CLIMATIC RISK MANAGEMENT IN RAIN-FED CROP PRODUCTION, TANZANIA

by

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DECLARATION:

This project report is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with my approval as university supervisor.

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DEDICATION

This work is dedicated to my little treasures; baby Gabriel (Gabi) and William (Willy). I thank them for their patients during my studies. "Gabi, you were just two months foetus (Oct-2012) when I started my studies. You tolerated all the hassle and late sleep when I prepared for exams and you were patient even the time you needed rest". "Willy, you were just 4 years (2012) when I left home to studied". I was always lying to you telling that I'm going to work and I will be home in two hours time but I went away for some months, but you were very patient to me. Thanks you all and I wish all the best in your lives. May the Holy Spirit protect you all from all the evils and grant you all an everlasting prosperity future life. Amen.

Yours lovely Mom

Pamela

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ABSTRACT

Rain-fed crop production is one of the dominant farming practices in developing countries and plays a major role in providing food and livelihoods for an increasing world population. In recent years climate related risks on crop production has become the centre of concern in rain-fed areas because losses from climate-related risks are rising. Limited understanding of the local climatic-related risks compromise better climatic risk management in rain-fed crop production system.

Site specific or tailored studies that address particular crop at a particular area have shown to minimize climate-related challenges and uncertainty. For the sake of local climatic challenges, this study carried out a study to identify local climatic risk, assess the effect of those risks to crop and biomass yield and suggest methods to minimize local climatic risks of groundnut production in central Tanzania.

The main objective of this study was to improve the understanding of agricultural project managers and extension officers on the effect of local climatic risks, with the aim to better manage climatic risk in crop production. To achieve the study objectives, there were three distinctive components in this study. The first components was to examine local climatic risks available in the study site, the second component examined the impact of selected local climatic risk to biomass and crop yield, and the third component explored options to minimize local climatic risk using climatic data.

In the first component, Instat statistical package was used to analyse local climatic risk named planting date, raindays, length of the season, and dry spell length variability including temperature extremes. In the second component, the Agricultural Production Systems Simulator (APSIM) was used to assess the impact of different planting dates to biomass and groundnut yield. In the third component, Statistical package Instat was used to address options to minimize local climatic risks by

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calculating the risks of replanting or crop failure and box plot analysis for different planting date and seasonal length variability.

The analysis of the first component found that climate variability is a major challenge and was measured by standard deviation and R-squared values. The second component observed more yields to planting dates that has minimum variability. The third component observed reduction of local climatic risks by up to 30% by changing management practice (apply planting date with minimum variability).

This study concluded that local climatic risks are very unique and affect crops at various stages of development. Local climatic risks if not well understood are potential to decrease yield hence compromise efforts of increasing crop production by farmers and other key stakeholders such at crop researcher, extension officers and insurance companies.

Further studies are needed to identify multiple climatic risks with spatial analysis. Analysis of the impact of individual risks should be done for each crop because each crop impacted different by different risks. There is a need for further study on other interventions on how to minimize local climatic risks to improve yield, and further studies is needed on communicating local climatic risks with key stakeholders with the aim to update new interventions to local farmers.

LIST OF ABBREVIATIONS

APSIM   Agriculture Productions System Simulator

CRM   Climatic risk management

Def_11   The first occasion with more than 15 mm in a three day period after first November and

Def_22   Def_11 with the addition of no dry spell of 12 days or more within the following 30 days

Def_33   Def_11, but after the first of December

Def_44,   the same as Def_22 but after the first of December

R-Squared   Regression Squared

STD Dev   Standard Deviation

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1. CHAPTER 1: INTRODUCTION

1.1 BACKGROUND INFORMATION

Rain-fed crop production is one of the dominant farming practices in developing countries and plays a major role in providing food and livelihoods for an increasing world population (Sivakumar, Das & Brunini 2005). The global rain-fed crop production system currently provides 60 percent of the world's food supply. Eighty percent of the agricultural land worldwide is rain-fed, with generally low yield levels and high on-farm water losses. This is true, especially in sub-Saharan Africa whereby nearly 90 percent of staple food originates from rain-fed farming systems (Cooper et al. 2008). Ninety-five percent of current population growth occurs in developing countries and a significant proportion of these populations still depend on a predominantly rain-fed-based rural economy (Sivakumar, Das & Brunini 2005).

In recent years climate related risks on crop production has become the centre of concern in rain-fed areas because losses from climate-related risks are rising. Climatic risks significantly have setback economic by years, if not decades. For example, between 1980 and 2007, nearly 7500 natural disasters worldwide produced economic losses estimated at over 1.2 trillion US dollars. Of this,78 per cent of economic losses were caused by climate related risks such as droughts, floods, windstorms, tropical cyclones, storm surges, extreme temperatures, landslides and wild fires (World Meteorological Organisation 2013). This is worse in developing countries especially in crop production where drought is a very limiting factor (Intergovermental Panel on Climate Change 2001).

The risk posed by the climate is unique. The most distinguishing characteristics of climatic risk could be linked to its span across long periods of time beyond the scales that human systems use in planning. In rain-fed areas, climatic risks are the most prominent random parameter beyond farmers' control. For example, rainfall is both a

critical input and a primary source of risks and uncertainty regarding production outcomes because it has become less predictable (Sivakumar, Das & Brunini 2005). Whilst seasonal rainfall totals and season-to-season variability are important, the nature of 'within season' variability can have a major effect on crop productivity and the patterns have become more irregular. If climate change is going to affect rainfall variability, ultimately it can affect crop production. Also the distribution of rainfall may induce risk and this could affect crop growth and final yields (Cooper et al. 2008).

It has been observed that different climatic risk may pose the same impacts but not all climatic risks are created equal (Jones 2012).There is also too little information on the exact nature of the full risk as climatic risks are evolving and our understanding needs to improve over time. There is a need for further studies on the understanding climatic risks and their influence on crop production, and this could be the first step in managing climatic risks.

The analysis on previous study on managing climatic risks on crop production showed that climatic risks uncertainty is the major concern in managing climatic risks. Different climatic risks impact crops differently in different locations. Site specific or tailored studies that address particular crop at a particular area have shown to minimize local climatic risks challenges and uncertainty. For the sake of local climatic challenges this study carried out a study to identify local climatic risk, assess the effect of those risk to crop and biomass yield and suggest methods to minimize local climatic risks of groundnut in central Tanzania.

1.2   PROBLEM STATEMENT

The problem statement to this study was that limited understanding of the local climatic risks compromise better climatic risk management in rain-fed crop production system. This implies that different climatic risks may affect crop yield differently. There is a need to understand the contribution of individual risks and this

could help in better climatic risks management. For example, the understanding of planting dates that consider minimum dry spell could be a starting point of better managing climatic risks.

1.3   THE OBJECTIVE THE STUDY

The main objective of this study was to improve the understanding of agricultural project managers and extension officers on the effect of local climatic risks, with the aim to better manage climatic risk in crop production. Climatic risks management brings the primary benefits of producing more per small unit land hence addressing food insecurity and land conservation in rural areas (Humphreys et al. 2008). For example producing more under multiple climatic risks (the effect of short seasons, the advantage of long season, rainfall variability, temperature variability, planting dates, and dry spells), which affects stages of individual crop growth hence influencing crop yield. This study also can bring secondary benefits, such as helping crop insurance agencies to prepare multiple indexes for insuring crops rather than continue with the current trend of just looking at the drought index only (Taylor 2007).

The specific objectives include;
1. to identify local climatic risks in the study area,
2. to quantify the influence of local climatic risks to biomass production and grain yield, and
3. to explore how to minimize local climatic risks using climatic data.

The research questions to this study were:
1. what are local climatic risks available in the study area?
2. What are the influence of local climatic risks to biomass production and grain yield?, and
3. how to minimize local climatic risks using climatic data?

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CHAPTER 2: LITERATURE REVIEW

In everyday lives human or human activities are surrounded by some risk, but some are much more risky than others. Before embarking on the understanding of climatic risks in the context of rain-fed crop production and what constitute managing climatic risks in crop production, it is worth elaborating definition and concept of risk, climate, climatic risks, and the history of climatic risks management.

The concept of risk appears to be unique to humans apart from the animal kingdom due to the ability to exercise rational thought. Our unique mental capabilities enable us to apply information from the past, react to the present, and plan for the future. Risk may be defined as unwanted event which may or may not occur. It may also be defined as the probability of an unwanted event which may or may not occur; or the statistical expectation value of unwanted events which may or may not occur (Hanssson 2012). A risk is an uncertain event or condition that, if it occurs, will have a negative or positive effect on the intended objectives. Risks in any activities may be seen as threats or opportunities. The latter means that taking a calculated risk may bring, For example, competitive advantage for a production or organization. If there are benefits associated with an opportunity, then one can take certain degrees of risk for the production or organization activity to be successful (Jones 2012).

Risk is also defined as the potential that a chosen action or activity, including the choice of inaction could lead to a loss or an undesirable outcome. The notion implies that a choice having an influence on the outcome sometimes exists or existed. Potential losses themselves may also be called 'risks'. Risk is seen as a probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through pre-emptive action (Jones 2012). In all these definitions, it is apparent that the risk involves the probability factor and the loss factor. Also risk can also be an opportunity in the context of crop production, and not only losses as always over emphasised. Let's also

elaborate the term climate before we come into the understanding of what constitute climatic risks.

