'W and $35^0$0'E (Ojakol, 2001). The country occupies 241,551 square kilometres of largely fertile arable land. It is bordered to the east by Kenya, to the north by South Sudan, to the west by the Democratic Republic of Congo, and to the south by Rwanda and Tanzania. The country is located on a plateau, averaging about 1100 meters (3,250 ft) above sea level sloping down to the Sudanese Plain to the north. Large parts of the country have fertile soil with regular rainfall and agriculture is the mainstay of both the national economy and the main source of livelihood for most Ugandans. Subsistence farming is the main source of household income for the majority of Ugandans. Agricultural products currently still supply nearly all of Uganda's foreign exchange earnings. The country is divided into four major regions - Western, Central, Eastern and Northern (GOU, 2010).

This study was carried out in Eastern Uganda. The region comprises 32 districts (GOU, 2010) with a total population of about 6,301,677 people, which is 25.5% of the total population of Uganda (UBOS, 2002). The region comprises of three distinct agro-ecological zones (AEZs) - Lake Victoria Crescent and Mbale farm lands (L.Victoria Crescent); Southern and Eastern Lake Kyoga basin (SE L. Kyoga); and Mt. Elgon high farmlands (Mt. Elgon) (Wortmann & Eledu, 1999). The AEZs are largely determined by the amount of rainfall, which drives the agricultural potential and farming systems and range from sub-humid to semi-arid (GRID, 1987). They also capture variability in altitude, soil productivity, cropping systems, livestock systems, and land use intensity. Table 1 shows the AEZ in Eastern Uganda, their biophysical characteristics and their relevance to Sub-Saharan Africa (SSA).

Although all the AEZs of Uganda are grappling with the effects of climate change and variability, the Eastern region is most affected. This is attributable to the fact that the region is less socially and economically developed, and even among the generally poorer parts of Uganda as a whole. It is characterized by a combination of acute poverty, vulnerability to drought, floods and landslides, and natural resource degradation. Recent floods in the Teso sub region and landslides in Bududa have led to crop loss and subsequent hunger and displacement of people (GOU, 2009). These climate challenges combined constrain crop production, increasing crop failure, thus exacerbating poverty.

## 3 Materials and Methods

### *3.1 Data and sampling procedure*

Data for the study were collected during August – September 2011 from both primary and secondary sources. Primary data were obtained from respondents on their perception of the long term rainfall variability and adequacy. The AEZs formed the study strata and from each, one district was randomly selected for the study. The districts included in this study are; Mbale, Pallisa and Sironko representing L. Victoria Crescent, SE L. Kyoga and Mt. Elgon agro-ecologies respectively. Using random sampling technique, nine sub counties were selected (three per district), and one village per sub-county from which respondents were drawn. Sample size was obtained using coefficient of variation method (Nassiuma, 2000). Three hundred and fifty three household surveys were conducted, nine focus group discussions (FGDs) involving 104 community members, and 23 key informant interviews (KIIs), using structured and semi-structured interview schedules. Observational rainfall data for these AEZs were obtained from Uganda Meteorological Department, of the Ministry of Lands and Environment, for the period extending from 1971 to 2010. At least one weather station exists in each of the AEZ of interest from which data were obtained.

### *3.2 Analytical methods*

To identify local rainfall variability in the study areas, this study quantified trends and variability in total seasonal and annual rainfall derived from monthly rainfall observations. Data were first evaluated for discontinuities by inspection of each time series and then tested for homogeneity using the Student’s t-test (von Storch & Zwiers, 1999) and found to be homogenous. Trend analysis was done to reveal the general movement of the rainfall pattern, examining evidence of any changes in the trend of rainfall amounts. Such patterns were investigated by use of both graphical and statistical methods. Graphical methods were used as a tool for visualization of temporal variation of annual rainfall amounts over the study period – 1971 to 2010. Regression analysis was done to determine the magnitude, direction and significance of the trends in annual and seasonal rainfall for each sample district. The regression equation was defined as:

$$Y_i = \beta_o + \beta_1 X_i + \varepsilon$$

Where $Y$ = total annual rainfall, and $X$ = time measure in years. It was hypothesized that there is no trend in the amount of rainfall over time. Thus the null hypothesis was stated as; $H_0$: $\beta_1 = 0$. Variability of annual and seasonal rainfall was assessed using Coefficient of Variation (CV), and Analysis of Variance (ANOVA) techniques. In addition, first moments of variation (minimum, maximum, mean, and standard deviation) were obtained using descriptive analysis. Standard rainfall anomalies were plotted against time (in years) to visualize the time series variation of annual and seasonal rainfall about the mean.

