UNIVERSITY OF NAIROBI

DEPARTMENT OF METEOROLOGY

RESEARCH PROJECT

ANALYSIS OF DRY SPELLS AND ITS EFFECTS ON MAIZE YIELD PRODUCTION IN TRANS-NZOIA COUNTY

BY

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REG NO: I10/1292/2012

A RESEARCH PROJECT PROPOSAL SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF BACHELOR OF SCIENCE IN METEOROLOGY

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DEDICATION

I dedicate this project research to my family, my ever supporting uncle and his enduring effort to see me this far and in entire of my studies. Thanks to all my friends for the support and encouragement for they will always remain to be my greatest motivator.

DECLARATION

This research project is my original work and has not been presented in any other institution for academic award.

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Great thanks to God for His protection, care and love in my entire studies and the gift of life He has granted to me.

I would like to take this golden opportunity and express my heartfelt appreciation to my supervisors Dr. Karanja and Ms. Bosire for their endless piece of advices and guidance in my entire project.

I acknowledge the Kenya Meteorological Service customer personnel and the Ministry of Agriculture for their assistance in getting the daily rainfall data and Maize yield data respectively. I do appreciate my family members, relatives, friends and my colleagues for their support and guidance in my studies. May God Bless you all.

Abstract

Dry spells is associated with strong winds, little or no rainfall to support plant growth, high temperatures which increases the rate of evapotranspiration and eventually results to wilting of maize crop. During dry periods, the level of humidity in the atmosphere is at its minimum point, this leads to water deficit creating a concentration gradient leading to excessive loss of water from the leaf to the atmosphere. Due to the effects of frequent dry spells, maize production in Trans-Nzoia County has drastically decreased due to frequent occurrence of severe and unpredictable dry weather conditions (dry spells) during crop growth which has caused huge damage to the social and economic practices not only to the region but in the whole nation at large

The frequency of droughts in Kenya and other nations in the horn of Africa has increased in recent years and this development has been linked to global climate change, which is claimed to have led to spatial and time scale reduction of rainfall (Steven Engler, 2015). There are numerous indicators based on rainfall that are being used for dry spell monitoring (Smakhtin and Hughes, 2007). Deviation of rainfall from normal i.e. long term mean is the most commonly used indicator for dry spells monitoring.

Trans-Nzoia County is the largest producer of maize in the whole country thus it goes without saying that it is the bread basket of our nation. Maize is grown on large scale and small scale farming consisting of individuals owning average parcel of land with some farmers tilling large tracts of land. Maize is a staple food for most Kenyans; it also contributes to the economic growth through exportation thus raising the living standards of the people. It creates employment to many Kenyans from the time of growing to the manufacturing industries due to its products. This study is aimed at improving the regional dry spells, reducing potential risk to maize crop and enhancing high maize yield production in trans-Nzoia County.

The meteorological data used in this study was daily rainfall for a period of 33 years and Maize yield in tons per hectare. Meteorological data was obtained from Kenya Meteorological Headquarters and maize yield data from the ministry of Agriculture.

The statistical methods used include time series analysis and single mass curve was used to test for homogeneity. Instat software was used to determine the dry spells. At the end of the study, it was found that dry spells has a great impact on maize yield. The annual increase of dry spells was 0.2 spells per year.

Verification was done on the model to test its skillfulness by use of contingency table. The results showed that the model was skillful with hit rate of 44.4%.

Contents

List of figures

List of Tables

List of Acronyms

K.M.S –Kenya Meteorological Services

MoA -Ministry of Agriculture

MAM –March April May season

OND –October November December season

HSS –Heidke Skill Score

PoD –Probability of Detection

FAR –False Alarm Ratio

CSI –Critical Success Index

CHAPTER ONE

1.0 INTRODUCTION

Dry spell is a prolonged period of dry weather. This causes serious lack of water for domestic and livestock production, crop growth and for industrial use. Due to insufficient water to support food crops through either natural or irrigation, food insecurity arises due to hunger and famine.

The difference between a drought and a dry spell is that, a drought is a prolonged period of abnormally low rainfall leading to a shortage of water, which can be disastrous and have a long term effect on crop and livestock production and also on human life whereas a dry spell is a short period of low rainfall, usually not more than a month.

Dry spells is associated with strong winds, little or no rainfall to support plant growth, high temperatures which increases the rate of evapotranspiration and eventually results to wilting of maize crop. During dry periods, the level of humidity in the atmosphere is at its minimum point, this leads to water deficit creating a concentration gradient leading to excessive loss of water from the leaf to the atmosphere. The dry spells are divided into smaller sub-periods in order to Provide a more reasonable distribution. The sub-periods are as follows:

i. Short sequences (mild dry spell): 1–10 days
ii. Medium sequences (medium dry spell): 11–20 days
iii. Long sequences (severe dry spells): 21–30 days
iv. Very long sequences (extreme dry spells): >30 days

In recent years, maize production in Trans-Nzoia County has drastically decreased due to frequent occurrence of severe and unpredictable dry weather conditions (dry spells) during crop growth which has caused huge damage to the social and economic practices not only to the region but in the whole nation at large. Dry spell analysis will be helpful in this study for improving the ability of regional drought management, maize yield production due to the effects of dry conditions and also reducing its potential risk to the other crops grown in the region.

Resources and effort alone do not lead to the increase in maize yield production; they have to be supported by nature in the form of favorable weather which is crucial to agricultural production (agriculture meteorology, 2002). Maize loss due to dry weather conditions is a complex issue because it changes according to the dryness intensity and duration, the development stage of maize when dry spell occurs (international journal of climatology, 2015).

Figure 1: Maize during the rainy season

Figure 2 : Showing maize affected by dry spells

1.1 PROBLEM STATEMENT

Dry spells produce a complex impact that spans many sectors of the economy and reaches beyond the area experiencing the physical dry spells. This complexity exists because water is integral to society's ability to produce goods and provide services. The impact of dry spells ranges from economic, environmental and social impacts. Dry spells causes damage to maize crop, permanent loss of biological productivity of land and decrease on farmers' maize productivity and also on his/her income.

It results to low maize yield, high prices of maize, unemployment. Retailers and others who provide goods and services to farmers face reduced business. This leads to food insecurity and local shortages may results in importation of maize from outside the dry spells stricken region. This study is therefore crucial in planning in advance and avoids shortages in near future or lack of maize production completely in the region.

1.2 OBJECTIVE OF THE STUDY

The main objective of this study is to analyze dry spells and their effect on maize yield production in Trans- Nzoia County. The specific objectives are;

1. To determine the annual and seasonal trends of dry spells and their intensity in Trans-Nzoia County for a period of 30 years.
2. To determine the annual trends of maize yield produced in tons per hectare.
3. To develop the relationship between the maize yield and dry spells for yield prediction.

1.3 JUSTIFICATION OF THE STUDY

Trans-Nzoia County is the largest producer of maize in the whole country thus it goes without saying that it is the bread basket of our nation. Maize is grown on large scale and small scale farming consisting of individuals owning average parcel of land with some farmers tilling large tracts of land.

Maize is a staple food for most Kenyans; it also contributes to the economic growth through exportation thus raising the living standards of the people. It creates employment to many Kenyans from the time of growing to the manufacturing industries due to its products.

Due to the changes in the climatological and weather variations, the production of maize has drastically dropped over the recent years due to the severe weather hazards like dry weather caused by lack of precipitation. This has led to less maize harvested in tons per hectare thus not meeting the growing demand of Kenyan population. Due to decreased maize production in Trans-Nzoia County, importation of Maize from neighboring nations has been the order of the day when the county of trans-Nzoia alone can be able to feed the whole Kenyan with proper farming and dry spells timing which leads destruction of maize in its immature stage of growth.

This study is aimed at improving the regional dry spells, reducing potential risk to maize crop and enhancing high maize yield production in trans-Nzoia County.

1.4 AREA OF STUDY

Trans-Nzoia County is in the former Rift Valley Province, Kenya, located between the Nzoia River and Mount Elgon with its main urban center at the town of Kitale which is the capital and largest town of the county, and 380 km North West of Nairobi. The county borders Bungoma to the west, Uasin Gishu and Kakamega to the south, Elgeyo Marakwet to the east, West Pokot to the north and the republic of Uganda to North West. Trans Nzoia covers an area of 2495.5 square kilometers.

Situated in the slopes of the Mount Elgon, Trans Nzoia County has a cool and temperate climate with average annual temperatures ranging between a minimum of 10°C to a maximum of 27°C. The county receives annual precipitation ranging between 1000 and 1200mm, with the wettest months being experienced between April and October during the MAM and OND seasons respectively. This weather favors conducive environment for the growth of maize.

The population of trans-Nzoia County was 818,735 according to the 2009 census of which 95% rely on farming.

