EFFECTS OF RAINFALL VARIABILITY ON SUBSISTENCE CROP PRODUCTION IN KAHANGARA DIVISION OF MAGU DISTRICT, TANZANIA

BY

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CHAPTER ONE: INTRODUCTION

1.1 Back ground to the study

Rainfall variability is a temporal dispersion in rainfall either from month to month, from season to season or from year to year from long-term average. This variability can cause floods, dry spells or drought (Ribot *et al.,* 1996). Rainfall being the primary source of moisture is probably the most important factor determining the productivity of the crops production (Medug, 2009). With the rainfall va

riability, subsistence crop production becomes uncertain.

Most of the world's food is produced under rain-fed systems and the long term rainfall variability is a big problem on crop production in most parts of the world (Slingo *et al.*, 2005) and yet, effects of this rainfall variability on subsistence crop production has not been critically researched by many researchers. Phillips *et al.* (1999) its effects have been, and continue to affect global food production throughout history. Further, Phillips *et al.* (1999) have shown that during the years 1982- 1983 and 1997- 1998 the U.S. Corn Belt region experienced variability in rainfall. These variabilities affected maize crop development which in turn affected its yields. However, that study focused on maize crop only apart from other subsistence crops like cassava, sorghum and sweet potatoes, which are studied in this study. Rosenzweig and Hillel, (1995) noted that high rain events occurred on the West Coast from November 1997 to March 1998, bringing damage to agriculture in southern California. The intense rain in December 1999, destroyed villages and croplands in Venezuela, (Rosenzweig, *et al* 2001).

Recent analysis indicates that African countries are more vulnerable to rainfall variability than the industrialized countries because those countries (Kenya, Tanzania, Somalia and Sudan) mostly depend on rain fed agriculture for their livelihood (Hulme, 1996) but these analysis have not clearly assessed the historical rainfall variability at annual, seasonal and monthly scales which is a major part of this study. Over 36 African states are today affected by prolonged dry spells and drought which causes reduction in crop yields (Ominde and Juma, 1991). The climatic data of Cameroon has shown that over the years the annual average rainfall has been on the decline between 1930 and 1995 from the average of 2000mm to 572mm, which led to the total maize crop failure in 1984 which in turn affected other economic sectors of the nation (Ayunghe, 2001). However, that study focused on annual rainfall variability analysis only leaving out seasonal and monthly rainfall analysis which also affects subsistence crop production. The Southern African's rainfalls of 1982/1983, 1991/19992, 1994/1995 and 1997/1998 caused floods which affected agriculture (Phillips *et al.*, 1999).

The East African countries have both unimodal and bimodal rainfall regimes with wet seasons starting from March to May (the long rains) and October to December (short rains) (WWF, 2006). The current climate in East Africa is characterized by large variability in rainfall of which rainfall changes over different periods that makes fluctuation on subsistence crop production (Schreck and Semazzi, 2004). These countries suffer both excessive and at the same time deficient rainfall with frequent occurrence of extreme events such as droughts and floods (Schreck and Semazzi, 2004). Shongwe *et al.*, (2009) reported an increase in the number of hydro meteorological disasters particularly floods, for example, the flood of 1997/98 Moreover, IPCC, (2007) reported that droughts occurred frequently over the last 20 years (for example in - 1983/84, 1991/92, 1995/96, 1999/2001, 2004/2005,). as a result affected also the agricultural sector.

According to the U.N. Food and Agriculture Organization (FAO, 2004), the number of East African food crises per year has tripled from the 1980s to 2000s., yet, rainfall variability which is a major factor in food crop production has not been keenly assessed. Flood and drought disasters affected subsistence crop production which resulted to low production and leading to starvation of millions of the people (Hulme *et al.*, 2001). Further, Hulme *et al.*, (2001) add that parts of East Africa will likely experience 5-20% increase in rainfall from December-February and 5-10% decrease in rainfall from June-August by 2050. Kenya for instance, has experienced frequent and more severe droughts, the most notable being in 1983/84, 1991/92, 1995/96, 1999/2001, 2004/05 and 2008/2009 and these affected subsistence crops production that caused acute shortage of food (Ng'ang'a, 2006).

Tanzania's average annual rainfall over the entire nation is 1,042 mm. About 75% of the country's rainfall is erratic and only 25 % of the country can expect an annual rainfall of more than 750mm with a 90% probability (Mwandosya *et al.* 1998). The analysis of annual rainfall time series by Tanzania Meteorological Agency (2007), indicated a decrease of rainfall trend for most of the stations but with greater variability in cycle. However, seasonal and monthly rainfall variability had not reported. In addition, the report did not assess how rainfall variability affects subsistence crop production in Tanzania. The rainfall variability is associated with the extreme events of floods and drought, for example, the floods of the 1990 and 1993 (United Republic of Tanzania, 2006). There were 37 occurrences of drought between 1872 and 1990 which impacted food security and people's livelihood (Morris *et al.*, 2003). The semi arid areas of Tabora and Dodoma experienced the decrease of seasonal rainfall by 65%, which caused the decline of potential maize yields between 1922 and 1998 (Mongi *et al*, 2010). Other subsistence crops for example, cassava, sorghum and sweet potatoes as the subject matter of this study were not examined.

The decrease was also attributed to other factors like increased insects and pests and decline of soil fertility (Mongi *et al*, 2010). The decrease of rainfall is estimated to reduce maize yields by between 80% and 90% and therefore, threaten the main source of food for millions of Tanzanians (Mwandosya *et al.*, 1998). However, the effects of rainfall decrease on cassava, sweet potatoes and sorghum were not also highlighted in the study. International Institution for Environment and Development (2009) reported that rainfall variability will trigger a 0.6 to 1% decline in GDP by 2030 and by 2085; the decline in GDP will range from 5% to 68% depending on the severity of the problem. The problem of rainfall variability has been observed in different areas in Tanzania but most of the study focuses on agriculture and crop production in general.

Rainfall variability has been also observed in Kahangara Division of Tanzania whereby rainfall is unpredictable and sometimes in its extremes, for example, the El-Niño related floods of 1997/1998 and the drought of 2008 and 2010 (MDDP, 2011). This variability in rainfall may have had an impact on subsistence crop production. However, no documented study has so far shown the relationship between rainfall variability and subsistence crop production. Therefore, this study was intended to examine the effects of rainfall variability on subsistence crop production through assessing the annual, seasonal and monthly rainfall variability and how this variability affected subsistence crop production in a small scale that is in Kahangara Division.

1.2 Statement of the problem

Rainfall is a major factor that determines the production of subsistence crops. Its variability may affect positively or negatively crop production. There was rainfall decline in Kahangara division between 2008 and 2010 (MDDP, 2011) which might have made subsistence crop production risky. Variations in rainfall is been increasing in Tanzania from season to season (Mongi *et. al.*, 2009). Yet, the effects of rainfall variability on crop production have not attracted adequate attention at national level in Tanzania in spite of the few studies that have already been conducted, for example, Mongi *et. al.* (2009) and Mwandosya *et al.* (1998). In addition, there is no known study conducted to evaluate the historical rainfall variability at annual, seasonal and monthly scales over the period between 1990 and 2010 in Kahangara Division. Moreover, the effects of rainfall variability on subsistence crop production in the division have not been critically studied. Therefore, there was a need to conduct this study so as to examine the effects of rainfall variability on subsistence crop production in Kahangara Division.

1.3 Objective of the study

The main objective of this study was to examine the effects of rainfall variability on subsistence crops production in Kahangara Division.

Specific objectives were:

1. To assess the historical rainfall variability at annual, seasonal and monthly scales over the period between 1990 and 2010 in Kahangara Division.

2. To establish the effects of rainfall variability on subsistence crop production in Kahangara Division.

1.4 Research questions

1. What is the historical variability of annual, seasonal and monthly rainfall in Kahangara Division between 1990 and 2010?

2. What are the effects of rainfall variability on subsistence crop production in Kahangara Division?

1.5 Justification of the study

Rainfall variability affects subsistence crop production. Paavola, (2003) observed the increasing problem of rainfall variability with rainfall pattern being much unpredictable in Tanzania. In addition, Paavola, (2003) noted that regions like Shinyanga, Mwanza and Dodoma were the most affected areas because most of the time they receive less than average annual rainfall. Rainfall variability may affect crop production in different ways due to different environmental characteristics and weather pattern in different areas. Kahangara division has been selected for this study because variability of rainfall has greatly been observed in the division, for example, the report by Magu District Development Plan (MDDP, 2011) reported that there was extreme rain in 1997/1998 (The El-Niño related flood) and that there was a period of no rainfall between the years 2008 and 2010. Yet this variability has not been shown to have related to subsistence crop production. Subsistence crops grown in the division include rice, maize, cassava, sorghum, sweet potatoes and legumes (beans, groundnuts, and Chickpeas) (MDDP, 2011). In this study, three crops (cassava, sorghum and sweet potatoes) have been selected because of being the main staple food in the division. Further, rainfall will be assumed to be distributed uniformly in all parts in the division since the area is fairly flat and the rain-gauge is located in the middle of the Kahangara division. The study only looked at 21 years that is between 1990 and 2010, mainly due to unavailability of data before 1990. This study might be useful to farmers on the need to practice proper farming methods in relation to rainfall variability so as to improve subsistence crop production in the Division. It may also of benefit to economic planners to find out alternative ways on helping subsistence farmers on adapting and mitigating the impact of rainfall variability in the Division. However, it also provide an understanding of the rainfall trends that help economic planners, the government, agricultural officers and farmers to plan appropriate coping strategies to improve subsistence crop production in relation to rainfall variability in Kahangara division.

1.6 Scope and limitations of the study

This study covered the area of Kahangara Division. This study was limited to evaluating the historical rainfall variability at annual, seasonal and monthly scales over the period between 1990 and 2010 in Kahangara Division and establishing its effects on subsistence crop (cassava, sweet potatoes and sorghum) production. Long time data for rainfall and crop productions was not available therefore; the study used the available data over the last twenty one years. Further, data collection was affected by language barrier in that, the questionnaire was constructed in Swahili language and few people were observed not to have known this language. The problem was solved by relying on a translator from the community. Subsistence crop production is also affected by declining soil fertility, pests and diseases, but these factors were not considered in this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of previous related research findings on rainfall variability and subsistence crop production. The chapter has been divided two parts; the first is dealing with the assessment of the historical rainfall variability at annual, seasonal and monthly scales from different areas over a long time. The second part examines the effects of the rainfall variability on subsistence crop production from the different parts of the world.

2.2 The Historical Rainfall Variability at Annual, Seasonal and Monthly scales from different areas

Both annual and seasonal rainfall exerts an overall control on water availability for plant growth. Rainfall variability imposes a degree of uncertainty whereby extreme rainfall events may increase the impacts of floods and drought (IPCC, 1998). In future, rainfall variability is predicted to affect water and agricultural sectors in the world (Cruz *et. al.*, 2007). The historical rainfall variability at annual, seasonal and monthly is very important variable in examining rainfall variability. Decreasing and increasing trends of annual and seasonal fluctuation of rainfall have been observed in different parts of the world. For example, NASA Space Flight Center (2007) reported that there was an increase of 5% annual rainfall in the tropics which concentrated over the oceans. However, there has been slight decline of the rainfall in the dry land regions.

World Meteorology Organization report (2000) showed the decline of annual rainfall between 1921 and 2000 with the occurrences of extreme drought cycle with a peak in 1940 and 1960 in Pampas province (Argentina). Brown (2005) reported that in 2003, Europe suffered very low rainfall throughout spring and summer. Dash *et. al.*, (2007) analyzed Indian rainfall amount for the period of 1871 and 2003 during different seasons and found a decreasing tendency in summer monsoon rainfall and an increasing trend during pre and post-monsoon months. But those studies focused on annual and seasonal rainfall while monthly and daily rainfall was not critically studied. Yeu and Hashino (2003) analyzed the long term trends in annual and monthly rainfall for Japan. They observed that there was high rainfall variability in monthly and annual total rainfall with great decline in December from 38% to 44.7%. However this study focused on annual and monthly rainfall and left out to asses seasonal and daily rainfall which also are very important in plant growth. Domonkos, (2003), analyzed the time series of monthly rainfall totals in Hungary between 1901 and 1998 to detect the long-term changes in rainfall characteristics and found that, annual total rainfall decreased by 15% to 22%. There has also been observed changes in rainfall intensity in India (Ramesh and Goswami, 2007) and numbers of rainy days are highly correlated with the seasonal and annual rainfall amount as a result of inter-annual and decal-scale fluctuations (Raisanen, 2005). However, this study focused on daily, seasonal and annual rainfall variability for the whole country of India, rather than specifically focusing on a small area within a country that this study focuses on. This is because the environment and rainfall patterns differs from one area to another either within or outside the country, hence generalizing rainfalls for the whole country can bring problem in understanding rainfall variability.

It is, however, worth noting that the entire Africa continent is affected by rainfall variability. Zinyowera and Unganai (1993) reported that SADC countries experienced the worst drought of the century. There was seasonal deficit of as much as 80% of normal rainfall from 1980 to 1992. Nicholson (2000) assessed the annual rainfall in Eastern Africa between 1950s and 1980s, without specifically assessing seasonal, monthly and daily rainfall variability. The study established a general annual rainfall reductión trend throughout Africa and abnormalities showed a less frequent occurrence of above average annual rainfall through the continent. Much of this variability (50%) was attributed to the conditions in October and November months which were not the main rain season. However, Ngongondo (2005) examined the long term rainfall variability trends and water available in Mulunguzi river catchment in Malawi between 1960 and 2002. The study found significant departures of rainfall from the mean annual rainfall and the annual rainfall coefficient of variability (CV) for the 44 years period was 0.30 which was relatively high. In addition, rainfall variability was also experienced in Sudan, indicating a decline by 20% throughout Sudan between 1965 and 1985 (Hulme, 1996). Masvaya *et. al.*, (2009) studied the impacts of rainfall variability on farmers crop management strategies in Insiza District in Zimbabwe between 2007 and 2008. The study found that rainfall was generally highest in the month of December than in any of the other months (October, November, January, February and March). The coefficients of variability for daily rainfall in each month from October varied from 17.5% to 182.1%.

The high coefficient of variability (CV) was obtained in October when rainfall was low and with most days recording zeros.

Rainfall in East Africa varies inter annually, its variability may result into extreme high rainfall and extreme low rainfall which may cause floods and drought occurrences. Drought and floods are common features in East Africa particularly Kenya (UNEP, 2000). Ogutu and Owen- Smith (2006) assessed the Southern Oscillations in large mammal populations and related this to predation or rainfall. The study reported the variability of rainfall in Mara-Serengeti reserve area which showed that an extreme drought occurred in 1999/2000, severe droughts in 1993 and 1997, moderate droughts in 1991 and 1994, normal years in 1989/90, 1992 and 1995/96, a wet year in 2002, a very wet year in 2003 and extremely wet years in 1998 and 2001. The extreme of 1999/2000 drought was caused by failure of season rainfall in both years. However, the study focused on seasonal rainfall rather than specifically focusing on analysis of annual, seasonal, monthly and daily rainfall variabilities which this study focuses on.

The problem of rainfall variability in Tanzania has also been observed from a few related studies. For example, Agrawala *et al.* (2003) in their project analysis observed that annual rainfall over the whole country will increase by 10% by 2100, although seasonal declines of 6% are projected for June, July and August, and increases of 16.7% for December, January and February. But the study focused only on annual rainfall rather than specifically focusing on seasonal, monthly and daily rainfall variabilities. Meertens *et. al.*, (1995 and 1999) indicated that distribution of rainfall in semi-arid areas of Northwest Tanzania during the rainy season was highly variable. Aondover and Ming-Ko, (1998) observed that most of rainfall variability exhibit such characteristics as false onset of rains, late onset of rains, pronounced breaks during the rainy season and early cessation of the rain; leading to drastic alterations in the optimum yields in semi arid area in Tanzania. Further, Hatibu *et. al.*, (1995) and Mahoo *et. al.*, (1999) reported that there is a wide variability on the onset of rainfall date while the cessation occurs within one month in semi- arid areas of Tanzania. However in this study effects of rainfall variability on subsistence crop production were not clearly studied.

2.3 Effects of Rainfall Variability on Substance Crop Production

Rainfall is known to be one of the most important weather factors for crop yields (Baigorria *et.al.*2008). Thus, rainfall variability may have positive and negative consequences on agricultural production and food security anywhere in the world. For instance, Baigorria *et. al.*, (2008) observed that, in South East United States in 1988 total rainfall amounts were 500 mm and 500 kg/ha[1] maize yield was harvested, whereas, in 1989 there was about above 550 mm of rainfall and 10,000 kg/ha[1] of maize yield was harvested. This suggests that increase in rainfall amount leads to high yields of maize while decrease of rainfall is associated with decline of maize production. However, this study focused only on maize crop while the effects of rainfall variability on cassava, sweet potatoes and sorghum were not critically studied that this study focuses on. Connor and Palta (2001) reported that rainfall deficit during at least two months of the early period can reduce root crop yields (cassava and sweet potatoes) from 32% to 60% hence decrease in crop yields. Prolonged dry spells and low rainfall caused complete crop failure in Bangladesh (Basak, 2009). In 2002, Karnataka in India experienced a severe drought for three consecutive years (2001 -2002, 2000-2003 and 2003- 2004. During these periods, the state received 23% of rainfall leading to decline in cereal yields to 640,000 tonnes against the target of 10,405,000 tonnes (Nagaratna and Sridhar, 2009). However, this study focused on cereal crops in general, while cassava, sweet potatoes and sorghum were not critically studied. Decline of rainfall affected the duration of physiological maturity of rice in Bangladesh in 2008 (Nagaratna and Sridhar, 2009). It is predicted that this variability in rainfall patterns will be responsible for the reduction in rice yield by 2070 in Bangladesh. Mortimore and Adams (2001) and (Usman and Reason, 2004) noted that the distribution and length of the period of rain during the growing season and the effectiveness of the rains in each rainfall event is the real factor that affects the effectiveness and success of crop farming.