In order to determine communities’ perceptions of rainfall trends and variability, respondents were asked two sets of questions. The first was asking farmers if they have observed any change in rainfall pattern, and if so, how many years back they had noticed this change. The second set consisted of asking farmers their perception of rainfall adequacy in the preceding agricultural season (August – November 2010, the base season for this study). The questions asked on rainfall adequacy included; whether rain came and stopped on time, whether there was enough rain at the beginning and during the growing season and whether it rained at harvest time (see Table 2). The responses for these questions were dichotomized in such a way that those who responded "on time" coded into one and others (early /late) into zero. The responses were summed and divided by the number of rain related questions (nine in this case). So the most favourable rainfall outcome is one and the least is zero. Quisumbing (2003) in the study of food aid and child nutrition in Ethiopia followed a similar approach in generating a rainfall satisfaction index. In the same token, Demeke and Zeller (n.d) used the same approach to study impacts of rainfall shock on smallholder food security in Ethiopia.

## 4 Results

### *4.1 Rainfall Variables*

Objective rainfall variables were computed based on observational rainfall data to obtain maximum, minimum and mean annual and seasonal rainfall as well as the standard deviation and coefficients of variation (CV). Table 3 shows summary information of annual and seasonal rainfall variables by AEZ. The two seasons recognized by farming communities were used to compute seasonal rainfall variables. That is, 1st season stretching from March to June (MAMJ), and 2nd season from August to November (ASON). From the table, it is observed that the mean annual rainfall in Eastern Uganda varies from 1374mm in parts SE L. Kyoga to 2058mm in Mt. Elgon. Mean seasonal rainfall varies from 522mm to 905mm in SE L. Kyoga and Mt. Elgon respectively. Results further show highest rainfall amounts both on the annual and seasonal scales in Mt. Elgon and lowest in SE L. Kyoga agro-ecologies. Results of CV for annual and seasonal rainfall amount show CVs less than 30% for all locations, except ASON season for Mt Elgon which shows a CV of 38%. The highest coefficients of variation are noted for Mt. Elgon area for both annual and seasonal rainfall. In addition, the variation is higher for ASON as compared to MAMJ for all locations.

In addition to observational rainfall variables, a subjective index was obtained from asking farmers a series of questions related to rainfall adequacy in the previous growing season, in order to understand their perceptions of rainfall variability and how it relates to actual variation computed from weather stations. Over 90% of the farmers interviewed had perceived change in rainfall pattern, dating as far back as 10 to 15 years. The rainfall subjective index of 0.19 was obtained, which indicates that during the growing season of August – November 2010 (the base year for this research), the rainfall situation was undesirable (Table 4).

Farmers' generally reported late on set of rain, poor distribution within the season, and sometimes early cessation. In particular, they noted that the first season had shifted from a start in early March to mid or late March and now ended in June rather than May. Meanwhile, they claimed the second season had shifted from a start in August to September and now ended in November rather than December. During the past 15 years, farmers highlighted specific problems of variability in the duration, timings and intensity of the rains, including in winds and heavy rains at the start of the seasons, such as in 2004, 2006 and 2007. In the lower lying areas (SE L. Kyoga), respondents highlighted drought in the first season as an increasing problem, and more frequent flash floods as a result of increased rainfall intensity. In the highland areas (Mt. Elgon and part of L. Victoria Crescent), increased rainfall intensity leading to increased ground water and water logging and landslides was reported. Comparing means across the sample locations indicates no significant differences in people's perception of climate variability ($P<0.05$).

### *4.2 Annual and Seasonal Rainfall Trends*

Graphical visualization of annual rainfall data for the period 1971 to 2010 in the studied agro-ecological zones is presented in Figures 1. There is an observed increasing trend of total annual rainfall for L. Victoria Crescent and Mt Elgon and a decreasing trend for SE L. Kyoga. Annual and seasonal rainfall totals were regressed against time scale and regression results are shown in Table 5. The results show statistically significant increasing trends ($P \leq 0.05$) in annual and seasonal rainfall for Mt. Elgon. Negative, but non-significant trend is observed for annual rainfall for SE L. Kyoga. On the seasonal scale, MAMJ rainfall shows a negative trend, while ASON shows increasing trend for L. Victoria Crescent and SE L. Kyoga. For Mt. Elgon, both MAMJ and ASON show increasing trends.

### *4.3 Annual and Seasonal Rainfall Variability*

The year-to-year variation of annual and seasonal rainfall over the studied agro-ecological zones was expressed in terms of normalised rainfall anomaly (Figures 2 and 3). This analysis of rainfall variability shows significant anomalies in annual rainfall in the recent past (2000 to 2010). While Mt. Elgon and L. Victoria Crescent seem to have received above average rainfall, SE L. Kyoga received more or less below average in the years from 2000 to 2010. Analysis of variance (ANOVA) shows significant variation in inter-annual rainfall as well as across AEZs. L. Victoria Crescent exhibits significant within and between season variations as shown in Table 7.

