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Following the Rains: Evidence and Perceptions Relating to Rainfall Variability in Western Uganda

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FOLLOWING THE RAINS: EVIDENCE AND PERCEPTIONS RELATING TO RAINFALL VARIABILITY IN WESTERN UGANDA

by

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Under the Direction of Dr. Jeremy Diem

ABSTRACT

There have been reports that rainfall in East Africa is changing or becoming more variable. This can have significant implications for conservation initiatives and the food security of this populace region that is heavily reliant on the rain fed agricultural system. The perceptions of farmers regarding rainfall along with 30 years of satellite data and 16 years of ground level observations were analyzed in order to characterize rainfall in and around Kibale National Park, a protected area in the Ugandan portion of the Albertine Rift. Two homogenous rainfall regions exist in the area, and the onset, cessation, and amount of rainfall during seasons is highly variable. The perceptions of farmers align with the analysis of rainfall data, indicating that the season beginning in March shows the highest degree of variability. Decreases in the amount of rainfall are found for both rainy seasons.

INDEX WORDS: Rainfall variability, Kibale National Park, Uganda, Perceptions, Adaptation, Climate

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DEDICATION

I dedicate this thesis to the participants of this study and the people of the Albertine Rift, who face so many challenges in their daily lives, yet took the time to share their experiences with me. This thesis is also dedicated to my husband, Daniel McIntyre. Without his endless support and encouragement none of this would have been possible.

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TABLE OF CONTENTS

DEDICATION .... **iv**

ACKNOWLEDGEMENTS .... **v**

LIST OF TABLES .... **ix**

1 INTRODUCTION **1**

1.1 Effects of climate variability and change on conservation and agriculture **2**

1.2 Rainfall variability and trends **4**

1.2.1 Rainfall variability ***4***

1.2.2 Trends in rainfall in East Africa and the Albertine Rift ***6***

1.3 The role of local perceptions in climate research **7**

1.4 Current status of knowledge on localized rainfall **9**

1.5 Adaptations to rainfall variability **10**

1.6 Research question and objectives **11**

2. STUDY REGION **12**

3. DATA AND METHODS **16**

3.1 Rainfall **16**

3.1.1 Satellite data ***16***

3.1.2 Rain gauge data ***17***

3.1.3 Principal Component Analysis ***18***

3.1.4 Seasonal onset, cessation, and rainfall amounts ***19***

3.1.5 Trend analysis ***19***

3.2 Surveys and focus groups **20**

3.2.1 Sampling strategy ***20***

3.2.2 Surveys ***22***

3.2.3 Focus Groups ***24***

3.2.4 Combining perceptions with rainfall data ***24***

3.2.5 Translation considerations ***25***

3.3.6 Positionality ***25***

4 RESULTS **27**

4.1 Rainfall **27**

4.1.1 Principal Component Analysis ***28***

4.1.2 Averages: amount and typical timing of seasons ***29***

4.1.3 Results from onset and cessation determination ***29***

4.1.4 Onset of MAM ***32***

4.1.5 Onset of SON ***33***

4.1.6 Seasonal rainfall totals ***35***

4.2 Surveys and focus groups **39**

4.2.1 Demographic characteristics of participants ***39***

4.2.2 General farming practices ***42***

4.2.3 The MAM season ***46***

4.2.4 The SON Season ***50***

4.2.5 Dry seasons ***54***

4.3 Adaptations to perceived changes in rainfall **57**

4.3.1 Modification of planting time ***58***

4.3.2 Desire for expansion of cropland *59*

5. DISCUSSION **60**

6. CONCLUSIONS **66**

REFERENCES **68**

LIST OF TABLES

Table 4.1 Average seasonal duration for ARC2 regions (1983-2012) and Ngogo (1996-2012) 30
Table 4.2 Earliest, average, and latest onset dates for the MAM and SON seasons, 1983-2012 34
Table 4.3 Earliest, average, and latest onset dates for ARC2 and Ngogo, 1996-2012 34
Table 4.4 Coefficient of variation for season onset 34
Table 4.5 Correlation between North- and South Regions and Ngogo, 1996-2012 35
Table 4.6 (a) Significant seasonal rainfall trends..37
Table 4.6 (b) Significant season rainfall trends 38
Table 4.7 Demographic characteristics of survey participants 41
Table 4.8 General farming schedule for first planting 44
Table 4.9 General farming schedule for second planting 45
Table 4.10 Relationship between demographic and location characteristics and survey responses regarding onset of MAM season 47
Table 4.11 Relationship between demographic and location characteristics and survey responses regarding onset of SON season...48
Table 4.12 Relationship between demographic and location characteristics and survey responses regarding cessation of SON season 51
Table 4.13 Relationship between demographic and location characteristics and survey responses regarding cessation of SON season 52

Table 4.14 Relationship between demographic and location characteristics and survey responses regarding amount of rainfall during DJF season 55
Table 4.15 Relationship between demographic and location characteristics and survey responses regarding amount of rainfall during JJA season 56

LIST OF FIGURES

Figure 2.1 Location of Kibale National Park in Uganda 12

Figure 2.2 Location of Ngogo rain gauge 18

Figure 3.2 Sampling strategy 22

Figure 4.1 Average monthly rainfall for Kibale National Park 27

Figure 4.2 Rainfall regions 28

Figure 4.3 Average daily rainfall by region 29

Figure 4.4 Seasonal variations of the North Region, 1983-2012..31

Figure 4.5 Seasonal variations of the South Region, 1983-2012..31

Figure 4.6 Seasonal variations of the Ngogo dataset, 1996-2012...32

Figure 4.7 Seasonal rainfall totals...36

Figure 4.8 Perceptions of farmers regarding onset and cessation of the MAM season.................46

Figure 4.9 Perceptions of farmers regarding onset and cessation of SON season.........................50

Figure 4.10 Do changes in the weather worry you? 58

1 INTRODUCTION

Our climates on earth are constantly changing and humans have been adapting to these changes for centuries. The way in which people perceive variability or change is significant because perception frequently drives behavior and subsequent adaptation, which in turn can impact the ecosystems and landscapes that people inhabit (Osbahr et al., 2011). The Albertine Rift is an important biodiversity hotspot in East Africa that is home to a rapidly growing human population who heavily relies on rain fed agriculture for sustenance. Most of the rainfall of this region occurs within two rainy seasons that are largely driven by the movement of the Inter-Tropical Convergence Zone (ITCZ) to the north and south of the equator throughout the course of a year (Camberlin and Phillipon, 2002). The first rainy season occurs roughly during the months of March, April and May (MAM), while the second rainy season generally occurs during the months of September, October, and November (SON), the respective rainy seasons are frequently referred to as the long rains (MAM) and the short rains (SON) in much of the existing literature on East African rainfall (Williams and Funk, 2011; Camberlin and Philippon, 2002; Lott et al., 2013).

There have been reports from this and surrounding regions in East Africa that rainfall is changing or becoming more variable (Hartter et al., 2012; Osbahr et al., 2011; Williams and Funk, 2011; Funk et al., 2008; Camberlin and Phillipon, 2002), which can have significant implications for conservation initiatives and the food security of this populace region. Much of the research on climate variability and change is done at regional or continental scales, subsequently little is known of localized rainfall patterns in the Albertine Rift, and how people perceive and adapt to current weather situations (Orlove et al., 2010; Wilbanks and Kates, 1999). This project takes a closer look at the spatial and seasonal rainfall around a protected area in Africa's Albertine Rift through incorporating ground level rain data, satellite rainfall estimates, and the perceptions of local farmers regarding the rainy seasons.

The following chapter looks at the impact of climatic changes and variability on conservation and agriculture, provides a review of existing literature on rainfall for the region, and discusses the role of perceptions in climate research.

1.1 Effects of climate variability and change on conservation and agriculture

The Albertine Rift, is located in the western part of the Great African Rift Valley within the countries of Burundi, Democratic Republic of the Congo, Rwanda, Tanzania, and Uganda. The Albertine Rift is a biodiversity hotspot that is part of the tropical rainforest biome. The region covers a wide range of altitudes and habitats, and is home to more vertebrate species and more endemic species than any other region on the continent of Africa (Plumptre et al., 2007; Plumptre, 2011; Cordeiro et al., 2007). Protected Areas (or parks) are frequently established to protect and conserve tracts of wild land in Africa, and it is one of the primary mechanisms that protect remaining tropical forests in Africa (Bruner et al., 2001). These parks are banks of biological diversity, they provide crucial habitat to wild animals, and they provide numerous ecosystem services to surrounding communities (Byron and Arnold, 1999).

The establishment of protected areas can be an effective measure in limiting deforestation, but even when the boundaries of protected areas are maintained degradation can still occur and is likely the result of intensifying land use in surrounding areas (Hansen and Defries, 2007). It is proposed that farmers may increase the area of land they farm or that they might intensify agricultural production on the land they already occupy as a coping mechanism to changes in rainfall (Hartter et al., 2012), which could potentially indirectly affect the ecosystems in which parks exist. Rainfall is the primary determinant of the types of crops that are grown in Uganda (Rugumayo et al., 2003), and variability or changes in rainfall are also likely to affect agricultural practices in this region (IPCC, 2007), further impacting overall ecosystems.

Overlap exists between the world's biodiversity hotspots and key socio-economic poverty indicators (Fisher and Christopher, 2007; Adger, 2013). The socio-economic conditions of an area can have a large impact on conservation efforts, and conservation efforts should aim to improve socio-economic conditions of the surrounding area if they wish to have long-term success (Fisher and Christopher, 2007). Agricultural production is a very important part of the Ugandan economy; it employs 80% of the labor force, accounts for 42% of the GDP, and brings in 90% of export earnings (EA, GEF, and UNEP, 2007). With the majority of agriculture in the Albertine Rift being rain fed, changes in rainfall have the potential to heavily influence the socio-economic conditions of this region by directly affecting food security and labor opportunities (James, 2010; Stern and Cooper, 2011).

Trends in population increases around protected areas can impact or place strain on the protected areas themselves, particularly if there is a high degree of dependence of rain fed agriculture and ecosystem services in such areas. Populations around protected areas in Africa and Latin America have increased between 1960 and 2000, with increases driven by immigration (Wittemeyer et al., 2008). The Albertine Rift is one of the most densely populated regions in all of Africa (Plumptre et al., 2007). Most of this population growth has occurred in the last fifty to a hundred years (Cordeiro et al., 2007; Hartter and Ryan, 2010). According to data from the United Nations (2010), Uganda and the surrounding countries of Burundi and the Democratic Republic of the Congo are among the top ten countries with the fastest growing populations in the world, a population that heavily relies on rain-fed agriculture and ecosystem services for sustenance (Pimm and Raven, 2000). According to the Uganda National Water Development Report (NWDR, 2005) climate in Uganda, and especially rainfall, has been particularly variable since the 1990's. The occurrence, duration, and amount of rainfall has varied from long-term means leading to droughts in years of lower precipitation, or catastrophic floods in years of higher precipitation (NWDR, 2005). The rapid population growth and dependence on rain-fed agriculture in this ecologically significant world region makes the relationship between changing rainfall and agriculture a necessary field of inquiry.

1.2 Rainfall variability and trends

1.2.1 Rainfall variability

Rainfall in Africa has been and continues to be highly variable. Rainfall variability refers to changes in the distribution of regional and seasonal patterns, increases or decreases in seasonal precipitation amounts, changes in seasonal or annual means, and changes in the frequency of extreme events (IPCC, 2007). Nicholson (1989) writes that fluctuations in rainfall are an inherent characteristic of the continent's climate. Africa has experienced periods of drying during the 1920's, 1940's and 1950's, and periods of increased rainfall in the 1960's and 1970's (Nicholson, 1989).

There are four main modes of rainfall variability in Africa that are characterized by strong teleconnections. The most common spatial mode exhibits below-average rainfall throughout the subtropics and increased rainfall in equatorial latitudes (Nicholson, 1989). This mode presented itself between 1968 and 1973, and again in 1982 (Nicholson, 1989). The second mode involves below average rainfall or droughts that occur throughout the entire continent (e.g. 1983)

(Nicholson, 1989). The remaining modes exhibit wet conditions over the entire continent (e.g. 1961), or above average rainfall in the subtropics that coincides with rainfall deficits in the tropics (e.g. 1950-1959) (Nicholson, 1989). This prevalent tendency for opposite rainfall anomalies to occur simultaneously in two different geographic sectors suggests that continental-scale teleconnections are strong in Africa (Nicholson and Kim, 1997).

The presence of strong teleconnections and the time scales at which rainfall variability occurs suggests that this variability may be influenced by the El Niño Southern Oscillation (ENSO). Fluctuations in rainfall for equatorial and East Africa occur at short time scales that range between two to six years (Nicholson, 1989; Nicholson and Kim, 1997). These time scales correspond to the time scale of ENSO and fluctuations in sea surface temperatures (Nicholson, 1989; Nicholson and Kim, 1997). ENSO is a large-scale atmospheric and oceanic phenomenon that occurs every two to seven years and involves warming of sea-surface temperatures in the central and east-central Pacific, off the coast of South America (NOAA, 2005). These changes in sea surface temperature influence patterns of tropical rainfall and weather patterns around the world (NOAA, 2005). La Niña, the cool phase of El Niño, involves cooling of the same oceanic sea surface temperatures and also influences rainfall and weather patterns around the world (NOAA, 2005). El Niño typically lasts for a year, but has lasted as long as three or four years and La Niña episode lasts between one and three years (NOAA, 2005).

While there are numerous factors that can affect rainfall variability in East Africa, the influence of ENSO and internal atmospheric variability are thought to have the greatest impact. In general, El Niño has been associated with above average rainfall in equatorial East Africa (Camberlin, 1995) while La Niña is associated with below average rainfall in this region (Nicholson and Selato, 2000; Lott et al., 2013). Overall, there is a much stronger spatial coherence between variability in the SON season and ENSO, while variability in the MAM season appears to only be linked to the oceanic component of ENSO (Camberlin and Philippon, 2002; Nicholson and Kim, 1997).