Figure 3. Map of Trans-Nzoia County showing Kitale

CHAPTER TWO

2.0 LITERATURE REVIEW

Dry spells is the earliest and the most explicit event in the process of occurrence and progression of drought conditions. Rainfall is the primary driver of dry weather conditions due to the absence of it. There are numerous indicators based on rainfall that are being used for dry spell monitoring (Smakhtin and Hughes, 2007). Deviation of rainfall from normal i.e. long term mean is the most commonly used indicator for dry spells monitoring.

The frequency of droughts in Kenya and other nations in the horn of Africa has increased in recent years and this development has been linked to global climate change, which is claimed to have led to spatial and time scale reduction of rainfall (Steven Engler, 2015). In most of the tropics and equatorial regions of the world, and across large areas outside the tropics, the yield of agricultural crops is limited more by the amount of water received by and stored in the soil than by the air temperature. The amount of water transpired by the crop is also determined by air humidity, with generally less matter produced in the drier atmosphere. Thus, changes in both rainfall and air humidity would be likely to have significant effects on crop yields (Martin Parry, 1990).

Rainfall reliability and variation, particularly at critical phases of crop development, can explain the much variation in agricultural potential. This is depicted in the high degree of inter-annual variability of rainfall which determines the soil water holding capacity to support the crops. It leads to a marked variation in crop yield between wet and dry years due to changes in rainfall over time and space as well. In this respect, many scientists choose to study the drought phenomenon by using the length of dry spells(Kutiel, 1985; Conesa and Martin-Vide, 1993; Dougueedroit, 1980).The spells of dry days can reveal significant changes in the structure of drought. The definition of dry spells, which is based on the number of days without precipitation, has been widely used

Agricultural droughts are caused by consequence of frequent dry spells of unpredictable intensity and duration (Sastri et al., 1982; van Oosterom et al.,1996), which are compounded by high evaporation rates and high soil and air temperatures, and by low levels of native fertility and limited water holding capacity of most soils (Y.S.R.S. Sastri.,2015).

Kenya has experienced the worst dry spells in the past which has claimed several thousands of people dead due to severe hunger and famine. In order to mitigate this weather hazard, several research have been done and others still going on by the government of Kenya. (Wilson Gitau., 2010) Very little work has been done at intraseasonal timescale that is paramount to most agricultural applications. Most of Eastern Africa has arid and semi-arid climate with high space-time variability in rainfall. The droughts are very common in this region, and often persist for several years, preceded or followed by extreme floods.

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CHAPTER THREE

3.0 DATA AND METHODS

3.1 Type of data

To achieve the objectives of this study, two data sets for Trans-Nzoia County were used. Annual maize yield data (yield in tons per hectare) for a period of 30 years (1984-2014)

1. Climate data (daily rainfall in millimeters) for a period of 30 years (1984-2014).
2. Maize yield data (tons per hectare) for a period of 30 years (1984-2014)

3.1.1Sources of data

The meteorological data was obtained from Kenya Meteorological services at Dagoretti Corner for Kitale meteorological station and the maize yield from Kenya Ministry of Agriculture.

3.2METHODS

3.2.1Data quality control

Data quality control was conducted in this study to examine errors and inconsistency in the data. This was done by filling in the missing data and testing for homogeneity.

3.2.2 Estimating the missing data

The data obtained for the Maize yield had no missing values and also the daily rainfall data had no missing values.

3.2.3 Test for homogeneity

This is very vital in detecting any discontinuities in the data that may have occurred from observation time, methods of observation, change of site of the instrument or due to vandalism of weather instruments. In homogeneity makes the records of data not sensible for usage. The test was done to ensure that data was consistent and realistic, single mass curve technique was used and a plot of cumulative data meteorological data against time and yield data also against time.

3.2.4 Single mass curve method

This method involves plotting the accumulated records of a weather parameter (e.g. rainfall) against time. The resultant straight-line plot means that the data used was homogeneous while heterogeneity would be shown by significant deviations of some of the data points from the previous straight line. In order to make the data consistent, the ratio of their gradients was adjusted.

3.2.5 Time Series Analysis

Time series curves were drawn for both Maize yield and annual and seasonal dry spell and the trend analysis done.

3.2.6 Data analysis

Analysis of dry spells was done by employing a rainfall threshold value for a dry day as 0.85 and below (Kutiel, 1985; Kutiel and Maheras, 1992). The trend of dry spells and maize production was analyzed by the graphical method using R-software and the intensities of the dry spells was done by use of **instat** software. Contingency table will be used in maize yield prediction.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Test for homogeneity

From the study, Maize yields and rainfall were found to be homogeneous as shown in the Figures 4 & 5 below respectively.

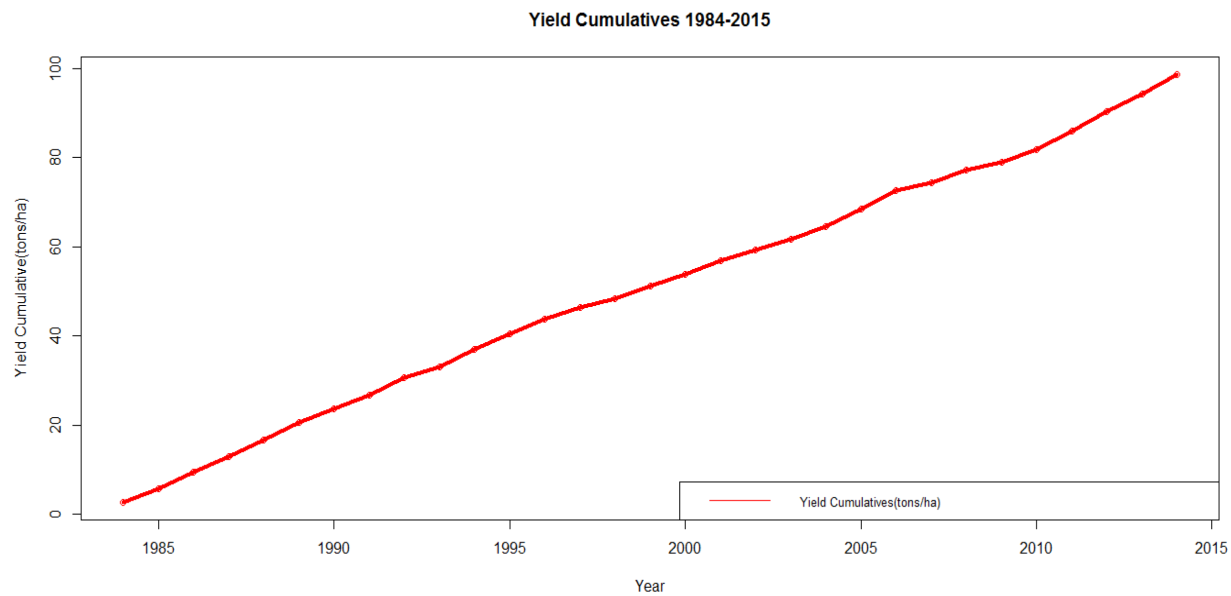

Figure 4: Maize yields for the period 1984 to 2015

From the Figure 4 above, it was observed that maize yield was homogeneous with time.

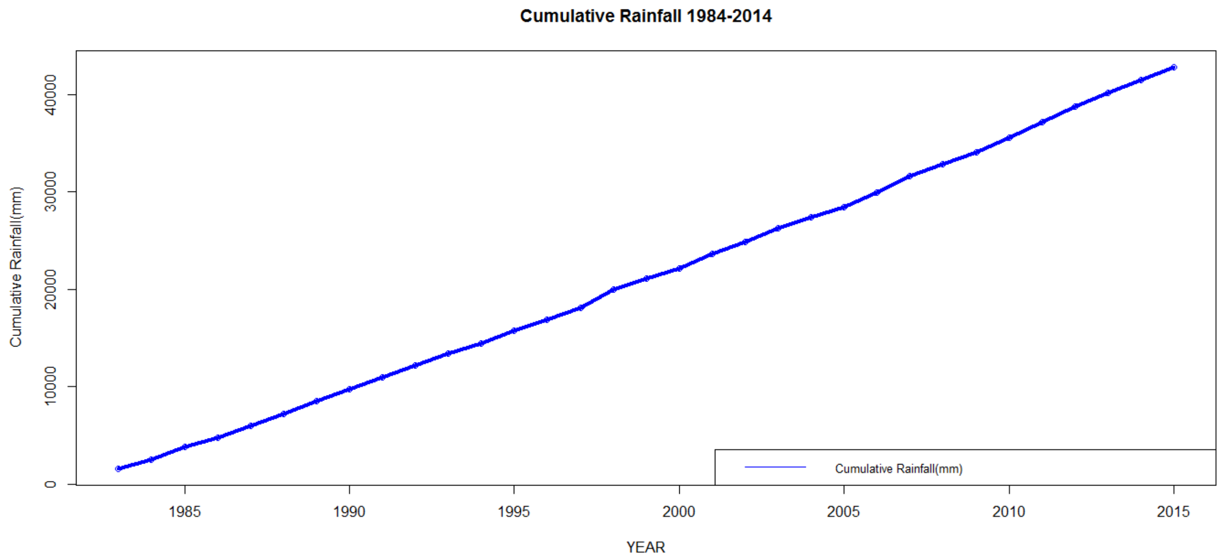

Figure 5: Annual Rainfall for the period 1984-2014

Annual rainfall was also homogeneous since a straight line was obtained.

