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The Effect of Rainfall Variability on Maize and Coffee Farming Activities between 1990 – 2014 in Machakos Sub County, Kenya

Christopher M. Indiatsy[#] and Dr. Paul O. Abuom (PhD)^

School of Environment and Earth Sciences, [#]Geography Dep., ^Department of Environmental Science, Maseno University Kenya

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Abstract

Varying climatic conditions with increased uncertainty mainly in rainfall and temperature are salient features in marginal areas globally, adversely affecting farming activities particularly in Africa. Kenya experiences variations of annual rainfall with considerable uncertainty. These variations ranging from below 500mm to above 2000mm annually, cause droughts and floods respectively, affecting farming activities and yields. This study focused on Machakos sub County, a semi arid area, east of Central Kenya highlands. Information on the effects of rainfall variability on farming activities in Machakos, have concentrated on small holder maize cultivation and covered broad areas of the Eastern region and Machakos County, leaving out other crops. They mainly cover the period between 1930 - 1990. After this period, very scanty information exists. The objective of the study was to investigate the influence of rainfall variability on farming activities in Machakos sub County, focusing on Maize and Coffee. A sample of 384 from 35,605 households was drawn using the Webster (1995) formulae and stratified into units based on the twelve locations. Primary data was collected through; household questionnaires, interviews, observation and photographs. Publications from Meteorological Department Nairobi and sub county Agricultural offices provided secondary data. Inferential statistics using Pearson's Correlation was used to determine relationships between variables. Correlation between annual rainfall totals and maize yields (r = 0.632) and coffee yields (r = 0.695) were statistically significant at 0.05 significance level. Maize and coffee yields increased with high rainfall. In conclusion, Rainfall variability has a strong relationship with Maize, Coffee yields. Disseminating information on rainfall forecasts, rainwater harvesting for irrigation, proper, a forestation and reforestation programs were highly recommended.

Keywords: *Rainfall variability, rain fed agriculture, arididty, marginal areas, areal variability, temporal variability, drought intensity, floods, el nino, lanina, sahelian regions and rainfall fluctuations.*

1. Introduction

Rain is the most important element determining climate and the world's climate is categorized based on rainfall and temperature. Variability of rainfall is a global problem disrupting farming activities in most parts of the world. The objective of the study was to investigate the effect of rainfall variability on farming activities. The study area was limited to Machakos sub County which is a semi arid area in Eastern Kenya. The farming activities studied included crop farming. The particular crops studied were coffee and Maize, focusing on yields. The study findings are expected to help in formulating development strategies to counter the problems of rainfall variability.

1.1 Background to the Study

Rainfall variability is the degree to which rainfall amounts vary across an area or over a given period of time. When this variation of rainfall amounts is taken at various locations across a region for a specific time, it is referred to as areal variability. Where the variation of rainfall amounts is taken at one location over a specified period of time is known as temporal variability. For the purposes of this study, the variability considered is temporal variability as the study area, is one area, Machakos sub County.

Temporal dispersion in rainfall can be either from month to month, season to season or from year to year from the long term average. This variability can cause drought or floods (Ribot *et.al.*; 1996). Rain fed agriculture in the affected areas suffers in terms of reduced yields, crop failure and to extremes livestock deaths. Subsistence crop production becomes uncertain (Medug, 2009)

Rainfall in many parts of the world is subject to variability and uncertainty as a result of fluctuations. According to Jose (2007), climate change has made rainfall in the tropical regions of the world more irregular. It used to start raining in October and continue in July

*Corresponding author's ORCID ID: 0000-0000-0000-0000
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every year in the Brazilian Semi-Desert region that currently suffers from drought. Today rainfall in this Brazilian region is unpredictable, streams are disappearing and water available for agriculture has drastically reduced.

An elaborate analysis of annual, seasonal and monthly rainfall of 16 rainfall stations over a period of 30 years between 1960 – 1990, was conducted in India. The results revealed high variability patterns across the country. The impact of the variability was seen in terms of environmental issues like desertification in northwestern India, river channel changes over the Gangetic plains and rising trend in surface temperature variation over the whole country (Nityanand, 2009). A study conducted by Phillips *et.al*., (1999) stated that the effects of rainfall variability have continued to affect global food production throughout history. Rainfall variability in Australia has adversely affected the eastern part of the country with the effects of expanding the desert condition (Nicholls *et.al*., 1977).

Rainfall variability has led to expansion of the Sahara desert and encroachment of the savannah and steppes land during modern times (Ngaira, 1999). African countries are the most vulnerable to rainfall variability as they mostly depend on rain fed agriculture for their livelihood (Alberto, 2013). A close study of documented rainfall datasets reveal that rainfall variability in Southern Africa experienced significant modifications affecting agricultural activities (Richard, 2000). Assessing rainfall variability is a frequent practice in climatology. An important application is the estimation of total rainfall over an area, e.g. a catchment area as an input of climate model (Barrow, 2003). Rainfall variability has been common in the Sahel South of Sahara, East and Central Africa. Many countries of the Sahelian region of Africa are today affected by prolonged droughts adversely affecting crop yields (Ominde and Juma, 1991). In West Africa, a study by (Gribin, 1975), indicated that the area experienced prolonged droughts, which were responsible for decline in agricultural harvests.