The factors that influence variability in the MAM season are less understood than those that govern variability for the SON season, but are thought to be linked to internal atmospheric variability (Camberlin and Philippon, 2002). Nicholson (1997) writes that cold sea surface temperatures increase rainfall in Africa, while warm sea surface temperatures decrease rainfall. This coincides with theories that imply that changes in the sea surface temperatures in the Indian Ocean also contribute to changes in the rainfall of East Africa. While the beginning of the MAM season tends to be influenced by the oceanic component of ENSO, the latter part of the season is more impacted by east-west signals over the equatorial Indian Ocean (Camberlin and Philippon, 2002). Recent studies tie variability and changes in MAM season to warming of sea surface temperatures (Funk et al., 2008; Williams and Funk, 2011; Lott et al. 2013; Lyon and DeWitt, 2012).

1.2.2 Trends in rainfall in East Africa and the Albertine Rift

There is not agreement within the scientific community regarding the trends in rainfall amounts for East Africa. Reports by the IPCC (2007) that rainfall will increase in East Africa are in contrast with recent studies that have found decreases in the rainfall of the region (Funk et al., 2008; Williams and Funk, 2011).

Camberlin and Philippon (2002) write that the MAM rains show less interannual variability than the SON rains, which has made it the major East African growing season. Various studies suggest that the MAM season is becoming more variable, which is concerning due to the importance of the MAM season to food security. Sub-regional assessments performed by Seimon and Picton-Phillips (2010) found that the greater Virunga landscape within the Albertine Rift, including the important protected areas of Kibale, Queen Elizabeth, and Rwenzori Mountains National Parks, experienced fluctuations in rainfall for early May and September, and showed strong intra-seasonal variability in precipitation (Seimon and Picton-Phillips, 2010). Mubiru et al. (2012) found that the growing seasons during the months of April and May has diminished, and that the onset of the MAM season was sometimes delayed by 30 days across 14 rainfall regions in central Uganda for the period of 1950-2008. Likewise, a localized study in the Alberinte Rift by Stampone et al. (2011) indicates that the timing and distribution of seasonal transitions vary substantially between years (Hartter et al., 2012). There is also indication that the rainy season that the MAM season has had increases in dry days, and that the SON season has also become drier, with fewer heavy rainfall events (Hartter et al., 2012). Another study by Osbahr et al. (2011), performed in southwest Uganda, found that the MAM rainy season has become more variable and less reliable than the SON season, with an increased risk of drought during the MAM season (Osbahr et al., 2011). McSweeney et al. (2009) also indicate that rainfall during the MAM season is decreasing.

1.3 The role of local perceptions in climate research

Within the last two to three decades local knowledge has emerged out of the shadows from being a field that was once thought of as inefficient in relation to modern science, to now being seen as having inherent value in guiding research agendas and for use in participatory research aimed at sustainable development (Sillitoe, 2000; Alexander et al. 2011). Local knowledge has been applied more frequently in research relating to forestry, biodiversity, and agriculture, but recently it has begun to be incorporated into work relating to development and climate as well (Orlove et al., 2010; Sillitoe, 1996, 2000; Vedwan, 2006; Waddell, 1995; Salick and Ross, 2009; Green and Raygorodetsky, 2010). Currently, there is a growing body of research within climate science that combines the perceptions, which forms the basis of local knowledge, of farmers, indigenous communities, and herders with meteorological observations in order to gain a more complete understanding of climatic events, and the resulting impacts, vulnerabilities, and adaptations (Parry et al., 2007; Smithers and Smit, 2009).

While local knowledge has a rather broad definition, it has specific characteristics that pertain to this particular study. Local knowledge refers to knowledge that is held by indigenous, local, and traditional cultures (Salick and Ross, 2009). Local knowledge is frequently referred to as indigenous knowledge or traditional knowledge, and these terms are synonymous. Local knowledge is local in extent and it can have patterns that are based on demographic factors (Sillitoe, 2000). Local knowledge is relevant in assessments of local level phenomena that may not be noticeable on larger scales (Sillitoe, 2000). Demographic factors such as age, gender, wealth, education, experience, access to extension services can influence if and how farmers perceive climatic changes, and how they adapt (Sillitoe, 2000; Gbetibouo, 2009). Indigenous climate knowledge has been found to be social in nature (Orlove et al., 2010). Information on agricultural practices and climatic phenomena are frequently discussed among community members. The information that is shared can be current as well as historic. Indigenous knowledge involves learning across generations by experiential or oral means; in this way the younger generation and newcomers may gain access to the knowledge held by long-term residents (Sillitoe, 2000).

Local knowledge can make many positive contributions to scientific inquiry into climate change. The changes in rainfall that have been noted by the scientific community have been observed by farmers in many parts of Africa (Apuuli et al., 2000; Cooper et al., 2008; Hartter et al., 2012; James, 2010; Osbahr et al., 2011; Roncoli et al., 2002). The knowledge of local communities can aid in determination of patterns of climate change in regions with limited or discontinuous climate and weather data, especially relevant to data-scarce regions in developing countries (Alexander et al., 2011). Local knowledge can put scientific observations of climate change in the context of a human landscape (Alexander et al., 2011), and in reviewing local knowledge in the context of scientific observations the two bodies of knowledge can validate or enhance one another (Orlove et al., 2009; Roncoli et al., 2002; Thomas et al., 2007; West et al., 2008). When incompatibilities between local knowledge or perceptions and climatological observations emerge, potential new areas of inquiry are brought to light (Nightingale, 2003; Osbahr et al., 2011).

1.4 Current status of knowledge on localized rainfall

There is a need to gain a better understanding of localized rainfall events in East Africa, and especially the Albertine Rift. Many studies that consider rainfall variability in East Africa tend to focus on rainfall at continental or regional scales (e.g. Nicholson, 1989; Nicholson and Kim, 1997; Camberlin and Philippon, 2002; Williams and Funk, 2011). There has been indication that even regional studies that have delineated homogenous climatological rainfall zones within regions of East Africa, such as Ogallo (1980; 1989) and Basalirwa (1995), are more complex than was initially thought (Stampone et al., 2011; Seimon and Picton-Phillips, 2010). While the analyses by Ogallo (1980; 1989) and Basalirwa (1995) can be appropriate for regional, national, or continental scale decision-making, more localized rainfall analyses can be more useful to farmers and conservation managers in decision-making (Stampone et al., 2011). More in-depth knowledge of localized climatic events can aid in determining local impacts and responses and can be particularly relevant in areas where both conservation and food security are intricately linked to weather patterns.

The major obstacle to performing localized studies of climate is that long-term, high density climate data is frequently scarce or non-existent (Fischer et al., 2005; Stampone et al., 2011; Basalirwa 1995; Kigobe et al., 2011; Asadullah et al., 2008). While rain gauges exist in some areas in the Albertine Rift, many tend to be newer with shorter periods of record, and therefore less relevant for studying long-term changes. Data from long-term rain gauges is frequently incomplete due to political or socio-economic reasons. A solution exists in the availability of satellite derived rainfall data that can supplement the data from rain gauges.

1.5 Adaptations to rainfall variability

Human adaptation will be fundamental to the wellbeing of communities in the face of climatic changes (Adger, 2003). Adaptation is defined as the process through which adjustment are made to lessen the adverse effects or take advantage of opportunities that are associated with climatic changes (IPCC, 2007). In general, communities can either plan adaptation or it can occur autonomously, in which case it is done without awareness of climate change predictions and is instead based on experience (Smithers and Smit, 2009; Nyanga et al., 2011). Research conducted on agriculture in developing regions indicate that the impacts of climate change on agriculture can be reduced through human adaptations such as adjusting sowing or harvesting dates, changing cropping patterns, and adoption of new cultivars (Mendelsohn et al., 1994; Tingem and Rivington, 2009; Traerup and Mertz, 2011; Winters et al., 1998). Challinor et al. (2007) add that another adaptive measure by farmers may be to expand into new cropland, which could be challenging in areas with high deforestation and high population such as equatorial Africa. Work involving perceptions have confirmed the aforementioned theories, and illustrate how they have been implemented. Changes in planting times, continuous changes in agricultural practices throughout growing seasons based on weather conditions, diversification of crop varieties, and changes in land management practices have all been reported (Crane et al., 2011; West et al., 2008). Perceptions have furthermore shed light on risks that are faced by farmers, including increases in sickness, increased worry and stress over food security, losses of crops due to false starts of rainy seasons, the indication that planting is considered the riskiest time during the growing season, and increased attacks of pests and weeds (Haque et al., 2012; West et al., 2008).

1.6 Research question and objectives

Broadly, the research presented here is intended to improve the understanding of rainfall variability in a protected area within the Albertine Rift region of East Africa for the period of 1983 to 2012. Knowledge of rainfall variability can be useful for conservation, food security, and development. The major objectives of this research are: (1) To determine the local rainfall characteristics for the study area, (2) to assess if changes have occurred with regard to season onset and seasonal rainfall amounts for the period of 1983 to 2012, (3) to determine if or how farmers perceive changes in the rainy seasons, (4) to examine whether spatial or demographic patterns affect farmers' perceptions of change or variability, (4) and to assess how farmers are impacted by or responding to any perceived changes.

2. STUDY REGION

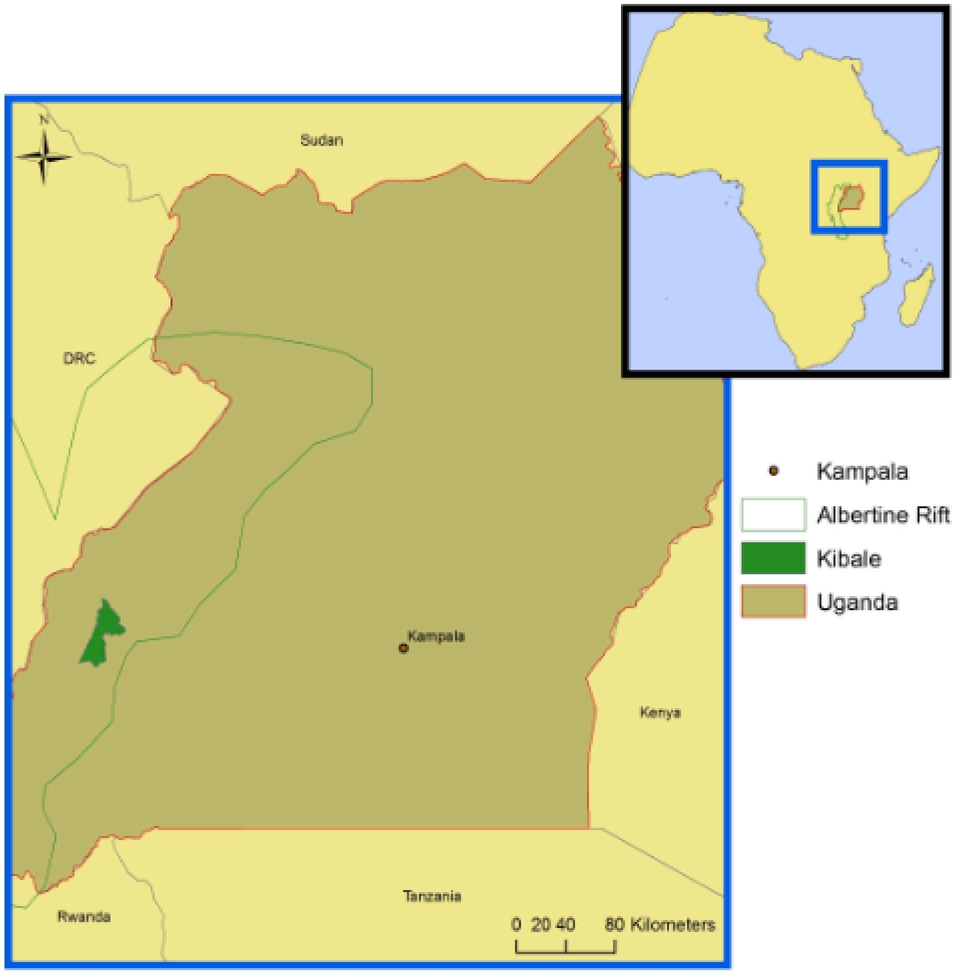

Figure 2.1 Location of Kibale National Park in Uganda

This research was carried out in and around Kibale National Park in western Uganda. Kibale is a protected area that is situated within the Albertine Rift region of East Africa. Much like other areas within the Albertine Rift, Kibale is characterized by high levels of biodiversity, and is particularly known for its diverse and abundant primate population (Chapman, et al., 2005). The human population around Kibale has tripled between 1959 and 1990 (Naughton-Treves, 1998) and in 2006 population densities ranged between 262 and 335 individuals per square kilometer (Hartter, 2007). It is worth noting that this region is heavily dependent on the rain fed agricultural system. The landscape surrounding the park is comprised of intensive small-holder agriculture, tea estates, and small forest fragments and wetlands. Kibale provides an excellent opportunity for a localized rainfall study through the incorporation of meteorological data along with the perceptions of farmers due to existence of rain gauges in the park, and the high density of smallholder farms that are located directly outside of the park boundary.

Kibale was established as a Crown Forest Reserve in 1932, and obtained national park status in 1993 (Struhsaker, 1997). Kibale (Fig. 2.1) is a remnant forest that covers approximately 795 km^2. The elevation within the park ranges from 900m to 1590m, and elevation increases to 5000m west of Kibale towards the Rwenzori Mountains that are along the western border of Uganda (Hartter et al., 2012). Lakes dot the landscape surrounding the parl. Kibale is considered a medium altitude tropical moist forest that transitions from lowland and montane rainforest in the north of the park to grasslands and savanna towards the south. The temperature is constant throughout the year due to Kibale's proximity to the equator, with annual temperatures ranging between 15-23°C (Stampone et al. 2011).

The park has a tropical humid climate, and is between the tropical wet and tropical wet-and-dry climate types (Trewartha, 1954). The region has an average annual rainfall of 1719 mm (Hartter, 2010) and the Inter-tropical Convergence Zone (ITCZ) is the primary driver of seasonal rainfall (Trewartha, 1954). The ITCZ occurs near the equator as a low-pressure zone that is formed when air masses converge and ascend and is characterized by cloud formation and rainfall (Trewartha, 1954). The ITCZ migrates a few degrees to the north or south of the equator throughout the year as it follows the sun's zenith (Trewartha, 1954). Rainfall decreases from the northeast to the southeast of the park, which accounts for the change in vegetation from forest to grassland across this landscape.