## 5 Discussion

Descriptive study results show that Eastern Uganda experiences a bimodal seasonal pattern: the long rainy season starts around March and runs through to June, with the peak centred on March to May; the short rains run from August and taper off in November. Mean annual rainfall varies from 1374 mm in SE L. Kyoga to 2058 mm in Mt. Elgon. In comparison, the average long-term annual rainfall for Uganda is 1318 mm, which is considered adequate to support agricultural activities (Osbahr *et al*., 2011). This implies that Eastern Uganda receives adequate rainfall to support agriculture. Despite this seemingly desirable rainfall situation, the study shows significant variation in its distribution both on the annual and seasonal scales. Statistically significant increasing trends in annual rainfall are observed for Mt. Elgon and L. Victoria Crescent AEZs, and negative but non-significant trends for SE L. Kyoga basin. Seasonal trends indicate decreasing rainfall for MAMJ rainfall for L. Victoria Crescent and SE L. Kyoga, while in Mt. Elgon it is increasing, while ASON rainfall is increasing in all the three agro-ecologies.

This result confirms earlier studies by Basalirwa (1995) who predict an increase of approximately 10-20% in rainfall for high ground areas, and more drying conditions for low areas like Uganda’s cattle corridor. Other studies in Uganda and government analysis papers also confirm these results indicating increasing trends in inter-annual rainfall, and decreasing trends in March-April-May (MAM) rainfall (GOU, 2007; Goulden, 2008; Hepworth & Goulden, 2008; Osbahr *et al*., 2011). Although McSweeney *et al*. (2008) report decrease in annual rainfall, they agree that the MAM rainfall is decreasing.

Analysis of Variance shows significant within and between season variations for L. Victoria and less significant variations for Mt. Elgon and SE L. Kyoga. However, Mt. Elgon exhibits a very high coefficient of variation for ASON (CV > 30%). According to Araya and Stroosnijder (2011), a CV > 30% is an indicator of large rainfall variability. This may be linked to the 2007 El Nino rains that characterised the OND season in Uganda (GOU, 2009). Links between El Nino and climate variability have also been suggested by other studies (e.g. Anyah & Semazzi, 2007). Shisanya *et al*. (2011) also report above normal rainfall during OND season than preceding MAM rainfall in ASALs of Kenya during El Nino years. In terms of variability, seasonal rainfall in Eastern Uganda varies a lot around the mean, with occasions of subsequent below average rainfall. The variations are more pronounced for ASON than MAMJ seasons, and in the years from 2006 to 2010. Mutai *et al*. (1998), and Phillips and McIntyre (2000) also observed that OND variability is stronger than MAM.

Farmers’ perceptions of climate variability are in line with actual climatic data, noting variability in the duration, timing and distribution within seasons, including in winds and heavy rains at the start of the seasons. This is a common finding from other studies on perceptions of resource users of climate change such as in the Sahel (Mertz *et al*., 2009), Nile basin of Ethiopia (Deressa *et al*., 2008), Zambia (Nyanga *et al*., 2011), semi-arid central Tanzania (Slegers, 2008); Uganda (Magrath, 2010), and Asia (Marin, 2010), where farmers perceived increased variability of rainfall and shifts in the growing seasons. Osbahr *et al*. (2011) indicates that the potential crop growing period is shrinking. Seasonal distribution of rainfall affects the decisions made by farming households on what type of crops to grow and land management practices to adopt (Komutunga and Musiitwa, 2001). In addition, excessive rains both in intensity and duration lead to water logging conditions that negatively affect crops and pasture (GOU, 2007; Komutunga & Musiitwa, 2001). For example drought in 2008 caused an average reduction in yield of 50% of simsim, sorghum, groundnuts, cassava and maize in Uganda (Ocowunb, 2009). Heavy rainfall experienced between 2006 and 2010 is responsible for massive floods in the low land areas and numerous landslides in the mountainous regions in Eastern Uganda (GOU, 2009).

In related studies in East Africa, Recha *et al*. (2012) report that persistence of below normal rainfall is a great risk to people's livelihood in Tharaka district in Kenya, where majority of people have been left vulnerable to hunger and famine. Similar observations have been reported by various scholars studying, for example intra-seasonal factors, such as the timing of the onset of first rains affecting crop-planting regimes (Tennant & Hewitson, 2002), the distribution and length of period of rain during the growing season (Mortimore & Adams, 2001), and the effectiveness of the rains in each precipitation event (Usman & Reason, 2004), are the real criteria that affect the effectiveness and success of farming. IPCC (2007) reported that changes in rainfall amount and patterns also affect soil erosion rates and soil moisture, both of which are important for crop yields.