The term climate refers to the average weather conditions and their ranges expected at some location or region and time of the year. This includes the mean values of variables such as the temperature precipitation humidity cloudiness, pressure, wind, visibility, and air quality together with their variability and extremes. The state of the climate is determined collectively by local thermodynamic heating or cooling and energy transported by motions. The climate attributes such as ranges, variability and extremes mostly constitute fluctuations term, hence are more of concerns to various human economic activities, For example, in crop production, climatic fluctuations mostly composed of a random pattern which may poses risks to human activities if not well understood. These fluctuations are also considered in this study. In the following paragraph, lets explain what brings about climatic risk into details (Aguado & Burt 2007).

Many authors acknowledged the difficult to visualize what constitutes climatic risk. According to (Prabhakar & Srinivasan 2009), climatic risk constitutes the probability of a drought or flood to happen and the result in terms of impacts such as loss of agricultural production, damage to infrastructure, animal and human loss. Since climate is changing and since such changes cannot be anticipated with the current level of understanding local climate system, then uncertainty involved in such changes could lead to anticipatory adaptations which may turn out to be maladaptation. For example, if farmers anticipated that the rainfall will continue to decline and adapted to grow upland crops with less production potential, and if such changed do not happen, the decision of selecting upland cropping systems could be considered as a maladaptation (Prabhakar & Srinivasan 2009).

The risk posed by the climate is unique. The most distinguishing characteristics of climatic risk could be linked to its span across long periods of time beyond the scales that human systems use in planning. There is also too little information on the exact

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nature of the full risk, for example in rain-fed areas as climatic risks are evolving due to climatic change and our understanding needs to improves over time. Also different climatic risk may pose the same impacts but not all climatic risks are created equal (Jones 2012). Other author put forward that climatic risks are unique in the knowledge about probability and uncertainty in basic scientific principles of what define climatic risk, of which has not fully explored, with good examples in localized rural areas (Prabhakar & Srinivasan 2009). The figure below (Figure 1) shows the details on the wide classification of knowledge, ambiguity, ignorance and probability about climatic risks.
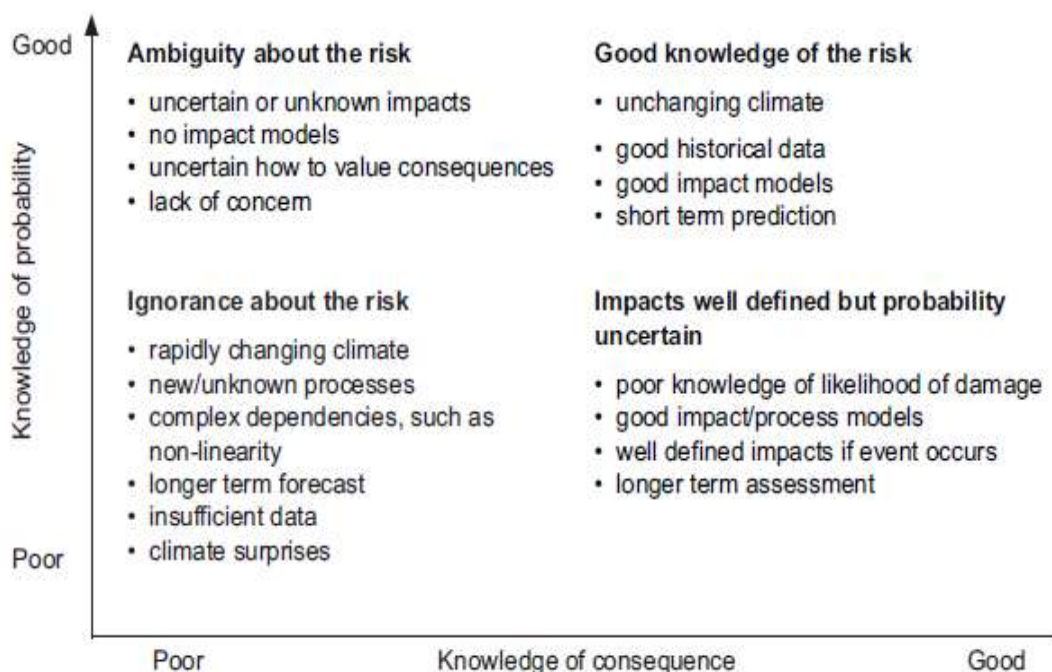
Figure 1: Climatic risks ambiguity

Source: (Chichilnisky 1998; Prabhakar & Srinivasan 2009)

From the figure above it is clear that climatic risk ambiguities, knowledge, ignorance, and probability uncertainty were concerns for this study. The understanding of local climatic risks and how they affect crop production is important in any risk management study, especially those studies targeting marginal communities. The Figure 1 above also showed that incomplete information about uncertainty of climatic

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risk makes it unique and distinguishing from other forms of risks such as environmental degradation being faced by the humanity today. For example, ignorance about changing climate could arise from partial understanding of the local current climatic risk, which included uncertainty about the future risks. The ambiguity about climatic risk should not be taken as an excuse for not dealing with climatic risks. The acknowledge of uncertainty associated with climatic risk is important hence making decision making process transparent and the local community become well informed about the choices made in managing climatic risks.

Risk management is not a new technique or concept. It has been around since humans first started to walk on Earth. Even though it is getting a considerable amount of attention today, the practice of risk management is a very special characteristic of people that hasn't changed over the millennia. What has changed are the data and the methods we apply in this concept (Jones 2012). The world had experienced earthquakes and other large disasters before, but never in history were these and other horrific events broadcast and 'texted' in real time to people all over the world. Risk management is an old concept once was for intellectuals, gamblers, mathematicians, politicians but now it is a household term in many sectors.

Climatic risk management can be defined as (CRM) an approach to climate-sensitive activities and is increasingly seen as the way forward in dealing with climate variability and change and seeks to promote sustainable development by reducing the vulnerability associated with climatic risk. CRM involves proactive 'no regret' strategies aimed at maximizing positive and minimizing negative outcomes for communities and societies in climate-sensitive areas such as crop production, water resources and health. The 'no regrets' aspect of CRM means taking climate-related decisions or actions that make sense in development terms, whether or not a specific climate threat actually materializes in the future (Taylor 2007).

Managing climatic risk in crop production is not a new activity. For example, in medieval England, a farmer's land was broken into many widely dispersed parcels.

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Economic historians interpret this as a way of hedging climatic risk. Because land in different locations can be affected differently by droughts, floods and fires; by spreading landholdings over different regions and by buying insurances; farmers have managed climatic risk for centuries (Taylor 2007).

In recent years climatic risk management has become the centre of concern because losses from climate-related risks are rising. Climatic risks significantly have setback economic by years, if not decades. For example, between 1980 and 2007, nearly 7500 natural disasters worldwide produced economic losses estimated at over 1.2 trillion US dollars. Of this,78 per cent of economic losses were caused by climate related risks such as droughts, floods, windstorms, tropical cyclones, storm surges, extreme temperatures, landslides and wild fires (World Meteorological Organisation 2013). This is worse in developing countries especially in rain-fed dependent community where drought is a very important limiting factor. Farmers in rural areas are marginalized in terms of infrastructure and ability to cope with climatic risks and impact because of low adaptive capacity (Intergovermental Panel on Climate Change 2001).
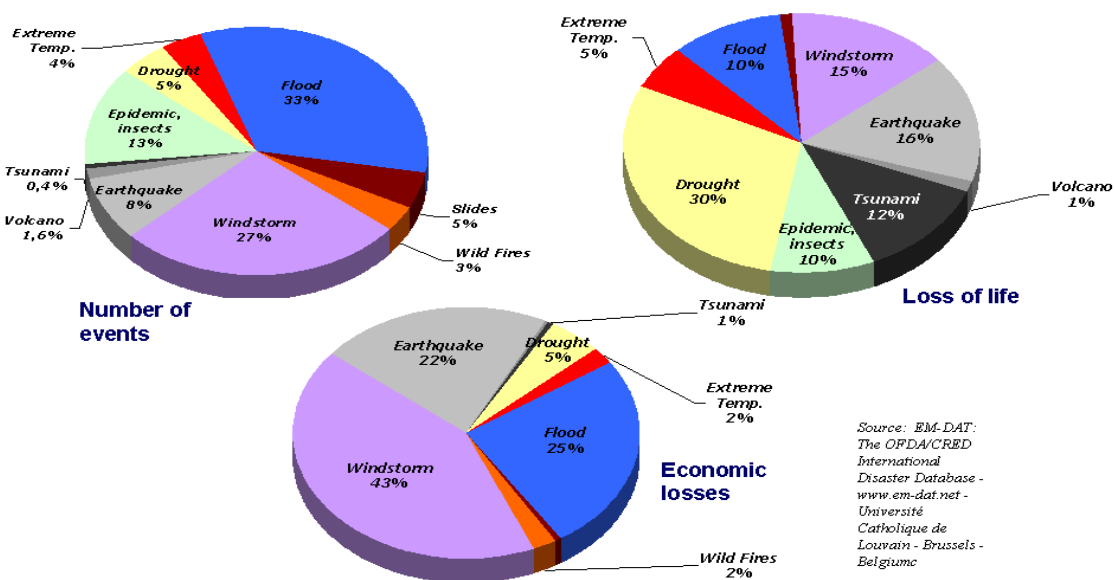

Figure 2: Comparisons of various disasters

Source: (World Meteorological Organisation 2013)

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Many authors have done studies on the effect of climatic risks on crop production (Cooper et al. 2008; Lobell et al. 2008; Semenov & Porter 1995; Shi, A Tao & A Zhang 2013; Viner, Morison & Wallace 2007). For example, Lobell et al. (2008) conducted a study on prioritizing climate change adaptation needs for food security in 2030 over the South Asia and Southern Africa using statistical tools and models and found that there is a negative impact on several crops that results from climatic risks and this could compromise food security in 2030. He also found that uncertainty in climatic risks vary widely by crops therefore climate change adaptation priorities depends on the attitude of the investment institution. The study did not indicate whether the production area is rain-fed or not, hence it is an opportunity for new study to investigate local climatic risk with the aim to quantify risks using crop models in rain-fed area.