Kibale has a bimodal rainfall pattern. This bimodal pattern has four seasons that coincide with stages in the route of the ITCZ (Stampone et al., 2011; Basalirwa, 1995). The first dry season occurs during the months of December, January, and February (DJF); any rains that do occur during this season are the result of regional features. The long rainy season corresponds with the months of March, April, and May (MAM) and is the product of the convergence of southeasterly airflow from the Indian Ocean into the approaching ITCZ (Basalirwa, 1995). When the ITCZ migrates north, the second dry season begins, and occurs during June, July, and August (JJA) (Basalirwa, 1995). Any rains that may occur during this season are due to humid air masses out of the west, which are known as the Congo air masses (Basalirwa, 1995). The short rains start during early September, with the approach of the ITCZ out of the North, continues through October and November (SON) (Basalirwa, 1995).

Kibale National Park is situated within the montane farming system of western Uganda. Most farms are less than five hectares in size, and farmers tend to grow a variety of crops. Dominant crop that are grown are Irish potatoes, sweet potatoes, beans, groundnuts, bananas, cassava, maize, yams, sorghum, and millet. Avocado, coffee, tomatoes, sugar cane, and various fruits such as pineapple, mango, guava, and papaya are grown to a lesser extent. Farmers may also keep a small number of livestock such as chickens, pigs, sheep, or goats on their farms. The bimodal rainfall pattern makes it possible to have two growing seasons per year (NEMA, 2001).

Farmers around Kibale predominantly belong to two ethnic groups; the Batooro and the Bakiga. The Batooro are longtime residents of this region, and mostly live to the west of the park. The Bakiga mostly live to the east of the park, and started immigrating to the area in the

1950’s and 1960’s (Naughton-Treves, 1997; Turyahikayo-Rugyema, 1974). Farm sizes average 1.4 hectares, and for both groups, and women generally tend to food crops while men tend to cash crops (Naughton-Treves, 1997).

3. DATA AND METHODS

3.1 Rainfall

3.1.1 Satellite data

The lack of long term, high density, and serially complete rainfall data poses a significant challenge to studying rainfall in this region, but a solution exists in the availability of satellite derived rainfall estimates that can supplement the data from existing rain gauges. There are numerous satellite rainfall products that are available for the Albertine Rift: the African Rainfall climatology version 2 (ARC2), Climate Prediction Center Morphing Technique (CMORPH), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), African Rainfall Estimation Algorithm (RFE), and Tropical Rainfall Measuring Mission (TRMM) (Diem et al., forthcoming). From these five products, ARC2, RFE, and TRMM are the only products that have long-term measurements, and ARC2 has the longest period of record and is the only product currently feasible for climatological purposes (Diem et al., forthcoming). Data from the ARC2 satellite of the Famine Early Warning System was found to be the most accurate product to predict rainfall days (Diem et al., forthcoming). Benefits of ARC2 include a high-resolution long-term data set, with minimal, continuous inputs that minimize bias and error, with availability in near real-time (Novella, 2013). A limitation to ARC2 includes a dry bias that occurs during the Northern hemisphere summer (Novella, 2013).

ARC2 consists of daily gridded rainfall estimates available from 1 January 1983 to the present and is available at a 0.1-degree (~10km) scale for the spatial domain of 40 degrees South to 40 degrees North and 20 degrees West to 55 degrees East. ARC2 uses inputs from three-hourly geostationary infrared satellites from the European Organization for the Exploitation of

Meteorological Satellite (EUMETSTAT) that report 24-hour rainfall accumulations over Africa (Novella, 2013). ARC2 is consistent with the Global Precipitation Climatology Project (GPCP) and Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP), with correlation coefficients of 0.86 over a 27-year period (Novella, 2013).

Daily ARC2 rainfall estimates for the period of January 1, 1983 to December 31, 2012 were obtained from Columbia University's online IRI/LDEO Climate Library (http://iridl.ldeo.columbia.edu). The 37 grid cells that correspond to Kibale National Park along with a 10 km buffer around the park for the period were included in this analysis. The daily data set was 97% complete.

3.1.2 Rain gauge data

Daily rainfall observations from the Ngogo rain gauge, located in the center of Kibale at the Ngogo ranger station (fig. 3.1), were chosen for this study since it represents a near complete record for which to compare the satellite rainfall estimates to. The Ngogo data set is 99% complete and is available for the period beginning in July 1, 1996. The Ngogo set was chosen above the data set from the Makerere University Biological Field Station (MUBFS) that has a longer period of record, because Ngogo contains fewer missing days. Although it is only available for the period beginning on July 1, 1996, it will serve as a validation for satellite data because satellite data tends to be estimations rather than precise measurements. If the ground level rainfall observations show similar results to ARC2 estimates for the period beginning in 1996, it will serve as a justification to use the ARC2 data set for the entire 30-year period of record. Daily rainfall records were obtained for the period of July 1, 1996 to October 31, 2012.

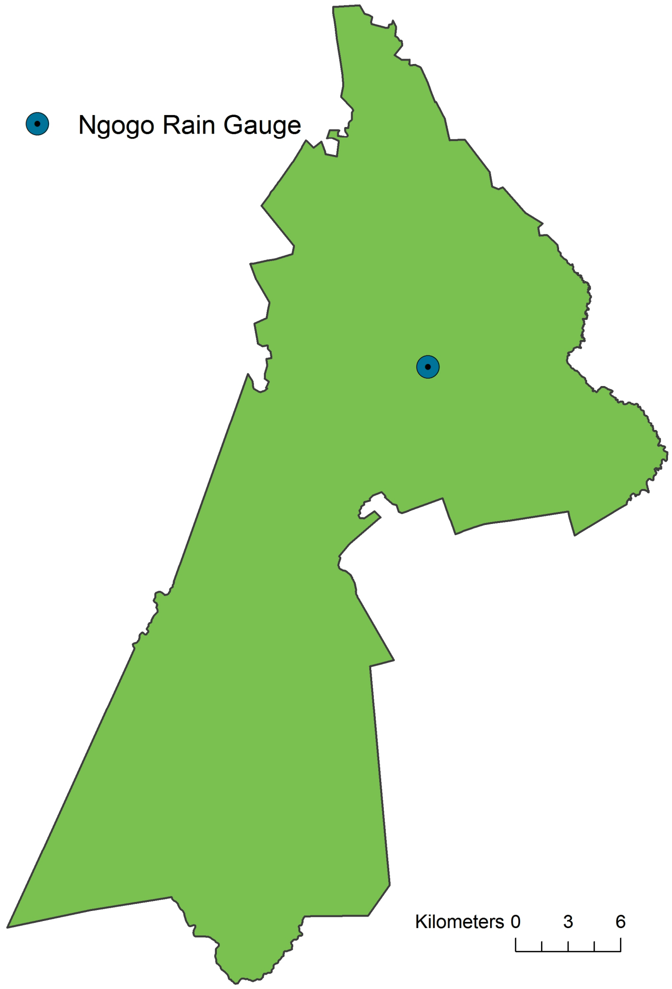

Figure 3.1 Location of Ngogo rain gauge

3.1.3 Principal Component Analysis

A Principal Component Analysis (PCA) of ARC2 data will be used to determine if homogenous rainfall regions exist in the area. Following the methods of Diem et al. (forthcoming), the square roots of 22-day totals were used for the 37 grid cells that correspond to the study area. Diem et al. (forthcoming) determined that larger temporal scales (22-day totals versus 11-day or 4-day totals) produced higher accuracy in rainfall estimation. The square roots of 22-day totals were calculated to produce a normal distribution within the data (Diem et al., forthcoming). Rotated PCA modes were used to determine the spatial characteristics of the zones. Daily averages of rainfall were then computed to determine the average daily rainfall for each homogenous rainfall region throughout the year.

3.1.4 Seasonal onset, cessation, and rainfall amounts

Season onset was determined following the methods of Osbahr et al. (2011) and Stern et al. (1982), who have both worked with rainy season onset in Uganda. Season onset occurs on the first dates after February 1st or July 1st on which at least 20 mm of rain falls in a 3-day period, permitting there is not a 7-day dry spell in the 30 days directly after onset (Osbahr et al., 2011; Stern et al., 1989). A threshold of 0.85 mm was used to classify a rain day.

Few clear methods have been published regarding determination of cessation of rainy season in Uganda or equatorial Africa. I consequently looked to work on season cessation that has been done in the Amazon by Marengo et al. (2001) as a guide for determining cessation due to climatic similarities between equatorial Africa and the equatorial Amazon. Season cessation was defined as the first pentad with a daily average of less than 4mm, permitting that 6 of the 8 subsequent pentads also have daily averages of less than 4mm and 6 of the 8 preceding pentads have daily averages above this (Marengo et al., 2001).

Daily rainfall data from ARC2 (1983-2012) and the Ngogo rain gauge (1996-2012) was used to calculate the number of monthly rain days (with a threshold of 0.85mm), and seasonal rainfall totals based on the classification of season onset and cessation.

3.1.5 Trend analysis

Trend analyses were performed for the onset, cessation, duration, and amount of rainfall for each of the four seasons over nine different periods over the 30-year ARC2 period of record. Nine different periods were analyzed in order to eliminate the effects of possible anomalous 1983 or 2012 years. The trend for each time series will be checked for significance with a confidence level of 95%. Positive trends will indicate later onset or cessation dates, or increases in the duration or amount of rainfall during a season. Negative trends will indicate earlier onset or cessation, or decreases in the duration or amount of seasonal rainfall.

3.2 Surveys and focus groups

Household surveys and focus group interviews were used to gain insight into local farmers' perceptions of changes in rainfall near Kibale. This research is part of a larger project, funded by the National Science Foundation, titled: "Hotter Hotspots: Land-Use Intensification and Protected-Area Vulnerability in Africa's Albertine Rift" (NSF CNH-EX grant number: 1114977). The broader project aims to quantify how and where land use around protected areas in the Ugandan portion of the Albertine has intensified due to changes in climate, land-use, and population change over the last decade. The Principal Investigator's Internal Review Board at the University of New Hampshire approved the broader research protocol, which involves research with human subjects. Permission to conduct to work with human subjects was obtained from Georgia State University's Institutional Review Board, Uganda National Council for Science and Technology, Uganda Wildlife Authority, and local council leaders.

3.2.1 Sampling strategy

Since this research project is part of a broader interdisciplinary project, it shares a similar sampling strategy to the broader project. The "Superpixel" sampling strategy has been successfully used in interdisciplinary research around Kibale since 2004 (e.g., Goldman et al., 2008;

Hartter, 2009; 2010; Hartter and Ryan, 2010, Hartter and Southworth, 2009; Hartter and Goldman, 2011; Hartter et al., 2012). Nine ranger stations exist in Kibale. Seven of these stations are proximate to villages where agricultural activities take place, of the other two, one is located in the center of Kibale National Park, and the other in an area where pastoralist activities dominate, and thus not appropriate to address research objectives of this study. Surveys and focus groups took place surrounding the seven ranger stations of Sebatoli, Kayawara, Isunga, Nyabatusi, Mainaro, Kanyanchu, and Bihehe (fig. 3.2).

Five-kilometer radii were drawn around these seven ranger stations, and ten sampling locations, or “superpixels”, were randomly determined within each of the 5-kilometer radii (fig. 3.2). Each of these 10 sampling locations, or superpixels, was a 9-hectare circle. Households that rent, borrow, or own land within these 9-hectare circles represented a pool of potential participants for surveys, even if the physical location of the house was not actually within the superpixel. A trained local enumerator who was fluent in the local language conducted the surveys and none of the researchers were present. A total of 180 households were surveyed between June 2012 and September 2012.

Two focus group interviews were held for each of the seven ranger station buffers between June 18, 2012 and June 28, 2012. For each pair of focus groups, one was held closer to the park (within 1 km), and one was held further from the park (4-5 km), but not within superpixels, so as not to bias or contaminate ongoing household surveys. Focus group interviews were conducted with a trained local translator. Only female farmers were recruited for focus group interviews since women more than men engage in food cropping activities. Recruitment took pace by first notifying local council leaders (LC1) that this activity would be taking place, deciding on a suitable time and location with their input, and then the details of the meeting would spread through the local community by word of mouth. Each focus group consisted of 8 to 30 participants, and was representative of the larger community, including a diverse range of ages, educational backgrounds, and wealth. Figure 2.3 shows the location of the ranger stations along with the 5 km boundaries around them that contain the survey and focus group locations.

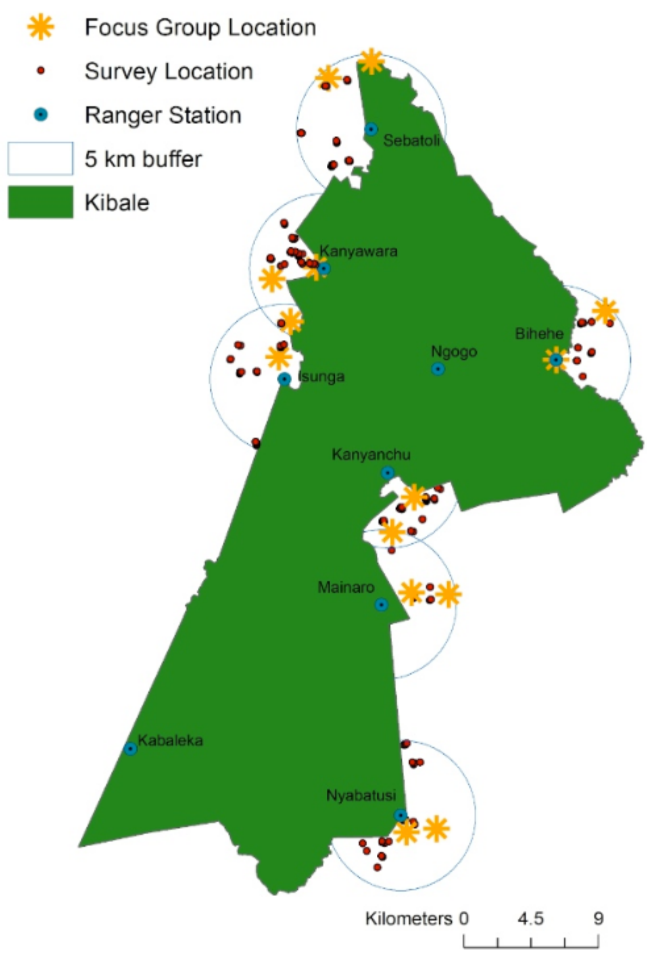

Figure 3.2 Sampling strategy

3.2.2 Surveys

A total of 180 farmers were interviewed using a semi-structured survey with closed and open-ended questions. Information was collected on the basic spatial and demographic characteristics of respondents such as their age, gender, tribe, education, and home construction type.