4.2 Time Series Analysis

Annual Maize yields and rainfall was plotted against the years and their trends were as shown below.

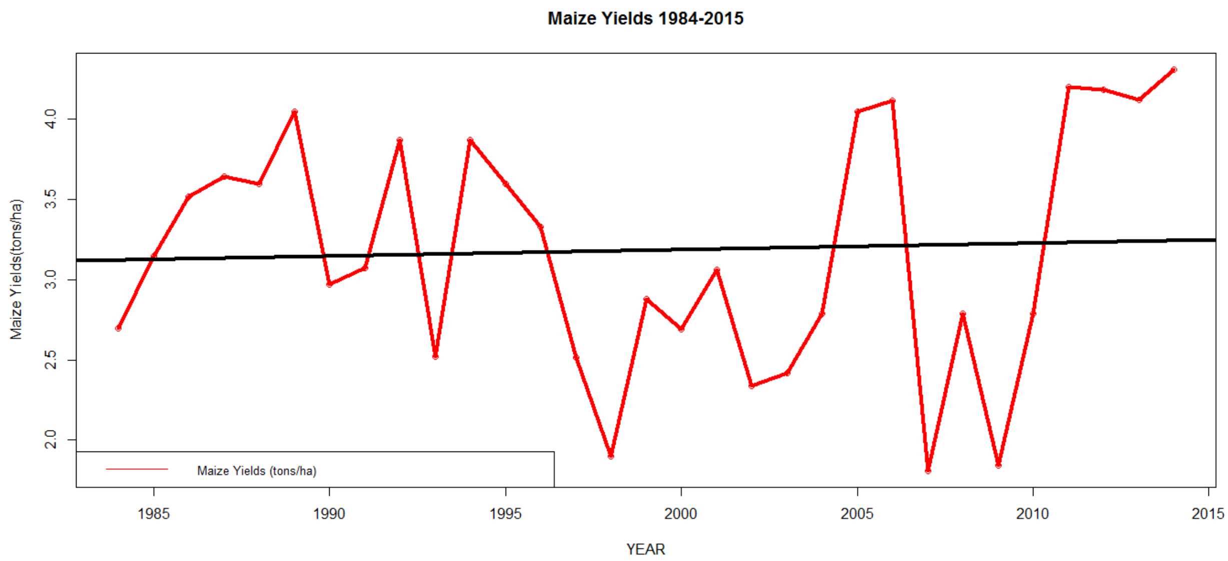

Figure 6: Maize yield trend from 1984-2014

There has been a slight increase of Maize yields over the years as shown in the figure 6 above. The highest yield of 4.2 tons/ha was recorded in the year 2011 and the lowest yield of 1.8 tons/ha in 2007. The increase could be attributed to some other factors like fertilizer application and methods of farming.

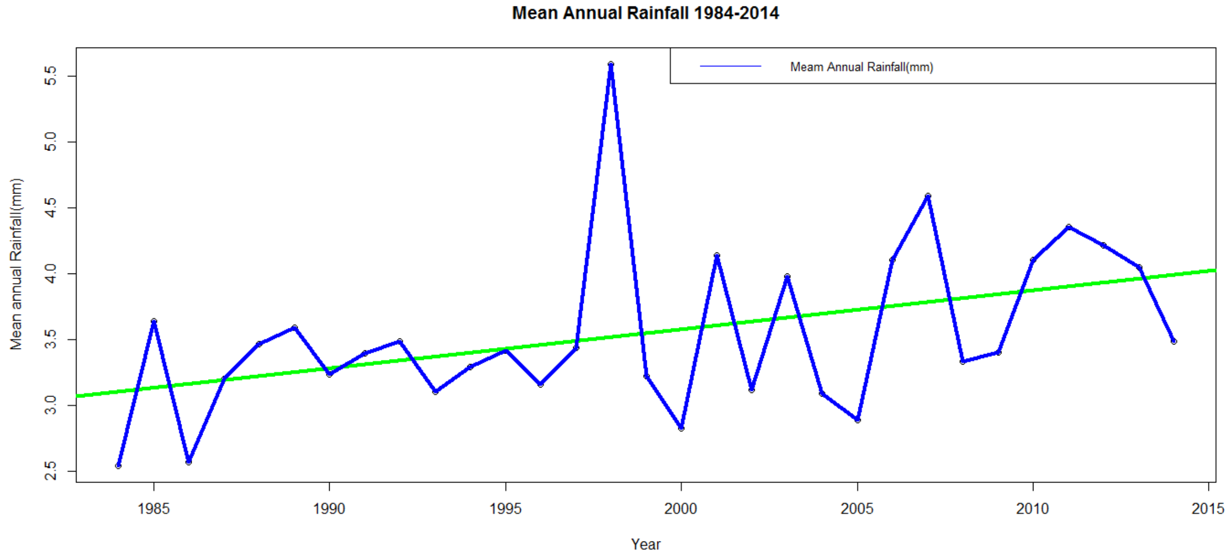

Figure 7: The trend of annual rainfall from 1984-2014

There has been an increase in the trend of rainfall as shown above in figure 7 over the years.

4.3 Results from Zero-order Markov Chain Model

From **Zero order Markov chain**, the day is defined as either **dry (d)** or **rain(r).** The threshold of rain was 0.85mm which defines the rainfall below 0.85mm as a dry day and the amount of rainfall above 0.85mm as a rainy day in 33 years of study**.** In the calculated values, the data contains the number of occasions in a period of 33 years that each day was either dry or rainy. From the graph shown below, the two peaks of rain was observed. In 223 day of the year (10 August) was rainy in 24 of the 33 years which was the maximum while 20th January and 7th February was rainy in only 1 of 33 years. The probability of having rain per day is low in the first two months of the year (January and February) while from March the probability is high per day in May in all the years. P_r is the overall probability of rain per day in 33 years. This shows that maize crop which cannot withstand long dry spells of 5 days in a month can't be sown before the end of April and May.

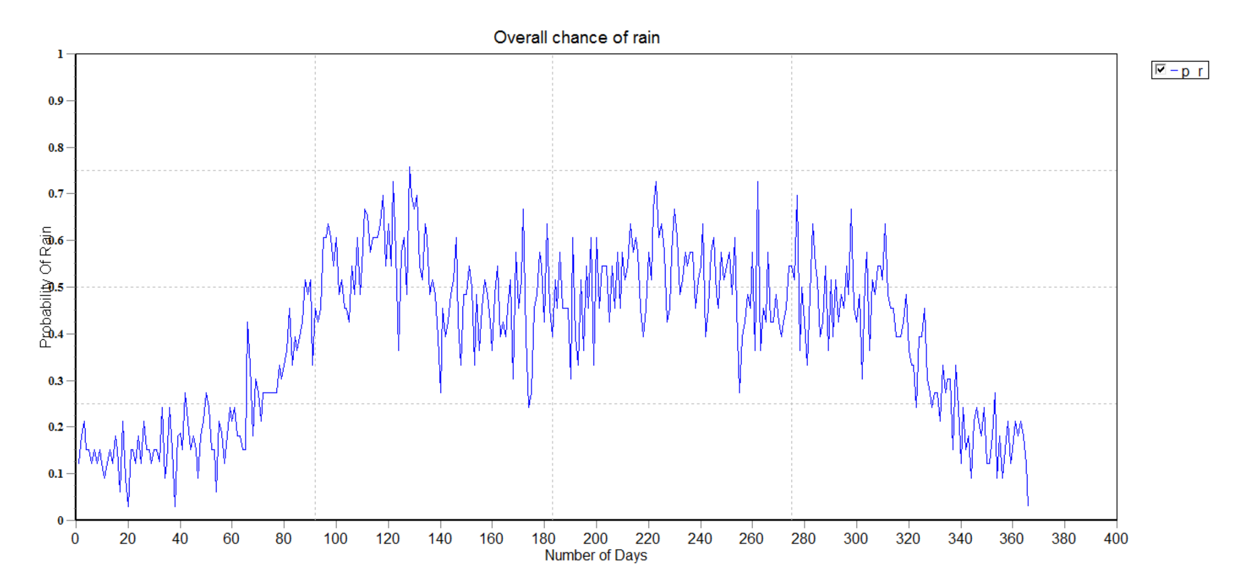

Figure 8: Showing overall chance of Rain from 1983-2015

The chances of rain was low during the beginning of each year and increases towards the beginning of March to May which is probably the appropriate time for planting in Trans Nzoia County. It then decreases from mid-May to July which signifies the dry days. It was observed that the maximum probability of rain was 0.5 to 0.6 during March, April and May (MAM) and August, September and October. The minimum chances of rain in December, January and February was 0.1 to 0.2 as shown in figure 9 below. The overall planting season is from the end of March due to increasing trends of rainfall hence little dry spell days experienced.