From the farmers' perspective, this uncertainty in addition to increasing food insecurity due to crop failure, it generally increases the cost of production as sometimes farmers have to re-plough and replant destroyed crop fields. As noted by Olupot John (37 years) from Kadengerwa village, Pallisa district: *"We've stopped adopting seasonal planting, because it's useless. Now we just try all the time. We used to plant in March, and that would be it. Now we plant and plant again. We waste a lot of seeds that way, and our time and energy. Sometimes we've hired labour and end up losing all that money for preparing land"*.

## 6 Conclusions

This study sought to provide empirical evidence of the extent of annual and seasonal rainfall variability in EasternUganda. The null hypothesis being tested was thus: *Ho*: There is no variation in the pattern of annual and seasonal rainfall in Eastern Uganda. Contrary to the expected direction of trends and variability, this study found significant variation in the amount and distribution of annual and seasonal rainfall. This is attributed to increase in extremes of rainfall on the annual scale such as high intensity rainfall and droughts thus affecting the variability. Significance of the variations varies by agro-ecological zone, attributed to variations in altitude, cropping systems and land use intensity in the specific locations. High land areas showed increasing amounts and higher variability in rainfall as opposed to low lying areas which showed decreasing amounts and less variability within and between seasons. Greater variation was observed for ASON, than MAMJ season for all the locations. Communities' perceptions of rainfall adequacy were in line with observational data, where they acknowledged late rainfall onset, mid season droughts and early cessation, especially in the first season, and increase in high intensity rainfall, and climate related disasters such as floods, droughts and landslides during second season. Several others studies conducted in Uganda and SSA in general are in agreement with results of this study confirming increasing rainfall trends and variability for ASON, and decreasing trends for MAMJ season.

Study findings have the following implications: First, significant within season variability negatively affects crop and livestock production, where in extreme cases there has been total crop failure either due to prolonged droughts or heavy erosive rainfall or floods washing away the crop. An example is the long rains in Uganda in 2007, 2008 and 2010. It is evident that ASON rains are increasing in magnitude and variability as compared to MAMJ rains, and farming communities are aware of the changing trends in seasonal rainfall, which greatly affects their farming decisions. Adaptation to the observed variability may include; development of early warning systems based on a combination of meteorological data and communities' knowledge, adoption of crops adapted to water logging or stress conditions for the different seasons and locations, and local institutional preparedness to anticipate and manage the climate variability induced risks.

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**Table 1: Agro-Ecological Zones in Eastern Uganda, their biophysical characteristics and their relevance to SSA**

| **Characteristic** | **Agro-Ecological Zone** | | |
|---|---|---|---|
| | **L. Victoria Crescent** | **SE L. Kyoga** | **Mt. Elgon** |
| Soils | Petric Plinthosols (Acric) | Gleysols (for Kumi area) | Vertisols |
| Mean altitude (m.a.s.l) | 1174 | 1075 | 1299 - 1524 |
| Population density | 166.3/km2 (431/sq mi) | 252/km2 (650/sq mi) | 770/km2 (2,000/sq mi) |
| Mean annual rainfall | Bimodal high rainfall >1,200 mm/year | Bimodal high rainfall >1,200 mm/year | Bimodal high rainfall (>1,200 mm/year) |
| Farming systems | Montane (Millet/ Cotton) System | Teso Systems | Montane (Millet/ Cotton) System, |
| Major crops | Arabica coffee, banana, cotton, maize, bean, wheat, millet, rice, Irish potato, sweet potato | Cotton, finger millet, sorghum, groundnut, sesame, sweet potato, cassava, Robusta coffee, beans, maize | Arabica coffee, banana, cotton, maize, bean, wheat, millet, rice, Irish potato, sweet potato |
| Major climate related disasters | Mid to high ground areas vulnerable to floods and landslides | Lies in the low land areas and in the cattle corridor vulnerable to droughts | Lies in so called highland areas of Uganda vulnerable to landslides and water logging |
| SSA countries with similar biophysical characteristics | West-central (Democratic Republic of the Congo, Congo, etc.), and coastal region of western Africa | Countries along the desert margin (e.g., Burkina Faso, Northern and central Nigeria, Namibia, central Sudan) | Highlands of Cameroon, Ethiopia, Kenya, Malawi, Rwanda, and Tanzania (southern highlands) |
| Sample districts and location | Mbale<br>(00$^0$ 57'N, 34$^0$ 20'E) | Pallisa<br>(01$^0$ 01'N, 33$^0$ 43'E) | Sironko<br>(01$^0$ 14'N, 34$^0$ 15'E) |
| Representative weather station and location | Tororo<br>(0.93$^0$N, 33.97$^0$E) | Soroti<br>(1.72$^0$N, 33.62$^0$E) | Sipi<br>(1.33$^0$N, 34.37$^0$E) |

Source: Adapted and modified from Komutunga and Musitwa (2001) and Wasige (2009)