Questions mainly focused on climate variability and change, farming practices, risks, and the impacts of neighboring Kibale National Park.

Basic characteristics included the approximate location of the survey site and how long the respondent has lived here, as well as demographic information such as age, gender, ethnicity, and highest level of formal education reached. No identifying information was recorded. A wealth classification was computed in SPSS by using a k-means cluster analysis (Hartter, 2009). Total amount of land, housing construction type, gender of the head of household, and the level of education were inputted into the K-means cluster analysis in order to determine three wealth categories (above average, average, and below average) within the larger group of respondents.

Survey respondents were asked about the onset, cessation, and amount of rainfall for all seasons. Questions compared the current situation to the past (10 years ago or longer). Questions regarding adaptation and impact compared current planting schedules of various crops to past planting schedules. Descriptive statistics were used to analyze quantitative data on perceptions of seasonal changes and adaptations of planting schedules. Chi-Square tests were used at a significance level of 0.05 to determine if any association exists between perceptions of seasonal changes or adaptations and basic categorical characteristics (ethnicity, gender, location, wealth, education, and resident status). Since the overwhelming majority of responses fell within only a few categories, the reduced categories that contained the majority of responses were again analyzed using Chi Square tests for independence. The distance that a respondent lived from the park was recoded to separate those that lived within one kilometer from the park from those that lived over a kilometer from the park. A Chi square test was used to determine if there was any association between this distance category and perceptions of rainfall. A Kruskall Wallis test was also used to determine if relationships existed between perceptions or adaptations distance from the park as a continuous variable (not coded).

3.2.3 Focus Groups

Respondents were asked a series of questions that compared current weather conditions to those of the past (10 or more years ago). On the perceptions of seasonal changes in rainfall, respondents were asked about the onset, cessation, and amount of rainfall for all seasons. Questions compared the current situation to the past (10 years ago or longer). To determine if farmers were adapting their agricultural practices, they were asked questions regarding planting time, crop choices, and land management. Although the questions were predetermined, farmers frequently brought up relevant issues through their discussion of the predetermined questions. At the end of the discussion they were also asked open-ended questions about other concerns they may have, in order to assess other risks they face.

Qualitative data analysis started with the transcription of interviews and followed typical procedures outlined by Creswell (2007). After multiple readings of transcripts and reflection on the content, the responses were coded. After coding major themes were identified, these themes frequently corresponded to the predetermined questions. Themes were not predetermined, but instead emerged out of the coded responses.

3.2.4 Combining perceptions with rainfall data

Results from the analyses of rainfall and social data will be compared and contrasted to determine where similarities or differences exist between the two bodies of data. Statements made by focus group respondents and data gathered from surveys will be cross-referenced with rainfall data to determine where similarities and differences exist within the two bodies of data.

3.2.5 Translation considerations

Care should be taken to ensure that misinterpretation or bias is avoided when translation is involved. Esposito (2001) suggests that the presence of a real-time translator with a mutual natal language to participants that performs instantaneous translation allows for validation of responses while avoiding misinterpretation. Likewise, the recruitment of community members as translators and their subsequent involvement in the recruitment of participants, translation, and analysis can help to overcome misinterpretation (Wong and Poon, 2010).

Both the survey enumerator and the translator that assisted in this research conformed to all the aforementioned suggestions. They were members of the local community, and fluent in the local languages. During focus group interviews, I posed a question to the group. The question was then translated, and participants most often answered in their own language. The translator would then translate the responses of participants back to me. I would then write down the responses, and I could ask the translator (who could in turn verify with respondents) whether my interpretation of their responses was accurate. Likewise, respondents could verify that they understood the questions. The presence of a real-time translator allows for the immediate clarification of any questions or confusion that may arise, further reducing potential misinterpretation.

3.3.6 Positionality

Due to having spent my formative years in a rural region of South Africa I find matters that concern rural Africa particularly engaging, and this is what initially drew me to this topic.

Although Uganda and South Africa are vastly different countries, they do share a few commonalities and I believe that my experiences from South Africa do contribute to my ability to interpret the experiences of many participants to a certain extent.

Although I am South African, I went to Uganda representing an American research institution. As a foreign researcher I must acknowledge my status as an outsider doing research within a marginalized population. Many debates exist regarding the ethical considerations in cross-cultural research that involves participants from diverse cultural, ethnic, or marginalized populations (Tillman, 2002; Block et al., 2012; Villenas, 1996). I subscribe to Tillman's (2002) theory that it is permissible for researchers to conduct cross-cultural work as long they take culturally sensitive research approaches. Villenas (1996) argues that by objectifying the lives of the researched and through assuming authority, researchers can act as colonizers in disenfranchising communities they work with. Throughout this research project I have made an effort to acknowledge that cultures are not homogenous or fixed, and that dissenting voices exist and carry weight.

4 RESULTS

4.1 Rainfall

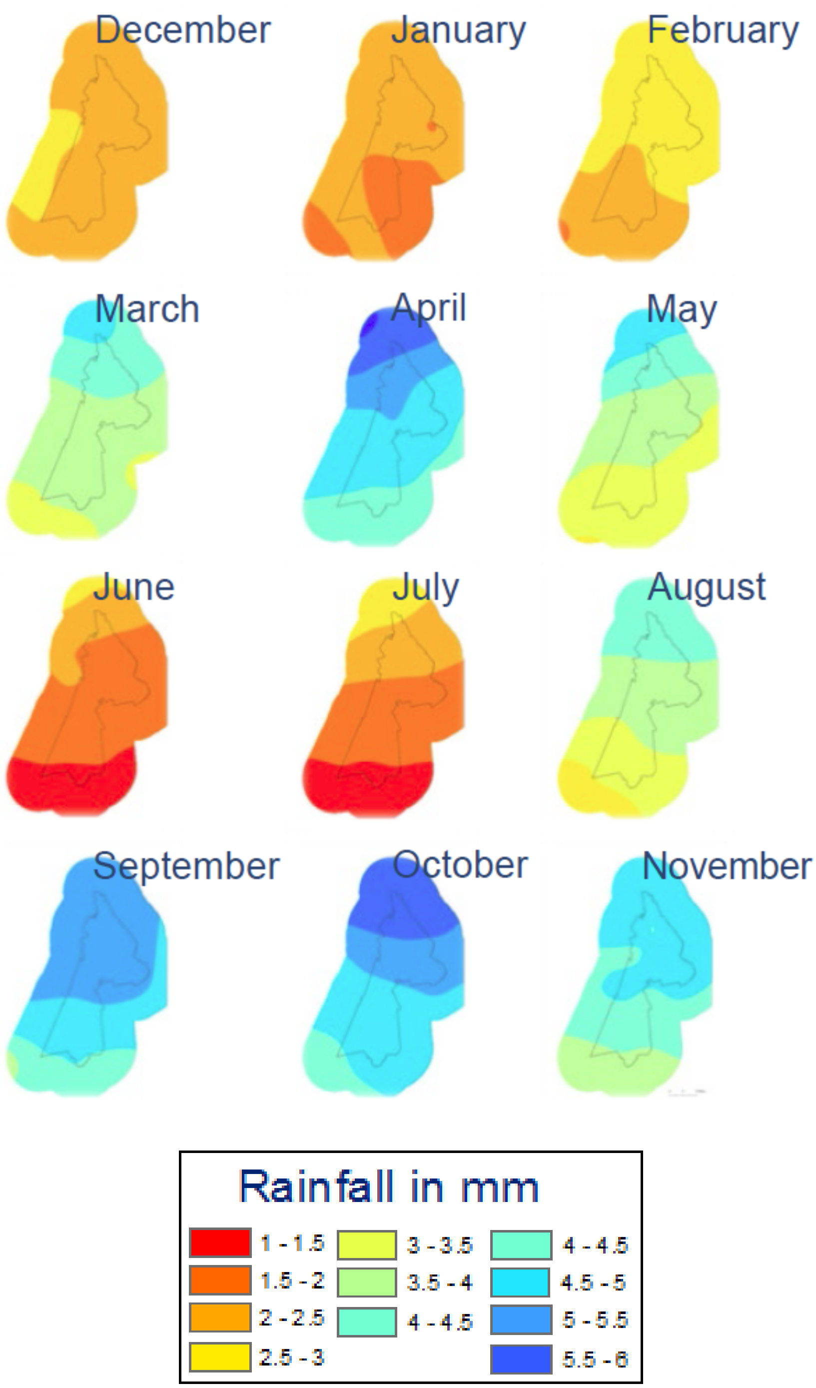

Figure 4.1 Average monthly rainfall for Kibale National Park

The 30-year averages of monthly rainfall totals, as shows in figure 4.1, clearly shows the influence of the ITCZ on the rainfall of Kibale. MAM and SON show up as the rainy seasons, while DJF and JJA appear to be much drier. The wettest months are April and October while the driest months are June and July. It is also evident that there is a decrease in rainfall from North to South.

4.1.1 Principal Component Analysis

The Principal Component Analysis of ARC2 data identified two homogenous rainfall regions: a wetter region to the north and a drier region to the south. The variance that is explained by these two regions that was initially based on 37 grid cells totals 90.34%. Figure 4.2 shows the location of these distinct regions in proximity to Kibale.

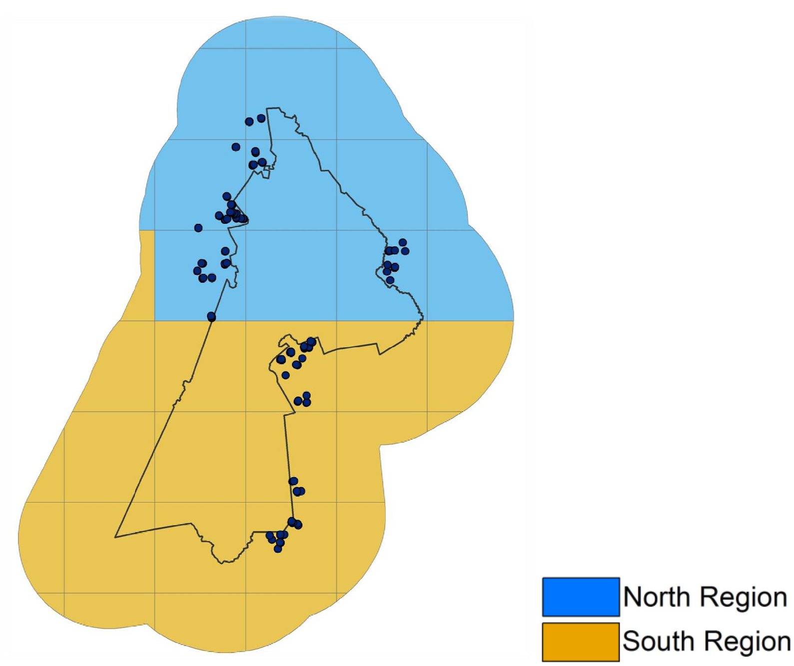

Figure 4.2 Rainfall regions

4.1.2 Averages: amount and typical timing of seasons

The bimodal rainfall pattern created by the ITCZ is evident in both rainfall regions (figures 4.1 and 4.3). Figure 4.3 show the average rainfall for 30 years of ARC2 data and the difference in the amount of rainfall that each region experiences. Increases in rainfall clearly coincide with the months of March, April, and May (MAM), and again for September, October and November (SON), with dry periods in between. The peak rainfall month in the North Region is October, while it is September in the South Region. The largest difference in the amount of rainfall between the two regions appears to be in April and October, and the rainfall for the two regions appears to be the most similar during the DJF dry season.

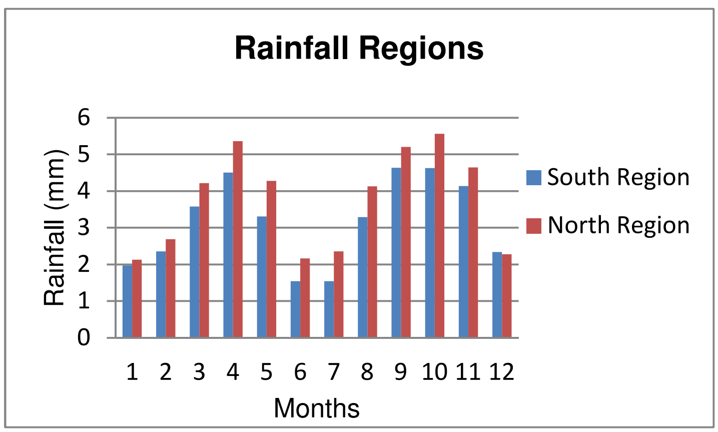

Figure 4.3 Average daily rainfall by region

4.1.3 Results from onset and cessation determination

The MAM rainy season is shorter than the SON rainy season for both regions, as well as the Ngogo data set (figures 4.4-4.6, table 4.1), which is in contrast with other parts of East Africa where the MAM rains are considered the long rains (Williams and Funk, 2011; Camberlin and Philippon, 2002; Lott et al., 2013) but corresponds to the definition given to the season by Hartter et al. (2012). For the period of 1983 to 2012, the MAM season on average lasts 68 and 67 days respectively in the North and South Regions, while the SON season lasts 110 days in the North Region and 102 days in the South Region. The 1997 – 2012 Ngogo dataset indicates a similar result, and shows the MAM season to last an average of 60 days while the SON season has an average duration of 95 days. The JJA dry season lasts longer in the South Region (95 days) than in the North Region (80 days). The North Region tends to experience both the onset of the MAM and SON seasons earlier than the South Region; however, the onset of the MAM and SON seasons appear to be very variable for both regions with a lot of fluctuations over the entire 30-year period.