In Africa over the past 30 years, unusually severe and/or prolonged dry season, dry spells and drought in the dry lands has seriously affected agriculture, thus resulting in many deaths and severe malnutrition (UNEP, 1992). Currently, 36 countries in Africa are affected by recurrent drought and some degree of desertification. The risk of drought is highest in Sudan Sahelian belt and in Southern Africa (Intergovernmental Panel on Climate Change, 1993). Makadho (1996) added that rainfall variability affects crop yields and alter planting dates, though the study did not specifically focus on cassava, sweet potatoes and sorghum. In 1995 excessive rains were received in parts of the higher altitude zones in Meher in Ethiopia, which resulted in water logging, and caused delay in land cultivation and planting. It also caused retarded growth of the crops, and serious weed infestations which also affected yields (FAO, 1995). The crops most affected were the long cycle crops (maize and sorghum).

East Africa depends heavily on rain fed agriculture, making rural livelihoods and food security highly vulnerable to rainfall variability such as shifts in growing season conditions (Intergovernmental Panel on Climate Change (IPCC, 2001). Thornton *et. al.* (2007) reported that in parts of East Africa, change of rainfall periods is also likely to result in substitution of some crop species. For example, maize might be substituted by sorghum and millet, since the letter are more suited to drier environments. Rainfall variability may result to abnormally high amounts of rainfall in parts of East Africa resulting in flooding. To date floods have continued to be frequent phenomena in Kenya thus threatening 75% of subsistence farmers who depend on rain fed agriculture (UNEP, 2000). Funk *et. al.* (2005) reported that from 1996 to 2003, there was a decline in rainfall from 50mm to 15mm per season that corresponded to decline of maize crop yields across most of East Africa countries. The effects of rainfall decline on cassava, sweet potatoes and sorghum were not reported in the study.

Agricultural practices in Tanzania mainly depend on seasonal rainfall which varies from season to season. The report by United Republic of Tanzania (2004) stated that one of the factors that contribute to risk in agricultural sector in Tanzania is the unpredictability of rainfall and the recurrence of drought and floods. As study by Paavola (2003) indicated dramatic fluctuations in rainfall from seasons to seasons which in turn affects the agricultural sector through reduced maize yields. This study focused on maize crop only while the effects of rainfall variability on cassava, sweet potatoes and sorghum were not critically studied. Rainfall fluctuation and variability may increase the burden on food insecurity and low income among many families. The analysis by Hatibu *et. al.* (2002) revealed that more than 33% of disasters in Tanzania over the last 100 years were related to drought which impacted negatively the subsistence agriculture in the semi arid regions. Mongu *et. al.* (2009) reported that farmers observed a continuous decline in amount of rainfall in Semi-Arid Tanzania. Its decline was not related to subsistence crop production.

The report by Mc New *et. al.* (1991) suggested that farmers expect to receive adequate rainfall at the right time throughout the growing season and input decisions are often made on the assumption that average rainfall will occur during the cropping seasons. Semoka (2003) noted that the impact of rainfall on crop production can be related to intra-seasonal rainfall distribution in the area. But more subtle intra-seasonal variability in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. Rainfall variability also affects seasonal planting date. Basak (2009) reported that low rainfall and long dry spells lead to either decline of yields or crop failure. The study did not specifically mention the types of crops which can be affected through low rainfall and long dry spells. Tanzania villages struggled with shifting weather and prolonged drought from 2006 to 2009 whereas over the last four consecutive farming seasons (2006 to 2009) people of Monduli district had no good rain. They had no crop to harvest, everything failed and they were surviving on emergency food brought by the government (Alert, 2010).

In summary, it may be observed that the above studies stressed the effect of rainfall variability on agriculture in general, and covered large areas without specific focus on traditional African food crops like sorghum, cassava and sweet potatoes which are main staple food in many areas including Kahangara division in Tanzania. Farmers in Kahangara practice rain fed subsistence farming and hence they are at risk of crop failure due to rainfall variability which may affect house hold food security. This study therefore, is aimed at analyzing the effects of rainfall variability at annual, seasonal, monthly and daily basis and their effect on subsistence crop production.

2.4 Conceptual Framework

Rainfall variability in Kahangara division like any other parts of the world may result into below average rainfall or above average rainfall. This may have positively or negatively effects on subsistence crop production (Figure 1).

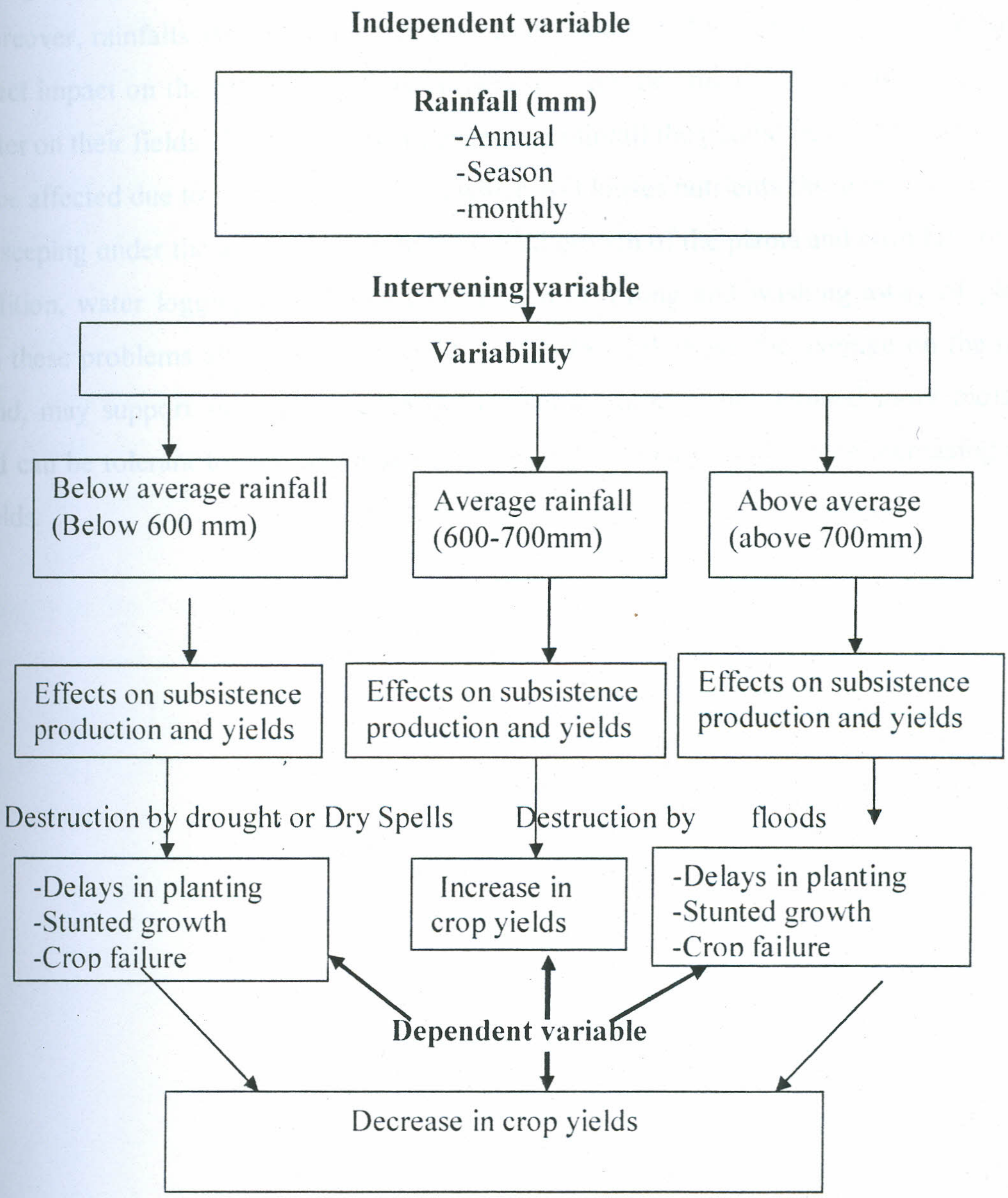

Figure 1: Conceptual Framework

Source: Authors' work, 2013

Rainfall is a very important factor in crop production. The variability in annual, seasonal, and monthly rainfall which can either be below or above the average may affect subsistence crop production and yields. The rainfall below the average may result into drought or dry spells which have devastating effects on production of subsistence crops, through delays in planting, stunting of crops and crop failure which also affects yields. Moreover, rainfalls above the average may cause floods and water logging, which have a direct impact on the planting time as farmers may not be able to till the land due excess water on their fields. In addition, with excessive rainfall the plants' development is likely to be affected due to leaching process in which soil looses nutrients through soluble water by seeping under the ground resulting to stunted growth of the plants and crop failure. In addition, water logging and floods can cause root rotting and washing away of plants. All these problems affect the crop yields too. Rainfall above the average on the other hand, may support subsistence crop growth since, some plants demand more moisture and can be tolerant to flooding and water logging for many days, hence increasing crop yields.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter presents the study area, research design, various sources and methods of data collection, sampling procedures, method of data analysis and presentation. Both primary and secondary data on rainfall, and subsistence crop production and yields were collected using different approaches including structured interviews, questionnaires, personal observation and documentary review which involved reviewing records of historical rainfall variability and subsistence crops yields from Magu Weather Station and division archives. Simple random sampling and purposive sampling techniques were used to select farmers' respondents and key informants in the study area.

3.2 Study Area

3.2.1 Location and Size

The study was conducted in Kahangara division which is located in Magu district in Mwanza region of Tanzania. The division lies within $2^0 10'$ and $2^0 5'$ latitudes South and 33^0 and 34^0 East. Kahangara division is bordered by Sanjo division in the west, Kwimba District in the south, Itumbili division in the East and Lake Victoria in the North. The division covers an area of 423 km^2 of which grazing area covers 102Km^2 and agricultural land 92km2. The remaining area is covered by residential settlement and natural resources (MDDP, 2011)

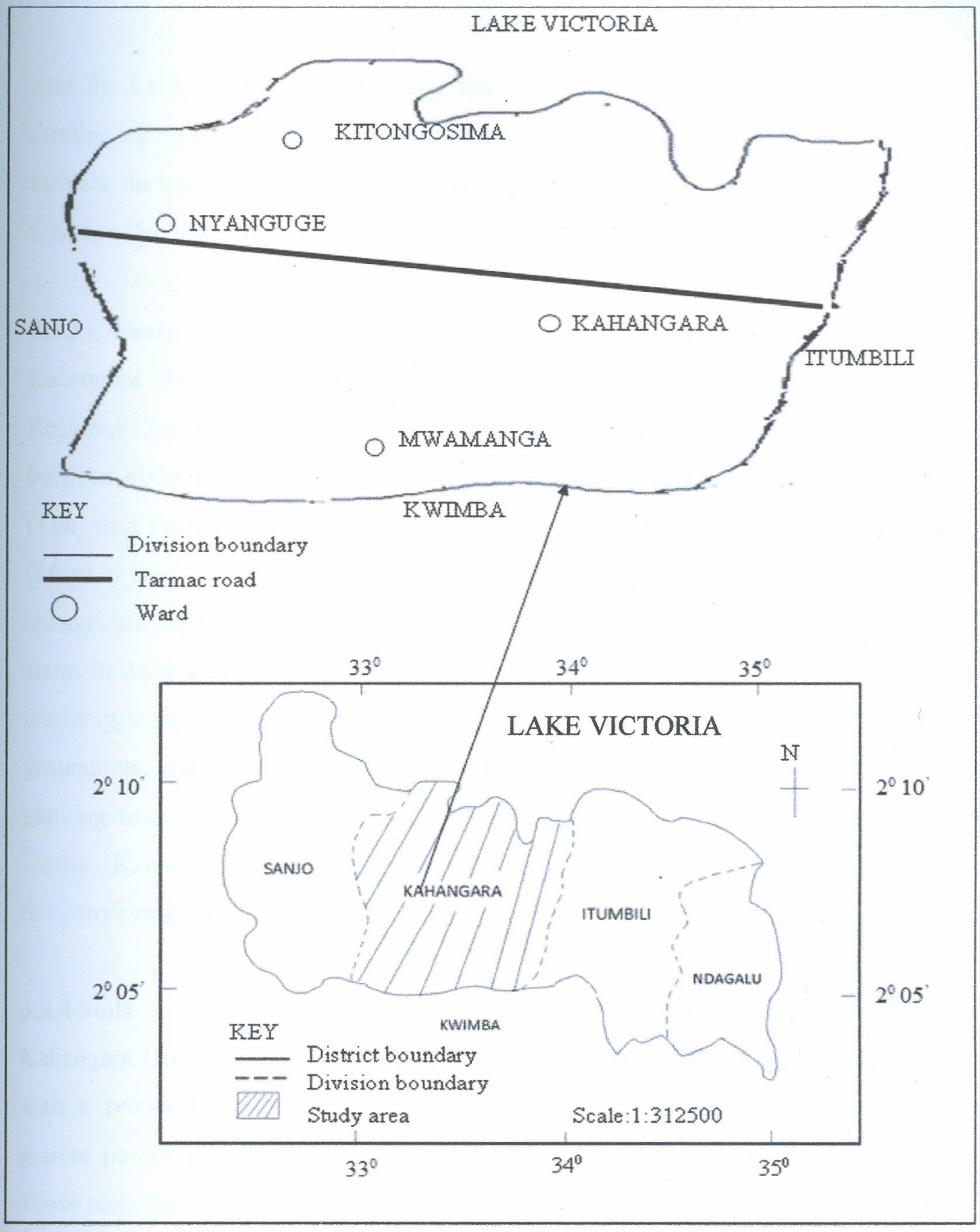

Figure2: Map of Kahangara in Magu District

Source: (MDDP, 2011)

3.2.2 Physiography

Kahangara Division lies on the altitude of 1120m above sea level. It is characterized with rivers draining into Lake Victoria which extends from West to North East. Nyangoma and Kisumuye are major rivers that flow to Lake Victoria. There are also swamps found near the Lake shore. These drainage systems attract farmers who practice horticultural farming along the Lake during the dry season. These rivers are not well utilized by the farmers during the dry seasons due to lack of irrigation projects and facilities in the Division (MDDP, 2011).

3.2.3 Climate

Kahangara division has one ecological zone classified as Sukuma heartland (Mwanza Regional Development Plan, 2012). The area receives an average annual rainfall of between 600mm to 700mm. The zone has a bimodal rainfall pattern. The short rains (*Vuli*) start from October to December with the peak in December, whereas the long rains (*Masika*) start from March to May with the peak in April. The short and long rainy seasons are separated by a not so dry period in January and February. The dry season starts in June and ends in September. Both the short and the long rains provide a cropping season for cassava, sweet potatoes, sorghum, rice, maize and legumes (beans, groundnuts, and chickpeas) (MDDP, 2011). Farmers in this study area have adopted one planting season from October to May making it appear as if there is a single rainfall season. Kahangara Division has maximum temperatures range from 18^0C to 20^0C during the rainy season and 26^0C to 30^0C during the drier season.

3.2.4 Soils

Kahangara Division has two soil types; clay loam soil and has moderate natural fertility, with a relatively high moisture holding capacity (8-11 mm/10cm), developed from granite parent material with good potential for agricultural activities (MDDP, 2011). These soils therefore, support subsistence crop production in the division. The other soil type is sandy loam with relatively low moisture holding capacity (4-8 mm/10 cm) and occupies a smaller area within the division. Variability of rainfall within the seasons (dry spells and wet spells etc) affects the soil water balance during the cropping season, and does also affect crop growth and yield. Prolonged dry spells, drought and extremely wet periods are likely to reduce soil suitability that in turn, may affect subsistence crop production in the Division. The potential evapo-transpiration rates are relatively high throughout the year. The minimum values of 4mm/day occur in the division during the rainy season where as maximum values of 7.2 mm/day are reached during the long dry season (MDDP, 2011).

3.2.5 Condition for the Growth of Cassava, Sweet potatoes and Sorghum

Cassava has a long growing cycle with a maturity period of between eight to twelve months. However, it may grow in the broad range of agro climatic conditions such as from 0 to almost 2000 metres above sea level. Cassava is commonly grown in areas receiving average rainfall of 800 mm to 1500 mm but it can also stand rainfall as low as 500 mm but well distributed throughout the growing season. It can stand dry periods of up to five months and can adapt to wide range of soil types. Cassava roots can extract water to a depth of 2.5m (El-Sharkawy, 1992). Cassava is widely known as a traditional food and subsistence crop and grown by small scale farmers (Alves and Setter, 2000).

Sweet potato is a perennial crop but cultivated as an annual crop. Ahn (1993) noted that the crop is tolerant to a wide range of soil conditions and is a tropical and subtropical plant. Therefore, it can be cultivated under different climatic conditions, with annual rainfall of between 750mm to 1000mm being ideal, with a minimum of 500mm, but well distributed during the growing season. In general, the crop requires a warm humid climate with a temperature average of 25^0C and 29^0C. Sweet potato roots can extract water to a depth of 120 cm. Its maturity may take four to five months or longer than this since it is a tuber crop and may stay in the soil for longer period. However, sorghum is best adapted to areas having an average annual rainfall between 450 mm and 650 mm. It requires about 20^0C to 30^0C temperatures. Sorghum is fairly drought tolerant but does well on deep well drained fertile soils, although it still performs better in soil with relatively high clay content.