**Table 2: Rainfall Satisfaction Index Construction**

| | **During the growing season preceding the last main harvest:*** | **Codes** | **Recorded into:** | |
|---|---|---|---|---|
| 1 | Did the rainfall come on time? | 1=on time; 2=too early; | On time | 1 |
| | | 3=too late | Others (2 and 3) | 0 |
| 2 | Was there enough rain on your fields at the beginning of the rainy season? | 1=enough; 2=too little; | Enough | 1 |
| | | 3=too much | Others (2 and 3) | 0 |
| 3 | Was there enough rain on your fields during the growing season? | 1=enough; 2=too little; | Enough | 1 |
| | | 3=too much | Others (2 and 3) | 0 |
| 4 | Did the rains stop on time on your fields? | 1=on time; 2=too late; | On time | 1 |
| | | 3=too early | Others (2 and 3) | 0 |
| 5 | Did it rain near the harvest time? | 1 = no; 2 = yes | No | 1 |
| | | | Others (2) | 0 |
| 6 | Number of rainfall days | 1=No change; 2=Reduced; | No change | 1 |
| | | 3= Increased | Others (2 and 3) | 0 |
| 7 | Frequency of heavy rains | 1=No change; 2=Reduced; 3=Increased | No change | 1 |
| | | | Others (2 and 3) | 0 |
| 8 | Frequency of dry spells | 1=No change; 2=Reduced; 3=Increased | No change | 1 |
| | | | Others (2 and 3) | 0 |
| 9 | Duration of the growing season | 1=No change; 2=Reduced; 3=Increased | No change | 1 |
| | | | Others (2 and 3) | 0 |

* Reference was made to August - November 2010 rainy season

**Table 3: Summary of Rainfall Variables for the Study Locations**

| Agro-Ecological Zone | Rainfall | Annual (1971-2010) | Mar-Jun (MAMJ) | Aug-Nov (ASON) |
|---|---|---|---|---|
| L. Victoria Crescent | Minimum (mm) | 1018 | 445 | 283 |
| | Maximum (mm) | 2068 | 932 | 840 |
| | Mean (mm) | 1503 | 659 | 522 |
| | Std. Dev. | 226 | 123 | 137 |
| | Coef. of Variation | 15.04 | 18.66 | 26.25 |
| SE L. Kyoga | Minimum (mm) | 895 | 306 | 271 |
| | Maximum (mm) | 1844 | 936 | 74 |
| | Mean (mm) | 1368 | 574 | 539 |
| | Std. Dev. | 231 | 14 | 115 |
| | Coef. of Variation. | 16.89 | 2.44 | 21.34 |
| Mt. Elgon | Minimum (mm) | 1409 | 528 | 420 |
| | Maximum (mm) | 3001 | 1287 | 2546 |
| | Mean (mm) | 2058 | 812 | 905 |
| | Std. Dev. | 349 | 166 | 328 |
| | Coef. of Variation | 16.96 | 20.44 | 38.24 |

Source: Authors' computation based on observational rainfall data from Meteorological department

**Table 4: Rainfall Subjective Index**

| **During the main growing season of 2010** | **Mean (Std. Dev.)** | | | |
|---|---|---|---|---|
| | L. Victoria Crescent | SE L. Kyoga | Mt. Elgon | Overall |
| 1. Did the rainfall come on time? | 0.26 (0.44) | 0.10 (0.30) | 0.13 (0.33) | 0.16 (0.37) |
| 2. Was there enough rain at the beginning of the rainy season? | 0.52 (0.50) | 0.12 (0.32) | 0.25 (0.44) | 0.30 (0.46) |
| 3. Was there enough rain during the growing season? | 0.56 (0.50) | 0.18 (0.38) | 0.31 (0.46) | 0.35 (0.48) |
| 4. Did the rains stop on time? | 0.23 (0.42) | 0.07 (0.25) | 0.18 (0.39) | 0.16 (0.37) |
| 5. Did it rain near the harvest time? | 0.02 (0.14) | 0.88 (0.32) | 0.04 (0.19) | 0.31 (0.46) |
| 6. Did the number of rainfall days change? | 0.26 (0.44) | 0.01 (0.10) | 0.03 (0.17) | 0.10 (0.30) |
| 7. Did the frequency of heavy rains change? | 0.30 (0.46) | 0.01 (0.10) | 0.01 (0.10) | 0.11 ()0.31 |
| 8. Did the frequency of dry spells change? | 0.07 (0.25) | 0.00 (0.00) | 0.03 (0.17) | 0.03 (0.18) |
| 9. Did the duration of the growing season change? | 0.38 (0.49) | 0.23 (0.42) | 0.08 (0.27) | 0.23 (0.42) |
| Average | 0.29 (0.40) | 0.18 (0.24) | 0.12 (0.28) | 0.19 (0.37) |
| F-value | 1.69 | | | |
| P-value | 0.21 | | | |
| F crit (5%) | 3.40 | | | |