Inter annual rainfall variations in equatorial East Africa are tightly linked to the Elnino Southern Oscillations (ENSO) with more rain and flooding during elnino and droughts during lanina years both having severe impact on human habitation and food security (Gerald,2011). According to Young and Lowry (1977), variability in the rainfall total is one of East Africa's handicaps from year to year; the total might fluctuate from half the average causing drought, to double the average causing floods. Many areas of East African countries suffer from excessive and deficient rainfall with frequent occurrences of drought and floods. It is characterized by extreme variability of rainfall amounts with patterns of rainfall changing over different periods and causing fluctuating subsistent crop production (Shongwe, *et.al*., 2009).

Kenya's rainfall is characterized by variability in the annual total and considerable uncertainty in the time of the year the rains are expected (Ngaira,1999). This is mainly witnessed in marginal areas like Garisa, Mandera, Magadi and Kajiado, Samburu and Machakos which are semi arid (Ojany and Ogendo,1973). A study conducted by Ovuka (2016) analysed rainfall trends of the Central highlands of Kenya, between 1972 – 2012. Results indicated that rainfall decreased over the 40 year period and that extreme fluctuations were recorded between 2000 – 2012. The drought periods elongated over the same period adversely impacting on agricultural production. A study by Sisanya *et.al*.(2016) on semi arid lands in Kenya, indicated that variability is persistent in the arid and semi arid lands of Kenya and continues to affect vegetation condition and consequently crop production.

Machakos Sub county receives erratic and unpredictable rain, less than 500mm per annum in the southern lowlands. The higher areas towards the North and North East receive more rainfall (slightly above 1000mm) than the lowland areas in the Southern parts (less than 500mm) and particularly those in the rain shadow of the hills in the East. The rainfall is associated with erratic patterns and fluctuations in distribution over different years. Droughts are a common feature in the district with records revealing an occurrence of 4 out of 10 years (GOK, 2013). Studies conducted on rainfall variability in Machakos District such as Michael and Tiffen (1992) mainly cover the period 1930 –1990. The current study covers the period 1990 – 2014 and focuses on Machakos sub county which was the Central Division of the former larger Machakos District, currently Machakos County. The study therefore brings out a clearer picture on the current levels and effect of rainfall variability on farming activities in Machakos Sub county, focusing on maize and coffee farming.

In addition, these existing studies on rainfall variability in Machakos reveal some inadequacies which the current study attempts to address. The current study focuses on Machakos sub County, a smaller area as compared to the larger former larger Machakos District (Now Machakos County). Focus on a smaller area will bring out the variability patterns more clearly than the generalized results for the larger area.

The effects of rainfall variability include disruption of farming calendars and activities, reduced productivity, and uncertainty in planning farming activities and diversification of economic activities. Either high or low extremes of rainfall from the average (700mm-1200mm) can be disastrous to agricultural activities (Young and Lowry, 1977). Agricultural activities include, crop farming in maize and coffee (Warah, 2009). The effects of rainfall variability on these activities include reduced crop yields, crop failure, livestock deaths, and diversification of agricultural activities.

Studies conducted on the effect of rainfall variability in marginal areas such as Ngaira, (1999) and Briggs and Smithson, (1985) have concentrated on the environment in general. Their findings revealed the effects of rainfall variability on both agriculture and environmental features such as lakes, rivers and vegetation. Other studies on the effect of rainfall variability in Machakos sub County, such as Baron (2004) and Wanjala (1978) have concentrated on maize cultivation by small scale farmers. Other crops were not covered. The current study goes beyond general studies on the environment and the focus on small scale maize cultivation to investigate the effect of rainfall variability on coffee, maize and cattle farming by the people living in Machakos sub County. Studies on the influence of rainfall variability on farming activities in Machakos sub county covered in the literature review have concentrated mainly on small scale maize production and generally the effect on the environment such as that of Mua and Ndunda (2013), focused on the whole county giving generalized results. This study looked at coffee, maize and cattle farming on both small scale and large scale making the study more detailed by focusing on a smaller area as compared to the previous studies in the area**.**

The study aimed at establishing the extent to which rainfall variability affects farming activities in the district to come up with diverse mechanisms of adaptability of the harsh climatic conditions and mitigating the effect of rainfall variability. It is against this background that the study intended to assess the effect of rainfall variability on farming activities among the people living in Machakos sub county. The crops studied were coffee and maize.

1.2 Statement of the Problem

Rainfall variability is a global predicament that impedes the success of farming activities, particularly in marginal areas. High intensities of rainfall such as that above 2,000mm per annum cause floods as those experienced in the Gangetic plains of Asia, Congo basin and parts of Kenya including Tana delta, Kano plains, Budalangi and Athi-kapiti plains where Machakos County falls (Mburu, 2011). Low intensities particularly below 500mm per annum cause drought and desertification in the affected areas (Ngaira,1999).