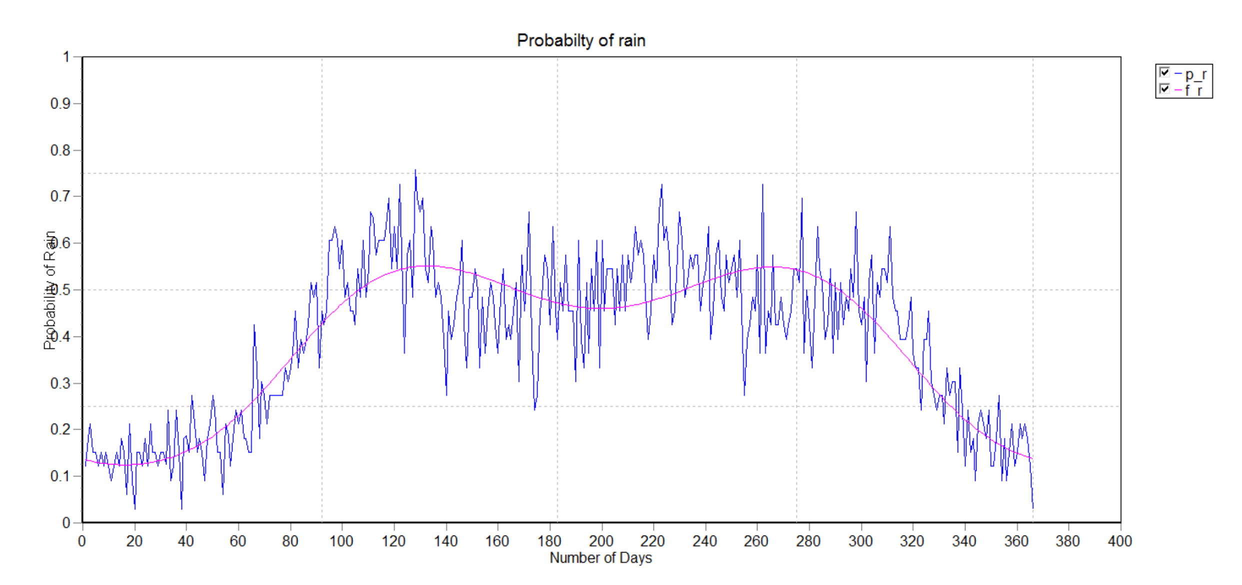

Figure 9: Showing the probability of rain in a day

The mean rain per rain day was found to be 105 day of the year (14th of April) with a mean total of (9-12mm) as compared to the whole year which experiences a mean rain of below per rain day as shown in the following figure.

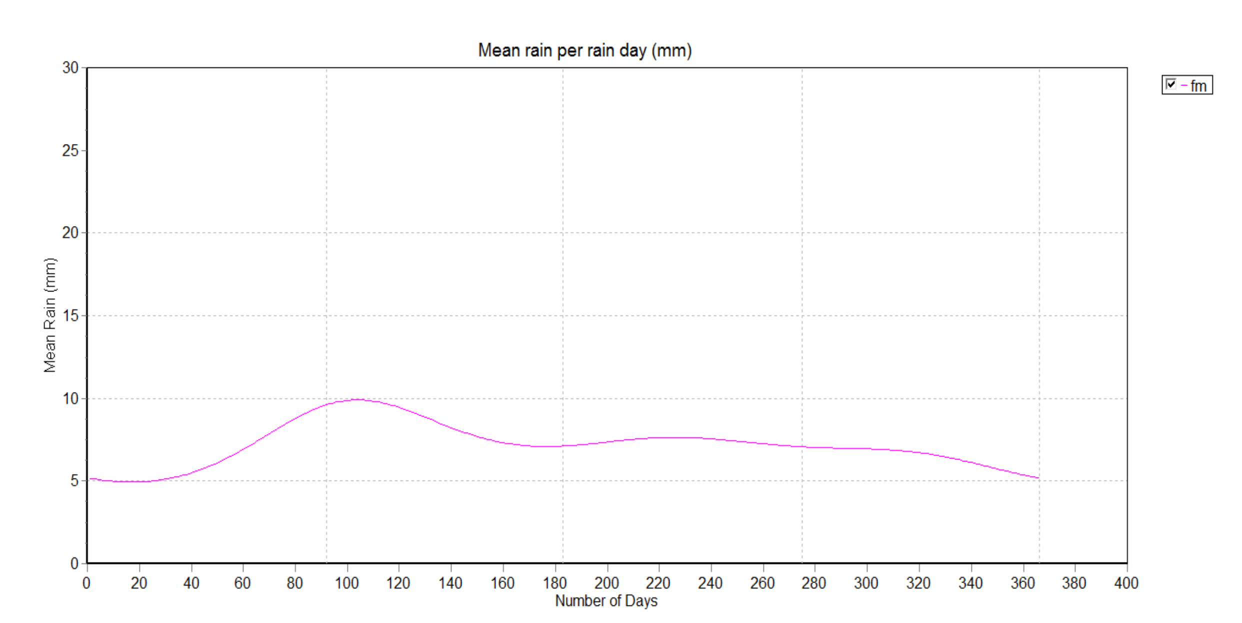

Figure 10: Showing Mean Rain per Rain Day from 1983-2015

The risk of a 5 and 7 day long dry spell in 30 days in a year was highest in January, February and November, December (almost 1). From mid-February, the probability decreases due to the onset of rains to mid-April and the risk of long dry spell increases to the end of June. During the maize growing season there is a higher probability of 5 day long dry spell as compared to the 7 day long dry spell in 30 days of a given period in a year.

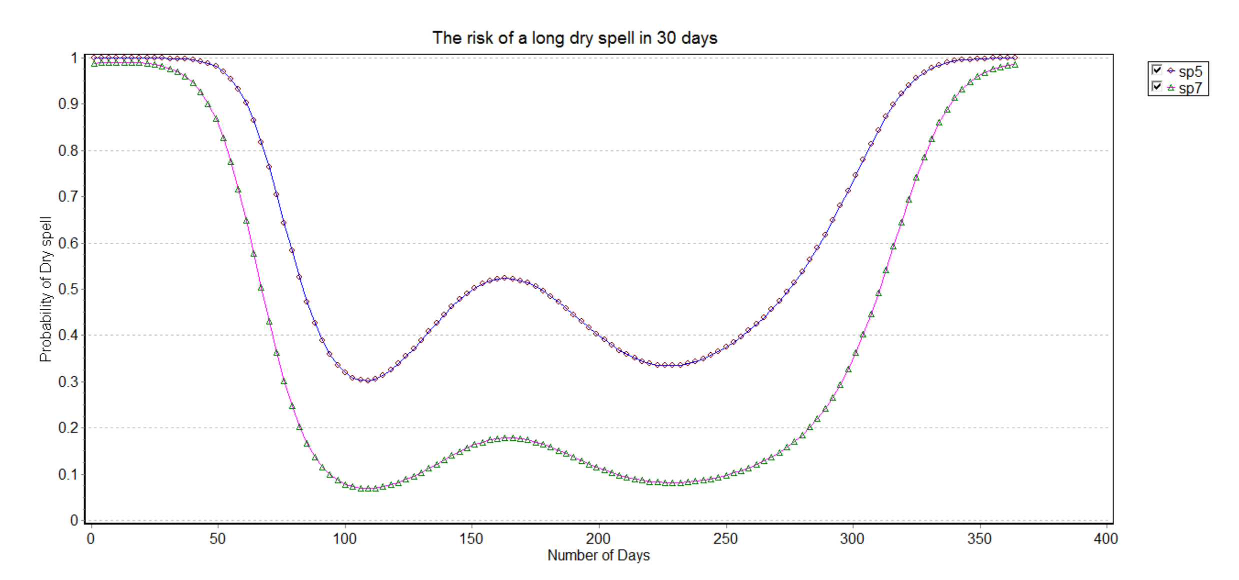

Figure 11: Showing the risk of long dry spells in 30 days from 1983-2015

It was observed that in estimating the total rainfall amount per week in the whole year was highest in the 14 week with 30% was estimated to be 120mm, and 50% and 80% to be 150mm and 198mm respectively as shown in the Figure 12 below.