Sandy soils which are found in areas within Kahangara have low water holding capacity and therefore require well distributed rainfall within the season if sorghum and other crops have to perform. The best time to plant is when there is sufficient moisture in the soil. Sorghum matures within 120 to140 days. Sorghum roots can extract water to a depth of 180 cm. Sorghum will therefore perform better in clay loam soils compared to the sandy loam soils given the same rainfall distribution due to high water storage within these soils (Alves and Setter, 2000).

3.2.6 Human Population

During 2002 Tanzania National census the population of Kahangara Division was 32,754 with household numbers being 5,459 of which 3,235 households were subsistence farmers. The 2012 population projection is estimated to be 42,192 people living in 7,032 households of which 4,711 households were subsistence farmers (MDDP, 2011). This farming population and the households formed the basis for the sampling during the primary data collection among the smallholder farming community in Kahangara.

3.2.7 Crop Farming

The majority of the people living in Kahangara division depend on subsistence crop farming. The subsistence farming is characterized by a mixed farming system whereby crop production and livestock rearing are practiced. Subsistence farming contributes 85% of the District's Gross Domestic Product. Sorghum, sweet potatoes and cassava are grown as subsistence crops in the division (MDDP, 2011). These crops have the ability to tolerate low and sometimes variable rainfall conditions. The variability of rainfall at different temporal scales within the division may have an effect on growth and yield of these staple food crops.

3.3 Research Design

This study used cross- sectional survey research design because data was collected at one point in time. The data collected were used to analyze the effects of rainfall variability on subsistence crop production in Kahangara Division. In this study the household was the unit of analysis of which house hold heads were surveyed because these people are responsible in provision of daily food to their family members.

3.4 Study Population and Sample Size.

According to MDDP (2011) the 2012 population projection is 42,192 of 7032 households of which 4711 are subsistence farmers. Therefore, the sample study was drawn from the target of 4711 farming households. Mugenda and Mugenda (2003) provided the formula for calculating sample size. They suggested that if the target population is less than 10,000, the following formula is to be used to obtain the sample size.

$$nf = \frac{n}{1 + (n / N)}$$

$$nf = \frac{384}{1 + \frac{384}{4711}} = 355$$

nf =The desired sample size

n = Desired sample size (when the population is more than 10,000=384) at 95% confidence level.

N= The estimate of the population size (4711)

Therefore, the sample size consisted of 355 respondents who were subsistence farmers from Kahangara Division. The list of household farmers was obtained from Kahagara Division agricultural extension office.

3.5 Sampling procedure

3.5.1 Simple random sampling

Simple random sampling was used to obtain 355 respondents from 4711 farming households. In this study, every subject was given a number then the list of numbers was randomized through computer programme (Microsoft Office Excel). The 355 random numbers from the computer program were selected as a subject of the study. The importance of this method is that every individual is free of being included in a sample. Different household heads were visited with the help of administrative officers from the division who most of them lived in the area for over ten years. They were assumed to have more information about the effects of rainfall variability on subsistence crop production in the division.

3.5.2 Purposive Sampling

Purposive sampling was used to obtain 4 key informants who were Agricultural extension officers from out of 5 Agricultural extension officers in the Division. In addition purposive sampling was also used to obtain 1 meteorologist from 2 meteorologists in the division. These key informants with relevant information were interviewed. According to Mugenda and Mugenda (2003), purposive sampling technique refers to where a researcher targets a group of people believed to be typical or average or group of people specially picked for some unique purpose. It allows a researcher to use cases that have the required information with respect to the objectives of his or her study. The technique was mainly used to identify key informants to provide focused information on rainfall variability and subsistence crop production.

3. 6 Sources of Data

In this study both primary and secondary data were collected.

3.6.1 Secondary Sources

Secondary data were collected from published and unpublished reports including government reports. The source centres of these data were the libraries at Maseno University in Kenya, Saint Augustine University in Tanzania, Magu weather station and Kahangara Division agricultural office. Magu weather is the only meteorological station which provided rainfall data for the whole Kahangara division. These sources provided requisite background information. Annual, seasonal and monthly rainfall data for a period of twenty one years and daily rainfall data for a period of ten years was provided. The crop yield data formed the basis for correlation analysis with rainfall data. Annual, seasonal and monthly rainfall totals for the period between 1990 and 2010, were used to calculate the long term mean rainfall of the area. The data was also used to assess the rainfall variability of which coefficient of variability (CV), trends and anomalies were also analyzed over the twenty one years period.

3.6.2 Primary sources

Primary data on crop production and yields which was mainly perception information on cropping activities and performance was collected from the field by surveying household heads and key informants. This information was collected to complement secondary data. Key informant interviews were administered to elicit data which served to confirm some of the information collected from household interviews.

3.7 Methods of data collection

Questionnaires, interviews and personal observation were used for collecting primary data.

3.7.1 Questionnaires.

Both open and closed-ended questionnaires were used to collect information from 355 household heads (See appendix 1). The questionnaires were to collect opinions from the household heads about annual, seasonal, monthly and daily rainfall and subsistence crops production (sorghum, sweet potatoes and cassava), the dominant crop and other challenges faced by subsistence farmers. Data obtained were used in explaining the effects of rainfall variability on subsistence crop production in the study area. The use of questionnaire is advantageous because it can be administered to respondents in their own private settings. Both qualitative and quantitative data were collected. Quantitative data collected was on the annual, seasonal, and monthly rainfall distribution on the area and on subsistence crop yields harvested over the years. While qualitative data was on opinions from the household heads about annual, seasonal, monthly and daily rainfall and how affect subsistence crops production (sorghum, sweet potatoes and cassava).

3.7.2 Interviews

Both structured and un-structured questions were used to collect qualitative data from key informants (Agricultural extension officers and a meteorologist) (Appendix 2). The data collected was on the annual, seasonal, monthly and daily rainfall distribution in the area and its effects on subsistence crop production in the division. These key informants were targeted because of their experience of working with subsistence farmers in the Division and had information about the study area.

3.7.3 Direct Observation

Direct observation was used in identifying the dominant crops at the time of the study in the field. During the survey, the researcher observed and took photographs in specific cropped fields. The photos obtained represented the real situations in the field. Data obtained supplemented the information given by the farmers and the agricultural extension officers on the dominant crops. It particularly helped in identifying and documenting dominant crops and their conditions.

Secondary data collection method

3.7. 4 Documentary Review

Documentary review was used to collect rainfall data and subsistence crop yields collected from 1990 to 2010. Rainfall data were obtained from Magu weather station and subsistence crop yields was obtained from the Kahangara divisional agricultural office.

3.8 Methods of Data Analyses

Quantitative data was analyzed using descriptive statistics such as frequency distribution, percentages, means, standard deviation, coefficient of variability, anomalies and correlation analysis. These data were processed using Statistical Package for Social Science (SPSS version 11.5) and Instat software version 3.36. Qualitative data were edited and organized by creating themes and patterns then evaluating the usefulness of information in answering research questions.

Seasonal rainfall data was taken as independent variable and yields of subsistence crops as the dependent variable. Statistical correlation analysis and Pearson Product-Moment Correlation Coefficient (r) were used to measure the strength of relationship and the direction of the linear relationship between seasonal rainfall amounts and yields of subsistence crops. These analyses were conducted separately for each of the three crops. Seasonal rainfall (mm) total for each season were compared with the yields of subsistence crops of each growing season. If the correlation coefficient (r) varied between -1 and +1 or closer to +1 or -1; the two variables are related (Hill, *et al.*, 2001). Positive relationship in this study implies that as rainfall increases, the crop yields increases as well. While negative relationship implies that as rainfall increases, the subsistence crop yields decreases. The correlation coefficient (r) was used to decide if there was significant relationship between the two variables.

3.9 Results presentation

The results were presented in the form of description, graphs, tables, and photographs. Graphs were in the form of trend lines, bar and scatter graphs which were used to show variability of rainfall at various temporal scales and crop yields. Scatter graphs were used to show the strength of association between rainfall and yields (sorghum, cassava, and sweet potatoes). Tables were used to present summarized rainfall data, respondents' responses (frequency of responses) and annual subsistence crops yields over the period of the years. *Photographs (plates 1-3) were used to show observational information on the types of planted crops and the effects of rainfall variability on crop performance.*

3.10 Reliability and validity of the instruments.

3.10.1 Reliability

To ensure reliability in this study, pre-testing was done. According to Ary *et al* (1996) pre- testing is the best way to minimize ambiguity, enhances clarity and ascertains responses to the style and content of the questions. Test- re-test technique of measuring reliability was used of which questionnaire was to be administered to 35 (10%) sample of subsistence farmers who were not included in the study sample. This involved administering the questionnaires to the pilot respondents twice, with a break of two weeks, and then the correlation coefficient (r) was calculated for the two tests by using Pearson Product-Moment Correlation Coefficient. After computing, a correlation coefficient (r) of 0.81 was obtained. According to Mugenda and Mugenda (2003), a correlation of 0.8 is considered to have high degree of reliability. Therefore, the questionnaire was accepted as reliable.

3.10.2 Validity

Validity means the extent to which the concept one wishes to measure is actually being measured by a particular scale or index (Creswell, 2003). To ensure validity in this study, content validity was tested. Mugenda and Mugenda (2003) content validity is a measure of the degree to which data collected using a particular instrument represents a specific domain of indicators or content of a particular concept, that is an instrument should provide adequate coverage of a topic. Expert opinions and pre-testing of instruments helps to establish content validity (Wilkinson, 1991; and Mugenda and Mugenda 2003). The instruments for data collection were edited and approved by the supervisors whose expert judgment helped to improve content validity. These instruments for data collection were also pre-tested during the pilot survey. Moreover, data was collected from various categories of respondents which included farmers, agricultural extension officers and a meteorologist, also secondary data were collected from Kahangara Division Agricultural office and Magu Weather Station. These also helped to maximize data validity.

Table 1 above and figure 3 show the statistical characteristics of annual rainfall distribution in Kahangara Division between 1990 and 2010. From the analysis it was observed that there were significant departures from the mean annual rainfall. The annual rainfall coefficient of variation (CV) for the 21 years period is 0.4 (Table 1). This coefficient of value is high which could be a feature of an area receiving convection rainfall (Nieuwolt, 1982). This is an expected result, as this area is relatively low lying and bordering the Lake Victoria with convection type of rainfall. Three of the years (2001, 2009 and 2010) had annual totals far below the mean of 679.4 mm. On the other hand, a few years had rainfall totals significantly above the mean. The of coefficient variability (CV) value in annual rainfall (Table 2) obtained shows that rainfall is highly variable and is very unreliable in the division. Doorenbos (1976) suggested that rainfall data with coefficient of variability of 0.2(20%) or above, is highly variable. There was high variability of annual total rainfall with some years having more rainfall than other years. As may be seen from Table 2, in 1998, 2002, and 2006 had high rainfall compared to the years 2009 and 2010. The highest annual rainfall was recorded at 1427.7mm in 2002 and the lowest recorded at 99.5 in 2009. The overall long-term mean was 679.4 mm over the last twenty one years (between 1990and 2010). Moreover, the annual rainfall trend was also analyzed in Figure 3 whether; the rainfall had been declining over the past 21 seasons.

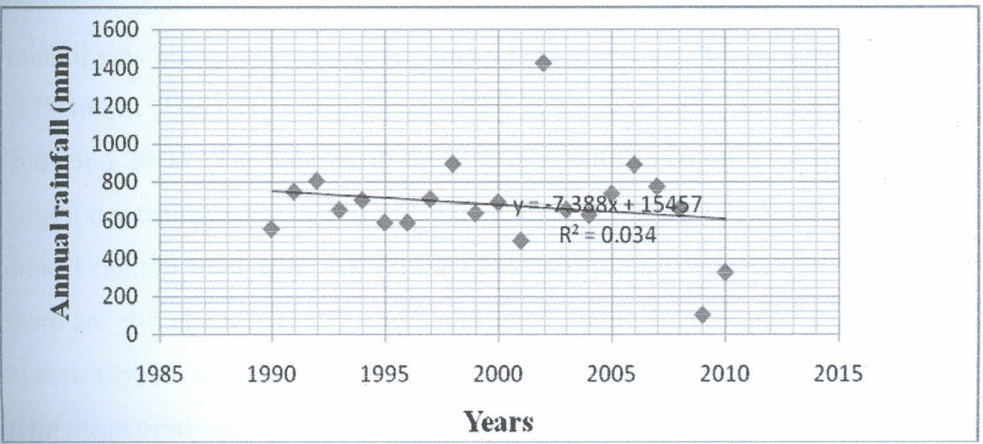

Figure 3: Annual rainfall trend in Kahangara division over the last 21 year historical period

The statistical record in Figure 3 shows the rainfall fluctuation over the twenty one year historical period. With interspersed by exceptionally high values of 2002 and the rather low values experienced at the end of the two years (2009 and 2010) at the end of decade. However, the rainfall trend shows no significant decline in rainfall amounts over the last 21 years. (r^2 = 0.034, $p>0.01$). The results of this study seem to differ with others previous studies, for example World Meteorology Organization, (2000) reported that in Pampas province (Argentina) there was significant decline in annual rainfall between 1921 and 2000 with the occurrences of extreme drought cycle with its peak was in 1940 and lasting until 1960. Domonkos (2003) analyzed time series of monthly rainfall totals in Hungary between 1901 and 1998 to detect the long-term changes in rainfall characteristics, and found that the significant decline of annual total rainfall by 15-22%. The analysis of annual rainfall time series by Tanzania Meteorological Agency, (2007) indicated a significant decrease of rainfall trend for most of the stations but with greater variability in cycle. Mary *and* Majule (2009) also noted the decreasing annual rainfall trend in Manyoni district of Tanzania between 1922 and 2007. The differences in results could be attributed to rainfall patterns and the geographical position of the areas.

In addition, Table 1 shows the results of analysis of annual rainfall anomalies in Kahangara division over 21years historical period. Anomalies show the percent on how annual rainfall varied from the long time mean. The analysis in Table 2 depicts that in 7 out of 21 years there was below normal rainfall (679.4mm), while in 8 out 21 years rainfall was above normal (679.4mm). And 6 out of 21 years had just normal rainfall (679.4mm). The wetter years were 1998, 2002, and 2006. Exceptionally dry years were 2009 and 2010. The long term mean was about 679.4mm over twenty one years. The largest departures were in 2009 with the annual rainfall of 99.5mm and in 2002 where the annual rainfall total was 1427.2mm. Normal rainfall is less likely in this area, though there are still chances that it can occur once within four years. This analysis shows that historically, there was still some variability of rainfall namely of either below the long term mean or above the long term mean. That normal rainfall can occur, but the tendency has been towards below the long term mean normal rainfall over the twenty one years. This confirms the aspect of rainfall variability in the Division.

Similar results have been reported by Nicholson (2000) who reviewed the climate dynamics and climate variability in eastern Africa between 1950s and 1980s. The study found that, generally the annual rainfall trends show that there was a reduction in rainfall throughout Africa. However, abnormalities analysis showed that there were less frequent occurrences of above average rainfall throughout the continent. Ngongondo (2005) examined the long term rainfall variability, trends and water available in Mulunguzi river catchment in Malawi between 1960 and 2002. The study found significant departures of rainfall from the mean annual rainfall, and the annual rainfall coefficient of variability (CV) for the 44 years period was 0.30. The differences in Kahangara is high than that of Mulunguzi river. The differences could have attributed to differences in environment, the weather patterns as well as the time series of the historical rainfall data of the two areas.

The analysis of annual rainfall provides significant reflection of the growing seasonal rainfall variability. It is however, a gross generalization of the seasonal rainfall totals in the division. It cannot provide a good correlation with subsistence crop production and yields as subsistence crop production and yields primarily depend on seasonal rainfall. Therefore, there is a need to analyze seasonal rainfall variability in relation to subsistence crop production and yields in the Division.

4.2.2 Analysis of Seasonal Rainfall in Kahangara Division

4.2.2.1 Seasonal rainfall total, trend and anomalies over the last 21 seasons

The analysis of seasonal rainfall was carried out to determine the seasonal total, historical trends, and anomalies in the study area. The crop growing season in Kahangara Division is between October and May. Therefore, the growing seasonal rainfall between October and May were analyzed. The crop calendars are based on the crop maturity periods with sorghum having the shortest period of between 120-140 days. Cassava and sweet potatoes have longer growing periods as they are tuber crops and may stay in the soil for longer periods. Table 2 shows the monthly rainfall distribution, seasonal rainfall total and anomalies in the study area from 1989/1990 to 2009/2010 seasons.