Kenya's rainfall is characterized by variability in the annual total and considerable uncertainty in the time of the year when the rains eventually are expected. Machakos Sub County receives erratic and unpredictable rainfall, less than 500mm per annum. The rainfall is associated with erratic patterns and fluctuations in distribution over different years. Droughts are a common feature in the district with records revealing an occurrence of 4 out of 10 years. Droughts disrupt farming calendars and activities; hence reduce crop and livestock yields, sometimes crop failure resulting into low harvests and food shortages especially in arid areas such as Machakos Sub County. Knowledge on the effect of rainfall variability on farming activities, will enable economic planners, the government and farmers to formulate alternative ways of adapting and mitigating the effect of rainfall variability in the study area.

1.3 Objective of the study

The objective of the study was to investigate the influence of rainfall variability on farming activities in Machakos sub County specifically to assess the relationship between rainfall variability and Coffee and Maize yields in Machakos sub County

1.4 Justification of the Study

The findings of this study will provide a deeper understanding of fluctuating patterns and trends of rainfall and how they affect agricultural activities in marginal areas. Understanding the effect of rainfall variability on farming activities, will help economic planners, the government and farmers to formulate alternative ways of adapting and mitigating the effect of rainfall variability in the study area. The choice of Machakos sub County as study area was guided by the fact that the area is a semi arid area with acute rainfall variability. Coffee was chosen as it was the major cash crop in the area, maize was chosen as the major food crop in the study area.

2. Literature Review

2.1 Introduction

Rainfall is an important element of both weather and climate (Ngaira, 1999). Rainfall is the most important element determining climate. Broad divisions of climatic types of the world have been based on rainfall and temperature (Karugah and Kibuuka, 2003). Variability is the degree or extent to which data points in a statistical distribution or data sets diverge from the average or mean. Variability describes how spread out or closely clustered, a set of data is. It may be applied to many different aspects e.g. climate variability, and Rainfall variability (Wenner, 2012). Variability also refers to the extent to which data points differ from each other (Bevan, 2002). Rainfall variability refers to the degree to which rainfall amounts vary across an area or over a given period of time. The variation of the amounts at various locations across a region for a specific time interval is known as areal variability and when the variation of the amount is at a particular location, within a given period of time is called temporal variability (Nicholls *et.al*., 1997). Assessing rainfall variability is a frequent practice in climatology. An important application is the estimation of total rainfall over an area e.g. catchment area as an input of climatic models (Wenner, 2012).

2.2 Rainfall Distribution, Patterns and Variability

2.2.1 Distribution, patterns and Variability at global, regional, and local levels

Precipitation, particularly rainfall is in many cases the most important input factor in a climatological modeling

(Wenner, 2012). However this input is subject to uncertainty as a result of fluctuations (variability), measurement errors and systematic errors in the interpolation method, due to random nature of rainfall (Barrow, 2003). Rainfall in many parts of the world is subject to variability and uncertainty as a result of the fluctuations. According to Jose (2007), climate change has made rainfall in the tropical regions of the world more irregular. It used to start raining in October and continue in January every year in the Brazilian semi-desert region that currently suffers from drought. Today rainfall in this area is unpredictable, streams are disappearing and water available for agriculture has drastically reduced.

Rainfall variability has led to expansion of the Sahara desert and encroachment of the savannah and steppes land during modern times. Remarkable fluctuations of rainfall have occurred over nearly the entire continent (Ojany and Ogendo, 1973). Rainfall variability has been common in the Sahel south of Sahara, East and Central Africa. Young and Lowry (1977) posits that variability in the rainfall total is one of East Africa's handicaps from year to year; the total might fluctuate from half the average causing drought, to double the average causing floods. Kenya's rainfall is characterized by variability in the annual total and considerable uncertainty in the time of the year when the rains are expected (Ngaira, 1999). This is mainly witnessed in marginal areas like Garissa, Mandera, Suguta plains, Magadi, Machakos, among others.

The above studies have generalized rainfall variability for the broad and large regions of the world prompting the need to focus on a smaller area within a country. Environmental and rainfall patterns differ from one area to another within or outside a country (Ovuka, 2016). Generalizing rainfall patterns for the whole country or region does not provide adequate understanding of rainfall variability in a given particular area (Richard, 2003). This study focused on a small area in Kenya's marginal lands, Machakos sub County.

Studies on the mean annual rainfall of Kenya reveal the general inadequacies of the amounts of rainfall received by large parts of the country. This is clearly revealed in Table 2.1. Drought is one of the most basic problems of development in Kenya.

Table 2.1 Rainfall Distributions in Kenya 1973

Rainfall in mm	Area in Km^2	% of Total Area	Cum percentage
0 – 253	157470	27.0	27.0
254 – 507	209 011	35.9	62.9
508 – 761	105692	18.1	81.0
762 – 1015	48692	8.4	89.4
1016 – 1269	28490	4.9	94.6
1270 – 1523	19425	3.3	97.6
1524 – 1777	9583	1.6	99.9
1778 – 2031	3885	0.7	99.9
2032 +	518	0.1	100.1

Source Ojany and Ogendo, 1973.