Semenov & Porter (1995) conducted a study on climate variability and modelling of crop yields in UK and Frace using crop model for winter wheat to analyse sensitivity to changes in mean and climatic variable and found that changes in climate variability have a more profound effect to yield and associated risks than changes in mean climate. He also observed that many interatiction between crops and weather are non-linear and many models do not include climate variability in the analysis. They also suggest that stochastic weather generators could add value that allow capturing variability for the data rather than using mean values. He also suggested that it is necessary to preserve the variability of weather sequence in order to estimate the effect of climatic risks on crop production. This study is validy in the developed world where there is good acess to computing facilities but it could be difficult to subsaharan african countires where scarce and course data sets.

There is also agreement in many studies that crop models and statistical tools are providing good results in the analysis of the effect of climatic risks on crop yield but the researcher should be careful in selecting what type of tools to be used. (Shi, Tao & Zhang 2013) reviewed the performance of statistical models on climate contributions to crop yields and found that there are three main statistical methods; time-series

model, cross-section model and panel model, which have been used to identify such issues in the field of Agro-meteorology. Generally, research on spatial scale could be categorized into two types using statistical models; including site scale and regional scale. They identified four issues that need attention when using crop models. The issues included the extent of spatial and temporal scale, non-climatic trend removal, co-linearity existing in climate variables and non-consideration of adaptations. These are key issues that should be taken into consideration when using statistical models for addressing climatic risks management.

The analysis of previous study showed that climatic risks have impacts in crop production. Also the studies showed that climatic risks uncertainty is a problem in managing climatic risks. There is a proof that climatic risks impacts crops differently in different locations. There is a need for customized or tailored studies that address particular crop, at a particular area, that experienced multiple climatic risks uncertainty with the aim to minimize site local climatic risks. To address these challenges this study examined climatic risks available in the study site, their impacts in biomass and crop yields and ways to minimize local climatic risks of groundnut in Dodoma, Tanzania.

CHAPTER 3: METHODOLOGY

This chapter explains the research methodology that underpins this study. It is organised in four sub-sections. Subsection 3.1 gives the overview of this chapter; sub-section 3.2 explains the theoretical framework of this study; sub-section 3.3 clarifies the research design of this study and sub-section four give details of the method for data analysis and interpretation. The full details of this chapter are found in the following sub-sections.

3.1   OVERVIEW

This study sought to fill a gap of limited understanding of local climatic risks in local community with the main objective to better manage climatic risk in rain-fed crop production system. Climatic risks management brings the primary benefits of producing more per small unit land to address food insecurity in rural areas. For example, producing more under managing different climatic risks at a time such as understating and manage the effect of short seasons, the advantage of long seasons, rainfall variability, temperature variability, planting dates, and dry spells, which affects different stages of crop production hence influencing crop production. The main objective was achieved by:

1.   examined climatic risks available in the study site,
2.   their impacts in biomass and crop yields, and
3.   exploring different options to minimize local climatic risks using climatic data.

3.2   THEORETICAL FRAMEWORK

The theory of this work is centred on the science of climatology and energy balance. The term climate refers to the average weather conditions and their ranges expected at some location or region and time of the year. This includes the mean values of meteorological variables together with their variability and extremes. The variability

component of the climate is the major uncertainty in rural rain-fed crop production due to randomness of the weather events and this is the key source to climatic risks.

The incoming solar radiation is received from the sun by the earth via solar rays. The earth absorb incoming solar radiation depending on the receptor such as the nature of soil, vegetation etc. Different surfaces absorb solar radiation differently hence creates local climatology of a particular area. These local climatic risks may produce local impact in addition to the influence of the general circulation.

3.3   RESEARCH DESIGN

To achieve the study objectives, there were four distinctive components in this study. The first components was to identify the study site and data quality control, the second component examined local climatic risks available in the study site, the third component examined the impact of selected local climatic risk to biomass and crop yield, and the fourth component explored options to minimize local climatic risk using climatic data. The following sub-sections explain the details.

3.3.1   **The study site and data quality control**

This study used purposeful sampling design to select the area for this study. This was achieved by reviewing government documents to identify areas with rain-fed crop production system. Dodoma region was purposely selected because it falls under the selection criteria. It is located in semi-arid with unreliable rainfall pattern in the area and the recent observed drought conditions. Its geographical coordinates are 4° to 7° south, 35° to 37° east and altitude is 1120 m located in the central part of the country. The average annual total rainfall ranges from 300mm to 900mm for the past 30 years. The highest annual total was 934.6mm in 1998 and the lowest total recorded was 301.4mm. Dodoma has a unimodal rainfall receiving just one season per year. Minimum temperatures and daytime humidity are much lower hence most of the time moisture deficit is prevailing. The seasonal rainfall occurs from November to April.

Crop production and livestock keeping are the major agricultural activities in Dodoma region. The main staples grown in the region include sorghum, bulrush millet, cassava and maize, while major cash crops are groundnuts, sunflower, simsim and to a lesser extent castor, and pigeon peas. The study site is located at Kongwa district, 20 kilometres from Dodoma town were groundnut is the major crowing crop. Figure 3 shows the location of the study site.
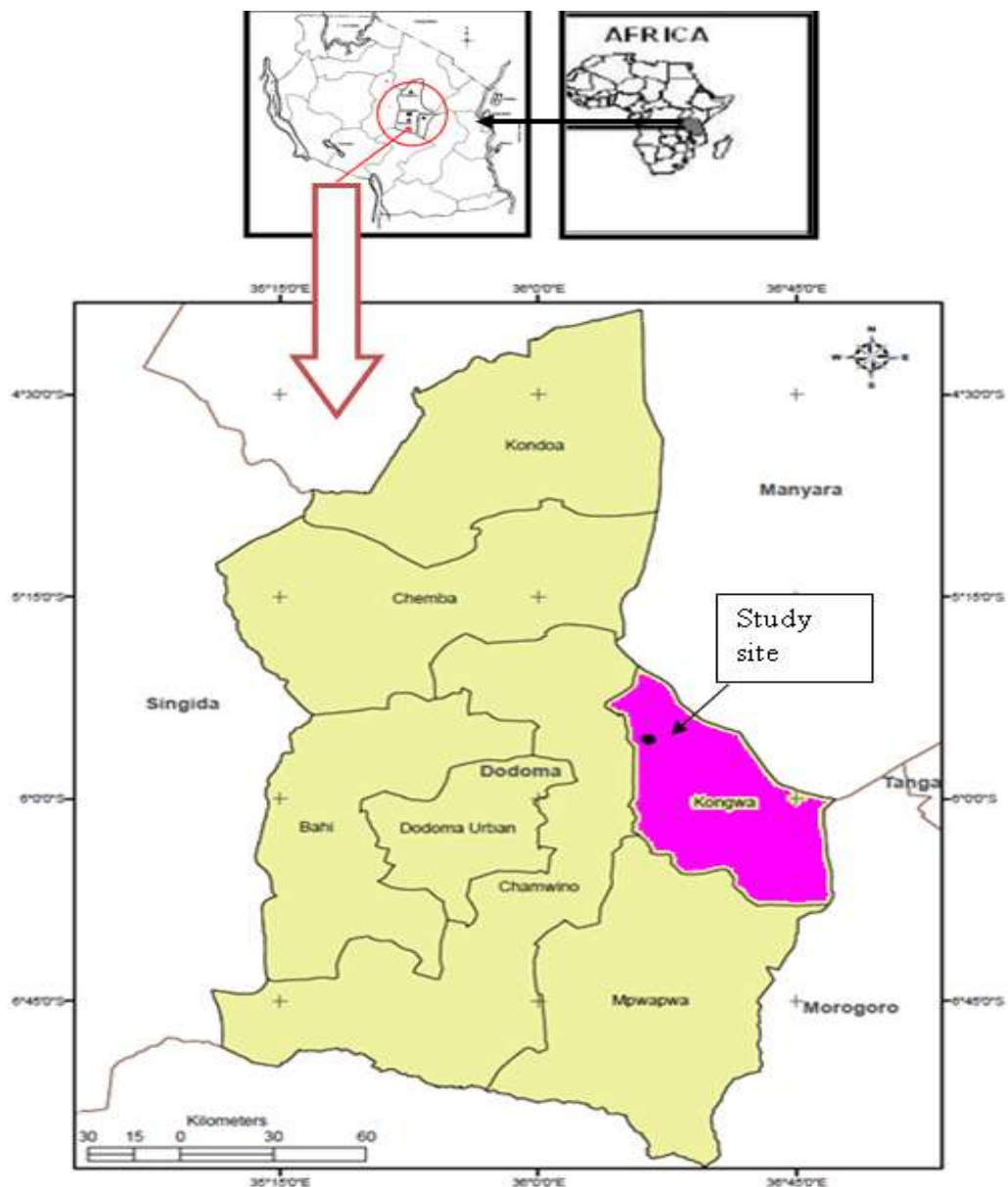

Figure 3: The map of Tanzania showing the study site in Dodoma Region

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Single mass curve was used to ascertain the quality of data. Cumulative plot for rainfall and temperature were plotted against time. R-squared values (also called the coefficient of determination) also calculated by assuming a linear trend line. R-squared value is a number from 0 to 1 and a trend line is most reliable when its R-squared value is at or near one.