Table 2: Monthly rainfall distribution, seasonal rainfall total and anomalies from 1989/1990 to 2009/2010 seasons in Kahangara Division

Season	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Rainfall total (mm)	Anomalies (%)
1989/1990	53	62.7	119.9	20.4	15.5	47.6	51	24.4	394.5	- 40
1990/1991	90.7	140.8	155.5	25	12.1	85.1	177.1	65.1	751.4	20
1991/1992	78.2	160.2	125.5	48.1	25.2	95.4	188.1	89.7	810.4	30
1992/1993	49.1	146.6	149.1	25	15.1	30.2	162.5	52.7	630.3	0
1993/1994	25.2	152.7	171.6	37.1	25	45.1	197.1	78.4	732.2	10
1994/1995	0	161.9	159.5	44.5	21.3	49.2	155.5	83.5	675.4	10
1995/1996	6.5	93	112.5	52.2	27.5	51.5	110.8	75	529	- 20
1996/1997	25.6	93.1	107.8	47.3	27.5	98.8	106.7	97.3	604.1	- 10
1997/1998	17.5	103.5	165.8	60.1	35	195.7	201.5	155.1	934.2	50
1998/1999	43.4	73.6	98.1	59.1	12.5	111.6	121.9	85.7	605.9	- 10
1999/2000	0	82.3	137.6	49.7	21.6	85.6	155.6	74	606.4	-10
2000/2001	64.1	87.7	138.5	27	15	23.6	122.9	57.2	536	- 20
2001/2002	44.1	77.7	123.5	127.5	91.8	271.8	344.6	131.9	1212.9	90
2002/2003	87.6	100.6	186	50.6	24.2	86.3	173.2	81.5	790	20
2003/2004	0	98.8	138.8	70.7	84.3	142.8	104.5	74.1	714	10
2004/2005	14.3	77.4	29.1	99.5	50.4	75.5	37.6	71.7	455.5	- 30
2005/2006	23.2	181.4	139.7	78.4	143.8	125.8	48.5	70.3	811.1	30
2006/2007	31.1	91.6	139	56.3	97.7	147.1	110.3	80.7	753.8	20
2007/2008	28.6	86.1	18	94.4	86.3	194.4	108.4	50	666.2	0
2008/2009	21.7	57.8	30.1	14.4	17.5	24.5	14.6	7.1	187.7	- 70
2009/2010	4.5	2.2	14.7	17.9	25	13.8	14.6	12	104.7	- 80
Mean	**33**	**101.5**	**117.2**	**52.6**	**41.6**	**95.3**	**128.9**	**72.23**	**643.1**	
SD									**239.7**	
CV									**0.4**	

Source: Magu Weather Station, (2012)

The results of the analysis of total seasonal rainfall for Kahangara (Table 2) shows that the long- term mean of the seasonal total rainfall for the 21 seasons is 643.1mm with the standard deviation value of 239.7mm. The coefficient of variation shows the variation in total seasonal rainfall amounts of 0.4 (40%) which was a relatively high. The highest rainfall was recorded in 2001/2002 season which was about 1212.9 mm while the lowest record was in 2009/2010 with the value of 104.7mm.). Ogutu and Owen- Smith (2006) observed that the /1997/ 1998, 2001/2002 seasons had extremely rainfall in Mara-Serengeti reserve area. The same seasons had also been observed in this study to have highest rainfall above the long term mean. This study also analyzed the total seasonal rainfall trends over the historical period between1989and 2010 was (Figure 4)

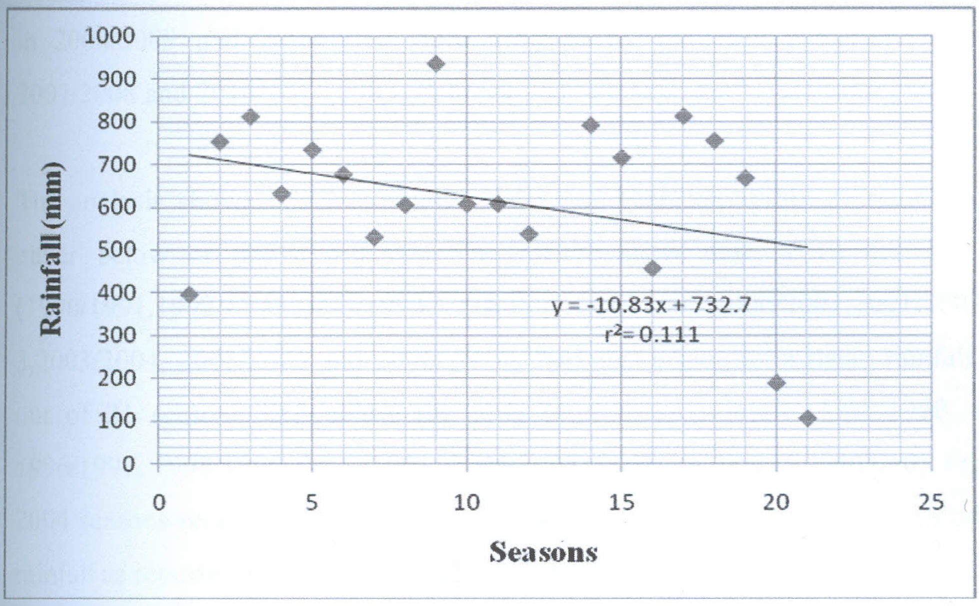

Figure 4: Total seasonal rainfall trends over the historical period 1989-2010

Source: Magu Weather Station, (2012)

Legend: 5=1993/1994 15= 2003/2004

10 = 1998/1999 20=2008/2009

The statistical record (Figure 4) shows the rainfall fluctuation with the highest rainfall recorded in 2001/2002 season while the lowest was recorded in 2009/2010 season. Thus, the fluctuation in rainfalls confirms the aspect of rainfall variability in the Division. However, the total rainfall from 1989/1990 2009/2010 seasons appeared to decrease at non significant rate (r^2 = 0.111, p>0.01). A similar results by Mongi *et al.* (2010) observed total rainfall during the seasons from 1973/74 to 2007/08 appeared to decrease at non-significant rate (R^2 = 0.018, p >0.47) in semi arid Tanzania. The seasonal rainfall variability was also depicted in the analysis of seasonal rainfall anomalies over 21 seasons in Table 2. The anomalies show the percent of seasonal rainfall variation from the long-term mean. The largest departures were in 2001/2002 and 2009/2010 seasons of which the later also had the lowest value of 104mm rainfall. The 2009/2010 season had anomaly value of -80%. The 2001/2002 season with the rainfall with 1212.9mm of rainfall had an anomaly value of 90%. The wetter seasons were 1997/1998 and 2001/2002 which coincided with the *El Nino* events recorded in 1997/1998 and 2002/2003 (Schreck and Semazzi, 2004; and Shongwe *et al.*, 2009). The driest seasons in 2008/2009 and 2009/2010 were affected by *La Nina* phenomenon recorded in 2007/2008 and 2010/2011/2003 (Schreck and Semazzi, 2004; and Shongwe *et al.*, 2009).

The analysis shows that historically, there has been variability of rainfall in terms of either below or above average. The results show that in 10 out of 21 seasons (1990/1991,1992/1993,1993/1994,1994/1995,1997/1998,2000/2001,2001/2002,2002/2003,2003/2004, 2005/2006 and 2006/2007) had above long term mean rainfall while in 8 out of 21 seasons had below the long term mean rainfall (1989/1990, 1995/1996, 1996/1997, 1998/1999, 2000/2001, 2004/2005, 2008/2009 and 2009/2010). From 2001 to 2004 seasons recorded, consecutive had above average rainfall. These periods had high rainfall as reported by Shongwe *et al.* (2009).

4.2.3 Analysis of monthly rainfall distribution in Kahangara distribution within the rainy seasons.

Table 3 provides the information of the historical trend of the monthly rainfall totals, means, standard deviations and coefficient of variation during each season from 1989/1990 to 2009/2010 seasons.

Table 3: Seasonal variation in monthly rainfall for Kahangara Division between 1990 and 2010

Season	Monthly rainfall (mm)												
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
1989/1990	0	0	53.0	62.7	119.9	20.4	15.5	47.6	51.0	24.4	0	0	394.5
1990/1991	0	7.5	90.7	140.8	155.5	25.0	12.1	85.1	177.1	65.1	10.2	0	769.1
1991/1992	3.6	8.1	78.2	160.2	125.5	48.1	25.2	95.4	188.1	89.7	15.6	0	837.7
1992/1993	0	0	49.1	146.6	149.1	25.0	15.1	30.2	162.5	52.7	8.8	0	639.1
1993/1994	0	8.7	25.2	152.7	171.6	37.1	25	45.1	197.1	78.4	2.3	0	743.2
1994/1995	0	0	0	161.9	159.5	44.5	21.3	49.2	155.5	83.5	15.2	0	690.6
1995/1996	0	5.1	6.5	93.0	112.5	52.2	27.5	51.5	110.8	75.0	36.6	0	570.7
1996/1997	0	5.7	25.6	93.1	107.8	47.3	27.5	98.8	106.7	97.3	42.7	0	652.5
1997/1998	1.1	3.8	17.5	103.5	165.8	60.1	35	195.7	201.5	155.1	30.1	0	969.2
1998/1999	0	3.7	43.4	73.6	98.1	59.1	12.5	111.6	121.9	85.7	25.7	0	635.3
1999/2000	0	0	0	82.3	137.6	49.7	21.6	85.6	155.6	74.0	16.9	0	623.3
2000/2001	0	0	64.1	87.7	138.5	27.0	15.0	23.6	122.9	57.2	0	0	536.0
2001/2002	0	0	44.1	77.7	123.5	127.5	91.8	271.8	344.6	131.9	70.9	0	1212.9
2002/2003	0	14.5	87.6	100.6	186.0	50.6	24.2	86.3	173.2	81.5	0	0	804.5
2003/2004	0	0	0	98.8	138.8	70.7	84.3	142.8	104.5	74.1	9.7	0	723.7
2004/2005	3.0	18	14.3	77.4	29.1	99.5	50.4	75.5	37.6	71.7	0	0	476.5
2005/2006	25.0	34.8	23.2	181.4	139.7	78.4	143.8	125.8	48.5	70.3	39.8	0	910.7
2006/2007	95.7	28.0	31.1	91.6	139.0	56.3	97.7	147.1	110.3	80.7	50.3	0	927.8
2007/2008	61.0	40.1	28.6	86.1	18	94.4	86.3	194.4	108.4	50.0	14.4	0	781.7
2008/2009	0	1.2	21.7	57.8	30.1	14.4	17.5	24.5	14.6	7.1	0	0	188.9
2009/2010	0	0	4.5	2.2	14.7	17.9	25	13.8	14.6	12.0	1.9	0	106.6
Mean	**9.0**	**8.5**	**33.7**	**101.5**	**117.2**	**52.6**	**41.6**	**95.3**	**128.9**	**72.3**	**18.6**	**0**	
SD	**24.3**	**12.0**	**28.2**	**42.4**	**51.5**	**29.1**	**36.6**	**66.2**	**76.2**	**34.1**	**19.8**	**0**	
CV	**2.7**	**1.4**	**0.8**	**0.4**	**0.4**	**0.5**	**0.9**	**0.7**	**0.6**	**0.5**	**1.1**	**0**	

Source: Magu Weather Station, (2012).

The monthly totals (Table 3) over 21 seasons provide information of the historical trend of the monthly totals during each season. The rainfall distribution in Table 4 reveals that in most cases rain started in September which was designated as dry month with long term mean of 8.5 mm and ended during June with the long term mean of 18.6mm. Except in the season between 1991/1992 (trace amounts), 1997/1998(trace amounts), 2004/2005(trace amounts), 2005/2006, 2006/2007 and 2007/2008 when it came in August which is also earlier than expected. This month is also designated as a dry month. In 1989/1990, 1992/1993, 2000/2001, /2001/2002, and 2009/2010 it came in October. And in 1994/1995, 1999/2000 and 2003/2004 it came late in November. There was a wide variability of monthly rainfall onsets in the division. It may start either early or late (Table 3) in 2004/2005, 2005/2006, 2006/2007and 2007/2008 the rain started very earlier (August), while in 1994/1995, 1995/1996, 1999/2000, 2003/2004 and 2009/2010 the rainfall started very late in November.

It may also be observed (Table 3) that in August (9 mm) and September (8.5mm) months had low mean rainfall over the last 21 seasons. While the rain started to increase in October from 33.7mm then to November (with 101.5mm) and peak in December (with 117.2mm). It then decreases in January (52.6mm) and February (41.6) and starts again to increase in March (95.3mm) with another peak in April (128.9mm), then, it decreased in May (72.3mm) and ends in June (18.6mm). The month of July has no rainfall completely over the last 21 seasons. The highest rainfall means was recorded in the month of April with the rainfall mean of 128.9mm (CV= 0.6) and the lowest was recorded in the month of September with the rainfall mean of 8.5mm (CV=1.4). The months of November, December, March and April had high monthly rainfall means over the last 21 seasons, while the months of August, September and June had low rainfall means over the last 21 seasons.

Yusri, *et al,* (2012) in their analysis of monthly rainfall variation in Benin Catchment area between 1948 and 2002, observed that November and April are the wettest months with the percentage rainfall of 10.9 % and 11.2, of the average annual total. Meanwhile, January as the driest month with 5.1% of the average annual total. The results obtained by Yusri, *et al,* (2012) agree with the results of this study that that November, December, March and April months had high monthly rainfall means over the last 21 seasons. These variations in rainfall indicate the existence of high variability in rainfall in Kahangara Division.

The growing season starts in October with the long term mean value 33.7mm and also ends in May with the long term mean value 72.3mm. Therefore, the main rainy and the growing season falls between October and May, and with the transition period of low rainfall in January (52.6 mm) and February (41.6mm). There is variability in total rainfall amount in different months over 21 years during the growing seasons. For example, in October when the growing season starts, had no rain at all in 1994/1995, 1999/2000, 2003/2004. In 1995/1996 and 2009/2010 October had lowest rainfall values 6.5mm and 4.5mm. The highest monthly rainfall in October was recorded in 1990/1991 with the value of 90.7mm (Table 3). However, monthly rainfall totals have been analyzed to show the spread around the long term mean by providing information on the standard deviations and coefficient of variations. The coefficient of variation in rainfall between the month of August and June were analyzed to assess the variability within the month. The results of the analysis show that the amount of rainfall received from each month varies greatly from season to season (Table 3). The coefficient of variation of monthly rainfall during the growing seasons ranges from the lowest of 0.4 which is in both months of November and December. And the highest CV was in February with the value of 0.9. The coefficient of variability for all months over twenty one seasons ranges from 0.4 (November and December) to 0.9 (February) (Table 3). According to Doorenbos (1976) if the monthly rainfall has a coefficient of variability of 0.2 or above, it considered to be highly variable. Therefore, the monthly rainfall during the growing season that is from October to May was highly variable in the division. November and December showed to have lowest variability with the value of 0.4 followed by January and May with the coefficient of variability (CV) of 0.5. Whereas, the greatest variability was in February (0.9). Therefore, it is possible to predict the variability in rainfall in the month of November and December rather than in other months. This is because they have low variability in rainfall over the seasons of which the amount of rainfall received in the months did not differ so much in all seasons.

Similar study by Yue and Hashino (2003) analyzed the long term trends in annual and monthly rainfall for Japan. They observed that there was high rainfall variability in monthly and annual total rainfall with the decline in rainfall with greatest decrease in December from 38% to 44.7%. Masvaya *et al* (2009), studied on the impacts of rainfall variability on farmers crop management strategies in Insiza District in Zimbabwe between 2007 and 2008 and found that rainfall was generally highest in the month of December than in any of the other months (October., November, January, February and March in the season 2007/2008). The coefficients of variability for daily rainfall in each month from October varied from 17.5% to 182.1%. The highest coefficient of variability (CV) was obtained in October when rainfall was of low intensity in which most days recorded zeros. Aondover, and Ming-Ko (1998) reported that most of rainfall variability exhibit such characteristics as false onset of the rains, late onset of the rains, pronounced breaks during the rainy season and early cessation of the rain; leading to drastic alterations in the optimum yields. Hatibu *et al.* (1995) and Mahoo *et al.* (1999) also reported that there is a wide variability in the onset of rainfall date while the cessation occurs within one month in semi- arid areas of Tanzania.

The crop growing calendar in Kahangara division is between October and May. Therefore, the percent anomalies between the month of October and May were analyzed to assess the percent rainfall variation from the long term mean within the month over the last 21 seasons, that is from 1989/1990 to 2009/2010 seasons (Table 4).

Table 4: Percent rainfall variation from long - term mean over 21 seasons (1989/1990 -2009/2010)

Seasons	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Marc (%)	Apr (%)	May (%)
1989/1990	57	-38	2	-61	-63	-50	-60	-66
1990/1991	169	39	33	-52	-71	-11	37	-10
1991/1992	132	58	7	-9	-39	0	46	24
1992/1993	46	44	27	-52	-64	-68	26	-27
1993/1994	-25	50	46	-30	-40	-53	53	9
1994/1995	-100	59	36	-15	-49	-48	21	16
1995/1996	-81	-8	-4	-1	-34	-46	-14	4
1996/1997	-24	-8	-8	-10	-34	4	-17	35
1997/1998	-48	2	42	14	-16	105	56	115
1998/1999	29	-27	-16	12	-70	17	-5	19
1999/2000	-100	-19	17	-6	-48	-10	21	2
2000/2001	90	-14	18	-49	-64	-75	-5	21
2001/2002	31	-23	5	142	120	185	167	83
2002/2003	160	-10	59	-4	-42	-9	34	13
2003/2004	-100	-30	18	34	102	50	-19	3
2004/2005	-58	-24	-75	89	21	-21	-71	-101
2005/2006	-31	79	19	49	245	32	-62	-3
2006/2007	-8	-10	19	7	135	54	-14	12
2007/2008	-15	-15	-85	79	107	104	-16	-31
2008/2009	-36	-43	-74	-73	-58	-74	-89	-90
2009/2010	-87	-98	-87	-66	-40	-86	-89	-83

Source: Magu Weather Station, (2012)

Anomalies of monthly rainfall totals show how the monthly total rainfall departed from the long- term mean monthly rainfall over the last 21 seasons from 1989/1990 to 2009/2010. Table 4 shows the monthly rainfall anomalies from October to May months.

These months have been considered because growing seasons in Kahangara Division are within the months of October and May.