Table 4.1 Average seasonal duration for ARC regions (1983-2012) and Ngogo (1996-2012)

	North Region	South Region	Ngogo
DJF	104	97	108
MAM	68	67	60
JJA	80	95	100
SON	110	102	95

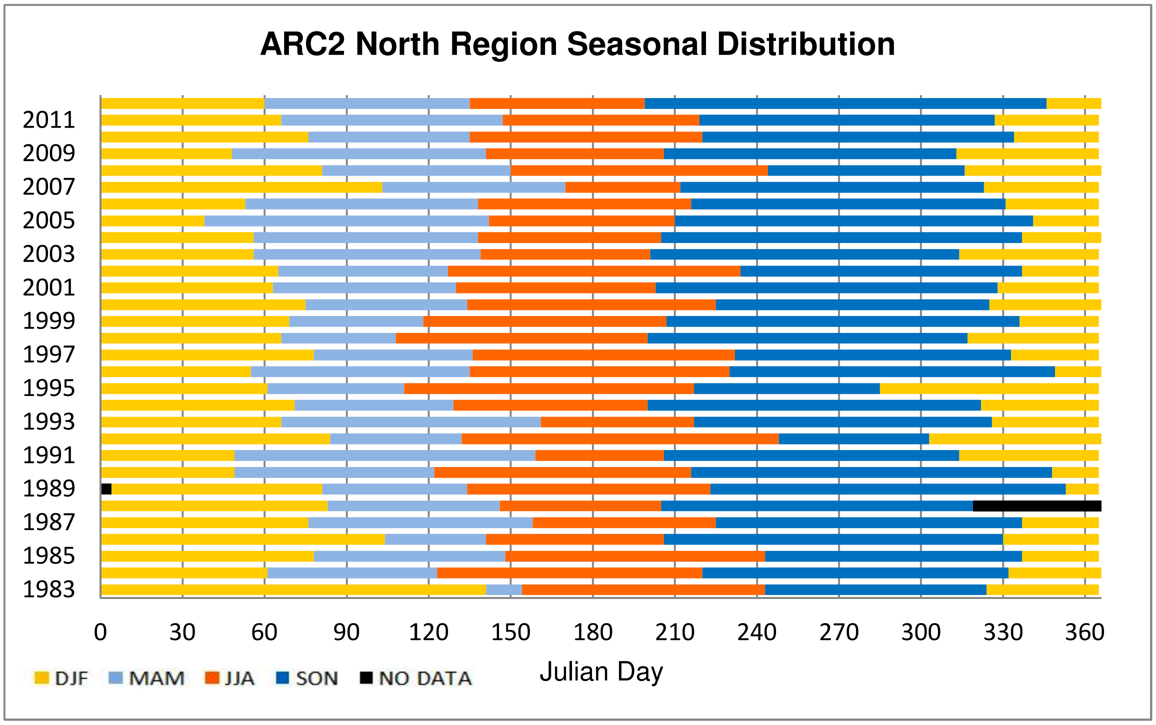

Figure 4.4 Seasonal variations of the North Region, 1983-2012

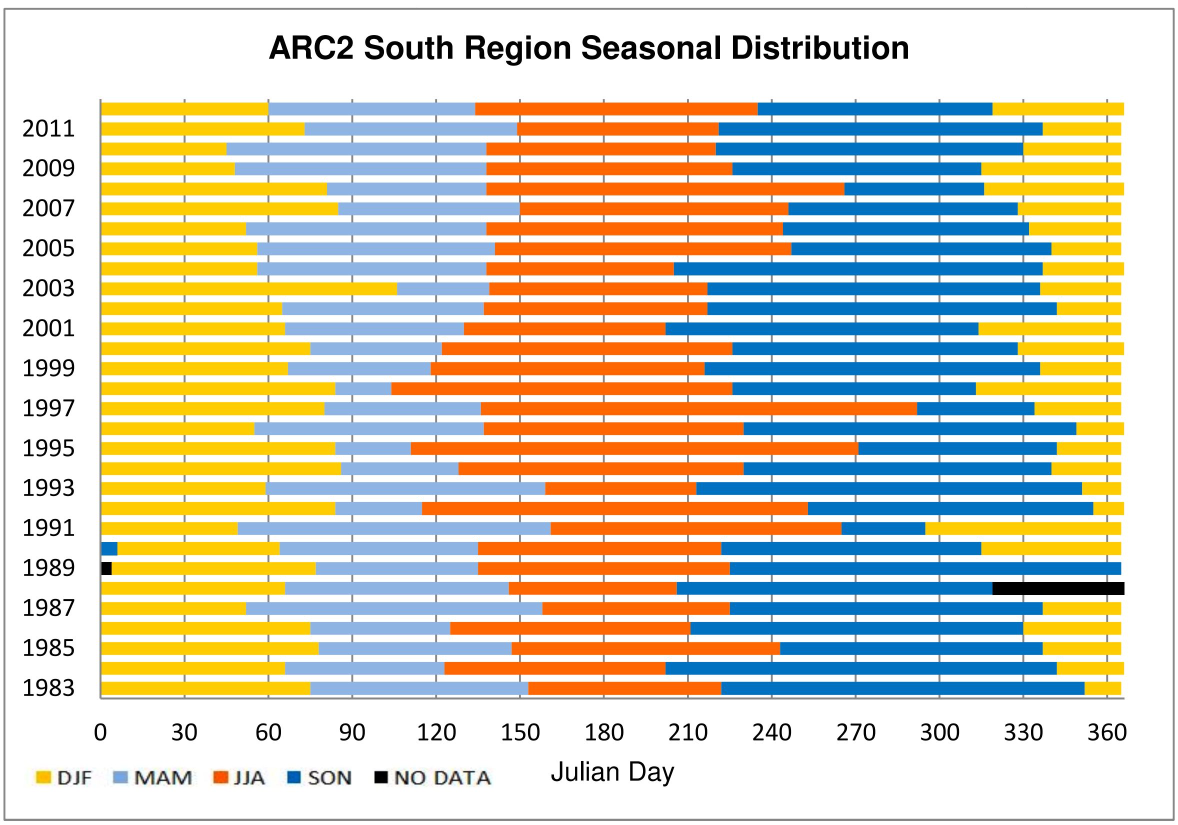

Figure 4.5 Seasonal variations of the South Region, 1983-2012

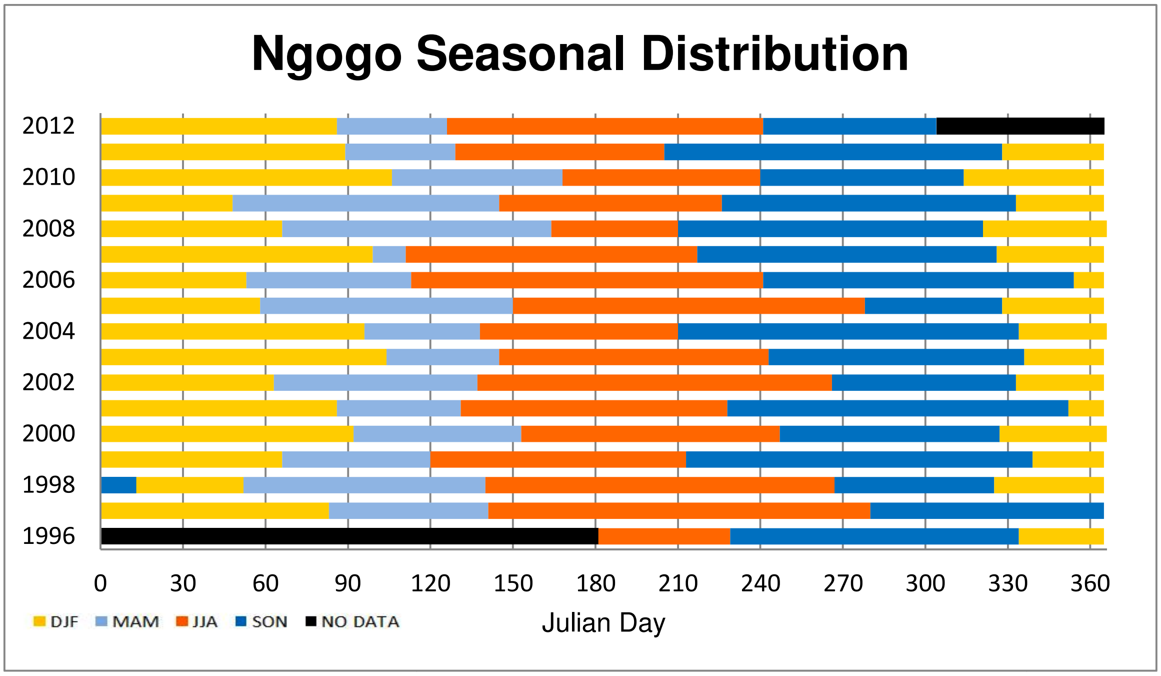

Figure 4.6 Seasonal variations of the Ngogo data set, 1996-2012

4.1.4 Onset of MAM

There is considerable variability associated with the onset, it has occurred as early as mid-February and as late as May, with the earliest onset and the latest onset being about two months apart in the South Region and three months apart in the North Region. The mean onset date for the MAM season for the period of 1983 to 2012 occurs in mid-March (tables 4.2 and 4.3). The coefficient of variation for the onset of the MAM season is higher than for the onset of any other season, and is between 0.286 and 0.374 depending on the region (table 4.4). The Coefficient of Variation for the onset dates of all seasons for the respective regions show that the onset of the MAM season had the highest variability in all three data sets. Table 4.4 illustrates the variability that exists for the onset of all seasons for the period of record. The onset of the MAM rains are more variable than the SON rains, which contrasts with reports for other parts of East Africa (Camberlin and Philippon, 2002) that claim that the MAM rains are less variable than the

SON rains. Figures 4.1 and 4.3 illustrate the progression of season throughout a year, and by looking at the averaged 30-year data it is not clear when the respective seasons officially begin.

When comparing the ARC2 data sets with the Ngogo data set, the highest correlation emerges between The North Region and Ngogo (0.4366) for the onset of the MAM season (table 4.5). The Ngogo rain gauge is situated within the North region, so this correlation appears logical. This also aligns with recommendations by Diem et al. (forthcoming) that ARC2 estimations are more accurate in the northern portion of western Uganda than the southern portion. Data from the Ngogo gauge, like ARC2 data, indicate considerable seasonal variability between years (figures 4.4-4.6).

4.1.5 Onset of SON

ARC2 data as well as Ngogo indicates that the average onset of the SON season occurs in early to mid-August (tables 4.2 and 4.3). The onset has occurred as early as mid-June and as late as early September in the North Region and mid-October in the South Region. Table 4.2 illustrates the variability that exists in the onset dates of the SON season for the two rainfall regions for 1983-2012, and table 4.4 contrasts the onset dates from the ARC2 data set with onset dates for Ngogo for 1996-2012.

The SON rains are show less variability than the MAM rains, but they do show the highest degree of variability in the South Region compared to Ngogo and the North Region. The SON onset shows higher correlation between the South Region and Ngogo, than between the North Region and Ngogo (table 4.5), which is opposite from the correlation for the MAM onset.

Table 4.2 Earliest, average, and latest onset dates for the MAM and SON seasons, 1983-2012

		MAM			SON	
	earliest	mean	latest	earliest	mean	latest
ARC2 North Region	35 (Feb 14)	70 (Mar 11)	141 (May 21)	199 (Jul 18)	217 (Aug 5)	248 (Oct 5)
ARC2 South Region	45 (Feb 14)	69 (Mar 10)	106 (Apr 16)	202 (Jul 21)	230 (Aug 18)	292 (Oct 19)

Table 4.3 Earliest, average, and latest onset dates for ARC2 and Ngogo, 1996 – 2012

	MAM			**SON**		
	earliest	mean	latest	earliest	mean	latest
ARC2 North Region	38 (Feb 7)	65 (Mar 6)	103 (Apr 13)	199 (Jul 18)	214 (Aug 2)	244 (Sep 1)
ARC2 South Region	45 (Feb 14)	68 (Mar 9)	106 (Apr 16)	202 (Jul 21)	231 (Aug 19)	292 (Oct 19)
NGOGO	48 (Feb 17)	84 (Mar 25)	106 (Apr 16)	205 (Jul 24)	238 (Aug 26)	280 (Oct 7)

Table 4.4 Coefficient of variation for season onset

	DJF	MAM	JJA	SON
North Region, 1983 - 2012	0.043	0.286	0.104	0.066
South Region, 1983 - 2012	0.047	0.277	0.145	0.115
Ngogo, 1997 - 2012	0.044	0.374	0.135	0.101

Table 4.5 Correlation between North- and South Regions and Ngogo (1996-2012)

	North and Ngogo	South and Ngogo	North and South
MAM onset	0.4366	0.2816	0.4296
MAM cessation	-0.2953	-0.2069	0.8531
MAM duration	0.1049	0.0452	0.5988
MAM amount	0.1124	-0.0355	0.2066
SON onset	0.0853	0.3587	0.5109
SON cessation	-0.1925	-0.08	-0.0265
SON duration	0.0315	0.1474	0.445
SOM amount	0.0945	-0.0341	0.135

4.1.6 Seasonal rainfall totals

There is considerable variability in the seasonal rainfall totals received by each region. Figure 4.7 clearly shows that the MAM season is the most variable, while the DJF and JJA dry season have the least variability. There appears to be a slight decrease in MAM rains beginning in the mid to late 1990's. The SON rains show a more drastic decrease, especially in the North region. The North Region has a higher amount of rainfall for the beginning of the MAM and SON rainy seasons, but the South Region experiences more rainfall towards the end of these rainy seasons. Rainfall in the North Region has increased during the DJF and JJA dry season beginning in the late 1990's.The North Region has a higher amount of rainfall than the South Region for the DJF and JJA dry seasons.