3.3.2   Analysis of local climatic risks available in the study site

In answering the first research question, what are the local climatic risks available in the study area? Maximum and minimum temperature and Rainfall data from 1932 to 2010 was collected from Tanzania Meteorological Agency. The tool used in the analysis of local climatic risk included free statistical package Instat from Reading statistical centre. Statistical method was used to analyse local climatic risk named planting dates, raindays, seasonal length, dry spell lengths variability and temperature extremes. Also expert judgement and literature review of the study site aided the selection of the criteria for the onset of rainfall and planting dates as shown in the next section.

1.   *Determining planting dates and raindays*

Four definitions were set to compare. For early planting, Def_11 is the first occasion with more than 15 mm in a three day period after first November and Def_22 the same as Def_11 with the addition of no dry spell of 12 days or more within the following 30 days. For late planting, Def_33 is the same as Def_11, but after the first of December and Def_44, the same as Def_22 but after the first of December. Daily rainfall data from 1981 to 2010 was used in this analysis using instat software. The graphs were drawn using excel software showing planting date and raindays variability for the four definitions and a summary table from instat was extracted, which contain Minimum, Median, Maximum, standard deviation (STD) and Mean as shown in the Result Chapter.

2. *Determining seasonal lengths*

This study examined seasonal lengths for the four definitions. This involved the use of the definition for the end of the season to identify the end of the season for the four definitions. This study used analogous definition of Mupangwa et al (2011) in an analysis of data from Zimbabwe, which defined the end of the season as the last day before 30 June with more than 10mm rain. Daily rainfall data from 1981 to 2000 was also used in this analysis. The instat software was then used in this analysis. The end dates for the four definitions were then subtracted from the start dates to obtain the lengths of the seasons. The graphs were drawn using excel software showing length of the seasons variability for the four definitions, and a summary table, which contain Minimum, Median, Maximum, STD and Mean as shown in the Result Chapter.

3. *Determining dry spell lengths*

This study also examined seasonal dry spell lengths variability for the four definitions. This study chose to define a dry day as a day with rain less than 0.85 mm. This study opted to identify the length of the longest dry spell in January. The reasons for this is that in January most of the groundnuts are at the intermediate stage (flowering) and most of the times are affected by the dry spell hence compromise groundnut yield. Daily data from 1981 to 2010 was also used by instat software to extract the longest dry spell of January. The extracted dry spells day were then extracted to excel where a graph was drawn shown the longest dry spell length variability for the month of January. The graph is found in the Results Chapter.

4. *Determine temperature extreme*

The temperature exceeding $34.5\,^0\,C$ (which always considered danger), is not common in Dodoma was examined using daily data from 1981 to 2010 and instat software. Bar graphs were drawn using instat showing the months were extreme temperature is most expected and another graph show how often that extreme reappears in 30 years lengths. The results are found in the Results Chapter.

3.3.3 Analysis of the impact of selected local climatic risk to biomass and crop yield

In answering the second question; how are the local climatic risks affect biomass and crop yield? The Agricultural Production Systems Simulator (APSIM) was used for this analysis. It is a modelling device that has been developed by the Agricultural Production Systems Research Unit in Australia. APSIM was developed to simulate biophysical process in farming systems, in particular where there is interest in the economic and ecological outcomes of management practice in the face of climatic risk (Keating et al. 2003). The initial motivation to develop APSIM came from a perceived need for modelling tools that provided accurate predictions of crop production in relation to climate and other soil management factors, whilst addressing long-term resource management issues in farming systems. The main function of APSIM plant modules is to simulate key physiological processes on a daily time step in response to input daily weather data, soil characteristics and crop management actions. Of interest to this study was simulating the effect of different planting dates green biomass production and crop yield (Dimes & du Toit 2008).

Evaluation of model performance is important to establish local credibility of its simulation output. Analogous field experiment data was used to evaluate model performance. The simulation parameters were selected based on previous simulation in the same environment. The details of the experimental design and model validation can be found in (Dimes & du Toit 2008).

Data input to the model involved meteorological files which composed of monthly temperature, radiation, and rainfall from 1935 to 2010. Management files for African farmers in rain-fed condition came pre-loaded in the software. And this included African soil type equivalent to that of Dodoma. The four definitions of planting dates were then used in the model to examine the impact to the yield and biomass for the four definitions. The bar chart drawn is found in the Result Chapter

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3.3.4 **Options to minimize local climatic risk using climatic data**

In answering the third research question; how to minimize local climatic risks using climate data? The following sub-section explained the details.

1. *Percentage risk reduction of crop failure or replanting*

The percentage risks reduction of replanting or crop failure was determined by observing the length of the season with unmanaged risks (without considering dry spells) Def_11 and Def_33) comparing it the options to the length of the seasons that consider dry spell (Def_22 and Def_44). The seasonal lengths analysis obtained in the second stage of the methodology chapter were used in comparison. Multiple bar charts were drawn for Def_11 and Def_22 and for Def_33 and Def_44 respectively. The risk reduction of replanting or crop failure was determined as follows; for early planting was when Def_22 is longer than D_11. This was done by counting the numbers of years where Def_22 has got the longer season than Def_11 then the percentage of it was then calculated. The same procedure also was done for Def_33 and Def_ 44. The results presented in form of multiple bar charts and percentage of the length of the season of Def_22 longer than Def_11 and of Def_44 are longer than Def_33 respectively and are found in the Result Chapter.

2. *Box plot and standard error mean analysis*

The box plots for planting dates and seasonal lengths were drawn using instat. The standard error mean for planting dates was also determined. The results of these analyses are found in the Result Chapter.

3. *Daily data display analysis*

The daily data display for three decades from 1981 to 2010 was done to study the pattern of the start of the season, the dry spell, the extreme events and the length of the seasons. The instat software was used in this analysis. The results are found in the Result Chapter.

3.4   METHODS OF DATA ANALYSIS AND INTERPRETATION

The purpose of data analysis is to identify, interpret and describe the themes and patterns that emerge from the results (Boyce & Neale 2006). This study analysed results separately for each research questions. Interpretation of the results involved triangulation method, where by the results from each questions discussed together. Triangulation is a method used in qualitative and quantitative research to verify and establish validity of the study from multiple perspectives (Guion, Diehl & McDonald 2002). The linkages of results and literature are also made in the Discussion Chapter to substantiate the findings of this study to draw concrete conclusions.

CHAPTER 4: RESULTS

4.1 DATA QUALITY CONTROL

The figures below, Figures 4, 5 and 6 show single mass curves rainfall and temperature of Dodoma meteorological station from 1932 to 2012. The R⁻squared value for the mass curve fit is close to one for rainfall data and minimum temperature and one for maximum temperature and it is clear from the plots that the trend line is almost straight line indicating the data are homogeneity. The rainfall and Temperature data were therefore declared of good quality and hence suitable for climatological analysis.
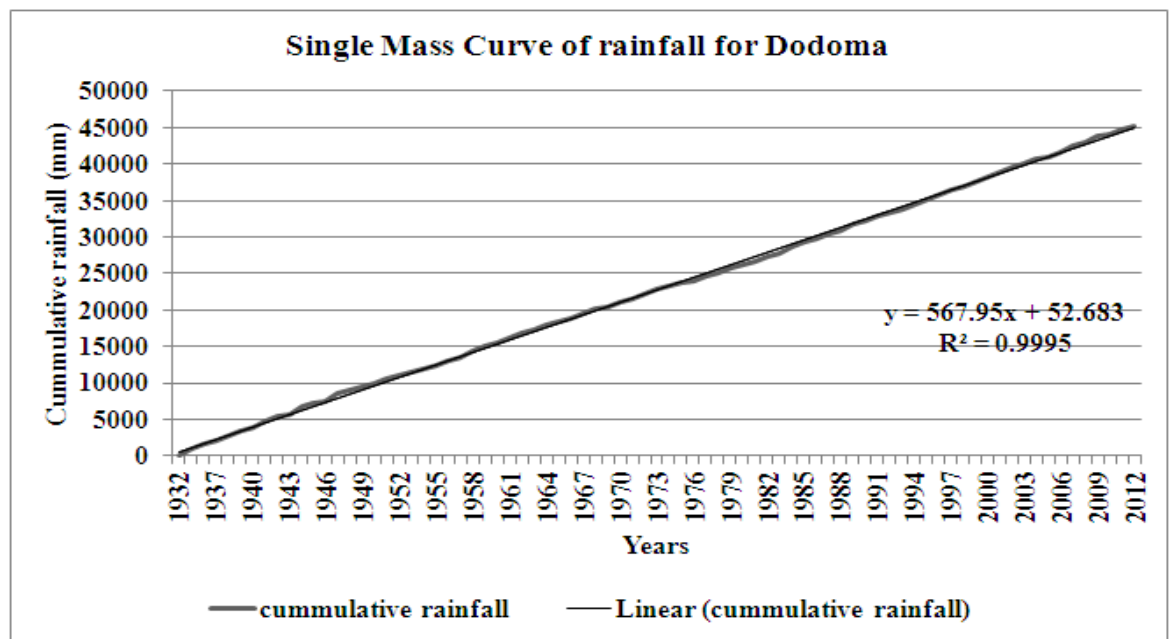
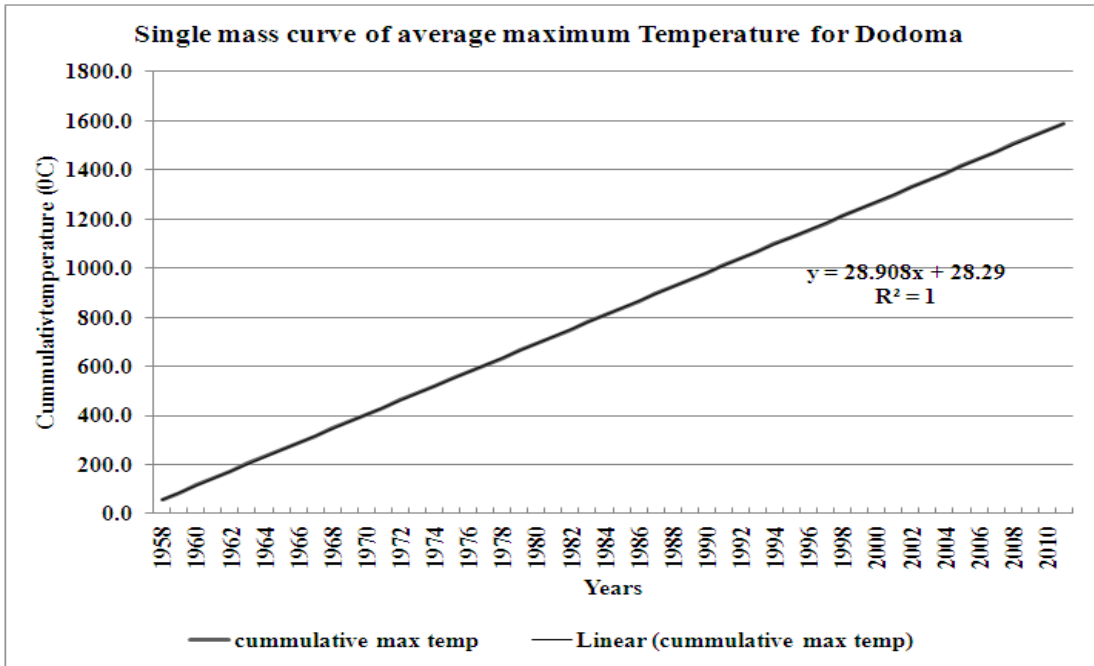Figure 4: Single mass curve of average annual rainfall for Dodoma from 1932 to 2012