October

In 1989/1990, 1991/1992, 1992/1993, 1998/1999, 2000/2001, 2001/2002 and 2002/2003 seasons, the monthly rainfall for October were above the long term mean. Wetter seasons were 1990/1991, 1991/1992 and 2002/2003. The 1993/1994, 1994/1995, 1995/1996, 1996/1997, 1997/1998, 1999/2000, 2003/2004, 2004/2005, 2005/2006, 2006/2007, 2007/2008, 2008/2009 and 2009/2010 seasons had below the long term mean rainfall amounts. The driest period were 1994/1995, 1999/2000 and 2003/2004. The results of analysis (Table 4) depict that in 8 out of 21 seasons the rainfall was above the long term mean. And in 13 out of 21 seasons, the rainfall was below the long term mean. The amount received from this month varies greatly from season to season. The highest departure from the long term mean ranged from the highest value of 169% (1990/1991) to the lowest departure value of -8% (2006/2007) seasons. In addition, the month of October, has the VC value of 0.8 which it is highly variable (Table 3). The results from the analysis imply that there is high variability in rainfall amount in October over 21 seasons. As this is the planting/sowing month, it means that there was also a variable performance by the crop during the early establishment and growth. The study by Zinyowera and Unganai (1993) reported that SADC countries experienced the worst drought of the century. There was seasonal rainfall deficit of as much as 80% of normal rainfall from 1980 to 1992. Their study showed the general decline in seasonal rainfall while the monthly rainfall was not critically analyzed, which this study focused on. The analysis of monthly rainfall is very important because it give the reflection of rainfall distribution on the area which may enable farmers to plan better their agricultural activities.

November

The results of analysis of monthly rainfall in November (Table 4) shows the highest anomalies value was recorded in 2005/2006 (79 %) which was the wetter season and in 2009/2010 dry (-90%) which was a driest season. While the lowest departure was recorded in 2002/2003 (-10%) with the rainfall below the long term mean. In 6 out 21 seasons (1990/1991, 1991/1992, 1993/1994, 1994/1995 and 2005/2006) experienced rainfall above the long term mean, while 12 out 21 seasons (1989/1990, 1995/1996, 1996/1997, 1999/2000, 2000/2001, 2001/2002, 2002/2003, 2004/2005, 2006/2007, 2007/2008, 2008/2009/and 2009/2010) experienced the rainfall below long term mean. Three had the rainfall near or the same as the long term mean (1997/1998, 2002/2003, and 2003/2004). The wettest seasons were 2005/2006, and the driest 2009/2010. In addition, the month of November, has the VC value of 0.4 which is relatively high (Table 3). Similar results were observed by Nicholson (2000) who assessed the annual rainfall in Eastern Africa between 1950s and 1980s. The results of the abnormalities showed a less frequent occurrence of above average annual rainfall through the continent with much of this variability (50%) was attributed to the conditions in October and November months which had rainfall below the long term mean over the seasons, as it has also been observed in this study. Thus, the results imply that in month of November most of the seasons received unreliable rainfall which was below the long term mean this, can also affects plant development.

December

The rainfall anomalies for December (Table 4) indicate the largest departures were in 2007/2008 (-80%) and in 2009/2010 (-87%) which were the driest December months of the 21 seasons. The wetter seasons were in 2002/2003, and the dry season were in 2004/2005 (-75%), 2007/2008 (-85%), 2008/2009 (-74%) and 2009/2010 (-87%). The result of analysis also shows that in 14 out of 21 December month had the rainfall above the long term mean. While in 7 out of 21seasons had the rainfall below the long term mean. In 1989/1990, 1991/1992, 1992/1993, 1994/1995, 1997/1998, 1999/2000, 2000/2001, 2001/2002 and 2002/2003, 2003/2004, 2005/2006 and 2006/2007 total monthly rainfall were above the long term mean, except in 1995/1996, 1996/1997, 1998/1999, 2004/2005, 2007/2008, 2008/2009 and 2009/2010 seasons had below the long term mean. Similar, results had been observed by Yue and Hashino (2003) who analyzed the long term trends in annual and monthly rainfall for Japan. They observed that there was high rainfall variability in monthly and annual total rainfall. Morever, Masvaya *et. al.* (2009) studied the impacts of rainfall variability on farmers' crop management strategies in Insiza District in Zimbabwe between 2007 and 2008. The study found that rainfall was generally highest in the month of December than in any of the other months (October, November, January, February and March). The coefficient of variability of rainfall amounts in the month December was 0.4 in Kahangara Division over 21 seasons (Table 3) which was relative high compared to other months (Table 4). Therefore, the result from Kahangara Division implies that in month of December most of the seasons received reliable rainfall.

January

The monthly rainfall in amounts in January (Table 4) were consecutively below the long term average in 1989/1990 - 1994/1995, 1996/1997, 1997/1998, 1998/1999, 1999/2000, 2000/2001, 2002/2003, 2008/2009 and 2009/2010. However, in 2000/2002, 2003/2004, 2004/2005, 2005/2006, 2006/2007 and 2007/2008 were above the long term mean. In 12 out of 21 seasons the January rainfall fell below the long term mean, while in 8 out of 21 seasons the rainfall was above the long term mean. In 1995/1996 season had the rainfall around the long term mean. The highest departures were recorded in 2001/2002 (142%) as the wettest January during the 21 seasons, while the driest January was in 2008/2009 with the value of -73%. The distribution of rainfall within the month is varied (CV =0.5), with the tendency of rainfall been below the long term mean. The results of the analysis of annual rainfall time series by Tanzania Meteorological Agency (2007) indicated a decrease of rainfall trend for most of the stations in Tanzania, such result may explain the decline of rainfall which also revealed in the analyses of rainfall in the month of January, which showed rainfalls most of the seasons fell below the long term mean. Hulme *et al.* (2001) observed that parts of East Africa will likely experience 5-20% increase in rainfall from December to February by 2050. The results of this study is contrary with this study, since, the East Africa rainfall patterns are not similar all over the area, due to physical characteristics and rainfall patterns in these areas, so the result was more generalized. The occurrence of rainfall depends on geographic location, sea and land surface temperatures, proximity to water bodies, topography, winds, vegetation cover, and others (Meher-Homji, 1991).

February

The rainfall anomalies for February (Table 4) indicates that 15 out of 21 seasons had below them long term mean, while 6 out of 21 seasons had rainfall amounts above the long term mean. The seasons, 1989/1990 to 2000/2001, 2002/2003, 2008/2009 and 2009/ 2010 had rainfall amounts below the long term mean, except for 2001/2002, 2003/2004 -

2007 seasons which had above the long term mean. The largest departures was in 2005/2006 (245%) which was a wet season and the lowest departure was recorded in 19997/1998 (-16%). Similar results by Mongi, *et al.* (2010) analyzed the monthly rainfall in Tabora region over the last 35, the study found that inter-seasonal dry spells between January and February appeared to increase both in duration and frequency as it was observed in this study. In addition, Yusri, *et al.* (2012) in their analysis of monthly rainfall variation in Malaysia over the last 50 years (1942-2002) observed that the monthly rainfall was more variable than that of annual rainfall. The coefficient of variation for, monthly rainfall lies between 0.3 and 0.4, except for January and February where range was 0.4- 0.7. The coefficient of variation was higher in as functions of low rainfall in Malaysia. The month of January and February seem to have high variability in rainfall in Malaysia as it has observed in this study. Generally, the result from this study implies that, the frequency of dry spells tends to increase in February, since, most of the seasons had unreliable rainfall and in fact, it shows a depression between the two seasonal peaks. Moreover, the distribution of rainfall within the month of February is highly variable and very unreliable with the CV value is 0.9 (Table 3). Therefore, the variations in rainfall within the month indicate the existence of high variability in rainfall within the months in Kahangara Division

March

The results of the analysis of monthly rainfall total in March (Table 4) show that the 2001/2002 (185%) season recorded the highest departure above the long term mean rainfall and was the wettest March of the 21 seasons. The March had the lowest monthly total rainfall of the 21 seasons was recorded in 2009/2010 with the value of -86% rainfall from the long term mean. The seasons 1989/1990, 1990/1991, 1992/1993-1995/1996, 1999/2000, 2000/2001, 2002/2003, 2004/2005, 2008/2009 and 2009/2010 had the rainfall below the long term mean. The seasons 1996/1997 – 1998/1999, 2001/2002, 2002/2003, 2003/2004, 2005/2006 - 2007/2008 had rainfall above the long term mean. In 12 out of 21 seasons had above the long term mean while 8 out of 21seasons had rainfall below the long term mean. And one season (1991/1992) had average rainfall. From the results the distribution of rainfall is variable within the month of March and less tendencies of rainfall was below the long term mean. Similar results by Meertens *et. al.* (1995 and 1999) noted that distribution of rainfall in semi-arid areas of Northwest Tanzania during the rainy season was highly variable. The distribution and length of the period of rain during the growing season and the effectiveness of the rains in each rainfall event is the real factor that affects the effectiveness and success of crop farming (Mortimore and Adams, 2001; and Usman and Reason, 2004).

April

From 1990/1991 to1994/1995, 1997/1998, 1999/2000, 2001/2002 and 2002/2003 seasons the April rainfall totals were above the long term mean (Table 4). The wettest April month was in the season 2001/2002. The 1989/1990, 1995/1996, 1996/1997, 1998/1999, 2000/2001, 2003/2004, 2004/2005 - 2009/2010 seasons had below the long term mean rainfall totals. The driest April of the 21 seasons occurred during 2008/2009 and 2009/2010. The results also show that in 9 out of 21 seasons had above the long term mean rainfall, while in 10 out of 21 seasons had below the long term monthly rainfall totals. The variability ranging from the highest anomalies value of 167% (2001/2002) to the lowest value of -5% (1998/1999) and -5% (2000/2001) seasons from the long term mean. The distribution of rainfall within the month is highly varied with the tendency of rainfall been below the long term mean. Significant number of researches reported a statistical evidence of changing of rainfall for example, Goswami *et al* (2006) in their study observed the decreasing trend and increasing variability of rainfall in Central India. Sen Roy and Balling (2004) found high variability in monthly rainfall in the north-eastern states in Uttaranchal.

May

The results of analysis of monthly rainfall totals in May (Table 4) show the highest anomalies value was recorded in 1997/1998 (115%) which was the wetter season. While the lowest departure from the long term mean was recorded in 1999/20000 with the percent value of 2. And the four seasons (1999/2000 (2%), 2004/2005 (-1%), 2003/2004 (3%) and 2005/2006 (-3%) had near or the same as the long term mean rainfall. The 1989/1990, 1990/1991, 1992/1993, 2000/2001, 2007/2008 – 2009/2010 seasons had below the long term mean rainfall. While 1991/1992, 1993/1994 – 1999/2000, 2001//2002 - 2003/2004, and 2006/2007 seasons had above the long term mean rainfall. In 12 out of 21 seasons, May month had above the long term mean rainfall. While in 9 out of 21seasons had below the long term mean rainfall. Similar results were observed by Mongi, *et al.* (2010) who noted the frequency increase of rainfall above the long term mean in May by a rate that was highly significant in Tabora region over the last 35 seasons. Therefore, there was high variability in rainfall within the month of May in the Division over the last 21seasons.

From the results of the analysis of monthly rainfall distribution over the last 21 seasons, it is revealed that the monthly total rainfall spread around the long term mean of 21 seasons was highly variable. Unexpectedly, a few onsets occurred during the months of August and September. And sometimes rainfall was missing during the expected onset months of October making crop establishment rather uncertain. In 1994/1995, 1999/2000 and 2003/2004, rainfall started in November, which traditionally is not the onset month. The discussion above presents the monthly total variability in terms of total monthly amounts, onsets and cessations. The monthly information provides an idea about the monthly variability; however for crop production daily variability occurring within the season is more important than just consideration of the monthly variability. In any case, monthly variability considers total rainfall values which may be interspersed with long dry spells. This, therefore, calls for consideration of daily seasonal variability including onset dates, water balances, and cessation in terms of dates.

4.2.4 Analysis of daily rainfall distribution (Onset, cessation and water balance) in Kahangara distribution within the rainy season over the last 9 seasons (2001/2002 to 2009/2010)

Water content in the soil decreases by evapo-transpiration and in the absence of water supply in the soil plants growth will be affected. The soil type for Kahangara Division can contains up to 80 mm/0.8 m of water soil depth for full profile (MDDP, 2011). This then depleted by the growing crop and by evapo-transpiration which an average is 4mm/day. Days with profiles of water that is greater than 80 mm (++) will experience runoff. Profile that is completely depleted will not support crop growth. The water balance therefore, defines the optimal crop growth periods and the dry spells. Table 5 and figure 5 show the variability of the onset dates of rainfall in Kahangara Division over the last 9 seasons.

Table 5: Rainfall onset over the last 10 years

Year	Start 1st Feb	Start 1st Oct
2001	93	302
2002	33	298
2003	67	331
2004	50	334
2005	35	285
2006	32	314
2007	36	320
2008	41	310
2009	0	0
2010	267	296
Mean	**61**	**277**
St dev	**76**	**98**
Min	**0**	**0**
Max	**267**	**334**
CV	**1.235**	**0.355**

Source: Magu Weather Station, (2012)

The results in Table 5 were further presented in Figure 5 to show the variability of the onset dates of rainfall in Kahangara Division over the last 9 seasons.

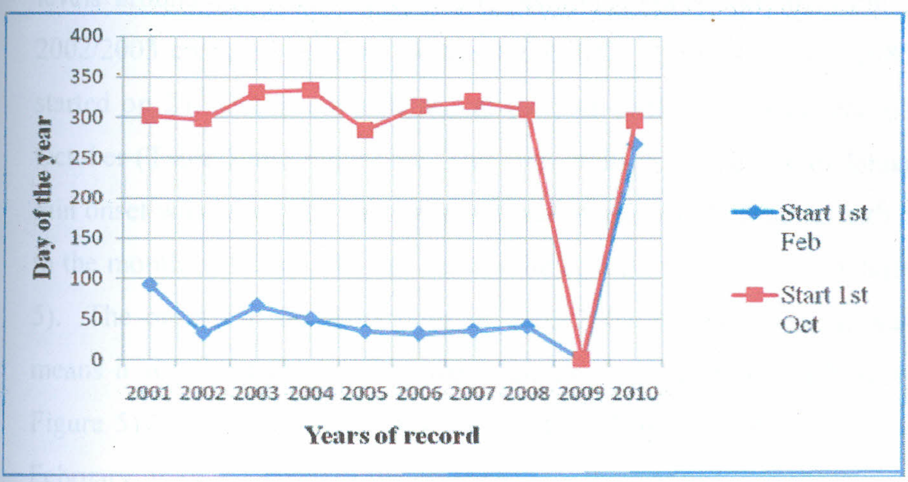

Figure 5: Rainfall Onset over the last 10 years
Source: Magu Weather Station, (2012)

Table 5 and figure 5 depict that in 2000/2001 cropping season, the long rain started on 2nd April instead of in February (Table 5 and Figure 5), and it ended in May (Appendix 3).

The result implies there was late onset of rainfall and it rained only in one month and followed by long dry spells. This was likely to affect sweet potatoes, cassava and sorghum in the division. The onset of rains season is a very important event in the lives of small-scale farmers. This onset marks the beginning of three main activities include planting, weeding and harvesting (Mortimore and Adam, 1999).

In 2001/2002 cropping season, short rain was on day 302 that means it was started on 28th October at the end of the month instead of on the 1st day of October (Table 5 and Figure 5) this wet spells continued up to January. While the long rain was on day 33 that means it was started on 2nd February, while in the months of March, April and May had runoff (++), this is because rainfall was greater than 80mm (++) which is the average capacity that soil can hold water (Appendix 3 and 4). The cessation was on 30th June. The results suggest the experienced runoff was likely to affected sorghum, cassava and sweet potatoes production through root rooting and stunted growth. Kozlowski (1997) excessive moisture in the soil causes oxygen levels in the soil to decrease, impeding proper roots respiration. As a results, carbon dioxide, methane, hydrogen, and nitrogen levels around the roots increase sharply, thus, roots can suffocate and die. While in 2002/2003 cropping season, the onset for short rain was on day 298 that means it was started on 24th October which was at the end of the month instead of on the 1st day of October (Table 5 and Figure 5). This wet spells continued up to January. While the log rain onset was on day 67 that means it was started on 7th March, with some dry spells up to the month of March. In this season the cessation was on 3rd in June (Appendix 4 and 5). The onset for the short rains in 2003/2004 cropping season was on day 331 that means it was started on 26th at the beginning of the month of November (Table 6 and Figure 5). While the long rain onset was on day 50 that means it was started on 19th February, with some dry spells up to the month of March and then wet days continued up to the month of May. The cessation was on 21st in May (Appendix 5 and 6). During these seasons rainfall was well distributed therefore, it could have contributed to high yields of cassava, sorghum and sweet potatoes.

Table 5 and Figure 5 depict the onset of rainfall in 2004/2005 cropping season. The onset for the short rains was on day 334 that means it was started s on 29 th at the end of the month of November, the rain started too late and characterized with dry spells in the months of December and January. While the log rain onset was on day 35 that means it was started on 18th May (Appendix 6 and 7). Generally this season had no good rains to favor subsistence crop production. Semoka (2003) noted that the impact of rainfall on crop production can be related to intra-seasonal rainfall distribution in the area, but more subtle intra-seasonal variability in rainfall distribution during crop growing periods, can also cause substantial reductions in yields. Therefore, late rainfall onset and dry spells during growing periods can affects plant growth, which then, affect yields. However, Table 6 and Figure 5 depict that in 2005/2006 cropping season, the rain onset for short rain was on day 285 that means it was started on 11th October, with some dry spells up to the end of the month. And experienced some run off (++) between the months of November and December. While the log rain onset was on day 32 that means it was started on 1st February, and it was characterized also by some runoff (++) between the month of February and March. While the months of April and June experienced some dry spells. The cessation was on 10th June (Appendix 7and and 8). These runoffs could have affected crop growth through water logging which could also have caused root rotting and stunted crop growth.