Two other characteristics of this rainfall are also important but not apparent from the maps. There are wide variability in the annual total and considerable uncertainty in the time of the year when the rains can be expected. Planned agriculture is therefore made difficult to carry out (Ojany and Ogendo, 1973).

The reasons for this large rainfall variations is partly, the tremendous topographical contrasts, including great altitudinal range and partly the distribution and presence of large water bodies such as lake Victoria (Karugah and Kibuuka, 2003). The alternate cooling and heating of the lake and surrounding land initiates on shore and off shore breezes. The prevalent easterly winds meet the land breezes and the two bring about subsidence of air and hence small amounts of rainfall. This is the reverse of the western shores. Prominent topographical features stand out as highlands or pockets of high topographic points initiating rainfall (Ojany and Ogendo, 1973). A more serious drought however characterizes the Northern and North Eastern Kenya which is in fact, part of the dry region that covers North Eastern Africa and Arabia (Minns, 1984). Table 2.1 shows rainfall distribution in Kenya. It shows that 27% of Kenya is arid and 40% of the total land area is semi arid and that a smaller area (10%) receives over 1000mm. This clearly shows the high variabilities of rainfall across the country.

The study area, Machakos sub County receives erratic and unpredictable rain, less than 500mm per annum. Rainfall varies with altitude. The rainfall has abnormal patterns with a significant difference in distribution over different years. The short rains occur in March to May while the long rains fall in October to December, although it is not very reliable. Historical data indicates that in 4 out of 10 years, there is a major drought in the district (GOK, 2013). The above studies have focused on annual and monthly rainfall distribution patterns and left out other characteristic aspects measurement of rainfall variability such as distribution patterns, drought intensity, relative variability, coefficient of variability and precipitation concentration index that makes deeper understanding of rainfall variability.

2.3 Effects of Rainfall Variability on Crop Farming

Rainfall variability has an effect on both farming activities and yields of crops. The effect includes crop failure and death of livestock, when the rains fail. Droughts destroy crops and farmlands leading to reduced harvest and hunger.

2.3.1 Effects of Rainfall Variability on Crop Farming in the World

According to Ngaira (1999), close to 630 million people or 14 percent of the world's inhabitants live in the arid or semi arid environments. Out of these, some 50 million people are constantly faced with malnutrition and possible deaths when the rains fail. Farm crops fail leading to reduced or no harvests at all leading to food shortages. The affected areas include regions like Middle East countries, Southern Brazil, California in the U.S.A, Australia among others. Variability of rainfall has affected the Eastern region of Australia with an effect of expanding the Australian Desert (Nicholls *et.al*., 1997). The Brazillian semi desert currently suffering from drought, was once an area receiving high equatorial rainfall beginning in October to January every year. This change has been triggered by acute rainfall variability that has affected many parts of the world (Jose, 2007).

2.3.2 The Effects of Rainfall Variability on Crop Farming in Africa

Climates of Africa during the Pleistocene and Holocene represent two extreme scenarios with the expansion of the Sahara desert at the peak of the last glacial period and encroachment of the savannah and the steppes lands during modern times (wenner, 2012). However remarkable fluctuations of rainfall have occurred over nearly the entire continent. During the 1950's drought affected more extensive areas of Africa especially the southern part. In the Sahel and other lands bordering the Southern Sahara, the drought which commenced in 1968 nearly extended to the 1974 and 1975 (Ngaira, 1999). Documented data sets observed fluctuating changes in rainfall amounts at monthly, seasonal and annual basis in southern Africa. Significant modifications were experienced in the variability of rainfall in the region adversely affecting farming programs (Richard, 2002).

Studies carried out by Gribbin, (1975) in West Africa revealed that persistent drought in the Sahara region of Africa in the early 1970's were responsible for decline in agricultural harvests associated with a south ward shift climatic zones. In the North Western states of Nigeria for example, the groundnut harvest fell from 765,000 tons in 1968 – 1969 to 400,000 tons in 1970 – 1971. In 1971 – 1972 it was down to 250, 000 tons and in 1973 it was 25, 000 tons. The drought shrunk Lake Chad from 22,000 Km^2 in 1962 – 6,000Km^2 in 1973. In Ethiopia, the famine was one of the causes of the civil war which led to overthrow of Emperor Haile Selassie (Ngaira, 1999). As people notice the increased effect of human activities on the environment such as accelerated cycles of rainfall, deforestation and pollution, the effects are affecting climate (KNAP, 1994). Rainfall variability has begun to affect the nomadic people of the Sahel region in Niger. Rainfall in this semi-arid area is becoming increasingly unpredictable, with changes in timing frequency and amount of rainfall. Temperatures are rising gradually.