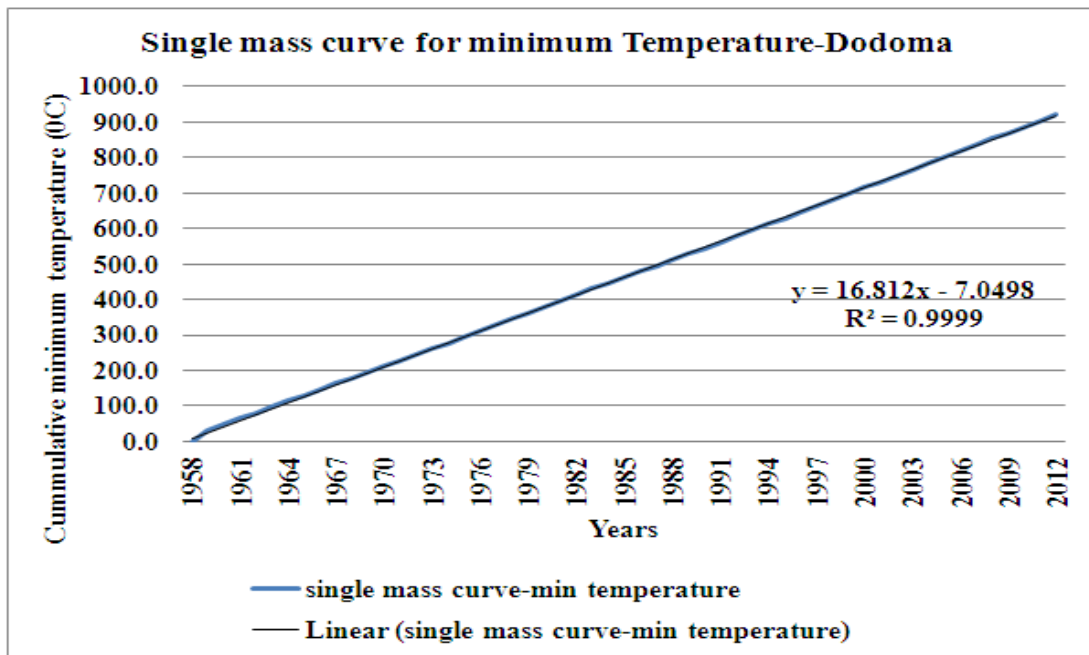Figure 5: Single mass curve of average maximum Temperature for Dodoma from 1958 to 2010

Figure 6: Single mass curve for average minimum temperature of Dodoma from 1858 to 2012

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4.2 ANALYSIS OF LOCAL CLIMATIC RISKS AVAILABLE IN THE STUDY SITE

Below are results on the analysis of local climatic risks available in the study site.

1. *Planting dates and rainday variability for the four definitions*

The planting date variability for Def_11, Def_22, Def_11, and Def_44 is shown in Figures 7, 8, 9, and 10 respectively. The figures predict high level of variability with very low number of R-square indicating no general relationship of the start of rainfall from year to year. Also there are weak signals of rising trend line except in Def_33 indicating late planting in recent years compared to previous years. Figure 7 below shows planting date variability for Def_11 from 1981 to 2010.
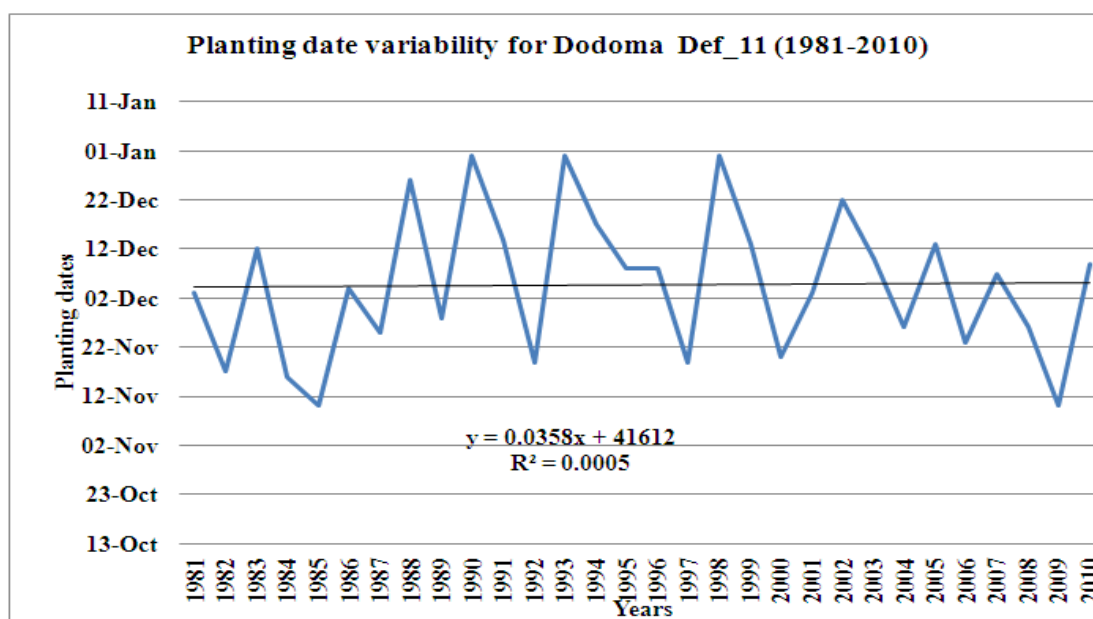

Figure 7: Planting date variability for Dodoma in Def_11 from 1981-2010

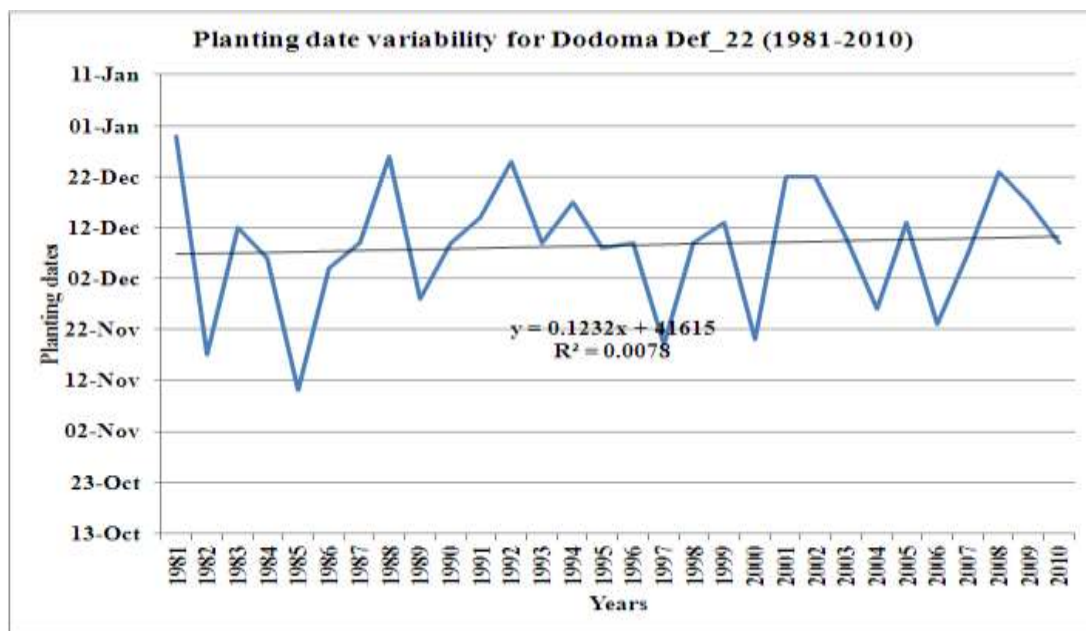Figure 8 below show planting date variability of Dodoma study site for Def_22 from 1981-2010.