The onset of rainfall in 2006/2007 cropping season was on day 314taht means it was started on 9th November (Table 5 and Figure 5), with some dry spells up to the month of January. While the long rain onset was on day 36 that means it was started on 5th February, and it was characterized by high rainfall with runoff (++) in one day in the month of March. The cessation was on 19th June (Appendix 8 and 9). The long dry spells could have affected plant germination between the month of November and January in that it might have affected crop yields. Guhathakurta and Rajeevan, (2008) observed high variability in rainfall in Kerala with extended dry spells for the last 2 decades, which contributing to the decline in agricultural production Kerala. In 2007/2008 cropping season, short rain onset was on day 320 that means it was started on 15th November (Table 5 and Figure 5), with dry spells in December and early January. While the long rain started on day 43 that means it was started on 2th February, and it was prolonged with wet spells from March to early May. Rainfall cessation was on 17th May (Appendix 9and and 10). The results agree with the study by Frich *et al* (2002) who also observed the significant increase of wet spells in the world between 1946 and 1999 seasons. The wet spells may have significant effects on crops production.

In 2008/2009 cropping season, onset for short rain was on day 310 that means it was started on 5th November (Table 5 and Figure 5), with prolonged dry spells between the months of December and May. Rainfall cessation was on 2nd May (Appendix 10 and 11). However, in 2009/2010 cropping season, there was prolonged dry spells between the months of October and May (Table 5 and Figure 5). Generally, during these cropping seasons there was no reliable rainfall to support crop growth (Appendix 11 and 12). The analyses of rainfall onset over the last 9 seasons shows there was variability of onset throughout all 9 seasons. Similar result by Mongi *et al.* (2010) noted increasing duration and frequency in inter-seasonal dry spells between January and February in Tabora region over the last 35 seasons (from 1973/1974 to 2007/2008) which affected maize production. Shorter dry spells lasting from one to two weeks during critical period of growing season can reduce crop yields significantly (Barron, *et al.,* 2003). Moreover, Figure 6 shows the analysis of the number of days with greater than 4mm of rainfall over the last 9 seasons.

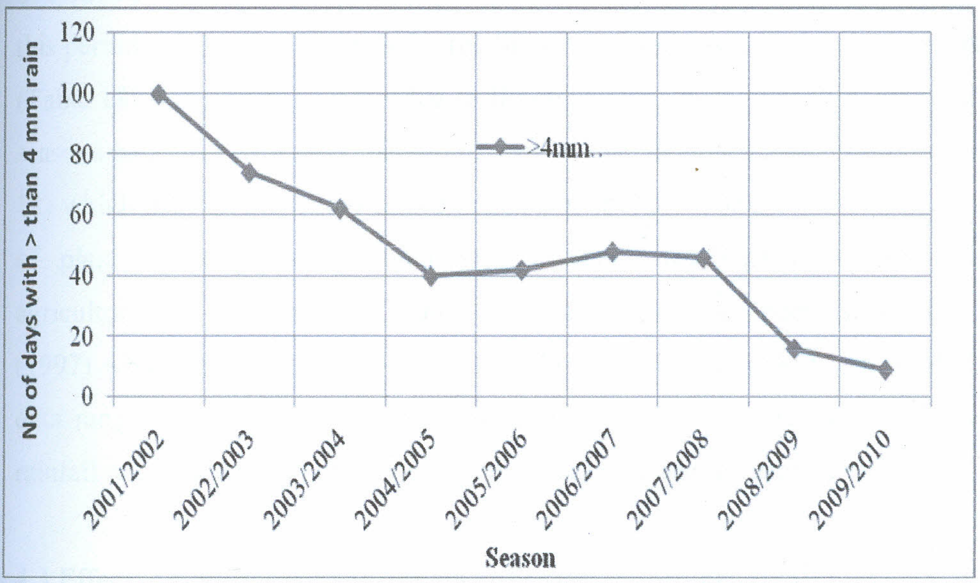

Figure 6: Number of days with greater than 4mm rainfall.
Source: Magu Weather Station, (2012)

The results of the analysis (Figure 6) depict that in 2001/2002 season had many number of days (100) of rainfall greater than 4mm. There was a probability of getting either good rains or excessive rains which could lead flood occurrence in this season. The implication to the farmers is that they had probability of harvesting good yields in the other hand they had also a probability of harvesting less than average due to flooding. While the 2002/2003 season experienced 74 days and 2003/2004 had 62 days with rainfall greater than 4 mm. These seasons had good rains to support plant growth and development. The 2004/2005 seasons had (40 days) and 2005/2006 season had almost similar numbers of days (42 days) of rainfall greater than 4mm. The 2006/2007 seasons had 48 days of rainfall. Whereas, the 2007/2008 season had 46 days of rainfall greater than 4mm. The seasons with the lowest were 2008/2009 with 16 days and 2009/2010 with 9 days of rainfall greater than 4mm. The lowest number of days with greater than 4mm rainfall was recorded in 2009/2010 season and the highest was recorded in 2001/2002. This analysis shows the daily rainfall variation in the division over time and this variability may have affected subsistence crop production in the division. The 2001/2002 season for instance had high number of days with greater than 4mm, during this period also had poor yields for the three crops (cassava, sweet potatoes and sorghum) (Table 18) this may have been due to flooding. However, the 2008/200/ and 2009/2010 seasons had 16 and 9 days of rainfall greater than 4mm and also had poor yields (Table 18) which may be attributed to prolonged dry spells. Long dry spells at sensitive times of plant development (germination, flowering, seeding) could spell disaster for agriculturalists (Barron *et al.*, 2003). The results are consistent with Pant and Kumar (1997) who also noticed similar outcome for the all Indian monsoon rainfall, where the data ranged from 1971 and 1995 observed the increasing high variability of monsoon rainfall with the prolonged dry spells this could affected the crops production.

4.3 Effects of rainfall variability on subsistence crop production and yields.

Secondary data analyzed was also supported by the primary data collected from 355 respondents who were household heads from Kahangara Division. The information collected was on historical rainfall events over the past six seasons (from 2005/2006 and 2009/2010 seasons) and on how rainfall variability affected production of subsistence crops in the Division that they could be remembered.

4.3.1 Socio-economic characteristics of the respondents

The age size, education level, farms sizes, the period respondents lived in the study area, were the data collected to explain the socio-economic characteristics of the respondents.

4.3 .2 Age group of the Respondents.

Breakdown of the respondents by age were as follows; between 20-30 were 14 (3.9%) 31-40 were 117 (33%), 41-50 were 162 (45.6%), 51-60 were 41 (11.6 %), and 61+ were 21 (5.9 %) (Table 6).

Table 6: Age group of Respondents.

Age	Frequency	Percentages (%)
20-30	14	3.9
31-40	117	33
41-50	162	45.6
51-60	41	11.6
61+	21	5.9
Total	**355**	**100**

Source: Field Data, 2012

From the results presented in Table 6; it is evident that most of the respondents' were in age range from 31 to 50. This suggests that most of the respondents were of active ages and were engaged in farming within the 6 seasons for which the rainfall data is available in Kahangara Division.

4.3.3 Education level of the Respondents

Table 7 shows the education level of the respondents..Those with primary level education were 307 (86.5%), secondary Ordinary level were 31 (8.7%), advanced levels were 12 (3.4%) universities were 0 (0%), and those with no education were 5 (1.4 %.)

Table 7: Respondents' level of Education Attainment

Level of education	Frequency	Percentage (%)
Primary	307	86.5
Secondary (Ordinary level)	31	8.7
Secondary (Advanced level)	12	3.4
University	0	0
None	5	1.4
Total	**355**	**100**

Source: Field Data, 2012

Most of the respondents (86.5%) have up to primary level education. This survey indicates that most of the subsistence farmers had at least primary school level education and were able to accurately respond to questions regarding farming in relation to rainfall variability in the Division.

4.3.4 The period respondents lived in the study area

The researcher considered the time the respondents had lived in the study area. Those who had lived in the area less than 5 years were 2 (0.6), 5 to10 years were 5(1.4%) and more than 10 years were 348 (98%) (Table 8)

Table 8: Period Respondents have lived in the Study Area

Period	Frequency	Percentages (%)
Less than 5 years	2	0.6
5 to 10 years	5	1.4
From 10 years and above	348	98
Total	**355**	**100**

Source: Field Data, 2012

The results presented in Table 8 show that most of the respondents (98%) have lived in the study area for more than 10 years, a relatively long period of time. This suggests that most of the respondents had lived in the division for a long period of time. Therefore, they have experience and their recollections about previous rainfall patterns and their effects on crop production over the six seasons (2006 and 2010) were likely to be accurate.

4.3.5 Farms sizes

The respondents were further asked to state whether they own farms and of which sizes. Table 9 shows the percentage of the respondents who own the specified farm sizes.

Table 9: Farm sizes Owned by the Respondents

Respondents	Frequency	Percentages (%)
Own the farm size of 3 to7 acres	312	87.9
Own the farm size of 1to 3 acre	33	9.3
Rent land for farming	10	2.8
Total	**355**	**100**

Source: Field Data, 2012

The findings from Table 9, show that majority of respondents (87.9%) owned farms of average sizes of 3 to7 acres, while 9.3% of the respondents owned farms of average size of 1 to 3 acres and 2.8% of the respondents rented land during growing seasons. These results suggest that most of farmers own more than three acres capable of supporting subsistence agriculture.

4.3.6 Onset of Rain in the Study area

The respondents were further asked about the onset of the rains before or when they start their seasonal farming activities (Table10).

Table 10: Onset of Rain in the Study area

Rain onset time	Frequency	Percentages (%)
August	72	20.2
September	231	65.1
October	33	9.3
Could not recall	19	5.4
Total	**355**	**100**

Source: Field Data, 2012

The results presented in Table 10 shows that majority (65.1%) of respondents perceive that start of the rainfall is in September. While about 20.2% of the respondents perceive that rainfall starts in August. This implies that in some years rainfall starts earlier in August.

This condition can create a lot of problems to the farmers, rain may find they had not prepared their farms and purchased inputs earlier. However, 9.3% of the respondents said rainfall starts in October. This implies that there are also some years during which rainfall started too late, thus affecting planting time. This therefore, confirms that rainfall has been variable in the last six years for which the questionnaire required them to recall.

Magu meteorologist reported that rainfall onset used to be in the beginning of the month of October between 1980's and 1990's, but from 2000's rainfall may start between August/September or late October/November. Farmers explained that during three consecutive seasons (2005/2006, 2006/2007 and 2007/ 2008), rainfall started in the month of August. This was contrary to their expectation of the onset which they knew normally started in September. This indicates a major shift in rainfall patterns. The early onset affected the planting time because it found farmers had not prepared their farms. For two consecutive seasons, 2008/2009 and 2009/2010, rainfall onset also shifted from August to October and November (Agricultural extension officers, personal communication, 13th, Oct, 2012). While, 5.4% of the respondents could not recall the onset of the rains (Table 10)

The empirical facts from the monthly rainfall recorded over 21 years (Table 3) show that, the perceptions by respondents with respect to increasing rainfall variability are closely related. The monthly rainfall data indicated a high variability in monthly rainfall onset. In most cases the rain started in September, except in the season between 1991/1992, 1997/1998, 2004/2005, 2005/2006, 2006/2007 and 2007/2008 when it came earlier than expected. In 1989/1990, 1992/1993, 2000/2001, /2001/2002, and 2009/2010 it came late in October. And in 1994/1995, 1999/2000 and 2003/2004, it came very late in November. The farmers' perception appears to confirm the variability in rainfall onset within Kahangara Division.

Similar results were reported by Hatibu *et al.*, (1995) and Mahoo *et al.*, (1999) who reported that there is a wide variation in the onset of rainfall with the cessation occurring within one month in semi- arid areas of Tanzania and this negatively affect crop productivity. Maddisson (2006) and Majule (2008) observed that subsistence farmers in African countries believed that rainfall had declined and the time of onset had become unpredictable, thus negatively affecting crop production. In Manyoni District in Tanzania, Mary *et al* (2009) indicated a shift in the onset of long rains from October / November to December/January, with shortening of rainfall periods and increased frequency of drought. These findings document the uncertainties concerning rainfall and the risks they pose to subsistence crop production in the Division.

4.3.7 Time for Land Preparation

About 163 (45.9%) of the respondents prepared their lands for planting between August and September, While 101 (28.5%) prepared their lands between September and early October and 91 (25.6%) of the respondents practiced no tillage and planted on unprepared lands (Table 11).

Table 11: Time for Land Preparation

Time for land preparation	Frequency	Percentages (%)
August-September	163	45.9
September- early October	101	28.5
Practice no tillage at land preparation	91	25.6
Total	**355**	**100**

Source: Field Data, 2012

The results in Table 11 show that majority of the respondents (45.9%) prepared their lands between August and September with assumed that the rainfall will be reliable and good for sowing in October. While 28.5% of the respondents prepared their lands between September and early October. Few of the respondents (25.6%) did not prepare their lands; they planted without tilling their lands. After planting they commenced weeding much earlier by third or fourth week after the rainfall onset. No tillage practice and early weeding enabled farmers to get rid of weeds much earlier and reduces the weed burden (Masanja, a farmer, personal communication, 15, Oct, 2012). Land preparation depends on the onset of the rains, but in most cases farmers in Kahangara division start preparing their farms between August and September; this is because they targeted the first rain in October for sowing seeds (Agricultural Extension Officer, Personal Communication, 11th, Oct, 2012). The empirical facts from monthly rainfall (Table 3) indicate that in most cases rainfall started in September except in the season between 1991/1992, 1997/1998, 2004/2005, 2005/2006, 2006/2007 and 2007/2008 when it came in August which was also earlier than expected. Majority of farmers in Kahangara Division prepare their lands between August and September. This coincides with the period of rainfall onset from empirical rainfall data.

4.3.8 Planting time

This study found that 169 (47.6%) of respondents said that they were planting crops in October after tilling their lands. While 121 (34.1%) of the respondents said planting done at the time when rain just starts, and 65 (18.3%) said planting was done in September during land preparation (Table 12)

Table 12: Planting Time

Planting time	Frequency	Percentages (%)
October after tilling their lands	169	47.6
At the time when rain just starts	121	34.1
September during land preparation	65	18.3
Total	**355**	**100**

Source: Field Data, 2012

From the results in Table 12, majority (47.6%) of respondents reported that they were planting crops in October after land preparation, because during this time rainfall was almost starting in the division. While 34.1% of the respondents said planting was done at the time when rains start, this is because rainfall is unpredictable; therefore, they wanted to utilize any rain to maximum. However, 18.1% of the respondents said planting was done in September during land preparation, that is land preparation and planting is done at the same time while intending to utilize the first rains. Variability in rainfall could have affected the seasonal planting dates in the Division. A study by Samoka, (2003) noted the variation in rainfall in Morogoro region, this variation affected farmers planting dates. Most of the farmers planted their maize crops at the beginning of the rain season while few of them planted at the dry period; the variability in plating dates affected maize yields too. Early planting is very important in farming practices since; it minimizes weeds and also allows farmers to utilize the first rains which are very important for plant germination and development (Mary *et al.*, 2009).

The planting depends on the rainfall pattern, generally, over the years planting in Kahangara Division has been done in October especially when the farmers observed that the soil is wet enough to support plant growth (Agricultural Extension Officer, Personal Communication, 11th, Oct, 2012). In 2005/2006, 2006/2007, 2007/2008 farming seasons, cassava, sorghum and sweet potatoes were planted between late September and mid-November because the rainfall started earlier in August. Exceptionally, in 2008/2009 and 2009/2010 seasons rainfall was very low and erratic, the farmers had delayed planting in which planting was between late November and late January (Agricultural Extension Officer, Personal Communication, 11th, Oct, 2012). This implies planting time in Kahangara division is varied depending on the rainfall onset of which some farmers' plant immediately after rains. While others plant after three to four weeks after the onset of rains. Similar results were reported by Mary *et al* (2009) who noted that, most of the farmers in Kamenyanga and Kintinku in Manyoni district (Tanzania) planted before rain onset (dry planting) on uncultivated land while others planted immediately after rains and few of farmers planted a few days after the first rains. As similar pattern was also observed in this study.

The empirical facts from the daily rainfall (Table 5 and Figure 5) recorded over the last 10 years indicate that in 2005/2006 cropping season, the rain fall onset for short rain was on 11th day in the month of October. While long rains onset was on 1st February. Therefore, crops planted in September were likely to experience a dry period with a likely negative effect on crop production. While in 2006/2007 cropping season the rain fall onset for short rain was on 9th in the month of November (Table 5 and Figure 5) and the log rain onset was on 5th February. If the planting, had done been before 9th of November, the plants were likely to be affected by dry conditions. Therefore, for optimum performance, planting of sorghum, cassava and sweet potatoes was supposed to be around 9th of November.

In 2007/2008 cropping season, short rain onset was on 15th November (Table 5 and Figure 5). While the long rain started on 10th February. Therefore, any planting done before mid November was likely to be affected by dry conditions. In 2008/2009 cropping season, onset for short rains was on 5th November (Table 6 and Figure 19) and therefore, the best planting time was around 5th of November. In 2009/2010 cropping season, short rain onset was on 27th October (Table 5 and Figure 5), and farmers planting around this date were timely.

Usually, the planting date for a given area depends on the rainfall pattern in the area and number of days that a given crop variety requires to mature. For example, Ahn, (1993) indicated that sweet potatoes maturity may take four to five months or longer, since is a tuber crop and may stay in the soil for longer period and Cassava maturity takes place between eight to twenty four months (Alves and Setter, 2000). Further, sorghum maturity takes place between 120 to140 days. Therefore, the rainfall pattern in the area and number of days that a given crop variety requires to mature are the determinants of the planting date in a given area.