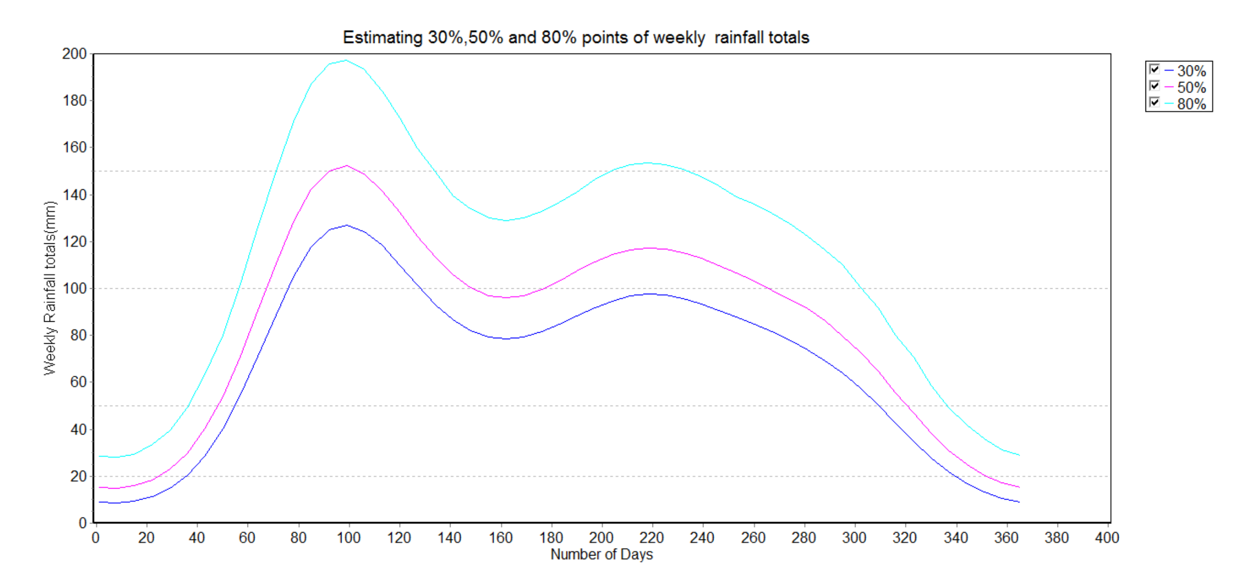

Figure 12: Showing the Estimate points of weekly rainfall totals from 1983-2015

4.4 Results from the First and second order Markov Chain Model

4.4.1 First order Markov Chain model

First order Markov chain model has only one day memory in that if yesterday was dry may affect (i.e. change the probability) that today is rainy. The day may be dry and also the previous day dry, it may be dry and the previous day rainy or rainy and previous day dry and lastly it rains and also the previous day was rainy. From the graph below, the probability of rain (p_r), the probability of rain and previous day rainy (P_rr) and the probability that it rains and the previous day was dry is clearly shown for the whole year. It shows the First order counts, zero amounts and log of amounts.

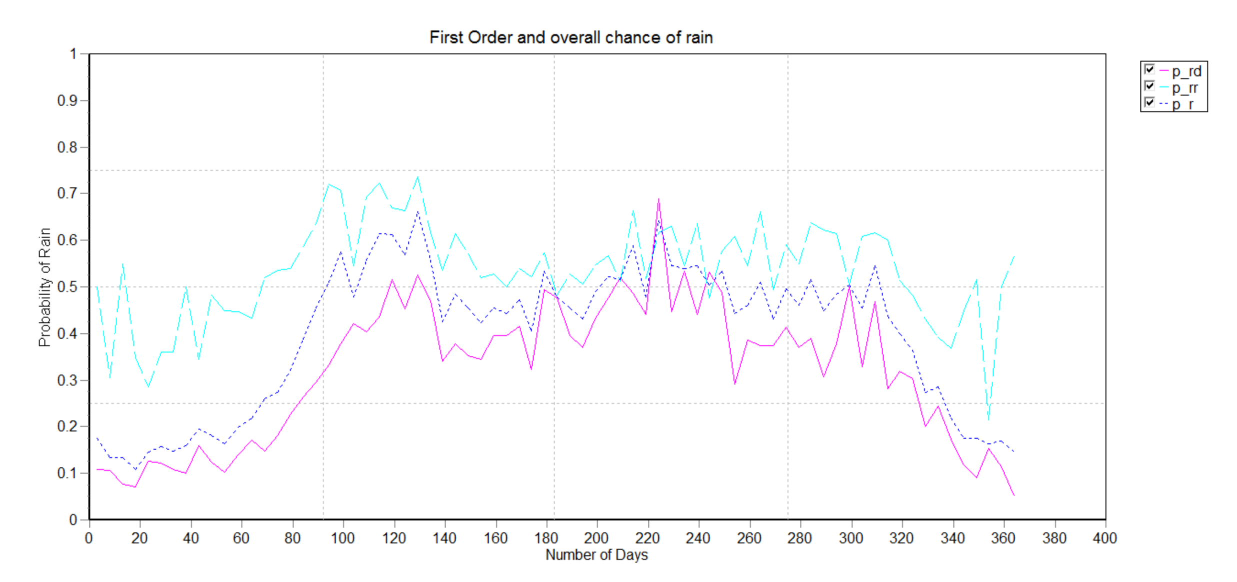

Figure 13: Showing First order and overall chance of Rain from 1983-2015

The chances of being rainy the following day and it was rainy the previous day increases exponentially from January till the end of April, i.e. 120 day (29 April), Compared to the probability of the rainy day and the previous day being dry and showing 3 harmonics throughout the year. The mean rain per rain day remains to be the same as in the Zero Order Markov chain model as shown in the Figure 14 below.

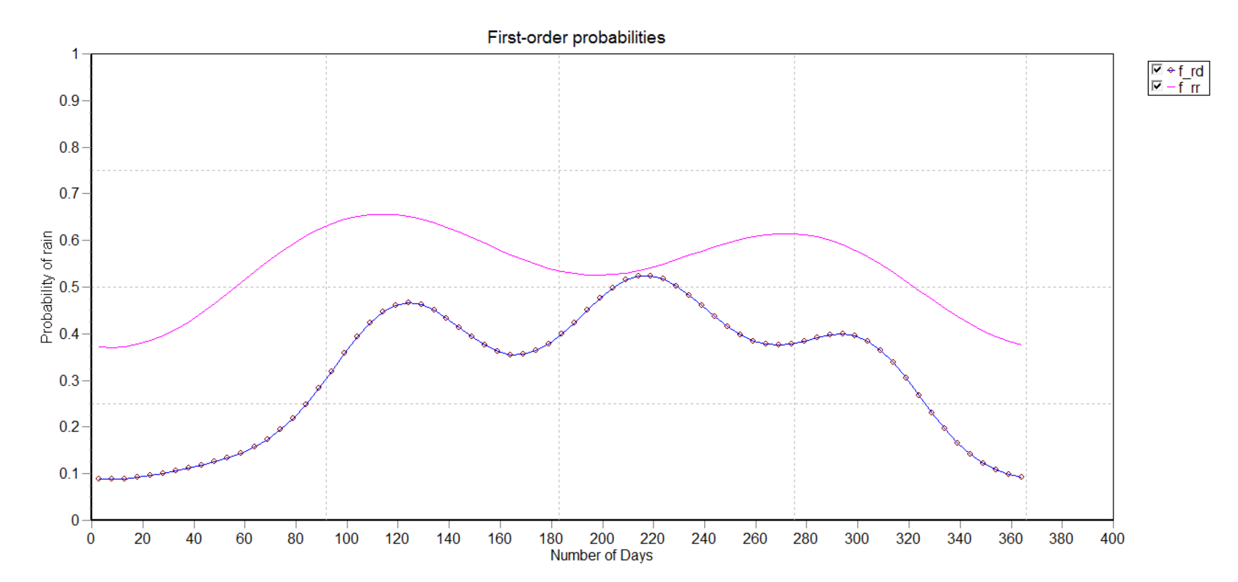

Figure 14: Showing First order probabilities from 1983-2015

The risk of 5 and 7 day long dry spells in 30 days is higher from November to February and it show 3 peaks in the whole year during the entire study period. The percentage estimations of the total weekly rainfall also do not change from Zero order Markov chain model.