Figure 8: Planting date variability for Dodoma in Def_22 from 1981-2010

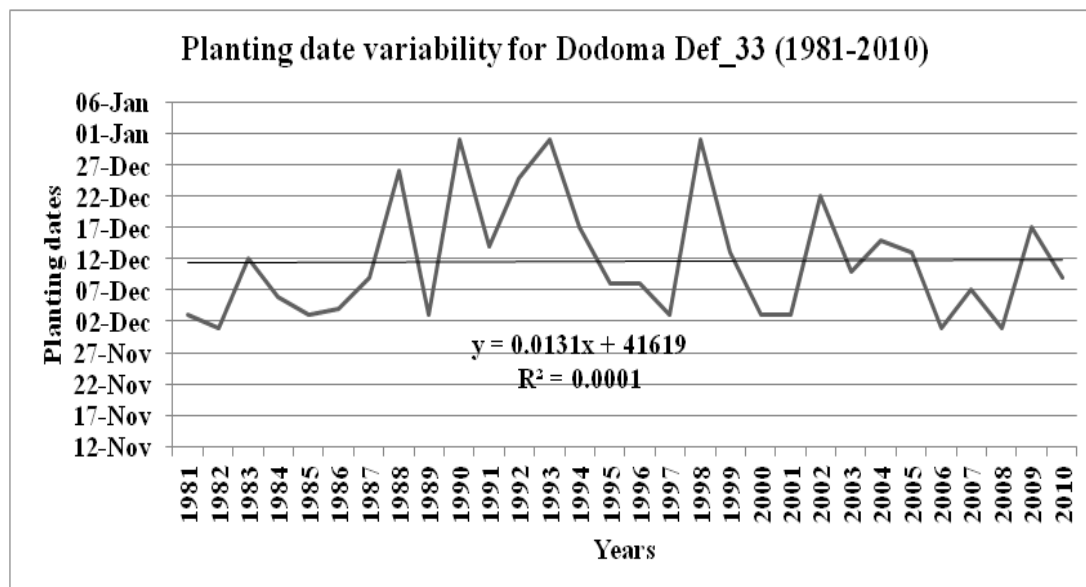The figure below is planting date variability for Dodoma in Def_33 from 1981to 2010.

Figure 9: Planting date variability for Dodoma in Def_33 from 1981-2010

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Figure 10 below is planting date variability for Dodoma in Def_44 from 1981-2010.
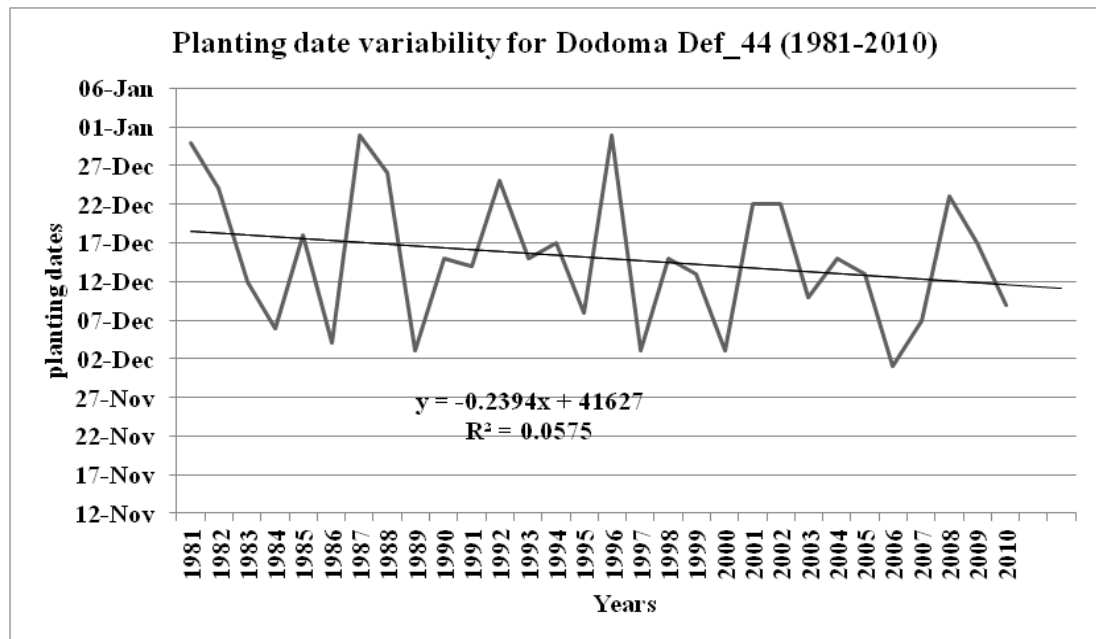

Figure 10: Planting date variability for Dodoma in Def_44 from 1981-2010

The Table below shows a summary of planting date variability for the four definitions. Higher variability (STD dev) observed in definition Def_11 and lower variability observed in Def_33.

	Minimum	Maximum	Range	Mean	STD Dev
Def_11	315	361	46	335.87	12.202
Def_22	315	365	50	342.97	13.338
Def_33	335	361	26	344.53	7.8333
Def_44	336	365	29	347.47	8.266

Table 1: Summary of planting date variability for the four definitions

Raindays variability for Def_11, Def_22, Def_11, and Def_44 is shown in Figures 11, 12, 13, and 14 respectively. The Figures predict high level of variability with very low number of R-square indicating no general relationship of raindays from year to year. Also there are weak signals showing rising of trend line except indicating more raindays in recent years compared to previous years.

Below is Figure 11 showing rainday variability for Dodoma of Def_11 from 1981-2010.
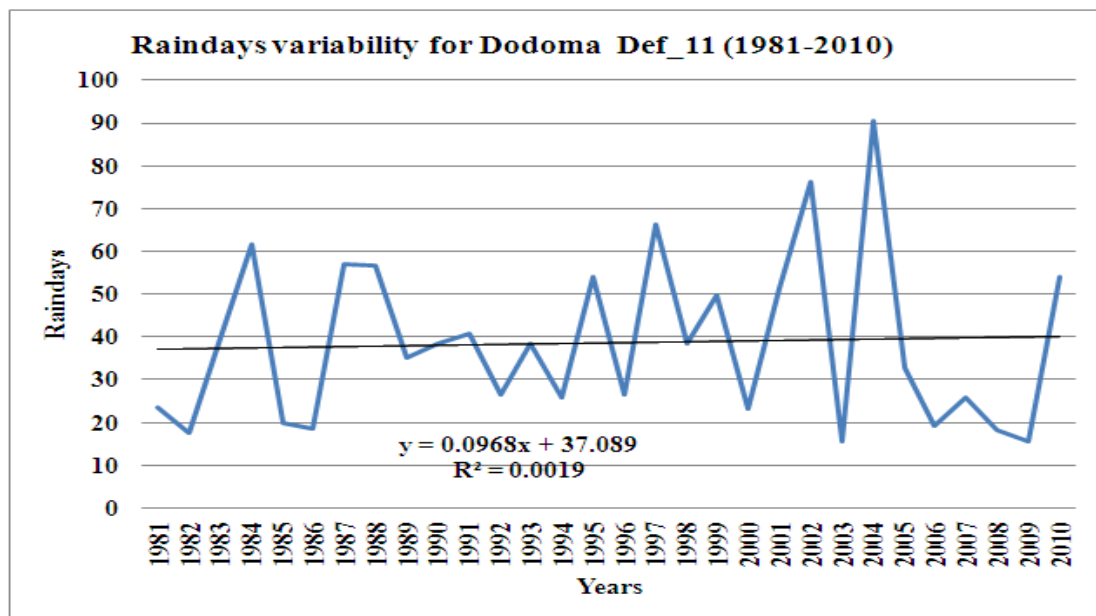

Figure 11: Rainday variability for Dodoma of Def_11 from 1981-2010.

Below is Figure 12 showing rainday variability for Dodoma of Def_22 from 1981-2010.
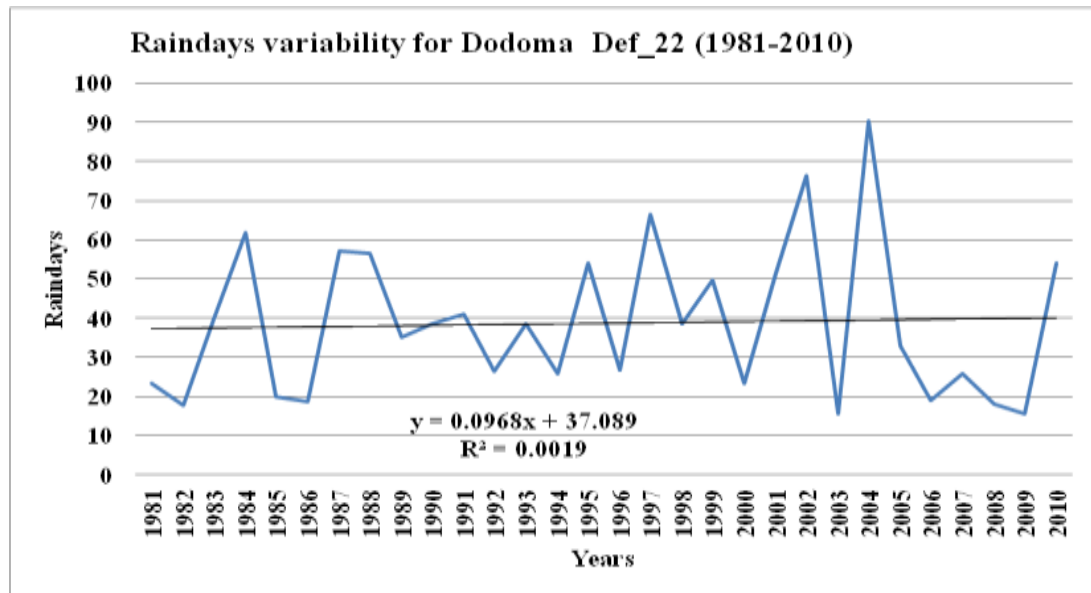

Figure 12: Rainday variability for Dodoma of Def_22 from 1981-2010.