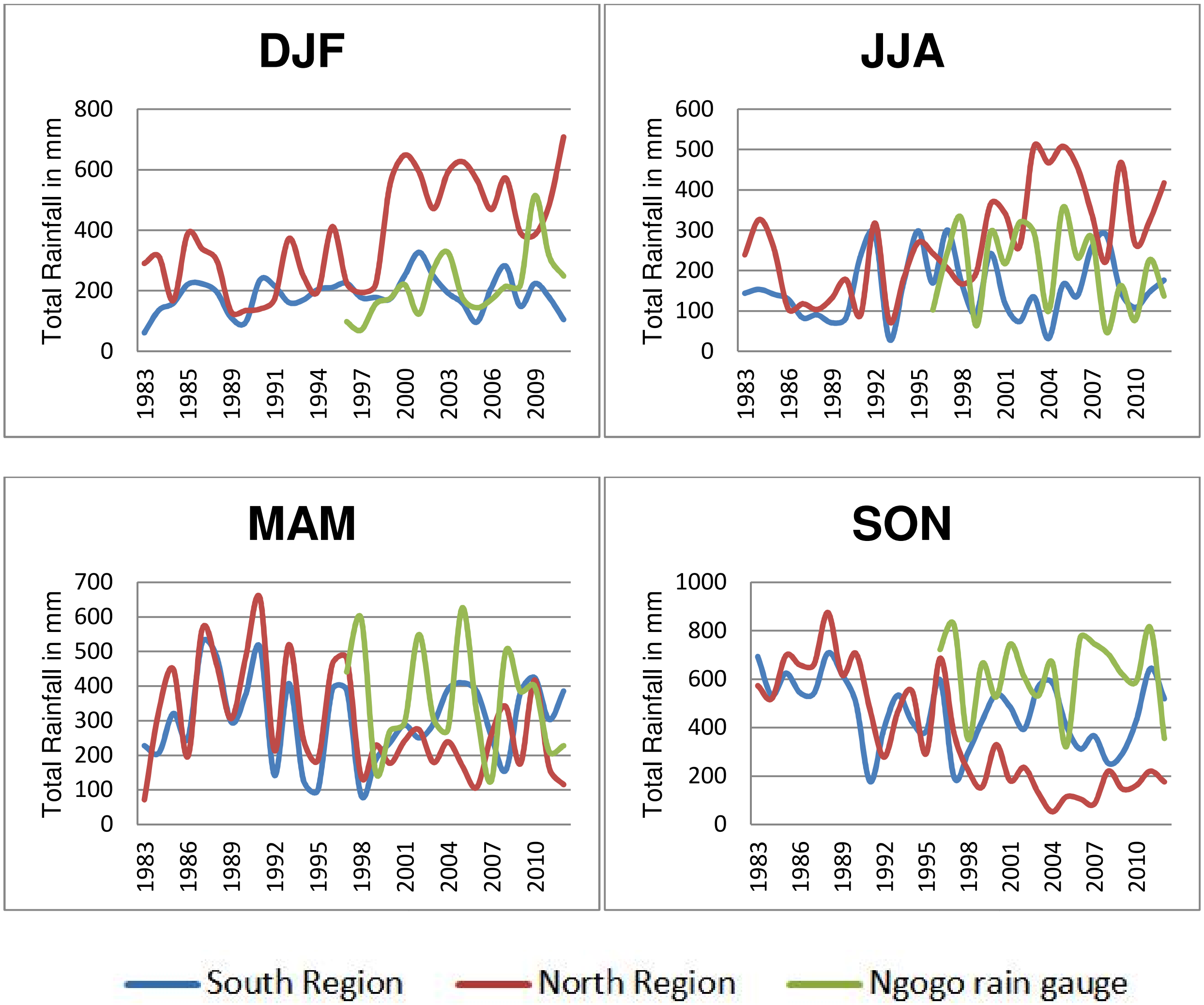

Figure 4.7 Seasonal rainfall totals

4.1.7 Seasonal trends in rainfall

Results of the trend analysis indicate a strong decrease in SON rainfall for the North region and a moderate decrease for the South Region (tables 4.6 (a) and 4.6 (b)). The trend analysis also indicated that the amount of rain during the MAM season is decreasing and that the amount of rainfall for the DJF and JJA seasons is increasing in the North Region. It is not clear whether the absence of many trends for the South Region is due to the fact that they do not exist, or because ARC2 products are less accurate towards the south (Diem, et al., forthcoming).

Table 4.6 (a) Significant seasonal rainfall trends

Season	Region	Trend	Period	Correlation Coefficient
DJF	North	Strong increase in rainfall	1983-2012	0.6911
DJF	North	Strong increase in rainfall	1983-2011	0.6911
DJF	North	Strong increase in rainfall	1983-2010	0.6568
DJF	North	Strong increase in rainfall	1984-2012	0.7083
DJF	North	Strong increase in rainfall	1984-2011	0.7083
DJF	North	Strong increase in rainfall	1984-2010	0.6746
DJF	North	Strong increase in rainfall	1985-2012	0.6838
DJF	North	Strong increase in rainfall	1985-2011	0.6838
DJF	North	Strong increase in rainfall	1985-2010	0.6458
MAM	North	Strong decrease in rainfall	1983-2012	-0.3949
MAM	North	Strong decrease in rainfall	1983-2011	-0.3473
MAM	North	Strong decrease in rainfall	1984-2012	-0.5443
MAM	North	Strong decrease in rainfall	1984-2011	-0.4970
MAM	North	Strong decrease in rainfall	1984-2010	-0.4499
MAM	North	Strong decrease in rainfall	1985-2012	-0.5512
MAM	North	Strong decrease in rainfall	1985-2011	-0.5031
MAM	North	Strong decrease in rainfall	1985-2010	-0.4557
JJA	North	Strong increase in rainfall	1983-2012	0.6191

Table 4.6 (b) Significant seasonal rainfall trends

Season	Region	Trend	Period	Correlation Coefficient
JJA	North	Strong increase in rainfall	1983-2011	0.5946
JJA	North	Strong increase in rainfall	1983-2010	0.5933
JJA	North	Strong increase in rainfall	1984-2012	0.6394
JJA	North	Strong increase in rainfall	1984-2011	0.6174
JJA	North	Strong increase in rainfall	1984-2010	0.6221
JJA	North	Strong increase in rainfall	1985-2012	0.7170
JJA	North	Strong increase in rainfall	1985-2011	0.7045
JJA	North	Strong increase in rainfall	1985-2010	0.7053
SON	North	Very strong decrease in rainfall	1983-2012	-0.8269
SON	North	Very strong decrease in rainfall	1983-2011	-0.8345
SON	North	Very strong decrease in rainfall	1983-2010	-0.8462
SON	North	Very strong decrease in rainfall	1984-2012	-0.8281
SON	North	Very strong decrease in rainfall	1984-2011	-0.8380
SON	North	Very strong decrease in rainfall	1984-2010	-0.8529
SON	North	Very strong decrease in rainfall	1985-2012	0.8325
SON	North	Very strong decrease in rainfall	1985-2011	-0.8455
SON	North	Very strong decrease in rainfall	1985-2010	-0.8646
SON	South	Moderate decrease in rainfall	1983-2012	-0.3664
SON	South	Moderate decrease in rainfall	1983-2011	-0.3911
SON	South	Moderate decrease in rainfall	1983-2010	-0.5178
SON	South	Moderate decrease in rainfall	1984-2011	-0.3262
SON	South	Moderate decrease in rainfall	1984-2010	-0.4652
SON	South	Moderate decrease in rainfall	1985-2010	-0.4632

4.2 Surveys and focus groups

4.2.1 Demographic characteristics of participants

Survey participants represented varied demographic characteristics. Table 4.7 illustrates the characteristics of the 180 survey participants. Overall the survey participants have varied and diverse backgrounds, and are representative of the larger community. Individual breakdowns of focus group participants are not available. Overall 223 women participated in focus group discussions; overall they represented a diverse range of ages (ranging from 18-87), tribes, and backgrounds.

Table 4.7 Demographic characteristics of survey participants

Continuous variables						
n = 180	Min	Max	Mean	St. Deviation		
Age (years)	18	92	40.24	15.298		
Sum of land (acres)	1	50	8.0783	7.65		
Residence time (continuous)	1	67	21.06	14.965		
Categorical variables						
Gender		Male	Female			
	%	39	61			
	#	71	109			
Head of household		Male	Female	No response		
	%	78	18	4.4		
	#	140	32	8		
Education		None	P1-P4	P5-P7	S1 and above	No response
	%	16	22	44	12	6
	#	29	40	79	21	11
Wealth		Above average	Average	Below average	No response	
	%	4.4	18	76	2.2	
	#	8	32	136	4	
Tribe		Bafumbira	Bakiga	Banyankole	Batooro	No response
	%	1.1	41.1	0.6	52.2	5
	#	2	74	1	94	9
Resident status		Newcomer	Resident			
	%	25	75			
	#	42	129			
Distance from park (categorical)		Within 1 km	over 1 km	No response		
	%	59	38	3		
	#	106	68	6		

4.2.2 General farming practices

The gardens (a term local people commonly used to refer to their fields) are prepared directly after the harvest. Garden preparation involves removal of all organic material, such as leaves and stalks, from the previous growing season. These materials can be tilled back into the ground or sometimes burned on top of the soil and then tilled back into the ground in an attempt to enrich the soil. The next step is to dig up the gardens; this is back-breaking work that involves turning the soil to aerate it with only the use of hand held hoes. Digging up the garden is the final step before planting. Farmers believe that the soil from a garden that has been dug up stays cooler, so that when it rains it will take less time for the soil to cool down which in turn allows them to plant sooner.

Most farmers plant approximately after two to three rain events. These rain events can occur within a few days or within a week or two, and involves farmers waiting for the soil to reach saturation before they will plant. After two to three rain events enough water will have soaked into the soil to soften and cool the ground sufficiently. It is worth noting that the two or three rain events need to occur within months that rain is expected in order for farmers to plant; rains are expected to begin in February for the MAM season and between July and August for the SON season. If the rain events occur before these expected time frames farmers will not plant. In general, sorghum, maize, and beans require two or three heavy rains, millet is planted at a set date (August 15) and sweet potatoes are planted towards the end of the rainy season.

Focus group discussions indicate that based on their environmental experiences in this region, people have come to expect the rainy seasons in mid-February and in mid-August and planting is supposed to occur during February and March for the MAM season, and August and September for the SON season. Tables 4.8 and 4.9 provide a general planting schedule for the region, indicating when crops are planted, harvested, and when garden preparation occurs. Throughout the growing season farmers engage in two activities; guarding fields against crop raiding from wild animals such as baboons (*Papio anubis*) and elephants (*Loxodonta africana*), and weeding their fields.

These methods of garden preparation were widespread around the park, as were perceptions of when seasons should start. Despite the fact that two distinct tribes inhabit the area surrounding the park and have done so for very different lengths of time, farming methods and the tendency to wait for the soil to be saturated appear to be common to both tribes.

Table 4.8 General farming schedule for first planting

1st Planting (MAM)						
	PLANTING		**HARVESTING**		**GARDEN PREPARATION**	
Crop	**Month**	**What part of month? (Early, Mid, end)**	**Month**	**What part of month? (Early, Mid, end)**	**Month**	**What part of month? (Early, Mid, end)**
Irish potatoes	Feb	Mid	Apr	Mid	April	End
Maize	Feb	Early	May	Mid	May	End
Groundnuts	Apr	Mid	Jul	Early	July	Mid
Sweet potatoes	Feb	Mid	May	Early	May	Mid
Yams	Jan	Early	Jan	Early	Jan	Mid
Millet	Feb	Mid	May	Early	May	Mid
Sorghum	Feb	Mid	Jun	Early	Jun	Mid

Table 4.9 General farming schedule for second planting

2nd Planting (SON)						
	PLANTING		**HARVESTING**		**GARDEN PREPARA-TION**	
Crop	**Month**	**What part of month? (Early, Mid, end)**	**Month**	**What part of month? (Early, Mid, end)**	**Month**	**What part of month? (Early, Mid, end)**
Irish potatoes	July	Mid	Oct	Early	Oct	Mid
Maize	Aug	Early	Dec/Jan*	Early	Dec/Jan*	Mid
Groundnuts	Aug	Mid	Dec/Jan**	Mid	Dec/Jan**	End
Sweet pota-toes	Jul	Mid	Oct	Mid	Oct	End
Yams	Jan	Early	Jan***	Early	Jan***	End
Millet	Dec^	Early	Dec^	Early	Dec^	End
Sorghum	Dec^	Early	Dec^	Early	Dec^	End

*Two different types of maize are harvested a month apart.
**Depends on weather conditions – needs less rain.
***Yams take1 yr to grow. Typically planted and harvested in Jan.
^ Millet/sorghum commonly planted together. There are also other varieties of both millet and sorghum.

4.2.3 The MAM season

<u>Surveys:</u>

The majority of survey respondents agree that this season has become increasingly variable from year to year. Figure 3.8 illustrates the opinions of survey respondents regarding changes in the MAM season, 94% of respondents indicate that the onset of the MAM is either variable or later, and 88% of responses indicate that the cessation of the MAM season is variable or occurs later. Rainfall results concur that the MAM season is highly variable, but they do not affirm the beliefs of farmers that the seasons are increasing in variability.

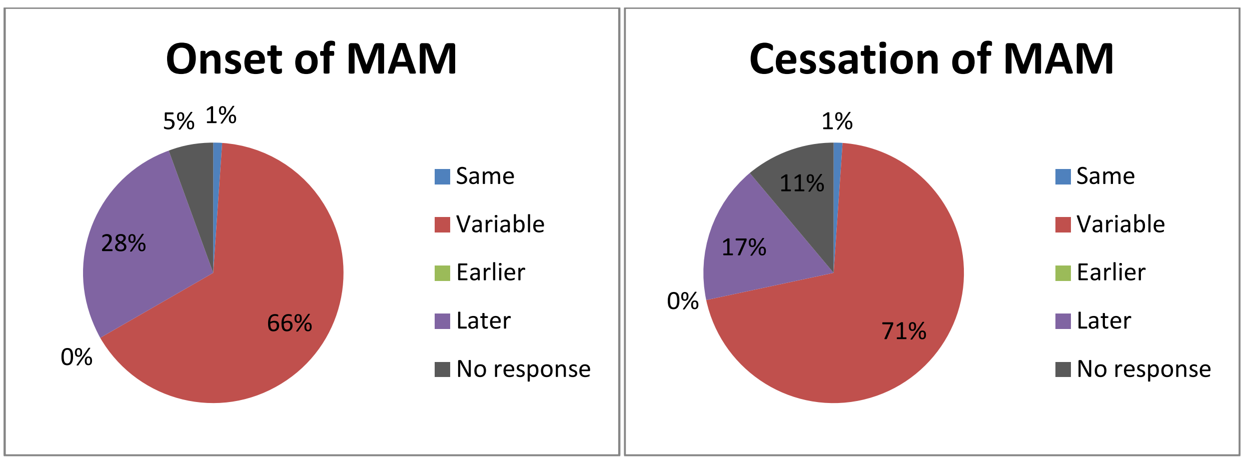

Fig. 4.8 Perceptions of farmers regarding onset and cessation of MAM season

The perceptions of farmers regarding the onset of the MAM season were not independent from park direction (table 4.10). Participants that live to the east of the park have more agreement that the onset is variably, but participants to the west of the park have slightly less agreement. There are a higher number of participants to the west of the park that feel that the onset of the MAM is occurring later. No significant relationships emerged between perceptions of changes in the MAM season and distance from the park, residence time, wealth, education, gender, or ethnicity, indicating that these factors did not influence perceptions of MAM onset. All participants shared perceptions of the cessation of the MAM season, and no significant relationships emerged in relation to any location or demographic factors (table 4.11).