Source: Field data, 2011

**Table 5: Summary Statistics of the Regression Analysis**

| AEZ | Rainfall | Coef. | Std. Err. | t stat | P value | $R^2$ |
|---|---|---|---|---|---|---|
| L. Victoria Crescent | Annual | 4.320 | 2.950 | 1.465* | 0.151 | 0.052 |
| | MAMJ | -0.258 | 1.726 | -0.150 | 0.882 | 0.001 |
| | ASON | 2.847 | 1.870 | 1.522* | 0.136 | 0.057 |
| SE L. Kyoga | Annual | -1.502 | 3.068 | -0.490 | 0.063 | 0.006 |
| | MAMJ | -3.090 | 2.033 | -1.520* | 0.137 | 0.057 |
| | ASON | 1.472 | 1.592 | 0.924* | 0.361 | 0.022 |
| Mt. Elgon | Annual | 4.436 | 4.617 | 0.961* | 0.341 | 0.023 |
| | MAMJ | 3.134 | 2.167 | 1.446* | 0.156 | 0.052 |
| | ASON | 7.466 | 4.411 | 1.693* | 0.099 | 0.070 |

* Significant at Alpha level = 0.05
Source: Field data, 2011

**Table 7: ANOVA of Annual and Seasonal Rainfall**

| | **Source of Variation** | **SS** | **MS** | **F-value** | **F crit.** |
|---|---|---|---|---|---|
| Annual | Inter-annual | 6324334 | 158108 | 1.636* | 1.545 |
| | Inter-AEZs | 12231595 | 6115797 | 63.263* | 3.111 |
| | Total | 26289740 | | | |
| Mbale | Between Seasons | 384928 | 384928 | 22.707* | 3.960 |
| | Within Seasons | 1356130 | 16951 | | |
| | Total | 1741058 | | | |
| Pallisa | Between Seasons | 23783 | 23783 | 1.340 | 3.960 |
| | Within Seasons | 1419921 | 17749 | | |
| | Total | 1443704 | | | |
| Sironko | Between Seasons | 178077 | 178077 | 2.636 | 3.960 |
| | Within Seasons | 5404352 | 67554 | | |
| | Total | 5582429 | | | |