The figure below shows Rainday variability for Dodoma of Def_33 from 1981-2010.
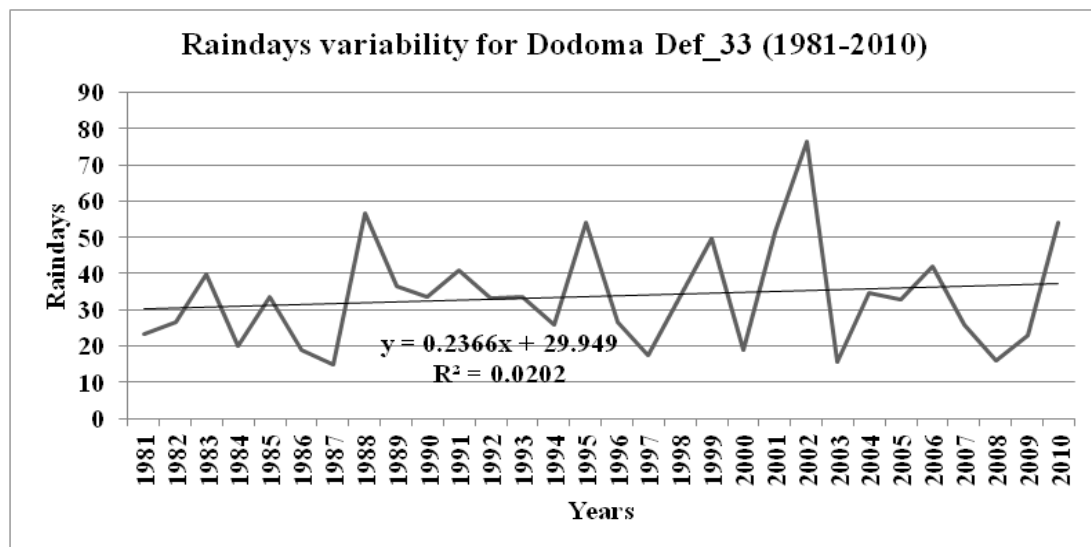

Figure 13: Rainday variability for Dodoma of Def_33 from 1981-2010.

The figure below shows rainday variability for Dodoma of Def_44 from 1981-2010.
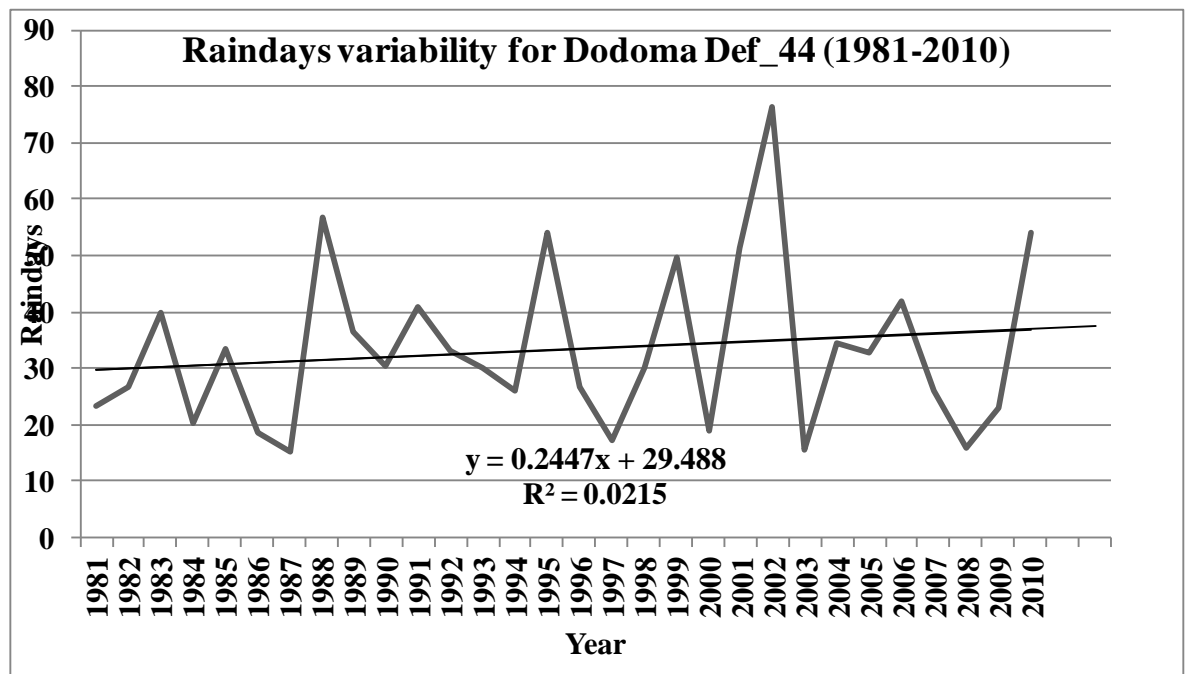

Figure 14: Rainday variability for Dodoma of Def_44 from 1981-2010.

The Table below shows a summary of raindays variability for the four definitions. Insignificant variability observed for the four definitions measured by standard deviation (STD dev) indicating little changes in number of raindays for all definitions.

Summary	Def_11	Def_22	Def_33	Def_44
Mean	39	39	34	33
Min	16	16	15	15
Max	90	90	76	76
Std Dev	19	19	15	15

Table 2: Summary of raindays variability for the four definitions

2. Seasonal length variability

The seasonal length variability for Def_11, Def_22, Def_11, and Def_44 is shown in Figures 15, 16, 17, and 18 respectively. The figures predict high level of seasonal length variability indicated by low R-squared value. This signifies no general relationship on the length of the season from year to year. Also there are weak signals of decreased trend line signify decrease in the length of the seasons by an average of 20 days in recent years compared to previous years.

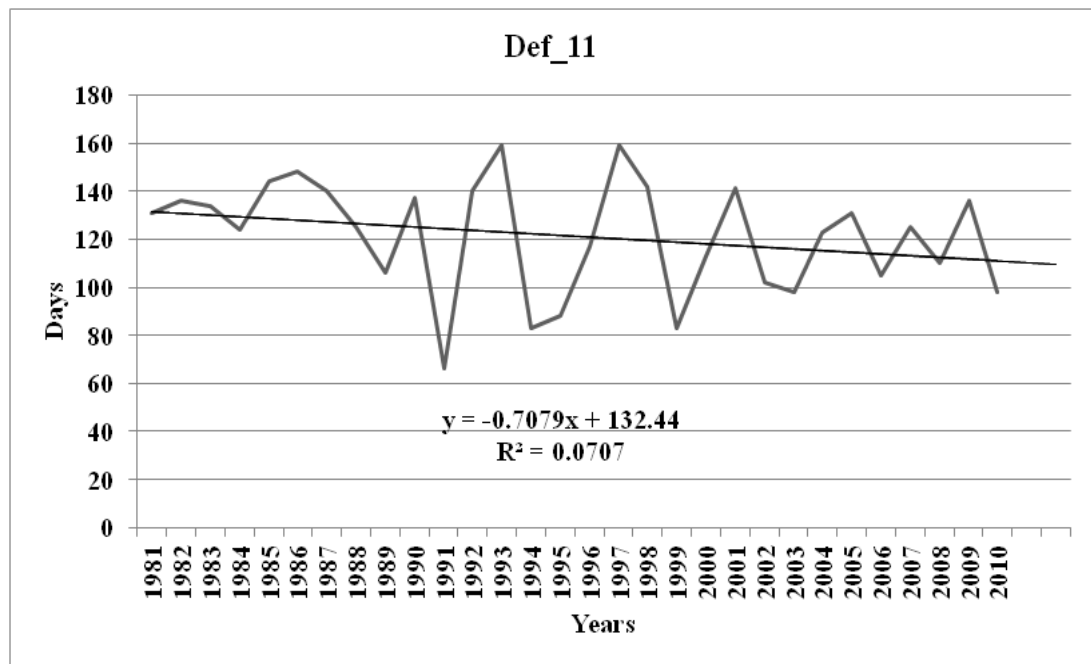Below is Figure15 showing seasonal lengths variability for Dodoma of Def_11 from 1981-2010.

Figure 15: Seasonal lengths variability for Dodoma of Def_11 from 1981-2010.

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Below is the figure 16 showing seasonal lengths variability for Dodoma of Def_22 from 1981-2010.

Figure 16: Seasonal lengths variability for Dodoma of Def_22 from 1981-2010.