There have been severe droughts in Eastern African regions since 1973 causing massive loss of crops (Mburu, 2011). Rainfall variability is having a major impact on the natural grasslands resulting in the spread of the desert and the loss of soil fertility (Ronald, 1997). Elnino Southern Oscilation (ENSO) has been associated with inter annual variations of rainfall in Equitorial East Africa. More rain and floods are experienced during elnino and droughts during lamina. The two scenarios have severe impacts on food security and human habitation (Gerald. 2011).

2.3.3 The Effects of Rainfall Variability on Crop Farming in Kenya

In Kenya both climatological records and oral knowledge show that major droughts with serious results to both man and animals have occurred in the following years: - 1928, 1933 – 1934, 1939, 1942 – 1944, 1952 – 1955, 1960 – 1961, 1965 and 1968. Major floods in certain low lying parts of the Nyanza, Western and lower Tana have occurred in 1937, 1947, 1951, 1957 – 1958, 1997 and 2007 (Ojany and Ogendo, 1973). The anomalies in rainfall have caused widespread famine as drought brings about crop failure while excessive rain causes flooding in the fields during crucial growing periods (Ngaira, 1999). The serious drought of 1991 – 1992 had a lot of negative socio-economic effects in many areas of Kenya. For example in 1992, there was widespread occurrence of malnutrition diseases, lose of human life and animals in Mandera, Wajir, Turkana Samburu and Machakos Districts (Ngaira, 1999). According to Ovuka (2016), farmers perception of rainfall are related to rainfall variability in the Central Highlands of Kenya. The source indicates that rainfall has decreased in the last 40 years and that extreme variations were recorded between 1972 – 2014. Drought periods were elongated in the same period impacting adversely on agricultural production.

About 57% of Kenyan population lives in poverty, largely reliant on climate sensitive economic activities including rain fed subsistence or small holder agriculture (Karanja, 2009). Small holder agriculture is used to describe the rural producers who farm mainly using family labor and whom the farm provides the principal source of income (Ojwang, 2012). These farmers are faced with a number of challenges including, abnormal onset of the rainy season which results in severe consequences, where abrupt droughts destroy infrastructure and hamper physical mobility, damage crop fields, increased diseases and epidemics.

Mwingi and Mutomo Districts. Long-term rainfall records from five meteorological stations within a 10 km radius from the survey locations were obtained from the Kenya Meteorological Department and were analyzed to compare with farmers' observations.

Farmers' responses indicated that they are well aware of the general climate in their location, its variability, the probabilistic nature of the variability and the impacts of this variability on crop production. However, their ability to synthesize the knowledge they have gained from their observations and discern long-term trends in the probabilistic distribution of seasonal conditions is more subjective, mainly due to the compounding interactions between climate and other factors such as soil fertility, soil water and land use change that determine the climate's overall influence on crop productivity. The study results of farmers perception could have weaknesses such as the human subjective nature and lack of adequate knowledge in farming activities. This could provide misleading results. The current study utilizes both questionnaire and secondary published data to outsource adequate data. The studies can help formulate development strategies that will counter the problems brought about by the effect of rainfall variability and also assist in economic planning. This study is similar to the current study as it was carried out in the semi arid Eastern province but covered five district which presently are Counties. This is a large and broad region as opposed to the current study which covers a smaller area Machakos sub County.

Ngugi *et.al*,. (2014) carried out a study to investigate the effect of soil and water conservation practices on grain yield of improved maize varieties (Katumani and Makueni) generated with and without Nitrogen fertilizers under both normal (< 250mm), normal (≥ 250mm – 350mm) and above normal season (≥ 350mm) in Katumani and Makindu in Machakos and Makueni counties in Eastern Kenya. Results indicated that yields were significant (< 0.01) under the different seasons and treatment with magnitude of the yields response varying. Highest yields were in Katumani (3370kg) were obtained during below normal seasons. The current study also indicated that Katumani was the most preferred variety as farmers showed that it was hardy and most productive. Shisanya *et.al*.,(2011) conducted a study on the effect of rainfall variability in semi arid lands of Kenya. Results indicated that variability was persistent in the arid and semi arid lands of Kenya affecting vegetation and consequently crop production. Climate change and rainfall variability are projected to contribute to increased drought episodes, food insecurity, irreversible decline in herd sizes and deepening poverty. The ASALs are inflicted by a major drought once in every five years resulting in widespread food insecurity, poverty, and irreversible decline in yields and herd sizes (Gichuki,1991). The constraints posed by climate change on agriculture range from pronounced seasonality of rainfall to severe and recurrent droughts. Evaluating the response of maize to a changing climate can provide viable options for enhancing adaptive capacity of small holder farmers in the ASALs (Omuoyo et. al, 2015). The above study cut across the South Eastern part of the country including Machakos County and Makueni County and Kitui County which is an expansive large area giving generalized results. It also looked at the effect of soil and water conservation practices on grain yield of improved maize yield. Soil and water practices depend on amount of rainfall. The study also involved fertilizer which the current study did not apply. The current study covers a smaller area, Machakos sub County.