*Significant at Alpha level =0.05
Source: Field data, 2011

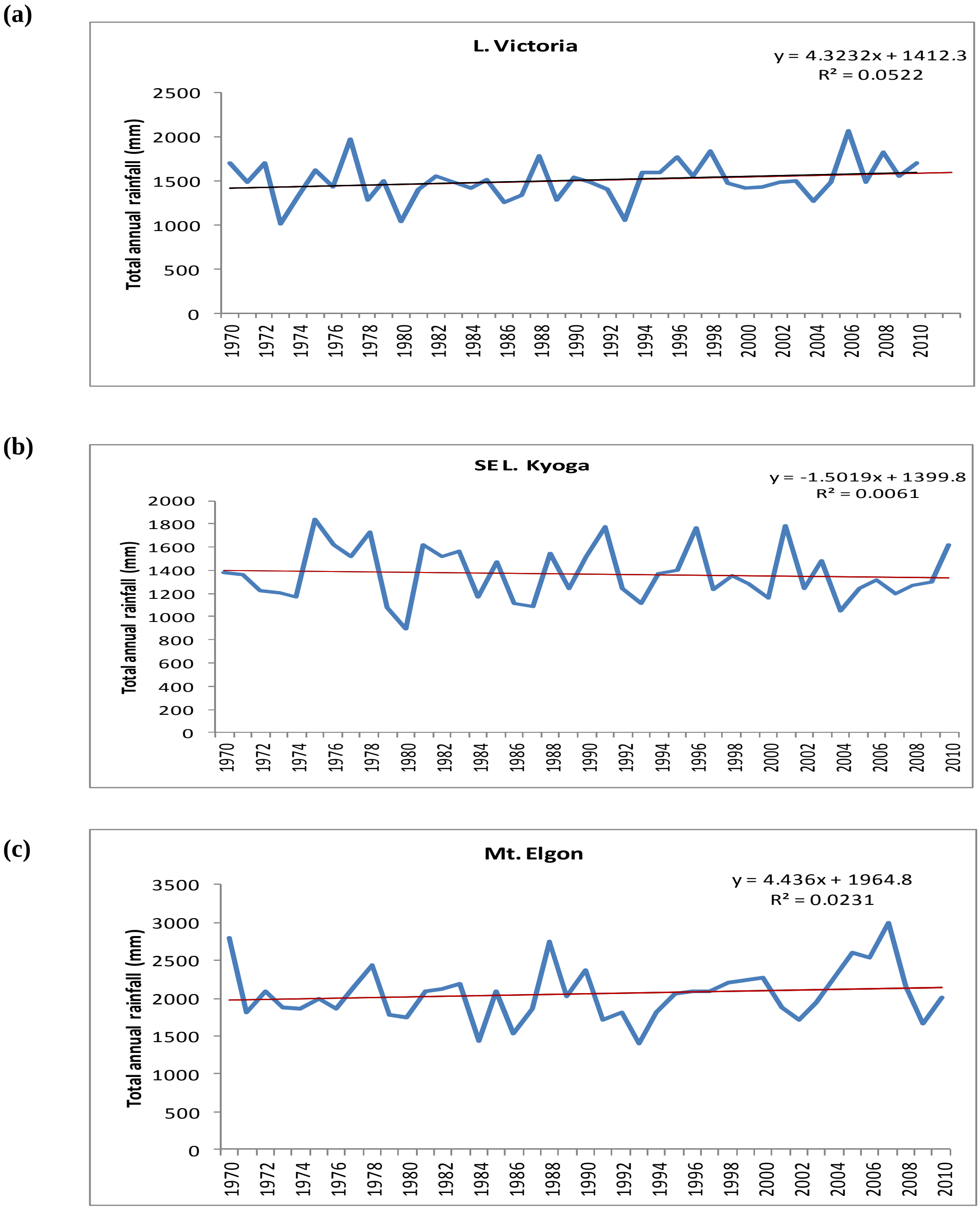

**Figure 1: Trend of annual rainfall for (a) L. Victoria, (b) SE L. Kyoga and (c) Mt. Elgon**

Source: Field data, 2011

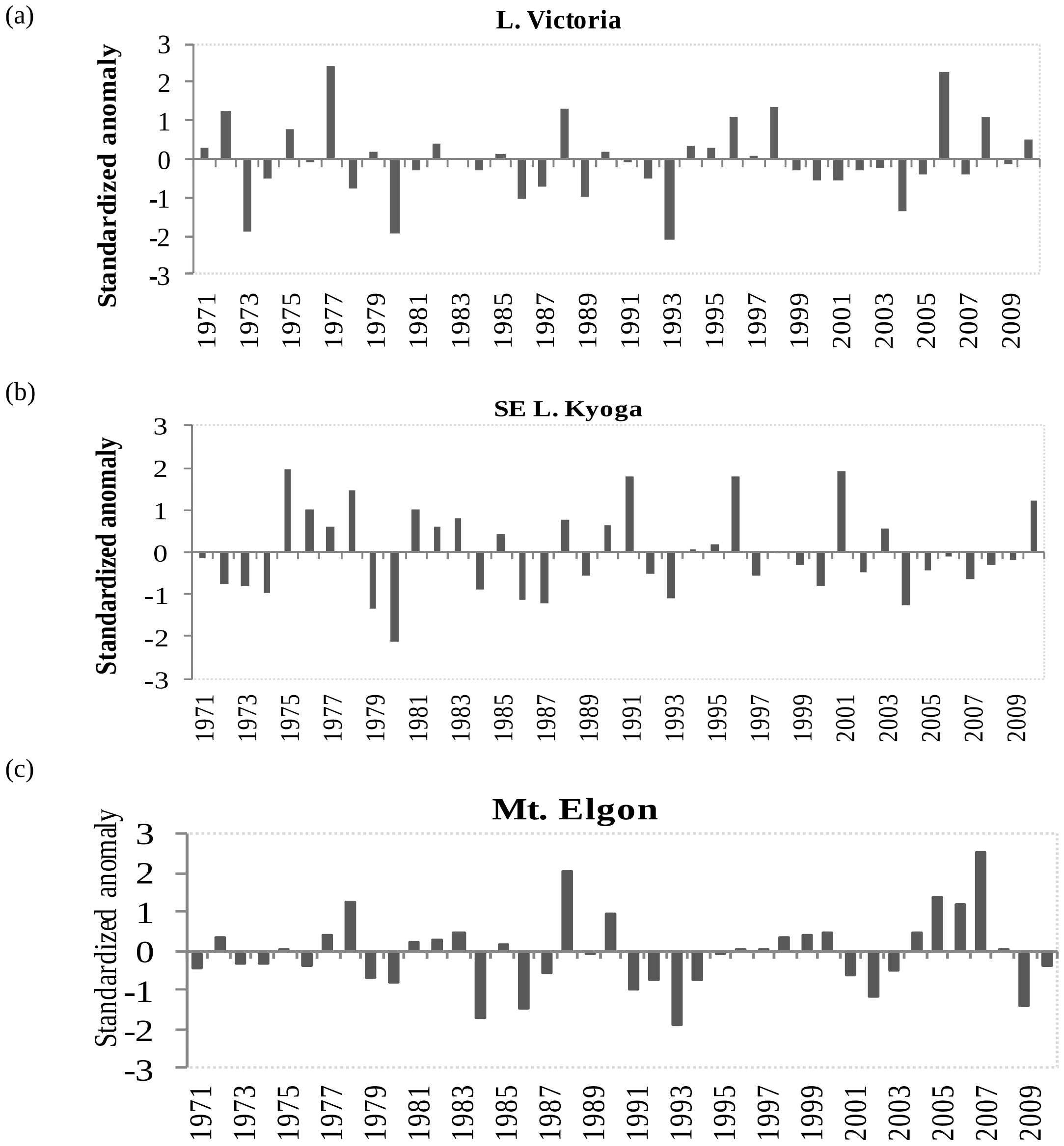

**Figure 2: Trends in annual rainfall anomalies relative to the 1971-2010 mean rainfall