Table 4.10 Relationships between demographic and location characteristics and survey responses regarding onset of MAM season.

How has the onset of the MAM rainy season changed now compared to 10 years ago? (n=180)				
Demographic or Location characteristic	Majority response (%)		Pearson's Chi Sq.	
	variable	later	Asymp. Sig. (2-sided)	Significant
Direction				
East	78	22	0.052	yes
West	64	36		
Tribe				
Batooro	70	30	0.86	no
Bakiga	72	28		
Gender				
Female	68	32	0.49	no
Male	74	26		
Wealth				
Above average	71	29	0.822	no
Average	74	26		
Below average	68	32		
Education				
none	74	26	0.6	no
P1 to P4	76	24		
P5 to P7	67	33		
S1 and above	62	38		
Distance				
within 1km	75	25	0.162	no
over 1 km	64	36		
Resident time				
newcomer	73	27	0.695	no
resident	68	32		
Distance (continuous)				
Kruskall Wallis Test p = 0.465			-	no

Table 4.11 Relationships between demographic and location characteristics and survey responses regarding cessation of MAM season.

How has the cessation of the MAM rainy season changed now compared to 10 years ago? (n=180)				
Demographic or Location characteristic	Majority response (%)		Pearson's Chi Sq.	
	variable	later	Asymp. Sig. (2-sided)	Significant
Direction				
East	86	14	0.158	no
West	76	24		
Tribe				
Batooro	81	19	1.000	no
Bakiga	2	18		
Gender				
Female	83	17	0.408	no
Male	76	24		
Wealth				
Above average (1)	75	25	0.730	no
Average (2)	85	15		
Below average (3)	80	20		
Education				
none	80	20	0.739	no
P1 to P4	88	12		
P5 to P7	79	21		
S1 and above	78	22		
Distance				
within 1km	82	18	0.302	no
over 1km	75	25		
Resident time				
newcomer (<10 yrs)	81	19	1.000	no
resident (>=10 yrs)	80	20		
Distance (continuous)				
Kruskall Wallis Test p = 0.590			-	no

Focus Groups:

For the MAM season, the rains are expected to gradually begin in mid-February, with increasing rainfall in March. These rains are expected to last until the end of May, but farmers perceive these rains to be ending before May. These perceptions are confirmed in figures 4.4 – 4.6, which indicate that although the MAM cessation has always been variable, it seems rarer for the MAM to last through the end of May nowadays compared to the past. Farmers claim that overall they feel that this season has become shorter, with a delayed onset and an advanced cessation, and they state that the rains keep disappearing in February. The distribution of rainy seasons for the Ngogo data set (fig. 4.6) and the distribution of the seasons for the ARC2 North Region (fig. 4.4) show that the MAM season has consistently started after February, which is also in line with the perceptions of focus group participants.

Focus group participants agree that the MAM season has become highly variable from year to year. They claim that some years the MAM season is similar to the way it was in the past, but that rainfall for this season is decreasing overall. Figure 4.7 indicates a decrease in seasonal rainfall totals for the MAM season beginning in the late 1990's. These perceptions are affirmed by the results from the trend analysis, which indicates a strong negative trend in the rainfall totals of the MAM season.

4.2.4 The SON Season

Surveys:

The majority of respondents indicated changes in the onset and cessation of the SON season, yet there is less of a consensus regarding the changes in the SON season than there is regarding the changes in the MAM season. The majority of responses were almost divided between the categories of "variable" and "later".

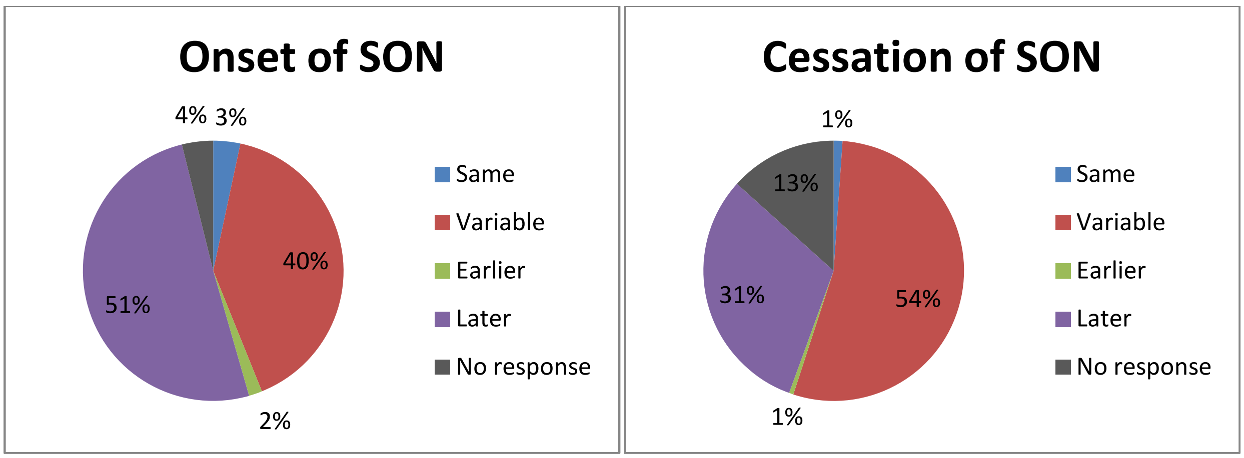

Fig. 4.9 Perceptions of farmers regarding onset and cessation of SON season

Cross-tabulations between demographic and spatial and responses that fell within "variable" and 'later" categories showed that respondents are almost divided between those that think the SON is either later or variable every year (tables 4.12 and 4.13). These perceptions of change are shared amongst the wider population. The only significant relationship to emerge out of the examinations of cross-tabulations is that those that live to the East side of the park feel that the cessation of the SON season is becoming more variable, whereas those that live to the West of the park are split between perceiving the season cessation to be later or variable. Farmers' responses regarding the cessation of the SON season are not evident in the rainfall analysis.

Table 4.12 Relationships between demographic and location characteristics and survey responses regarding onset of SON season.

How has the onset of the SON rainy season changed now compared to 10 years ago? (n=180)				
Demographic or Spatial characteristic	Majority response (%)		Pearson's Chi Sq.	
	variable	later	Asymp. Sig. (2-sided)	Significant
Direction				
East	48	52	0.520	no
West	42	58		
Tribe				
Batooro	48	52	0.516	no
Bakiga	42	58		
Gender				
Female	39	61	0.105	no
Male	53	47		
Wealth				
Above average (1)	57	43	0.476	no
Average (2)	52	48		
Below average (3)	42	59		
Education				
none	44	56	0.172	no
P1 to P4	53	47		
P5 to P7	36	64		
S1 and above	60	40		
Distance				
within 1km	47	53	0.415	no
over 1km	40	60		
Resident time				
newcomer (<10 yrs)	38	62	0.578	no
resident (>=10 yrs)	44	56		
Distance (continuous)				
Kruskall Wallis Test p = 0.220			-	No

Table 4.13 Relationships between demographic and location characteristics and survey responses regarding cessation of SON season.

How has the cessation of the SON rainy season changed now compared to 10 years ago? (n=180)				
Demographic or Location characteristic	Majority response (%)		Pearson's Chi Sq.	
	varia-ble	later	Asymp. Sig. (2-sided)	Significant
Direction				
East	79	21	0.002	yes
West	53	47		
Tribe				
Batooro	60	40	0.384	no
Bakiga	68	32		
Gender				
Female	60	40	0.305	no
Male	69	31		
Wealth				
Above average	86	14	0.282	no
Average	70	30		
Below average	60	40		
Education				
none	50	50	0.182	no
P1 to P4	62	38		
P5 to P7	73	27		
S1 and above	58	42		
Distance				
within 1km	66	34	0.484	no
over 1k	59	41		
Residence time				
Newcomer (<10yrs)	60	40	0.842	no
resident (>=10yrs)	63	37		
Distance (continuous)				
Kruskall Wallis Test p = 0.239			-	no

Focus Groups:

There is agreement among focus group participants that this season has more rainfall than the MAM season, with the amount of rainfall being heavier than for the MAM season. This is clear in the analysis of rainfall data (table 4.1, and figures 4.4-4.6). They mention that this season frequently has heavy rains with high winds that could damage crops, but that this has always been the case for the SON season.

There was a divide among focus group participants regarding potential changes during this season. Half of the focus groups felt that this season had not changed much compared to the past, and the other half felt that the SON season has become shorter, with a delayed onset, and that rainfall has become heavier during this season. An investigation into the timing of the SON season in figures 4.4-4.6 does not provide evidence that the season has a delayed onset. Interestingly, rainfall results show a very strong negative trend for this season that is not noted by focus group participants. There was no spatial pattern in the responses of focus groups.

SON is the main harvest season, this is in contrast to the rest of East Africa where the MAM season is said to be the main harvest season (Camberlin and Philippon, 2002; Funk et al., 2008; Williams and Funk, 2011). In other parts of East Africa the MAM season is the main harvest season because it has less variability than the SON season (Camberlin and Philippon, 2002). This appears to be the opposite around Kibale, where the SON season (table 4.4) shows less variability than the MAM season. The majority of participants say the SON season has always been the main growing season, but a few say it has become this way only after the MAM season became more unpredictable. They save more seeds for the SON season.

4.2.5 Dry seasons

Surveys:

There is more agreement among the Batooro that the amount of rain during the DJF season is more variable, and more Bakiga than Batooro feel that the amount of rain is less (fig 4.13). More agreement exists among residents that the JJA season is drier now compared to 10 years ago, and more newcomers than residents feel that the amount of rain during JJA is variable (fig. 4.14). No other significant relationships emerged.

Focus Groups:

The majority or focus group participants felt that the DJF dry season was variable from year to year, with a smaller amount of people feeling that it was drier now compared to the past. Perceptions of the JJA dry season were the opposite. For the JJA dry season, the majority of participants felt that the season was getting drier, with a smaller percentage of people claiming that the season is variable from year to year. No significant relationships emerged between any spatial or demographic characteristics and responses to either of the dry seasons (tables 4.14 and 4.15).

There is disagreement between perceptions of the dry season and the results of dry season analysis. Participants feel that the seasons are variable from year to year or becoming drier, while rainfall data shows that these seasons do not appear to be highly variable and they are becoming wetter.

Table 4.14 Relationships between demographic and location characteristics and survey responses regarding amount of rainfall during DJF season.

How has the amount of rain during the DJF dry season changed now compared to 10 years ago? (n=180)				
Demographic or Location characteristic	Majority response (%)		Pearson's Chi Sq.	
	variable	drier	Asymp. Sig. (2-sided)	Significant
Direction				
East	68.4	31.6	0.242	no
West	77.8	22.2		
Tribe				
Batooro	80.8	19.2	0.072	yes
Bakiga	66.1	33.9		
Gender				
Female	78.2	21.8	0.178	no
Male	67.9	32.1		
Wealth				
Above average	71.4	28.6	0.820	no
Average	79.2	20.8		
Below average	73.1	26.9		
Education				
none	80.0	20.0	0.205	no
P1 to P4	69.0	31.0		
P5 to P7	67.7	32.3		
S1 and above	92.9	7.1		
Distance				
within 1km	77.8	22.2	0.237	no
over 1km	67.9	32.1		
Residence time				
newcomer (<10yrs)	69.7	30.3	0.436	no
resident (>=10yrs)	76.5	23.5		
Distance (continuous)				
Kruskall Wallis Test P = 0.982			-	no

Table 4.15 Relationships between demographic and location characteristics and survey responses regarding amount of rainfall during JJA season.

How has the amount of rain during the JJA dry season changed now compared to 10 years ago? (n=180)				
Demographic or Spatial characteristic	Majority response (%)		Pearson's Chi Sq.	
	variable	drier	Asymp. Sig.	Significant
Direction				
East	13.9	86.1	0.872	no
West	16.1	83.9		
Tribe				
Batooro	18.0	82.0	0.833	no
Bakiga	15.9	84.1		
Gender				
Female	11.5	88.5	0.052	no
Male	22.7	77.3		
Wealth				
Above average	12.5	87.5	0.497	no
Average	22.6	77.4		
Below average	14.2	85.8		
Education				
none	3.8	96.2	0.282	no
P1 to P4	21.6	78.4		
P5 to P7	15.6	84.4		
S1 and above	15.8	84.2		
Distance				
within 1km	14.9	85.1	1.000	no
over 1km	15.9	84.1		
Residence time				
newcomer (<10yrs)	25.6	74.4	0.031	yes
resident (>=10yrs)	11.5	88.5		
Distance (continuous)				
Kruskall Wallis Test P = 0.729			-	no

4.3 Adaptations to perceived changes in rainfall

The majority of respondents feel that the onset of the MAM season has become more variable in recent years. They feel that the onset can be delayed, and that the February rains keep disappearing. They also feel that the MAM season ends prematurely, and while they expect it to last through May, it tend to end before this time. These perceptions are supported by the analysis of rainfall data, which does show that the MAM season is highly variable, but it does not affirm that the MAM is becoming increasingly variable. The rainfall data also shows that rainfall during February and May is more sporadic, aligning with perceptions. The majority of respondents perceived the SON season to have a delayed or variable onset, and that the cessation was variable between years. The rainfall data does not confirm that the onset is delayed. The cessation does appear to be variable, but to a lesser extent than the MAM season.

Only 1% of survey respondents indicated that they were not concerned with changes in the weather (fig. 4.10). Open-ended survey questions were aimed at finding out why respondents may be concerned with changing weather conditions. Four key themes of concern emerged from the open ended survey question: (A) lower yields, (B) uncertainty of when and what to plant due to changes in the seasons, (C) drying of crops, and (D) the long dry period (JJA) is perceived to be lengthening.

Participants mentioned how they were impacted by increased variability and changes in rainfall, and key themes of adaptation emerged from the focus group discussions. Adaptations implemented by farmers include modification of planting times based on season onset, and the desire to expand into new cropland, in particular forests or wetlands.