Studies identified in the literature review on rainfall variability in the study area have concentrated on small scale maize production. Others like Shisanya, (2011) above covered the environment in general, other major crops like Coffee have been left out. The studies cover the broad large areas of Eastern Kenya. This study covered a smaller area Machakos sub County. It covered both small scale and large scale Maize and Coffee farming and Cattle keeping. The period 1990 – 2014 has been chosen on the basis that existing studies on rainfall variability in Machakos like Michael and Tiffen (1992) and Gichuki (1991), cover the period up to 1990. This leaves another knowledge gap that the current study sought to address to cover the new Machakos sub County. The period 1990 – 2014 was adequate enough to determine the effects of rainfall variability on farming activities in the study area. The period is also adequate to determine climate change of an area.

2.4 Gaps identified in the literature review

The literature review above reveals some of environmental impacts of rainfall variability. It also reveals the impact of rainfall variability on farming practices in broad areas. Hence existing studies have concentrated on the impact of rainfall variability on the environment in general. These studies have also concentrated on the study of the impacts on broad or wider areas and therefore generalized studies. The impact of rainfall variability differs from one place to another and from one community to another. Hence generalized results may turn out to be untrue for certain particular areas. It is against this background that this study focused on a smaller area within the marginal areas of Kenya, Machakos sub County. The study goes beyond the past studies that have concentrated on the environment and generalized wider areas to study the effect of rainfall variability on farming activities in a smaller semi arid area of Machakos sub County.

In addition, studies made on the effects of rainfall variability on farming activities in Machakos, like Baron (2004) and Wanjala (2010) have also concentrated on small holder maize cultivation. This study focused on the effects of rainfall variability on both small scale and large scale maize, coffee and farming in Machakos sub County.

The study Objective

Sought to assess the influence of rainfall variability on Maize and Coffee Yields in Machakos sub county. Studies identified in the literature review on rainfall variability in the former larger Machakos District have concentrated on small scale maize production. Other major crops like Coffee have been left out. This study covered both small scale and large scale Maize, Coffee and Cattle production. The period 1990 – 2014 has been chosen on the basis that existing studies on rainfall variability in Machakos like Michael and Tiffen (1992) and Gichuki (1991), cover the period up to 1990. This leaves a knowledge gap that this study sought to address. The period 1990 – 2014 is adequate enough to determine the effects of rainfall variability on farming activities in the study area.

In summary, it is observed that the studies in the literature review focused on the effect of rainfall variability on farming in general, covering large broad areas and leaving out other major crops. The periods of the studies mainly covered up to 1990. Farmers in Machakos sub County

3. Research Methodology

3.1 Study Area (Position and size)

Machakos sub County lies within the foreland plateau between the Eastern Rift Valley and Nyika Plateau. It lies between latitude $0^0\ 50^{'}$ and $1^0\ 05^{'}$ South of the Equator and Longitude $37^0\ 15^{'}$ and $37^0\ 45^{'}$ East of Greenwich Meridian (GOK, 2013). It borders Kathiani sub County to the North, Konza North sub county to the South. Towards the East it borders Emali, Makueni County while Mavoko (Athi river) District to the West. The sub County has a total surface area of 808 Km^2 which is subdivided into two Administrative Divisions. It is a transitional zone from the cool wet Eastern highlands to the dry Nyika plateau (Ojany and Ogendo, 1973).

3.2 Research Design

A descriptive research design was used as data was collected from a cross section of response units at one point in time. The design guides the selection of sources and types of information. It is a framework for specifying the study variables (Ntale, 2010). The choice for descriptive research design was guided by; first, it is the most efficient design for collecting data from a large number of respondents at one point in time. Secondly it allows for comparative analysis between or among study variables or a group of variables. Thirdly, the approach enhances the credence of results by providing conclusions on data as at a given point in time (Baro, 2000). Time series technique was also used to analyze rainfall characteristics between 1990 – 2014 and relating it with production of coffee and maize over the same period.

3.3 Population of the Study

The population of the study involved the households of Machakos sub County in Machakos County. The target population was the rural households who engage themselves in a wide range of agricultural activities like crop farming and livestock farming, for their livelihood. Machakos sub county has a total population of 224,175 and the total number of households is 35,605.

3.4 Sampling Procedure

The main sampling method was stratified random sampling. Stratified random sampling was used in selecting respondents from Machakos sub County to provide information on maize and coffee farming. The study area was stratified into twelve locations of the sub County. This was followed by randomly picking the households to be involved in the study in every location. The method was used to ensure that all locations in the county participated in the study. Webster (1995) formula was used to estimate the sample size of **384 households.**. Targeted respondents were mainly adult female or male who have lived in the area for at least twenty years. The twelve locations were Kalama, Katheka kai, Kilima kimwe, Kimutia, Kola, Lumbwa, Masaku, Muwa hills, Mumbuni, Muvuti, Mutituni, and Ngelani.