4.3.9 Growing seasons with excessive rainfall (Above 700mm), normal rainfall (600-700mm) and low rainfall (Below 600) between 2005 and 2010

The results show that 310 (87.3%) said excessive rainfall was in 2005/2006 seasons, 2 (0.6%) of the respondents said the same season had normal rainfall while 43(12.1%) of the respondents said in 2005/2006 it had low rainfall. The 2006/2007 also was mentioned by 294 (82%) to have excessive rainfall. While 3 (0.9%) of the respondents said the same year had normal rainfall and 58 (16.3%) mentioned the 2006/2007 season to have low rainfall. The 2007/2008 season was mentioned by 297 (83.7%) respondents to have normal rainfall, while 42 (11.8%) mentioned same to have low rainfall and 16 (4.5%) respondents mentioned 2007/2008 season that had excessive rainfall. In 2008/2009 and 2009/2010 355 (100) mentioned occurrences of low rainfall during the growing seasons (Table 13)

Table 13: Growing seasons by Amount of Rainfall between 2005 and 2010

Seasons	Responses							
	Excessive rainfall (Above 700mm) (Respondents)		Normal rainfall (Respondents) (600-700mm)		Low rainfall (Respondents) (Below 600mm)		Total respondents	Total %
2005/2006	310	87.3%	2	0.6%	43	12.1%	355	100
2006/2007	294	82.8%	3	0.9%	58	16.3%	355	100
2007/2008	16	4.5%	297	83.7%	42	11.8%	355	100
2008/2009	0	0	0	0	355	100%	355	100
2009/2010	0	0	0	0	355	100%	355	100

Source: Field data, 2012

The results (Table 13) show that 310 (87.3%) of respondents said in 2005/2006 seasons had excessive rainfall, 2 (0.6%) of the respondents said the same season had normal rainfall while 43(12.1%) of the respondents said in 2005/2006 it had rainfall low rainfall. The 2006/2007 also was mentioned by respondents 294 (82%) to have excessive rainfall. While 3 (0.9%) of the respondents said the same year had normal rainfall and 58 (16.3%) mentioned the 2006/2007 season had rainfall low rainfall. While The 2007/2008 season respondents 297 (83.7%) said it had normal rainfall, while 42 (11.8%) respondents mentioned the same season had low and 16 (4.5%) respondents mentioned 2007/2008 season that had excessive rainfall. In 2008/2009 and 2009/2010 respondents 355 (100) said that both seasons had rainfall low rainfall during the growing seasons.

The results from Table 13 shows that most of the respondents (85.5%) had mentioned the two seasons 2005/2006, and 2006/2007 had rainfall excessive rainfall. While 2008/2009 and 2009/2010 were reported by most of the majority (82.8%) to have low rainfall. However, the 2007/2008 season was mentioned by 83.7% of respondents to have normal rainfall. These respondents reported variation in rainfall amounts from seasons to season. The information obtained from the Agricultural Extensional Officers appears to corroborate this observation. They said rainfall amounts varied from season to season sometimes is excessive, normal or lower than the average during the growing seasons. They also specifically mentioned the 2008/2009 and 2009/2010 seasons that were the worst of all the 21 growing seasons. The empirical seasonal rainfall data collected from Magu Weather Station recorded over the last 21 seasons (Table 2) corroborate the results from respondents and agricultural officers. The collected rainfall data show that in 2005/2006 and 2006/2007 the rainfall were above the long term mean, while the 2007/2008 season had average rainfall. Whereas, 2008/2009 and 2009/2010 had below the long-term mean rainfall and were driest seasons over the 21 years. Similar results were reported by Zinyowera and Unganai (1993) who reported that SADC countries had experienced the worst drought of the century. There was seasonal deficit of as much as 80% of normal rainfall from 1980 to 1992. Ng'ang'a, (2006) also observed the severe dry period in Kenya between 2008 and 2009 which has also observed in this study.

4.3.10 Rainfall cessation

The respondents were further asked to state the time for rainfall cessation over the last 6 seasons. The 343 (96.6%) of the respondents said in 2005/2006 rainfall ended late in June whereas 12 (3.4%) were not aware. In season 2006/2007 season, 346 (97.5 %) reported that rainfall ended late in June, while 9 (2.55) of the respondents could not remember. In 2007/2008, 352 (99.2%) reported that rainfall ended late in June, while 2 (0.8%) did not remember. In 2008/2009 season 354 (99.7%) reported that rainfall ended on time in May, while 1 (0.3%) of the respondent did not remember when it had ended. In 2009/2010 season was mentioned by 214 (60.3%) that rainfall ended on time in May, while 141 (39.7%) of the respondents reported that it ended in June (Table 14).

Table 14: Rainfall cessation between 2005 and 2010

Seasons	Responses						
	Ended late in June Respondents)		Ended on time May (Respondents)		Not aware (Respondents)		Total respondents
2005/2006	343	96.6%	0	0%	12	3.4%	355
2006/2007	346	97.5%	0	0%	9	2.5%	355
2007/2008	352	99.2%	0	0%	2	0.8%	355
2008/2009	0	0%	354	99.7%	1	0.3%	355
2009/2010	141	39.7%	214	60.3%	0	0%	355

Source: Field Data, 2012

The findings in Table 14 reveal that in the seasons 2005/2006, 2006/2007, 2007/2008/ 2008/2009 rainfall ended late in June. Except in 2009/2010 where majority of the respondents (60.3%) it ended on time that is in May. The results from the monthly rainfall data collected from Magu Weather Station recorded over the last 21 seasons (Table 3) show that in 2008/2009 and 2009/2010 rainfall ended within the month of May but in 2005/2006, 2006/2007, 2007/2008 seasons rainfall ended in June.

Moreover, the results from the analysis of daily rainfall (Appendix 8) depict that in 2005/2006 cropping season, rain cessation was on 10th June. While in 2006/2007 cropping season rainfall cessation was on 19th June (Appendix 9). In 2007/2008 cropping season rainfall cessation was on 17th May (Appendix 10). In the 2008/2009 cropping season, rainfall cessation was on 2nd May (Appendix 11). However, in 2009/2010 cropping season, there was prolonged dry spells between the months of October and May and inadequate rainfall to support crop growth (Appendices 11 and 12). This analysis clearly shows there was variability of rainfall cessation throughout the 9 seasons, sometimes rainfall ending on time (in May) and other times ending late (in June). Hatibu *et al.* (1995) and Mahoo *et al.* (1999) reported that there is a wide variability on the onset of rainfall date while the cessation occurs within the same month in semi- arid areas of Tanzania.

4.3.11 Irrigation programme in the Division

The survey revealed that 100% of subsistence farmers do not irrigate their farms during the dry periods. This is due to lack of irrigation facilities and related programme in the

Division. Incidentally, the area borders Lake Victoria and has rivers Nyangoma and Kisumuye that could be potential sources of irrigation water. Alves and Setter (2000) crops require soils with moderate moisture for vegetative growth, and during the first month of growth when the tubers are developing the, moisture requirements increases. During the final days of the cycle the moisture equipments reduces. So it is important for subsistence farmers to protect their crops through utilizing the available water sources in the Division.

4.3.12 Various crop types grown between 2005/2010

Respondents were asked to state various types of crops grown between 2005/2010. This study found that between 2005/2010, majority of the respondents 241 (67.9%) cited sweet potatoes, sorghum, cassava and beans as the most important crops grown. While 99 (27.9%) of the respondents cited sweet potatoes, sorghum and cassava as the major crops and rice and beans as minor crops, and 15(4.2%) of the respondents cited maize, sorghum and sweet potatoes as the main crops grown (Table 15).

Table15: Crops Grown by Subsistence Farmers between 2005 and 2010

Crop grown	Respondents' frequency	Percentages (%)
Sweet potatoes, sorghum cassava and beans.	241	67.9
Sweet potatoes, Cassava and sorghum as major crops. Rice, and beans as minor crops	99	27.9
Maize, sorghum and cassava	15	4.2
Total	**355**	**100**

Source: Field Data, 2012

The results presented in Table 15 suggest that 67.9% of the respondents grew sorghum, sweet potatoes, cassava and beans in the division between 2005 and 2010. While about 28% grew sorghum, sweet potatoes cassava as a major crops and also grew rice and beans as minor crops. Only about 4% of the farmers grew maize, sorghum and sweet potatoes. Majority of the farmers planted sorghum, sweet potatoes, cassava and beans as either intercrops or in relay cropping. This is a coping strategy to unpredictable of rainfall, when some crops fail other may do well. (Personal Communication, Masanja, 15th, Oct, 2012).

4.3.13 Crop types changes

The respondents were also asked to state whether they had changed their crop types over the last 6 years and for which crop types. This study found that 341(96.1%) had not changed the crop types over the last 6; they continued growing sweet potatoes, cassava and sorghum as their major crops. While 14 (3.9%) respondents stopped growing maize from their major subsistence crops had been grown before. They were just growing cassava and sorghum due to consecutive dry conditions in two seasons (2008/2009 and 2009/2010).

Secondary data collected from the Divisional Agricultural Office indicated various crop types grown by the subsistence farmers over the long period of time (from 1980 and 2010). It shows that in 1980's the mostly crops grown were rice, maize, beans and sweet potatoes while cassava, sorghum grown as minor crops. In 1990's mostly grown were maize, beans, sorghum, cassava and sweet potatoes while rice was grown as minor crops. In the 2000's majority of the respondents were mostly growing sorghum, cassava and sweet potatoes. This study argues that rainfall variability may have forced farmers to change crop types over time. Farmers may have opted to change crops as a copping strategy to low and unreliable rainfall (Agricultural Extension Officer, Personal communication, 13th, Nov, 2012). The seasonal rainfall analysis in Figure 3 show variability in rainfall totals over the 21 seasons that could explain the reasons for change of crop types in Kahangara Division.

These findings support an earlier assertion by Thornton *et al.* (2007) who noted that most parts of East Africa are likely to experience extreme rainfall variability, and that maize may be substituted by sorghum and millets. Sorghum and millets are better suited in drier environments. Burke and Lobbell (2010) reported that farmers' choices about what crops to grow depended largely on rainfall distribution and amounts. They further added that the highly variable rainfall in most parts of Africa force farmers to grow lower-value but drought – tolerant crops such as cassava. African farmers experientially usually change the crop types if new climatic conditions favor a different crop over the ones currently grown.

4.3.14 Problems affecting subsistence crop production in Kahangara

The multiple response questions were asked to the respondents on the problems affecting crop production in general. About 41.7 percent of the respondents reported unpredictable rainfall with early or late rainfall onset. While 39.2% reported experiencing long dry spells and drought, 12.9 % declining of soil fertility, 6.5% pests and diseases and 5.4% limited access to new technologies (Table 16).

Table 16: Problems affecting subsistence crop production in Kahangara Division

Problems	Frequency	Percentages (%)
Unpredictable rainfall with late and early onset	148	41.7
Experiencing long dry spells and drought	139	39.2
Declining of soil fertility	46	12.9
Pests and diseases	23	6.5
Limited access to new technologies.	19	5.4

Source: Field Data, 2012

Based on the information collected from key informants and the household surveys in Kahangara Division most farmers reported the rainfall variability related problems. These problems are ranked in the order of their importance (Table 16). The respondents particularly reported experiencing delays in rainfall onset and sometimes receiving rainfall earlier than expected. This affected their planting time and also led to poor germination, and sometimes they undertook multiple sowing which is expensive (Agricultural Extension Officers, 13th, Nov, 2012). Similar observations were made by Maddisson (2006) and Majule *et al* (2008) reported that subsistence farmers in African countries believed that rainfall had declined and the time of onset has become unpredictable, thus, negatively affecting crop production. Mary *et al* (2009) indicated the shift in the long rains onset from October/November to December/January with shortening of rainfall periods and increased frequency of drought in Manyoni District, Tanzania. Aondover and Ming-Ko (1998) reported that most of the rainfall variations exhibit such characteristics as false onset of the rains, late onset of the rains, pronounced breaks during the rainy season and early cessation of the rain leading to drastic alterations in the optimum yields in Semi arid areas Tanzania. Declined yields caused food shortages and malnutrition (Mortimore and Adams, 2001). .The results from the analysis of the monthly rainfall (Table 3) and daily rainfall (Table 5) obtained from Magu Weather Station is closely related with the respondents' perceptions. There was increasing rainfall variability in respect to unpredictable rainfall with late and early onset over the rainy seasons. This implies delayed propagation, for cassava, sorghum and sweet potatoes, consequently declining yields.

Reduction in rainfall, long and frequent dry spells can have significant effects on the growth and yields of crops which may lead to a fall in agricultural income and access to food for many farmers (Barron *et al*, 2003). However, (39.2 %) respondents reported experiencing long dry spells and drought. Prolonged dry spells can affects soil; leading to lose of more moisture content during dry periods due to high evapo-transpiration. Coors *et al* (1997) observed that yields are reduced when evapo-transpiration demand exceeds water supply from the soil at any time during the plant life cycle. In addition, dry spells during flowering and pollination periods reduce plant and leaf size, which affects also photosynthetic processes. And extended dry spells that results in leaf burning and loss will have greatest the impact on decline of yields, stunting growth or completely crop failure.

Connor and Palta, (2001) noted that water deficit during at least two months or in the early period can reduce root crop yields, (cassava and sweet potatoes) by 32% to 60%, respectively. Dry spells and also false onset of the rainfall create a lot of uncertainty to crops like drying of plants and delay in planting can also affect crop yields. Likewise, early onset in rainfall than expected can find farmers unprepared and without the required farm inputs. Sometimes farmers are forced to plant at the onset of the rainfall which may break at the early stages of plant germination, thus lead to crop failure. Occasionally farmers may be forced to undertook multiple sowings which is costly (Matias, a farmer 12th Oct, 2012). A similar study by Lema and Majule (2009) noted that frequent dry spells and shortening in rainy seasons have reduced crop yields in Tanzania. Mdulu (1996) revealed that the climatic conditions of most of Tanzania are characterized by short and unreliable rains that restrict the suitability of the land for crop production.

The farmers' perceptions are closely related with the results from the analysis of seasonal, monthly and daily rainfall data (Table, 2, 3, 4, and 5) collected from Magu Weather Station. In addition, 12.9 % of respondents mentioned declining of soil fertility as another problem that affects subsistence crop production in the Division. Linked to rainfall variability, soil loses more fertile due to prolonged dry spells and drought, since it affects chemical decomposition in the soil. However, excessive rainfall and flooding affects soil nutrients through leaching process, thus, affect the crop yields. Farmers sometimes practice fallow farming to allow replenishment of soil fertility in the Division. The fallow period generally last from one to two years (Teleza, a farmer, Personal Communication, 17, October, 2012)

However, (6.5%) of respondents reported insects and diseases as a problem to farming activities. Stalk borers are major pest of sorghum in the division; however, cassava crop is particularly heavily affected by Cassava Mosaic Disease (CMD) '*Batobato*'(Samwel, a farmer, Personal Communication, 17, October, 2012). Msabaha (1990) noted that plant pest population density is highest during driest periods. Hence, prolonged dry spells and drought could have attributed to increase of pests and diseases in the Division. Since majority of farmers cannot afford insecticides, they manage the disease by burning plant residues after harvest, and practice fallow farming so as to reduce pests and diseases. This finding is in line with study by Shao (1999) who noted that pests and diseases are among the critical factors contributing to unsustainable agricultural in most semi arid areas. Further, increased incidence of pests and diseases may arise from changes in rainfall patterns and farming systems.

The information collected from 5.4% respondents showed that the subsistence crop production is also affected by limited access to new technologies. Nearly all farmers lack access to irrigation facilities and most depend on rain fed agriculture which is in adequate and unreliable. Subsistence crop production could also be affected by other non climatic related factor such as declining of soil fertility, pest, and diseases which was not the focus of this study. From the findings most problems reported by the respondents were related to rainfall variability which was the focus of this study. Further, the rainfall and the estimated seasonal yields for cassava, sweet potatoes and sorghum were analyzed to examine the extent that the rainfall variability had affected the (Table 17).

Table 17: Estimated seasonal yields for selected subsistence crops (in kgs/acre) in relation to seasonal rainfall amounts between 1989 and 2010 seasons

Season	Cassava Kgs/acre	Sweet potatoes Kgs/acre	Sorghum Kgs/acre	Rainfall (mm)
1989/1990	498	413	387	394.5
1990/1991	1211	1020	1011	751.4
1991/1992	967	1389	712	810.4
1992/1993	1117	1311	1013	630.3
1993/1994	1401	1322	1121	732.2
1994/1995	1217	1107	1271	675.4
1995/1996	682	701	668	529
1996/1997	917	811	1072	604.1
1997/1998	702	1115	623	934.2
1998/1999	1231	1213	1311	605.9
1999/2000	1223	901	1127	606.4
2000/2001	657	721	699	536
2001/2002	357	612	371	1212.9
2002/2003	785	1127	705	790
2003/2004	1132	1300	1025	714
2004/2005	517	579	511	455.5
2005/2006	845	1291	791	811.1
2006/2007	712	1103	605	753.8
2007/2008	1213	1171	1271	666.2
2008/2009	152	201	189	187.7
2009/2010	112	131	171	104.7
Mean	**840**	**930**	**793**	**643.1**

Source: Kahangara Division Agricultural office, 2012

Table 17 shows the estimated seasonal crop yields from 1989/1990 to 2009/2010 seasons. For all the three crops, the lowest yields were recorded in 2009/2010 and 2008/2009 seasons. These were years characterized by drought and in these seasons, only about 105mm and 188 mm of rain was received, respectively, which were very far from the long term mean (643.1mm). The sorghum mean yields were 189 kgs/acre and 171 kgs/acre against an average of 793 kgs/acre. Cassava mean yields were 152 kgs/acre kgs/acre and 112 kgs/acre against the average yields of 840 kgs/acre. Sweet potatoes yields were 201 and 131 kgs/acre against an average yield of 930 kgs/acre. The observed poor yields could be attributed to low amounts of rainfall with prolonged dry spells during this season. Usually, very little rainfall during sowing period may affect plant germination and development. Plate 1 shows some stunted sorghum crop in a field in Kahangara Division taken during 2009/2010 season.