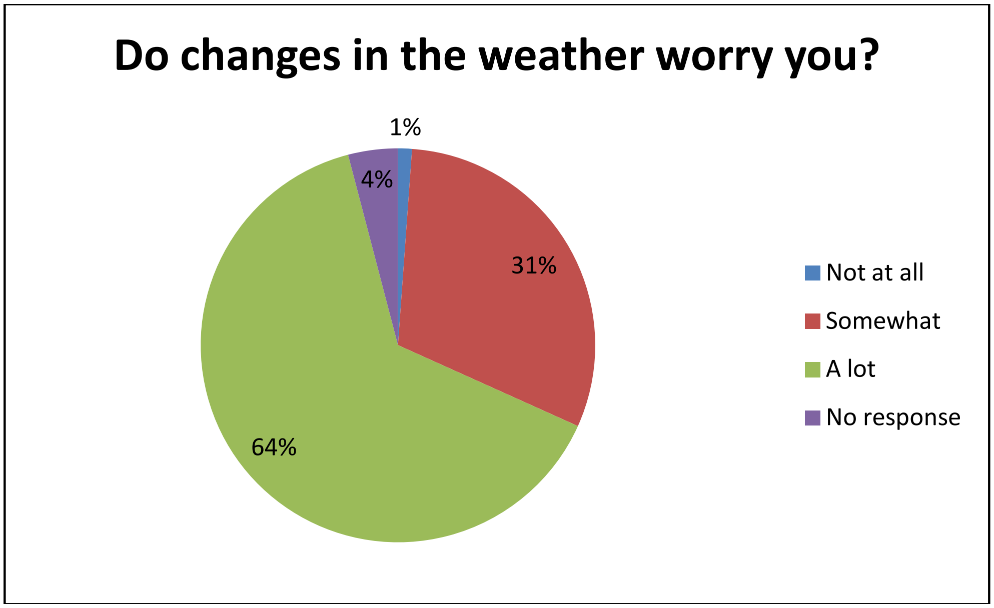

Fig. 4.10 Do changes in the weather worry you?

4.3.1 Modification of planting time

The majority of farmers have adjusted their planting schedules for specific crops. Farmers claim that they had set planting times in the past, but now they have to follow the rains to know when to plant. They used to plant crops from mid-February to the end of March for the MAM season, but in recent years the planting season has expanded and farmers have to be ready to plant anywhere from early February to the end of April. Planting time for the SON season used to range from mid-August to the end of September, but now farmers have to be prepared to plant from July through October, depending on when the seasons begin.

The majority of focus group participants claimed that October has always been their most important planting season, but a small number of participants felt that the October season became the main growing season only after the MAM season became less reliable, and that both seasons used to be equally important in the past. The increased reliance on the October season is another potential adaptive measure implemented by farmers. The MAM does show a higher degree of variability than the SON season (table 4.4).

4.3.2 Desire for expansion of cropland

A limited area of land is available to people in this region due to the rapidly growing population. Focus group participants claimed that farmers that have been able to start growing in wetlands, areas along rivers, or forested areas are getting better yields than others. According to focus group participants, wetlands or areas close to rivers have become more sought after cropland. In addition to climatic factors, limited land for a growing population as well as problems with soil fertility could motivate this behavior. Farmers claim that those who are growing in wetlands do not have to wait for two to three rain event before they start planting, and they can therefore maximize the length of the rainy season. Focus group participants have shared the following, for example, regarding motivation for expanding cropland into wetland areas:

“In cooler parts, closer to the swamp, you can plant before the soils are wet (because there is more water in the soils making it cooler), but in the drier parts you have to wait for soils to be wet enough. “

“Those that are getting good yields today are those that are planting in wetlands.”

5. DISCUSSION

Broadly, this research was intended to provide an understanding of the characteristics of rainfall and rainfall variability around Kibale National Park. Results align with studies that have indicated that the rainfall of this region may be more complex than was reported by the regional studies of Basalirwa (1995) and Ogallo (1980; 1989) (Seimon and Picton-Phillips, 2010; Stampone et al. 2011). The knowledge of the location and characteristics of the two distinct rainfall regions within this landscape can be useful to agricultural development and land management initiatives, since unique approaches may be required to suit the needs of the respective rainfall regions.

Further complexities also emerge within the seasons around Kibale National Park, and seasons elsewhere in East Africa. Many studies that consider East African rainfall indicate that the MAM season is considered less variable than the SON season, as well as the longer rainy season and main growing season (Camberlin and Philippon, 2002; Williams and Funk; 2011; Funk et al., 2008), this is not the case for Kibale. Results from this study indicate that the opposite is true: rains during the SON season are les variable than the MAM season, last longer than the MAM season, and that the SON season is also the main growing season for this region. Based on this, agricultural practices will be different around Kibale compared to other parts of East Africa. Changes in the SON season will impact farmers of this region more so than farmers in other parts of East Africa, which should be noted by developmental organizations and organizations concerned with aid and food security.

The differences that exist between the rainfall of Kibale and the rainfall of the rest of East Africa suggest that Kibale's rainfall may have less in common with East African rainfall, than was initially thought. This could provide an explanation for why the effects of strong ENSO years are not evident in the rainfall characteristics of the last 30 years around Kibale.

Decreases in seasonal rainfall totals of the MAM season was indicated by this analysis and aligns with studies by Camberlin and Philippon (2002), Funk et al. (2008), Williams and Funk (2011), and Hartter et al. (2012), but contradicts reports by the IPCC (2007) that rainfall is likely to increase for this region. Abrupt decreases in the seasonal totals of the MAM and SON rainy seasons occurred in the North Region of Kibale in the late 1990's.Lyon and Dewitt (2012) attribute abrupt decreases in MAM rainfall, beginning in the late 1990's, to changes in sea surface temperatures. The fact that the SON season experienced a similar abrupt decrease during the same period raises the question of whether changes in sea surface temperatures could be affecting the SON season in a similar manner to the MAM season.

Although the North Region showed more significant decreasing trends for the MAM and SON seasons, this analysis does not provide definitive proof that such trends are lacking in the South Region. Diem et al. (forthcoming) found that ARC2 estimates were more accurate towards the north, and due to potential inaccuracies that may be associated with the South Region, complexities and details regarding the South Region may still be obscured in this analysis.

The vast majority of respondents have indicated that the rainy seasons are now more variable than they were in the past (10 or more years ago). The most agreement existed regarding variability associated with the MAM season, and a perceived decrease in the length of the MAM season. Perceptions tend to be widespread among participants, with factors such as of age, ethnicity, residence time, gender, wealth, or proximity to the park bearing little to no influence over how people perceive the seasons. Participants had a better recollection of weather patterns of the recent past, than weather patterns from long ago. Participants claimed that the MAM season has been beginning later and ending sooner, which is a clear pattern that emerged in the North Region (fig. 4.4) since 2007.

The decreases in rainfall and the high degree of variability that is associated with rainy seasons, impact the lives of people that live in this region by affecting agricultural practices, causing worry among farmers, and potentially reducing yields. The majority of participants have indicated that they have adapted to changes in the seasons by modifying their planting times based on when the rains begin. Such modifications can have a domino affect on agricultural practices that occur later in the season, leading to much uncertainty and worry. If farmers plant late, they will harvest late, and subsequently be late in preparing their fields for the next season. Stress over timely field preparation could potentially lead to families keeping their children out of school to aid in the preparation, since it is not uncommon for children to partake in certain agricultural tasks during strenuous times (Mackenzie and Ahabyona, 2012). Potential reductions in yields due to the heavy reliance of this region in rain fed agriculture, can impact the food security of families. Reductions could limit the abilities of families to sell excess crops in exchange for some income to pay for dry goods, medicine, or schooling.

If decreases in rainfall persist and lead to reductions in yields, there is a possibility that farmers could turn to other natural resources in their surrounding environment as a coping mechanism. This could affect parks and protected areas in this region where deforestation and loss of habitat is already a concern, since natural resources are frequently located in such areas. The desire that was expressed by respondents to extend their cropland into areas such as wetlands or wooded areas may be the first signs that people here are already relying even more on natural resources than they did before.

Even though park boundaries are maintained, the overall health of a park is still intricately linked to its surrounding ecosystem (Adger, 2013; Fisher and Christopher, 2007). This study indicates that respondents are farming more extensively and intensively in response to perceived changes in rainfall, and there is a possibility that they may rely more heavily on natural resources if decreases and variability in rainfall lead to yield reductions, and these factors will inevitably affect the health of parks.

Much of the research on climate change has focused on top-down methods, and impact analyses that are based on the outputs of global models that are relevant at the international, national, or regional scales at which climate organizations work (Orlove et al., 2010). These broad climatic evaluations may have limited relevance to local manifestations of climate variability and change (Wilbanks and Kates, 1999), and they do little to answer specific questions posed by smallholder agriculturalists in impacted regions (Orlove et al., 2010). If adaptation is the path to weathering climatic changes, knowledge of perceptions in an important stepping stone towards this destination. Farmers claim that they used to have set planting times in the past, but they have been adjusting to changes in the current weather by waiting for the rains to begin, or as they say, "following the rains", before they plant. The evidence of constant variability in seasonal onset throughout the last 30 years suggests that the inclination of farmers to wait for the rains may not be a new adaptation. Decreases in the amount of rain in the MAM season may call for a new type of adaptation, an adaptation or plan that will simultaneously address declining rainfall while considering other concerns that farmers have (such as loss of soil fertility and crop raiding) because these stressors affect crop productivity and the related well-being of farmers in this area.

The adaptations of communities that were indicated by this study are considered autonomous adaptations, since they were implemented without knowledge of climatic predictions

(Smithers and Smit, 2009; Nyanga et al., 2011). While they may lessen the adverse effects of variability and change, they may not be sustainable and there may be other adaptive measures that could allow farmers of this area to take advantage of new situations that are arising and to build more resilience. The increases in rainfall during the JJA and DJF seasons could be one such situation. Future studies that consider adaptation should investigate possibilities for planned adaptations over autonomous adaptations in order to promote sustainability and food security within this region.

The events that are unfolding around Kibale are likely not an isolated occurrence. Kibale and its surrounding communities are fairly representative of the Albertine Rift, in that parks are frequently surrounding with large populations that are dependent on rain fed agriculture. Changes in rainfall have been noted for other parts of the Albertine Rift, but while little is known on how people from other parts of the Albertine Rift have perceived changes and adapted, there is a good chance that they perceive and adapt to these events similarly to the communities surrounding Kibale. If this is the case, other protected areas will face the same challenges that Kibale does.

Limitations:

The reliance on the recall of people is one of the biggest limitations in this work since it can be difficult for people to recall the past with great detail. In fact, this research shows that participants remember things in the near past much more vividly than they do things that happened or situations that have occurred further back. The use of multiple methods in this project is an attempt to address the limitation associated with recall and memory.

The reliance on satellite rainfall estimates is another limitation, and although these estimations us with a fairly detailed picture of what is happening in the region the estimations are inferior to ground level data. Comparisons between ARC2 data and Ngogo observations showed some similarities, but they also showed differences. A more ideal situation would have involved long term, complete rain data from multiple gauges on the ground. Ngogo provided very detailed and complete rainfall records, but it was only available for 1996-2012, which is not a period that is sufficient to build an understanding of regional climatic characteristics.

The methods used to determine season onset and cessation have successfully been used in peer-reviewed research in similar climatic regions (Marengo et al. 2001). I think better and more accurate methods can be developed to determine season onset and cessation, especially if people from local regions were consulted. Cessation is especially problematic since the rainy seasons slowly taper off, and a definitive moment in time that represents the boundary between the rainy season and subsequent dry season is frequently does not exist.

Ideally, all results should be validated and then shared with farmers to ensure that there is alignment between what farmers meant and the interpretation of their responses. At the current time this is not possible. It is my hope that these results can be shared with farmers around Kibale at a future date.

6. CONCLUSIONS

An analysis of 30 years of satellite rainfall data shows that two homogenous rainfall regions exist in the vicinity of Kibale National Park: a wetter region to the north and a drier region to the south. More importantly the results of this analysis emphasize that there is considerable variability in the seasonal timing and amount of rainfall in this region. The earliest and latest onset dates for the 30-year period were two to three months apart for both the MAM and SON seasons. An investigation into the variability of the onset dates of the four seasons shows that the onset of the MAM season is the most variable. Results from surveys and focus groups show that farmers are keenly aware of this variability, and the majority of farmers agree that the MAM season is variable. They claim that both the timing and amount of rainfall is problematic. Although some farmers believe that changes are occurring in the SON season, opinions regarding this matter are less cohesive. The extent to which there is agreement that the MAM rains are changing indicates that the MAM season is a large concern or farmers around Kibale.

It appears that the timing and amount of rainfall are inherently variable throughout the entire 30-year period, yet farmers feel that the variability has increased in recent years. The majority of respondents feel that the onset of the MAM season has become more variable in recent years. They feel that the onset can be delayed, and that the February rains keep disappearing. They also feel that the MAM season ends prematurely, and while they expect it to last through May, it tends to end before this time. These perceptions are supported by the analysis of rainfall data, which does show that the MAM season is highly variable, but it does not affirm that the MAM is becoming increasingly variable. The rainfall data also shows that rainfall during February and May is more sporadic, aligning with perceptions.

The majority of respondents perceived the SON season to have a delayed or variable onset, and that the cessation was variable between years. The rainfall data does not confirm that the onset is delayed. The cessation does appear to be variable, but to a lesser extent than the MAM season. A trend analysis of seasonal rainfall amounts indicated that both the MAM and SON rainy seasons have experienced negative trends in rainfall, while the DJF and JJA dry seasons appear to be getting wetter. The trend for the SON season was the most significant. Participants indicated that the dry seasons were variable, which do not match up to rainfall estimates that indicate that DFJ and JJA are becoming wetter.

Overall the majority of participants agree on perceptions of rainfall variability and change. A slight relationship between park direction (whether the participant lived to the east or west of the park emerged) and their perceptions of climate variability and change emerged, however perceptions tended to be widespread and shared by most participants. Participants have been adapting to perceived changes by modifying their planting time and they have also expressed the desire to obtain cropland in wetland or forested/wooded areas.

Final recommendations include: (1) The need to monitor the SON and MAM rains to assess seasonal rainfall amounts, variability, and changes, (2) Development of planned adaptations to climatic variability that moves beyond coping, (3) Development, promotion, and support for initiatives that blend conservation and development goals, (4) Maintenance and establishment of ground level rain gauges to aid in monitoring weather here, and (5) The development of rainfall prediction systems that could aid farmers in their decision making.

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