3.5 Methods of Data Collection

3.5.1 Primary Data

The unit of analysis was the household. Research instruments for primary data included household questionnaires, interview schedules for key informants, photographs and observation check lists. The instruments used in the study were pretested before actual data collection took place and correction on errors identified was done. Original and first hand data was obtained from Machakos sub County.

3.5.2 Secondary Data

This involved evaluation of the available literature on the research problem. Secondary data was obtained from documented sources including journals, textbooks, newspapers, magazines and publications. These sources were found in public university libraries and UNEP library in Nairobi. Documented Sources of data on rainfall totals and distribution patterns were gotten from four meteorological stations within the District and publications from meteorological department. They covered the period between 1990 – 2014

3.6 Measuring Production

Maize was measured by number of bags per year. Data was obtained from the sub county ministry agricultural offices. Coffee was measured in terms of tones per year, Data was obtained the sub county ministry of agriculture. Data was obtained from individual farmers and the Ministry.

3.7 Data Analysis and Interpretation

To establish the nature and magnitude of the relationship between the variables, the researcher considered the use of parametric tests in particular, Pearson's Product Moment Correlation. The relationship between rainfall variability and Coffee, Maize yields, was investigated by calculating, Pearson's Product Moment Coefficient (r). This determined the nature and strength of the relationship among the variables, rainfall variability Coffee and Maize.

4. The correlation analysis between annual rainfall totals and maize production in Machakos sub County

Table 4.23 shows maize production in sub County between 1990 – 2014. Yields are recorded in
terms of number of bags per year. The yields per year were correlated with annual rainfall totals of the 25 year period from 1990 – 2014, using Pearson correlation moment to establish the influence of rainfall variability on maize yields.

Table 4.23a Production of Maize yield and total annual rainfall Machakos sub County between 1990 - 2014

Year	Number of Bags	Annual Rainfall (mm) Average
1990	223,466	916.4
1991	210,266	609.35
1992	189,143	649.45
1993	197,000	757.9
1994	202,733	815.8
1995	193.600	648.8
1996	188,133	647.2
1997	80,100	471.1
1998	263,400	1143.65
1999	284,000	690.7
2000	80,000	488.35
2001	60,000	653
2002	188,000	798.8
2003	171,466	616.45
2004	140,226	573.25
2005	66,933	453.15
2006	154,666	938.2
2007	83,433	576.75
2008	147,658	418.85
2009	179,793	409.5
2010	172,933	671.6
2011	147,000	515.4
2012	150,333	708.9
2013	106,000	574.4
2014	176,666	696.9
TOTAL	6,533,250	16,443.85

Source, District Agricultural Office Machakos March,2015.

Table 4.24 Correlation between Maize production(yield) and annual rainfall from 1990- 2014

	Percentage Mean	Percentage Maize Production in Bags
Percentage Mean Pearson Correlation	1	0.632*
Sig (2 – tailed)		0.05
N	25	25
Percentage Maize Pearson Correlation production in Bags	0.632	1
Sig (2 – tailed)	0.05	
N	25	25

* Correlation is significant at the 0.05 significant level .
Source: Field data 2016

The results of the correlation analysis (Table 4.24) shows that the correlation between annual rainfall totals and maize yields between 1990 and 2014, is statistically significant since the calculated correlation r = 0.632. The level of significance being at 0.05, the relationship between annual rainfall totals and maize yields at r = 0.632 is statistically significant. This implies that as rainfall increases maize yields increase and as rainfall decreases maize yields equally decrease. The results of anomalies analysis shown in table mean. Therefore, there were significant relationships between rainfall anomalies with maize yield in each growing season. This analysis derives the premise that, as rainfall increases maize yields equally increase and as rainfall decreases, maize yields decrease too. These results imply that rainfall is very important in determining maize yields in Machakos sub County. Farmers are highly vulnerable to rainfall variability due to high correlation between maize and rainfall.

Similar results were reported by Alberto, (2013) who observed a significant relationship of r = 0.586 between seasonal rainfall with cassava, sweet potatoes and sorghum yields in Kahangara Division in northern Tanzania. A study by Miruka (2015) on the effects of climate variability on maize farming in the ASAL areas of south Eastern Kenya, showed that maize yields were highly declining in Machakos, Kitui, Mwingi, and Makueni Counties. The maize yields fluctuated in response to rainfall amounts. The effect of climate was predominately negative in the period 1994–2008 in all the counties. Rainfall trend analysis revealed that four of the six weather stations were declining up to 3 mm per annum.

The results of Miruka (2015) in the entire South Eastern ASAL areas conforms with the results of the current study. The study by Miruka (2015) further confirmed that the arid and semi arid Counties suffered from significant climate variability which had huge implications on maize yields and food security of lower Eastern Kenya. These findings were crucial in increasing the awareness of climate change and its impacts on agriculture, and develop appropriate mitigation measures and planning appropriate adaptation mechanisms in support of enhancing resilience of maize production and food security.