Plate 1: Stunted sorghum crops due to drought taken from Teleza's field in Mwamanga ward (Kahangara Division) in 2009/2010 season.

Source: Kahangara Division Agricultural office (2012).

For sorghum, the best yields were recorded in 1993/1994 season and appreciable good yields were also noticed in 1998/1999 and 1999/2000 seasons. For sweet potatoes, the seasons with relatively good yields were 1991/1992, 1992/1993 and 1993/1994. The good yields could be due to reliable and adequate rainfall which was above and around the long time mean. The highest amount of rainfall was received in 2001/2002 season. Incidentally, the yields of all the three crops in the same season were below the long term mean. For cassava the yield was 721 kg/acre, sweet potatoes, 669 kg/ha and sorghum, 536 kg/acre, the poor yield could be attributed to flooding in this season. Plants such as cassava and sweet potatoes demand adequate water during the stages of root initiation and tuberization (first eight weeks after planting). Connor and Palta, (2001) noted that water deficit during at least two months or in the early period can reduce root crop yields, (cassava and sweet potatoes) by 32% to 60%, respectively. Dry spells and also false onset of the rainfall create a lot of uncertainty to crops. False onset of rains frequently lead to serious seed loses due to poor and uneven germination which in turn affect yields (Agricultural Extension Officer, Personal communication, 13th , Oct, 2012).

Basak, (2009), low rainfall events may lead to drought events which lead to either yield decline or crop failure. El-Sharkawy, (2007) reported that late rainfall onset and inadequate rainfall may cause late planting and in particular leads to low crop yields. Bowman and Paul,(1990) suggested that drought conditions can affect plant water and nutrients absorption, seed germination, opening and closing stomata, photosynthetic activity, transpiration, and several other metabolic and physiological processes, however, the more obvious general effects with respect to water deficient is the reduction of plant size and mass, leaf and seed yields.

Similar results were observed by Mdulu, (1996) who noted that the climatic conditions of most of Tanzania are characterized by short and unreliable rains that affect crop production. Funk *et. al.,* (2005) reported that from 1996 to 2003, there was a decline in rainfall from 50mm to 15mm per season that corresponded to decline of maize crop yields across most of East Africa countries. Alert, (2010) observed that between 2006 to 2009 seasons farmers from Monduli District in Tanzania had no good rain for the last four consecutive farming seasons, they had no crop to harvest, everything failed and they were surviving on emergency food handouts brought by the government. Earlier reports of Majira, (1997); Ngana, (1993) and Kassase, (1992) reported the declining of food crop yields and food shortage due to frequent rainfall variability and drought in some parts of Tanzania. In particular, the rainfall patterns in Shinyanga, Mwanza and Dodoma have been unpredictable and thus negatively affect crop production (Paavola, 2003). Analysis by Hatibu *et al,* (2002), revealed that more than 33 percent of disasters in Tanzania over the last 100 years were related to drought that impacted negatively the agriculture in the semi arid regions.

Moreover, yields for cassava and sorghum were poor in 1997/1998, 2002/2003 and 2006/2007 and in 2001/2002 the yields for all the crops were poor also. These could be due to excessive rainfall which may have been resulted to flooding or water logging. Water logging causes rotting of root crops as most of Kahangara soil is clay loam with high water retention capacity (MDDP, 2011). Floods may affect crops through increased weed infestations that compete with crops for nutrients and hence reduced crop yields. Ahn, (1993) noted that sweet potatoes require annual rainfall of between 750mm to 1000mm which is ideal with a minimum of 500mm, but well distributed during the growing season. Sorghum requires annual average rainfall between 450 mm and 650 mm which is well distributed (Alves and Setter, 2000). With extremely rainfall, the plants' growth and development can be affected negatively

Similar results by FAO (1995) reported the excessive rains of 1995 in Meher in Ethiopia which resulted in water logging, causing delay in land cultivation and planting. It also caused retarded growth of the crops, and serious weed infestations on maize and sorghum crops, which also affected yields. UNEP (2000) reported floods occurrences have continued to be frequent phenomena in Kenya and this threatens 75% of subsistence farmers who depend on rain fed agriculture. Chiroma *et al.* (2006) noted that biotic stress such as drought or excessive rainfall reduced sorghum yields in Pakistan between 1975 and 2006 growing seasons. These findings reveal that crop yield varies in relation to variability of rainfall totals and distribution. Moreover, percent of crop variations from long - term mean over 21 seasons (1989/1990 -2009/2010) was analyzed further (Table, 18). The analysis shows how the yields of each season deviated from the long term mean.

Table 18: Percent of crop yields (Cassava, sweet potatoes and sorghum) variations from the long-term mean over the last 21 seasons.

Season	Cassava Kgs/acre	Anomalies (%)	Sweet potatoes Kgs/acre	Anoma-lies (%)	Sorghum Kgs/acre	Anoma-lies (%)
1989/1990	498	-40	413	-60	387	-50
1990/1991	1211	40	1020	10	1011	30
1991/1992	967	20	1389	50	712	-10
1992/1993	1117	30	1311	40	1013	30
1993/1994	1401	70	1322	40	1121	40
1994/1995	1217	40	1107	20	1271	60
1995/1996	682	-20	701	-20	668	-20
1996/1997	917	10	811	-10	1072	40
1997/1998	702	-20	1115	20	623	-20
1998/1999	1231	50	1213	30	1311	70
1999/2000	1223	50	901	0	1127	40
2000/2001	657	-20	721	-20	699	-10
2001/2002	357	-60	612	-30	371	-50
2002/2003	785	-10	1127	20	705	-10
2003/2004	1132	30	1300	40	1025	30
2004/2005	517	-40	579	-40	511	-40
2005/2006	845	0	1291	40	791	0
2006/2007	712	-10	1103	20	605	-20
2007/2008	1213	40	1171	30	1271	60
2008/2009	152	-80	201	-80	189	-80
2009/2010	112	-90	131	-90	171	-80

Source: Kahangara Division Agricultural office, 2012

Fluctuations in cassava yields over the last 21 seasons (Table 18) shows that in 10 out of 21 seasons yields of cassava were above the long term mean and in 10 out of 21 seasons the yields were below the long term mean. The yields were poor in 2001/2002 seasons; this was due to extreme rainfall which was evidenced in the analysis of daily, monthly and seasonal rainfall which caused flooding and water logging. This could have disturbed nutrient intake through weed infestation and also led to rotting of roots and stems and washing away of plants these in turn affected crop yields. The results of anomalies analysis (Table 18) depict that in seasons with extreme rainfall for example in 1997/1998 and 2001/2002 the yields were also below the long term mean. Likewise in 2008/2009 and 2009/2010 consecutively were extreme dry and also the yields were very poor below the long term mean. In most cases the amounts of rainfall around the long-term mean have good yields. This is also supported by the fact from Plate 2 which shows a cassava field in Kahangara Division during the period with the rainfall around the long term mean. This result implies that cassava does not need extreme rainfall and dryness in its growth and development stages. The period of low yields are the years when rainfall was not in favor of cassava production.

Plate 2: Cassava crop in Teleza's field taken at Mwamanga ward (Kahangara Division) in 2007/2008 season

Source: Kahangara Division Agricultural Office (2012).

Moreover, fluctuation in sorghum yields over the last 21 seasons (Table 18) shows that in 9 out of 21 seasons sorghum yields were above the long term mean in relation to rainfall amount and in 11 out of 21 seasons the yields were below the long term mean. The yields were poor in 2001/2002 season. This could be due to extreme rainfall which may have caused flooding and water logging. High amounts of rainfall can also cause leaching of essential plant nutrients in the soil. Fraser *et al.* (1999) reported that higher rainfall intensities could have a number of negative effects on agriculture both in the short and long-term. It increases the rate of erosion and loss of particulate nutrients from arable soils, thereby reducing soil fertility and productivity.

The results of anomalies analysis (Table 18) depict that in seasons with extreme rainfall for example in 1997/1998 and 2001/2002 the yields were also below the long term mean.

Likewise in 2008/2009 and 2009/2010 consecutively were extreme dry and also the yields were very poor below the long term mean. In most cases seasons with rainfall around the long term mean recorded good yields. Plate 3 shows a sorghum field in Kahangara Division during the period with the rainfall around the long term mean.

Plate 3: Sorghum crop in Teleza's field taken at Mwamanga ward (Kahangara Division) in 2007/2008 season

Source: Kahangara Division Agricultural Office (2012).

Fluctuations in sweet potatoes yields generally follow the inter-seasonal rainfall patterns (Table 18). Of the 12 out of 21 seasons, yields were above the long term mean and in 8 out of 21 seasons yields were below the long term mean. Poor yields in 2001/2002 season could be due to extreme rainfall. In 1998/1999 rainfall was below the long term mean but the production was above the average, this could be explained as the carryover effect of residual soil moisture of the 1997/1998 season that received excessive rainfall. Plate 4 shows a sweet potatoes field in Kahangara Division during the period with adequate rainfall.

Plate 4: Sweet potatoes crop in Masanja's field taken at Nyanguge Ward (Kahangara Division) in 2007/2008 season
Source: Kahangara Division Agricultural Office (2012).

The changing patterns of rainfall with increased dry spells in the year 2008/2009 and 2009/2010 could have contributed to reduced yields in cassava, sorghum and sweet potatoes. This is because each crop species demands certain amount of water for optimal performance during their life cycle. Sorghum for example, normally matures between 120 and 140 days and demands annual rainfall between 450 mm and 650 mm (Alves and Setter, 2000). Therefore, with prolonged dry spells at germination, flowering and grain filling stages the plant growth and development may be affected and thus, reduced yields. Similar results by Yengoh *et al*., (2010) reported that the amount of rainfall and its distribution over the years largely affect the productivity of agriculture in semi-arid regions of Africa.

Further, the correlation analysis was done to establish the relationship between seasonal rainfall and sorghum, cassava and sweet potatoes yields (Table 19). Cohen (1988) suggested that if the magnitude of effect is 0.2 is considered to be a weak correlation, and an effect size of 0.5 is considered as a medium correlation. However, the effect size of 0.8 is considered as a strong correlation between the two variables. Further, Cohen,

(1988) suggested that in correlation behavioral research, if r ≥ 0.5 meets the conventional definition of a strong effects. Therefore, in this study if r is ≥ 0.5 is considered to be strong relationship between rainfall and crop yields.

Table 19: Correlation Coefficient (r) between Seasonal rainfall Crop Yields

Crop	Calculated value (r^2)	Critical tabular value (r)	P-value	Level of significant
Sorghum	0.429	0.360	P=0.0006	0.05
Cassava	0. 586	0.492	P=0.0000	0.01
Sweet potatoes	0.799	0.492	P=0.0000	0.01

Source: Kahangara Division Agricultural office, 2012

The results of the correlation analysis (Table 19 and the figure in the Appendix 13) show that the correlation between rainfall and cassava yields is statistically significant, since the calculated correlation r = 0. 586 which is greater than the critical tabulated value of 0. 492 and $p < 0.01$. This implies that as rainfall increases cassava yields increase as well and when rainfall decreases the yields also decreases. These results also corroborated the results of anomalies between seasonal rainfall anomaly and of cassava yield anomaly (Table 18). The results of anomalies analysis showed that in 10 out of 21 seasons yields were above the long term mean in relation to the rainfall above the long term mean, thus, in most cases, there were significant relationships between rainfall anomalies and with anomalies of cassava yields in each growing season. As rainfall increases cassava yields increase as well and when rainfall decreases the yields also decreases. The results imply that rainfall is very important in plant growth and in determining cassava yields in Kahangara Division. Farmers are vulnerable to rainfall variability due to high correlation between cassava and rainfall. Similar results were reported by Ayanlade *et al.* (2010) who observed the significant relationship between seasonal rainfall with cassava yields in Shaki Ethiopia between 1990 and 2000.

Moreover, the results of the correlation analysis between rainfall and sorghum yields (Table, 19 and the figure in Appendix 14) show that there is moderate positive relationship between rainfall and sorghum yields, since the calculated r is 0.429. And the correlation is statistically significant, since the calculated correlation (r=0.429) is greater than the critical tabulated value (0.360) at the significant level of 0.05.), and $p < 0.05$. This means that as rainfall increases sorghum yields increase as well and when rainfall decreases the yields also decreases. The same results were also observed in the analysis of anomalies between seasonal rainfall anomaly and of sorghum yield anomaly (Table 18). The results of anomalies analysis showed that in 12 out of 21 seasons, yields were above the long term mean in relation to the rainfall above the long term mean. Therefore in most cases, there were significant relationships between rainfall anomalies and with anomalies of sorghum yields, as rainfall increases sorghum yields increase as well and when rainfall decreases the yields also decreases. It has also observed that the amounts of rainfall around the long term mean influenced high yields for sorghum. This supports the fact that sorghum does not need extremely high rainfall amounts for growth and development. It is generally known that sorghum is relatively more droughts tolerant. This may explain the moderate correlation relationship between rainfall and yields. The figure in appendix 14 shows the direction of relationship between rainfall and sorghum. Positive relationship in this study implies that as rainfall increase, sorghum yields increases as well and vice versa.

The results of the correlation analysis between rainfall and sweet potatoes yields (Table, 19 and the figure in Appendix 15) show that there is strong positive relationship between rainfall and sweet potatoes production because the calculated r is (0.799) which is above 0.05. And the correlation is statistically significant, since the calculated correlation ($r= 0.799$) is greater than the critical tabulated value (0.492) and p < 0.0.1. The same results were also observed in the analysis of anomalies between seasonal rainfall anomaly and of sweet potatoes yield anomaly (Table 18). The results of anomalies analysis showed that in 12 out of 21 seasons, yields were above the long term mean in relation to the rainfall above the long term mean, and in 8 out of 21 seasons yields were below the long term mean in relation to the rainfall below the long term mean. Thus, in most cases, there were significant relationships between rainfall anomalies and with anomalies of sweet potatoes yields in each growing season. As rainfall increases sweet potatoes yields increase as well and when rainfall decreases the yields also decreases, therefore, the higher rainfall the higher sweet potatoes yields and vise visa. This actually means that rainfall is very important factor that determines sweet potato yields in Kahangara Division.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMENDATION

5.1 Introduction

This chapter presents summary, key conclusions, subsequently recommendations based on the study and areas for further research.

5.2 Summary

This study analyzed annual, seasonal and monthly rainfall variability over 21 years and daily rainfall over 10 years. Different forms of rainfall such as anomalies, trends, coefficients of variation, rainfall onset and cessation have been identified. The statistical analysis and perception of farmers indicated that the rainfall in Kahangara Division varies in each growing season and within the months. The inter- easonal differences in rainfall amounts with non significant decreasing trends in seasonal rainfall have been observed. The high levels of variability within months have been observed; the months of October and February seem to have high variability than all months within the growing seasons. This study also noted the increasing dry spells with less wet spells within the months during the rainy season over the last 10 years (2001 – 2010). The variability of rainfall onset with false start of rainfall was also observed, of which the respondents particularly reported experiencing delays in rainfall onset and sometimes receiving rainfall earlier than expected.

This study also observed that variabilities in seasonal, monthly and daily rainfall affect subsistence crops production particularly, through delays in land preparation and planting dates. Variability in rainfall also affects plant growth since it causes stunted growth and sometimes leads to crop failure which in turn affects crop yields. It was observed that crop yields varied in relation to variation of rainfall totals and distribution in the Division. The significant relationship between rainfall variability and subsistence crop yields to all the three crops (sweet potatoes, cassava and sorghum) were observed. Thus, these results suggest that rainfall variability has an effect on subsistence crop production in Kahangara division.

5.3 Conclusion

The study attempts to assess in detail the characteristics of rainfall within the study area. Temporal variability of rainfall is high in the division. At annual and seasonal scales, it has been observed that total rainfall amounts were decreasing and increasing respectively both negatively and positively. However, high variability of rainfall within the months and on the onset of rainfall was also observed. These variabilities affecting production of subsistence crops both positively and negatively in the division. The negative effects are more frequent in the Division, this is evidenced in two consecutive seasons (2008/2009 and 2009/2010), low rainfall led to low production of subsistence crops; most farmers harvested almost nothing. These conditions put subsistence farmers into stress of no food for their families. If this problem continues, it would put subsistence farmers into risk of food insecurity. Therefore, a number of strategies should be introduced so as to help subsistence farmers in coping with rainfall variation. This study therefore, recommended the following strategies to be done.

5.4 Recommendations

Investment in water supply is very important, in the division, for example, through rain water harvesting projects and installation of modern irrigation systems so as to supplement rainfall and enable longer growing seasons for subsistence crop farming.

The meteorology department should disseminate information on rainfall forecast to farmers so as to create awareness on the effects of rainfall variability which may help them on farm decision making. Furthermore, the knowledge of rainfall variability and patterns can assist farmers in planning and managing agricultural activities.

Changing planting dates, for example, farmers are advised to plant cassava, sorghum and sweet potatoes since they flower and mature within the period of months with reliable rainfall. In Kahangara division there are two rainfall peaks with a dry spell between January and February, when rainfall is unreliable; cassava, sweet potatoes and sorghum should be planted during and up to the end of the first peak, so that vegetative growth occurs during the drier months and flowering occurs at the beginning of the second rains. Farmers are advised to grow different crop varieties because crops that are tolerant to floods or drought differ. So when one crop fails, the other may complement for food.

5.5 Areas for further research

Further research may be required to examine the effects of rainfall variability on population dynamics of agricultural pests and diseases in Kahangara division.

Another important area of research is to analyze the impact of rainfall variability on socio-economic development of the farmers in Kahangara division.

Thirdly, the status of subsistence farming and copping strategies on rainfall variability. Moreover, an Agro-climatologically research should be done.

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