for (a) L. Victoria, (b) SE L. Kyoga and (c) Mt. Elgon**

Source: Field data, 2011

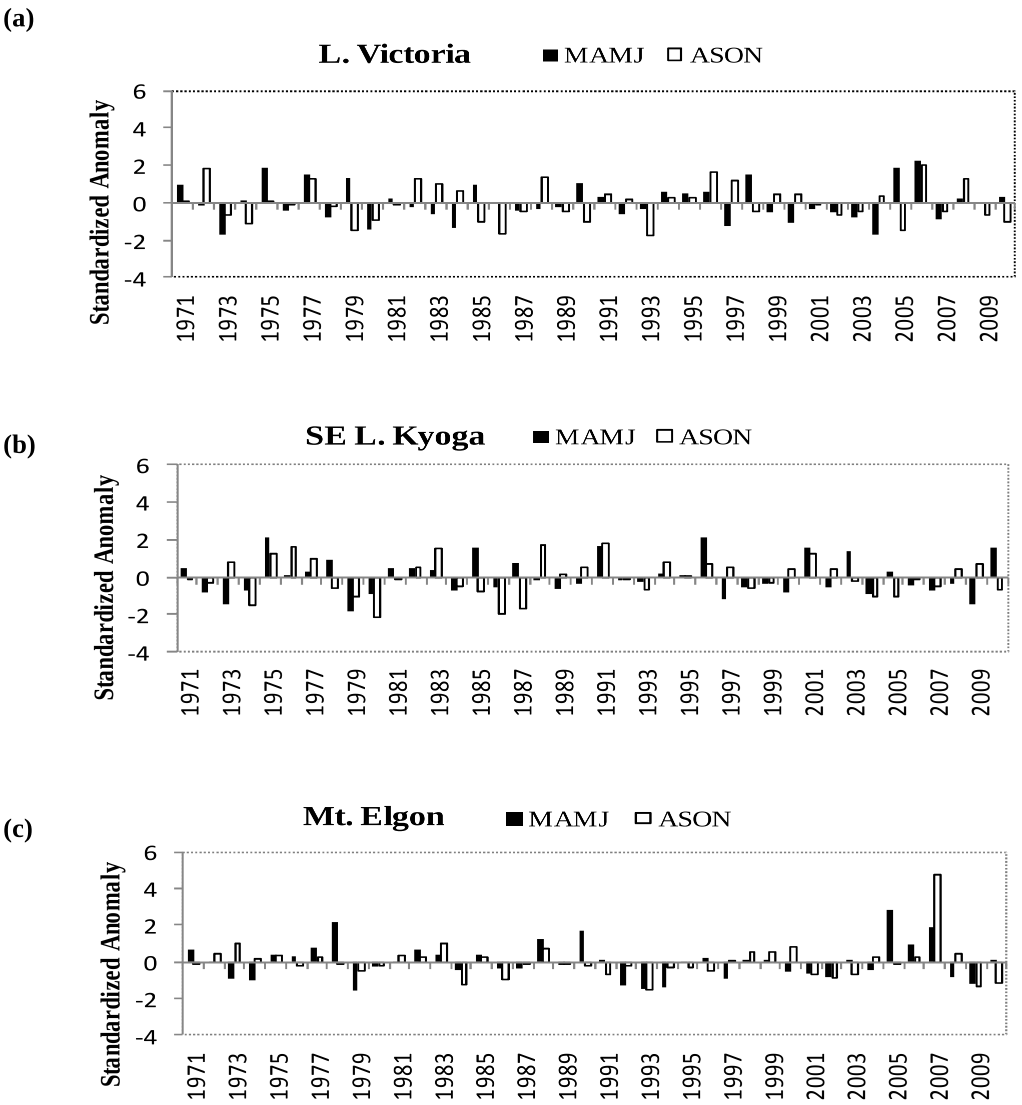

**Figure 3: Trend in seasonal rainfall anomalies relative to the 1971-2010 mean rainfall for (a) L. Victoria, (b) SE L. Kyoga and (c) Mt. Elgon**

**Source:** Field data, 2011

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