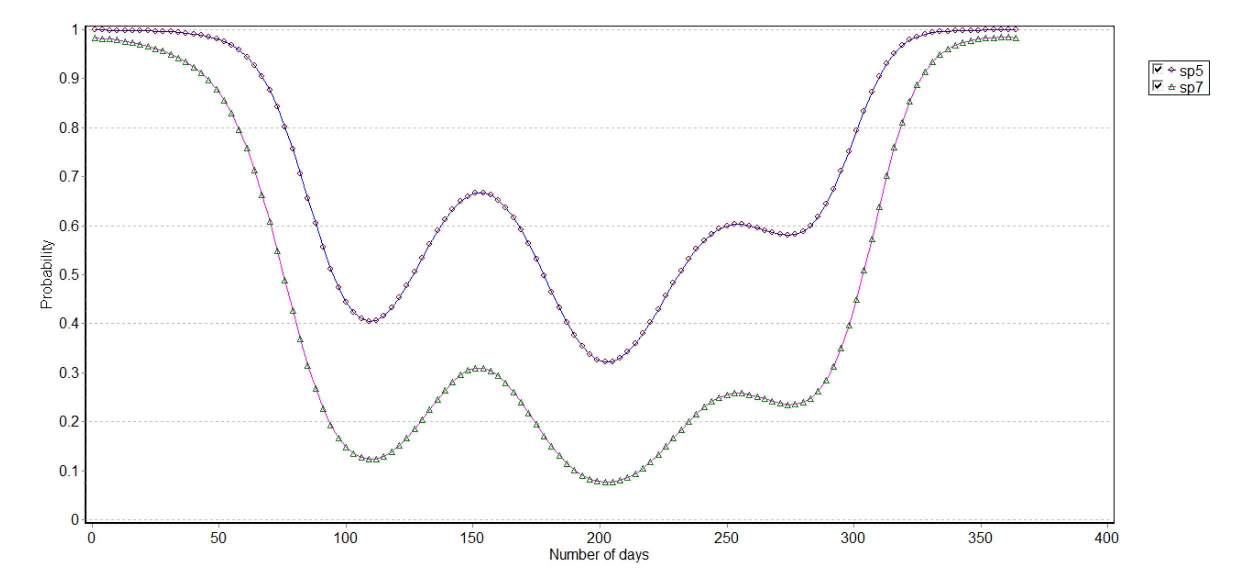

Figure 15: The risk of long dry spells in 30 days from 1983-2015

4.4.2 Second Order Markov chain model

The second-order Markov chain memory extends to two days and not more than two days. This entails that the chance that it rains, the previous day was dry and also the following day was dry. The day can be defined as dry if the rainfall was below 0.85mm, the previous day also being dry does not change the probability that the following day it will rain. The mean rain per rain day, the percentage of weekly totals of rain in the second order Markov chain do not change from the previous Zero and First Markov chain models as shown in the Figures 16 & 17 below .

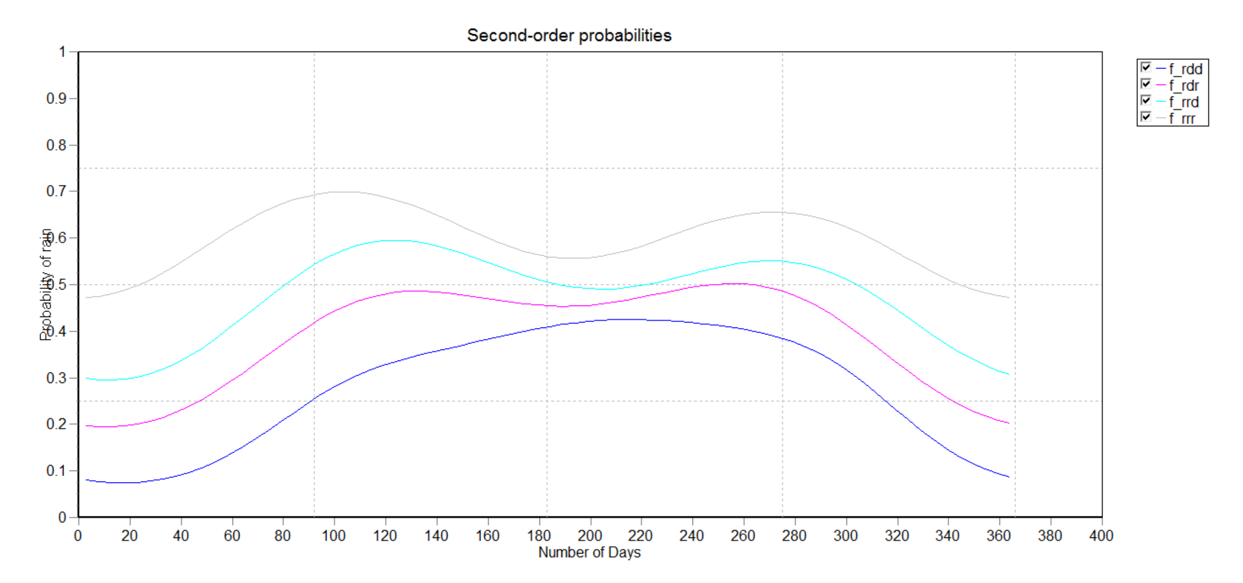

Figure 16: Second order probabilities and chance of rain from1983-2015

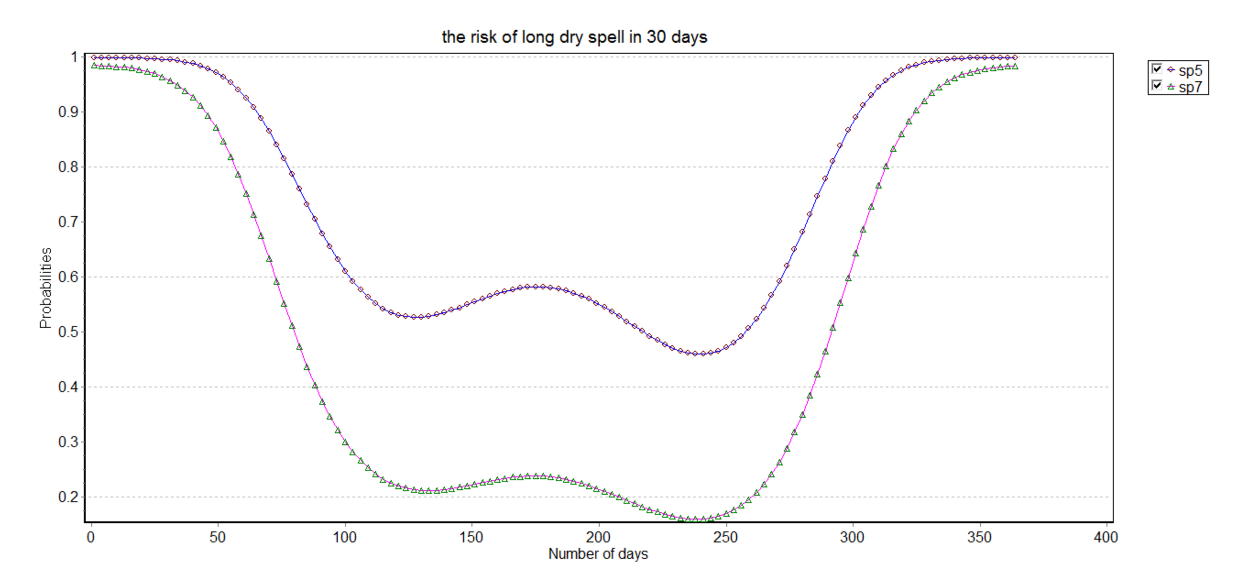

Figure 17: The risk of dry spells in 30 days from 1983-2015

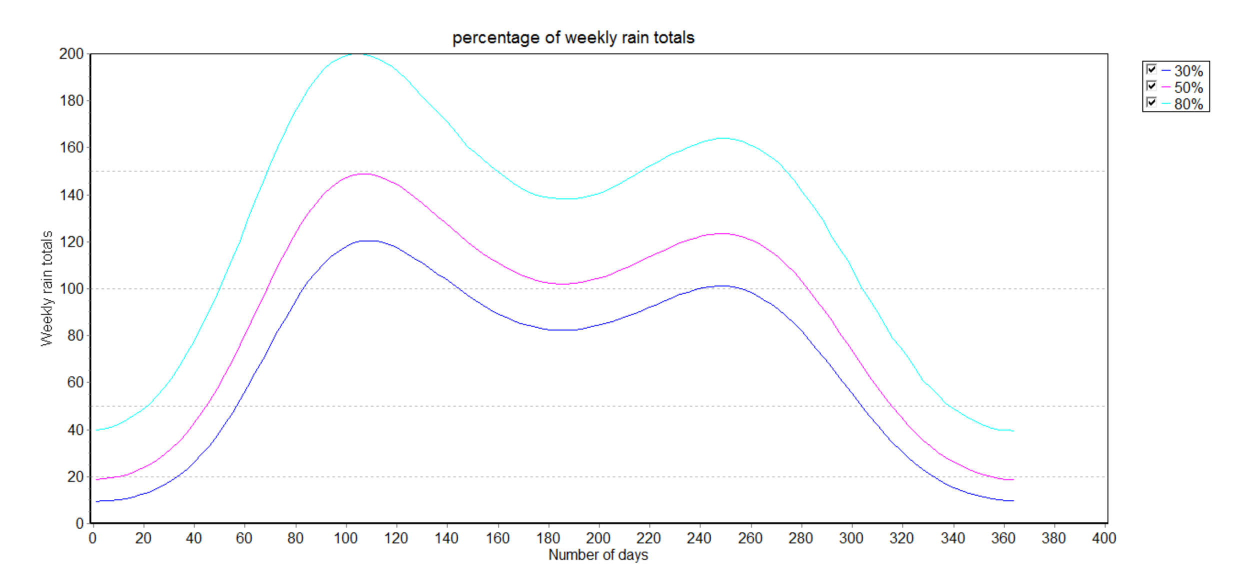

Figure 18: Percentage of weekly rain estimates from 1983-2015

Annual dry spells

The trend of annual dry spell lengths increases with time and the highest year with the highest dry spells are 1992, 1994, 2012 and 2015 each having a dry spell of 30 day dry days as shown in the table 1 and figure. In the 1983, the start of dry spell begun in 1982 that's why the instat cannot count how many dry spells have been there before 1983. The trend increase was found to be 0.2 dry spells per year.