4.2 The relationship between annual rainfall totals and coffee production in Machakos sub County 1990 - 2014

Table 4.28b Production of coffee in yields and total annual rainfall. Machakos sub County between 1990 - 2014

Year	Number of tons	Average annual Rainfall (mm)
1990.	2,973	916.4
1991	2,653	609.35
1992	3,053	649.45
1993	2,773	757.9
1994	2,560	815.8
1995	2,840	648.8
1996	2,493	647.2
1997	2,226	471.1
1998	1,333	1143.65
1999	2,413	690.7

2000	2,840	488.35
2001	2,640	653
2002	2,640	798.8
2003	2,700	616.45
2004	1,916	573.25
2005	1,926	453.15
2006	2,608	938.2
2007	2,626	576.75
2008	1,982	418.85
2009	2,010	409.5
2010	2,713	671.6
2011	1,973	515.4
2012	2,633	708.9
2013	2,840	574.4
2014	2,706	696.9
TOTAL	62,070	16,443.85

Table 4.29 Correlations between Coffee yields and annual rainfall totals from 1990- 2014

	Percentage Mean	Percentage Maize Production in Bags
Percentage Coffee Pearson Correlation Production in Tons	1	0.695 *
Sig (2 – tailed)		0.05
N	25	25
Percentage Mean Pearson Correlation Rainfall	0.695	1
Sig (2 – tailed)	0.05	
N	25	25

* Correlation is significant at the 0.05 significant level (2-tailed).

Source author 2016

The results of the correlation (Table 4.29) shows that the correlation between rainfall variability and coffee yields is statistically significant since the calculated correlation r = 0.695 at 0.05 significant level. Therefore, in this study, if r = 0.695, it is considered to be a strong relationship between two variables. In this case rainfall variability and coffee yields. The level of significance being at 0.05, the relationship between rainfall variability and coffee yields at r = 0.695 is statistically significant. This implies that as rainfall increases coffee yields increase and as rainfall decreases coffee yields equally decrease. The results of anomalies analysis shown in Table 4.7 showed season's yields were high in relation to rainfall above the long term mean. Therefore, in most cases, there were significant relationships between rainfall anomalies with coffee yield in each growing season.

These results imply that rainfall was very important in determining coffee yields in Machakos District. Similar results were reported by Alberto, (2013) who observed the significant relationship r = 0.586 between seasonal rainfall with cassava and sorghum yields in Kahangara Division in northern Tanzania.

5. Summary, Conclusion and Recommendations

5.1 Introduction

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

5.2 Summary of the major findings

Rainfall variability in seasonal, monthly and annual patterns affect maize and coffee farming particularly through delays in land preparation and planting, plant growth causing stunted growth, sometimes leading to crop failure and lowered crop yields. It was clearly observed that maize and coffee yields fluctuated in relation to rainfall variations and distribution. This was clearly shown through the analysis of person's correlation moment (Table 4.23 and 4.28). These results clearly show that rainfall variability has an effect on maize and coffee farming in Machakos sub County. Frequent and prolonged droughts cause frequent crop failure leading to food shortages, hunger and prevalent malnutrition.

5.3 Conclusion

Rainfall variability has had adverse effects on maize and coffee farming in the sub County, leading to reduction in maize and coffee yields and to extremes it extends to crop failure. This leads to food shortages and cases of hunger and starvation.

The residents of Machakos sub County need to have the right perception of rainfall variability if any meaningful solutions have to be sought. Otherwise if the problem continues it would put subsistence farming into a risk of constant food shortages and food insecurity.

5.4 Recommendations

A number of strategies need be put in place to assist subsistence farmers in coping with rainfall variability. These strategies come in the form of recommendations by this study as follows;

The meteorological department should disseminate information on rainfall forecasts to farmers so as to create awareness of the effects of rainfall variability which will help on farm decision making. Understanding of rainfall variability and patterns can assist farmers in planning and managing agricultural activities. The inhabitants of Machakos sub County should be sensitized to understand that droughts are a common occurrence and therefore pre-drought planning is important to cope up or overcome the problem. Investment in water supply where rain water is harvested and stored in reservoir tanks or dams for small scale irrigation projects to supplement rainfall. Elnino rains have caused flooding in most parts of the known dry district. If this water could be harnessed and stored in reservoirs, it would really benefit irrigation systems to supplement rainfall and enable longer growing seasons for subsistence crop farming.

It is recommended that farmers to be encouraged to plant short term drought resisting maize and coffee varieties at the onset of the rains in order to rehabilitate semi arid Machakos sub Counties which is adversely affected by rainfall variability. Intercropping of maize and coffee at early stages of coffee growth will maximize on returns in the event of the short rains. More so intercropping maize with coffee aims to intensively utilizing the small farms and to maximize on the available little rains

5.5 Areas of further research

Further research should be carried out to examine the moderating effects of intervening factors such as diseases, pests and farm inputs, on the effect of rainfall variability on coffee and maize yield in Machakos sub County

Another area of further research is to analyze and establish the coping strategies of rainfall variability in Machakos sub County.

Thirdly, further research can b e conducted on the impact of climate change on socio economic activities in Machakos sub County.

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