Table 1: Annual dry spell lengths

Year	Annual Spell Lengths
1983	*
1984	21
1985	16
1986	22
1987	19
1988	7
1989	25
1990	12
1991	16
1992	30
1993	5
1994	30
1995	17
1996	6
1997	22
1998	2
1999	14
2000	21
2001	10
2002	9
2003	17
2004	13
2005	25
2006	13
2007	22
2008	17
2009	24
2010	9
2011	16
2012	30
2013	19
2014	20
2015	30

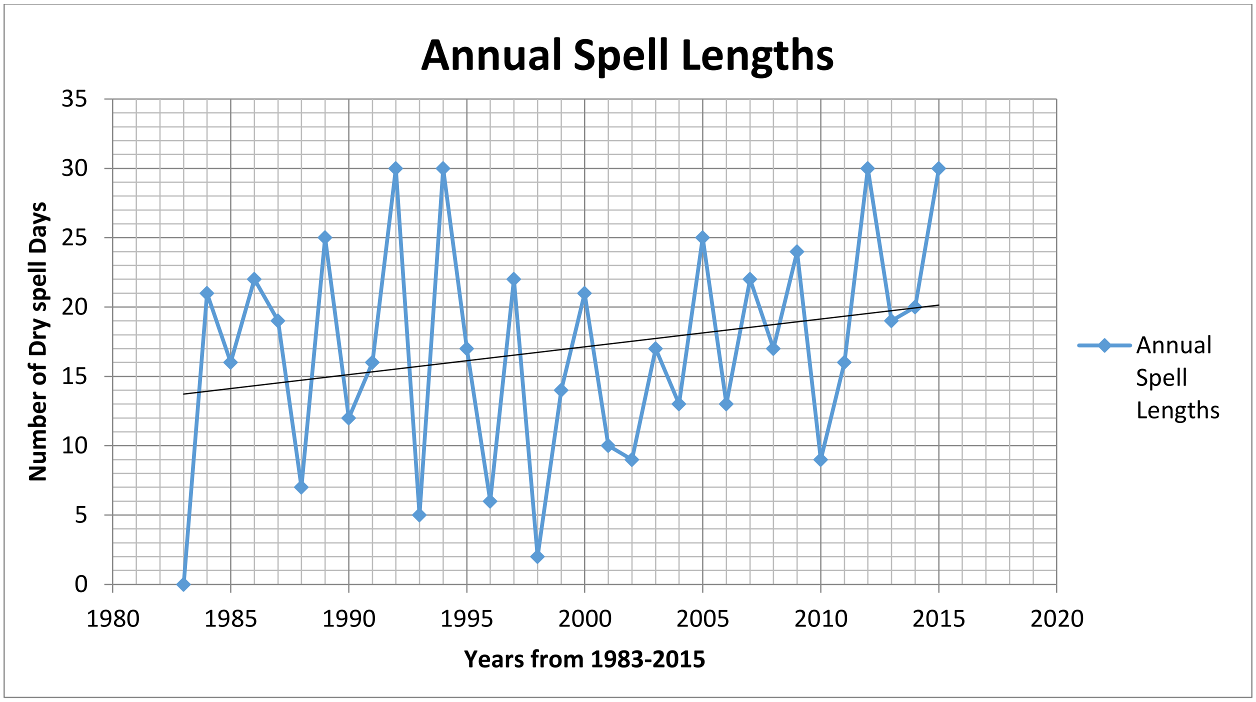

Figure 19: Annual dry spells from 1983-2015

4.4.3 Seasonal Risk of Dry spells from May to August

It was observed that the length of dry spells increases exponentially from mid-May to mid-July. The 5 day long dry spell having the high chances of occurrence than its counterpart 7 day long dry spell. The 5 day long dry spell has a probability of 0.55 to occur during the season compared to 0.2 probability of 7 day long dry spell. The figure 17 and 18 below shows the risk of a long dry spell from May to August.

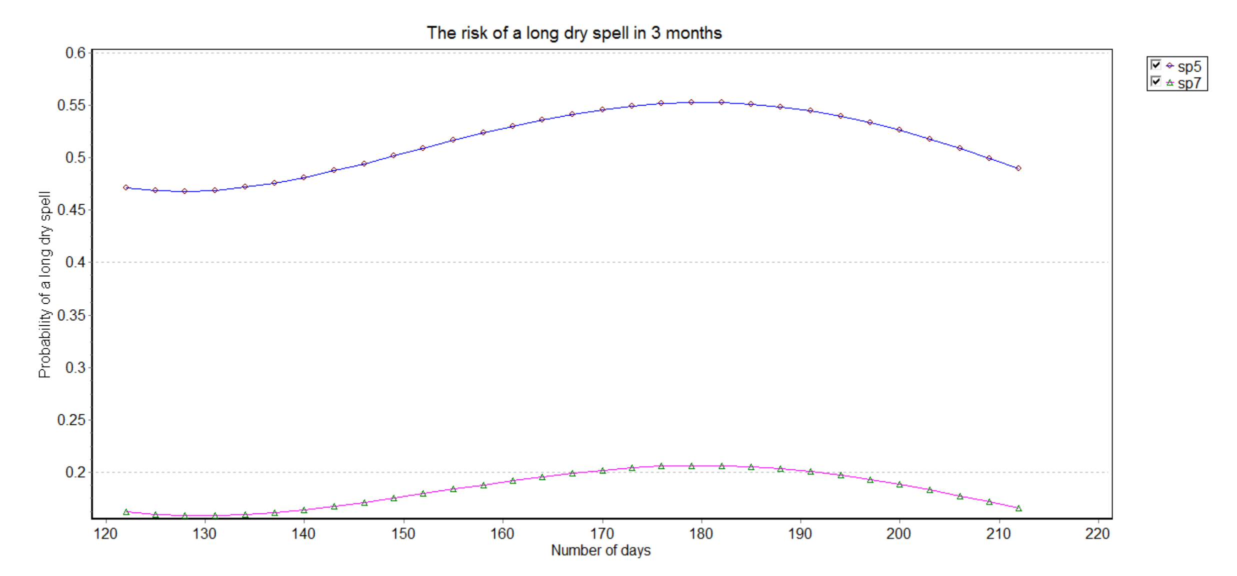

Figure 20: Seasonal risk of a long dry spell from May to August from 1983-2015

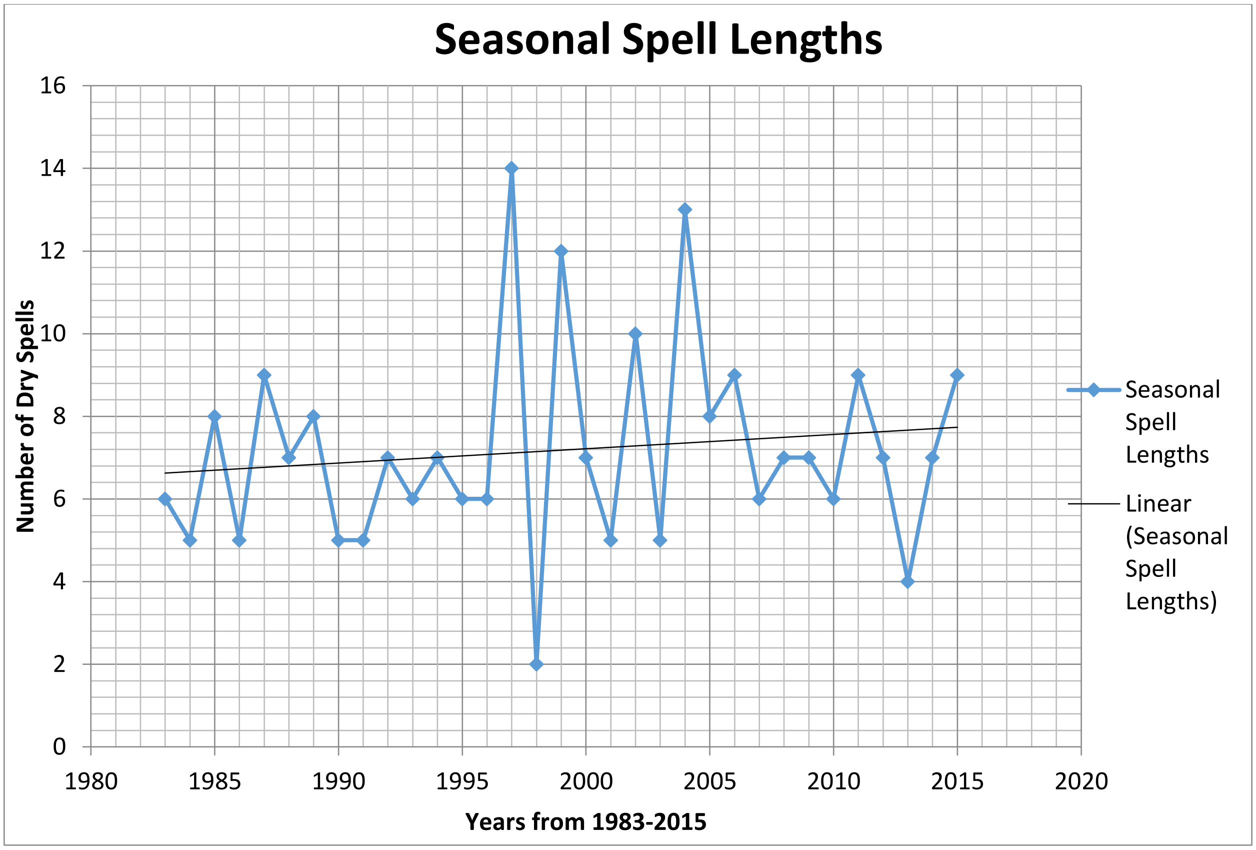

Figure 21: Seasonal spell lengths from May to August from 1983-2015

Table 2: Seasonal Dry spell lengths

Year	Seasonal Spell Lengths
1983	6
1984	5
1985	8
1986	5
1987	9
1988	7
1989	8
1990	5
1991	5
1992	7
1993	6
1994	7
1995	6
1996	6
1997	14
1998	2
1999	12
2000	7
2001	5
2002	10
2003	5
2004	13
2005	8
2006	9
2007	6
2008	7
2009	7
2010	6
2011	9
2012	7
2013	4
2014	7
2015	9

In terms of model testing, the number of dry spell days was anomalized and also the maize yield. This was then fed into a contingency table with a training period from 1984-2005, i.e. 22 years.

The results showed that the model was accurate with a percent correct of 54.5% and HSS of 0.319 that means it was better of than climatology. The results are as shown in the Table 3 below and the values and in the figure 22 showing the observed and the predicted maize yield.

Table 3: Contingency table for Training period (1984-2005)

		FORECAST			
		B	N	A	M-Totals
OBSERVED	B	3	1	0	4
	N	2	5	6	13
	A	0	1	4	5
	M-Totals	5	7	10	22

PERCENT	54.5	B	N	A
POST AGREEMENT		60	71.4	40
FAR (%)		40		60
POD - HIT RATE (%)		75	38.5	80
BIAS		1.25	0.54	2
CSI		0.5	0.33	0.36
HSS		0.319		

Table 4: Verification period(2006-2014)

		FORECAST			
		B	**N**	**A**	**M-Totals**
OBSERVED	**B**	**0**	**0**	**1**	**1**
	N	**3**	**2**	**1**	**6**
	A	**0**	**0**	**2**	**2**
	M-Totals	**3**	**2**	**4**	**9**

PERCENT CORRECT	**44.4**	**B**	**N**	**A**
POST AGREEMENT (%)		**0.0**	**100.0**	**50.0**
FAR (%)		**100.0**		**50.0**
POD - HIT RATE (%)		**0.0**	**33.3**	**100.0**
BIAS		**3.00**	**0.33**	**2.00**
CSI		**0.00**	**0.33**	**0.50**
HSS		**0.224**		

It was observed that during the training period the percent correct was 54.5% while the verification period was 44.4%. Although the there was a decrease in percent correct the model was good for prediction. The HSS was 0.224 thus better off than the climatology.

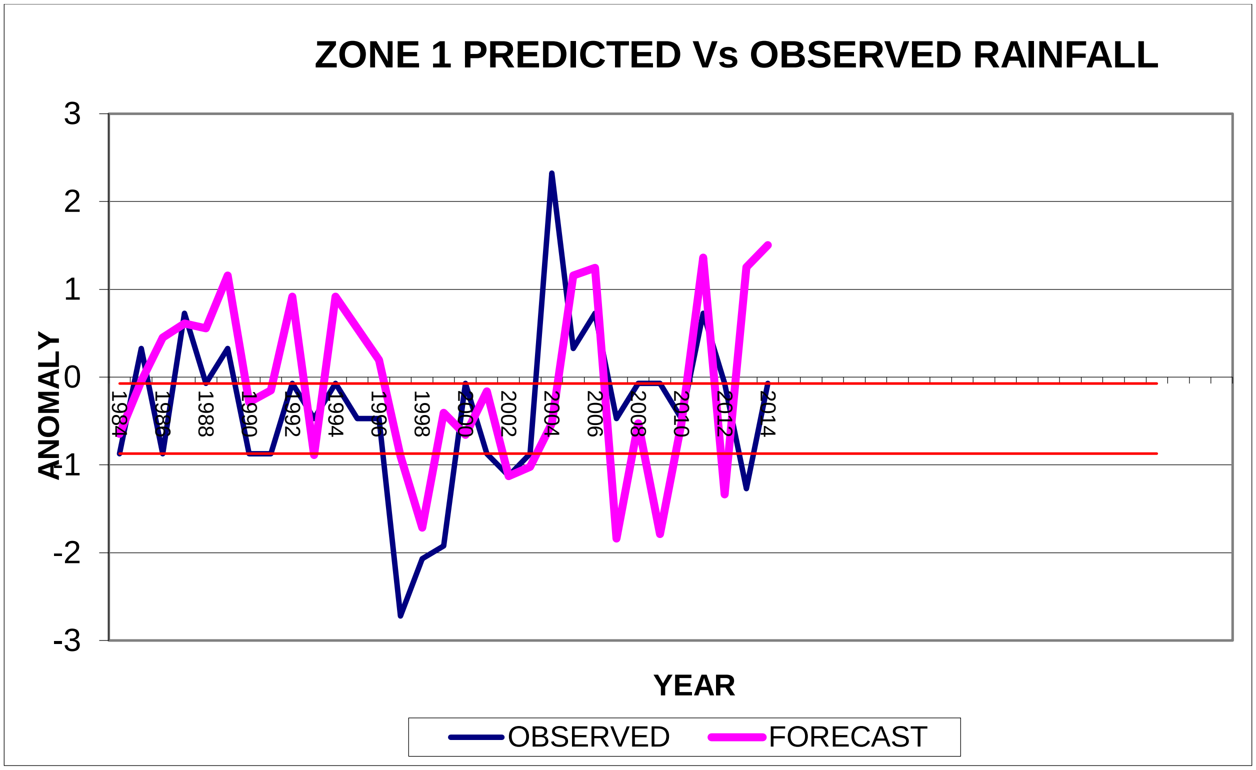

Figure 23: observed and forecasted maize yield.

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

5.1 Summary

The main objective of this study was to analyze the trend and intensity of dry spells and its effect on maize yield. From the results in chapter four, it was noted that the trend of dry spells increases both annually and seasonally. Trans Nzoia County receives rainfall during March, April and May (MAM) and October, November and December. The amount of Rainfall received during the plant growing period is much more important and should be well distributed throughout the plant season.

This is also shown on the crop phonological stage and the water requirement of the Maize crop. More water is needed during the developing stage and thus if a dry spell of more than 0.85mm in 5 consecutive will have an adverse impacts on the Maize crop leading to lower yields. Maize crop is usually grown on the onset of long rains which tends to decrease in quantity from as early June to mid-July during which Maize crop needs more water for growth and flowering.

Trans Nzoia County usually experiences long dry spell of 5 and more days. Although in some years like 1992 and 1994, the yields produced in tons/ha was nearly equal the annual dry spell was 30 days each but the seasonal dry spell was 7 and 6 days respectively. The maximum dry spell was in 1997 with dry spell length of 14 days and the Maize yields was 2.5 tons/ha. This good yield was properly accounted by good timing of planting period which utilizes the available water in the soil maximal.

5.2 Conclusion

It is evident from this study that maize yield is highly affected by the occurrence of dry spells in a certain critical phenological stage of growth i.e. crop development stage and mid-season stage. The occurrence of long dry spell during this stage, will lead to poor yields due to wilting and dying of the maize crop.

In this study, there was a major relationship between the Maize yields and the dry spells experienced during the growing season. From the results, it was observed that annual dry spell and seasonal dry spell plays a vital role in crop production.

5.3 Recommendation

I suggest that further studies to be carried out on the role of dry spells in critical phenological stage, water requirement for the Maize crop during each of the growth stages. i.e., initial stage, development stage, mid-season and late season stage. And also considering the soil moisture and the rate of evapotranspiration.

Advanced studies should also be carried out to find influence of other factors like pests and diseases and fertilizer application on maize production.

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