Below is the figure 17 showing seasonal lengths variability for Dodoma of Def_33 from 1981-2010.
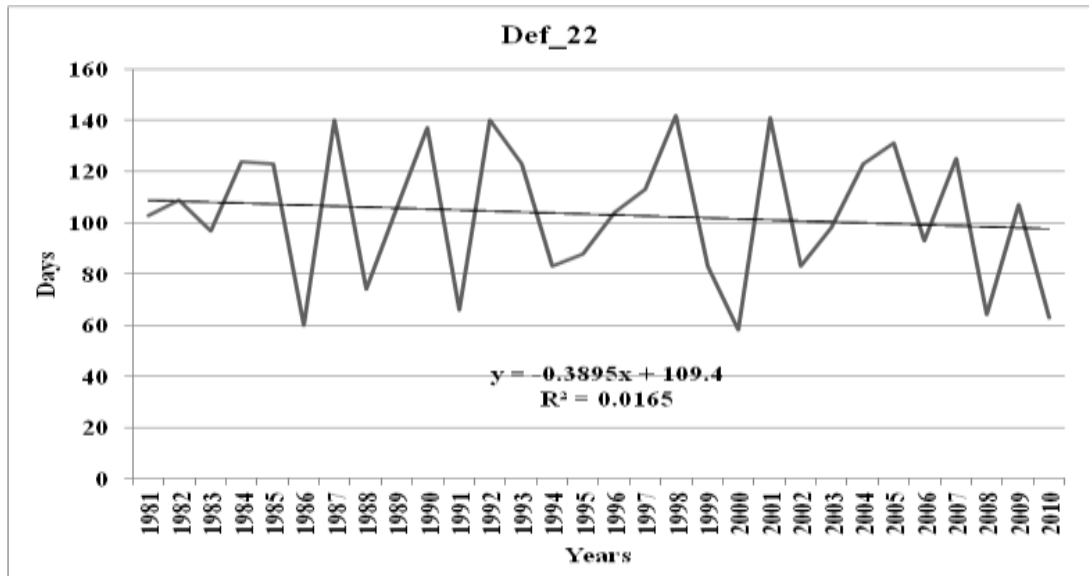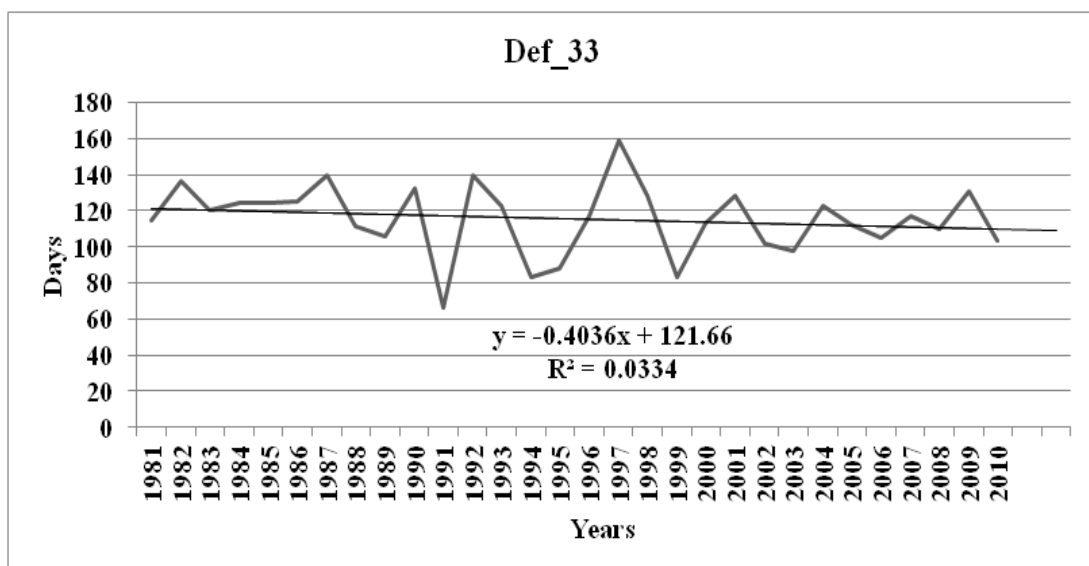

Figure 17: Seasonal lengths variability for Dodoma of Def_33 from 1981-2010.

Below is the figure 18 showing seasonal lengths variability for Dodoma of Def_44 from 1981-2010.
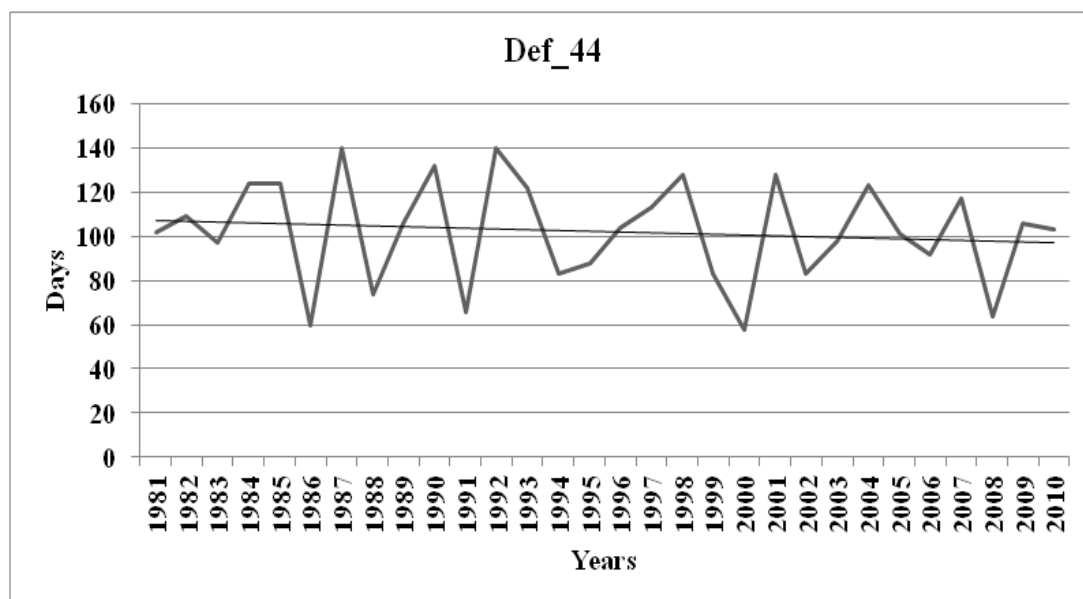
Figure 18: Seasonal lengths variability for Dodoma of Def_11 from 1981-2010.

Table 3 below shows a summary of seasonal length variability for the four definitions. Significant variability observed for the four definitions as measured by standard deviation (STD dev) indicating changes in the length of the season on average by 20 days for all definitions.

Summary	Def_11	Def_22	Def_33	Def_44
Mean	121.5	103.4	115.4	102.3
Min	66	58	66	58
Max	159	142	159	140
Std Dev	23.4	26.7	19.4	23.5

Table 3: Seasonal length variability for Def_11, Def_22, Def_33, and Def_44

3. *Dry spell length*

The figure below (Figure 19) shows the longest dry spell variability in January from 1981 to 2010. In this Figure, high variability of the longest dry spell observed in January as indicated by the R-squared value being very far from 1. This shows little connection of similarities of the number of the lengths of the longest dry spells from years to years. Also signals of increased length of dry spell in January of about 15 days (two weeks) for the past 30 years observed.
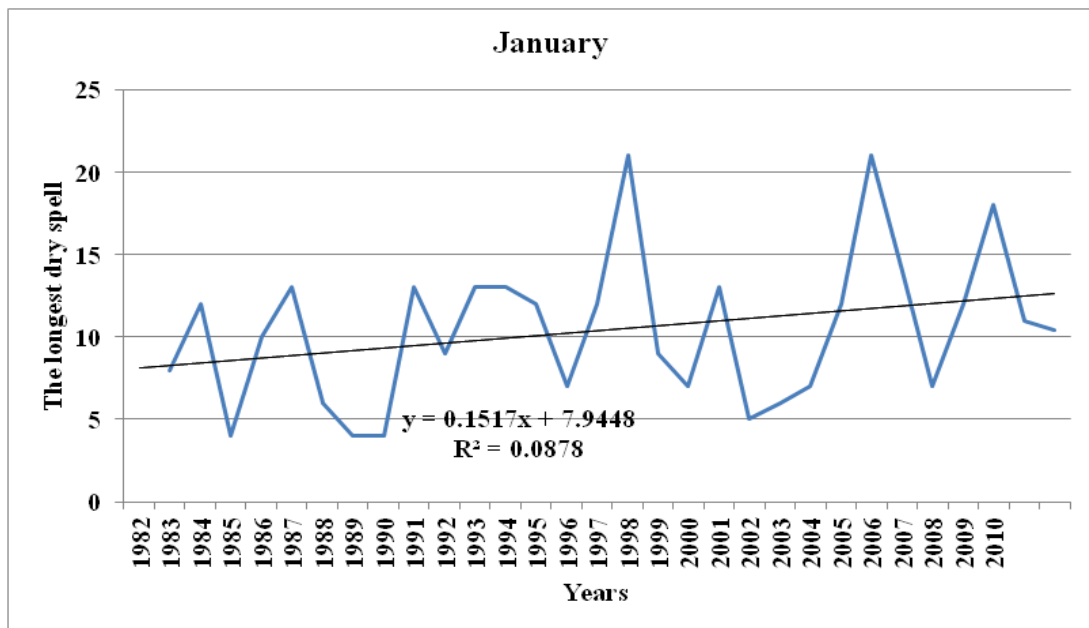

Figure 19: The longest dry spell variability for the January from 1981 to 2010

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4. Temperature extreme

The Figures below (Figure 20 and 21) shows the occurrences of extreme temperature exceeding 34.5 ^{0}C (on monthly basis and on yearly basis respectively) from 1981 to 2010. Figure 20 shows coincidence of extreme temperature with the growing season (November to March) and figure 21 shows the shortened period on the occurrence of extreme temperature as observed in recent years (2000-2010) compared to the previous years (1981 t0 2010).
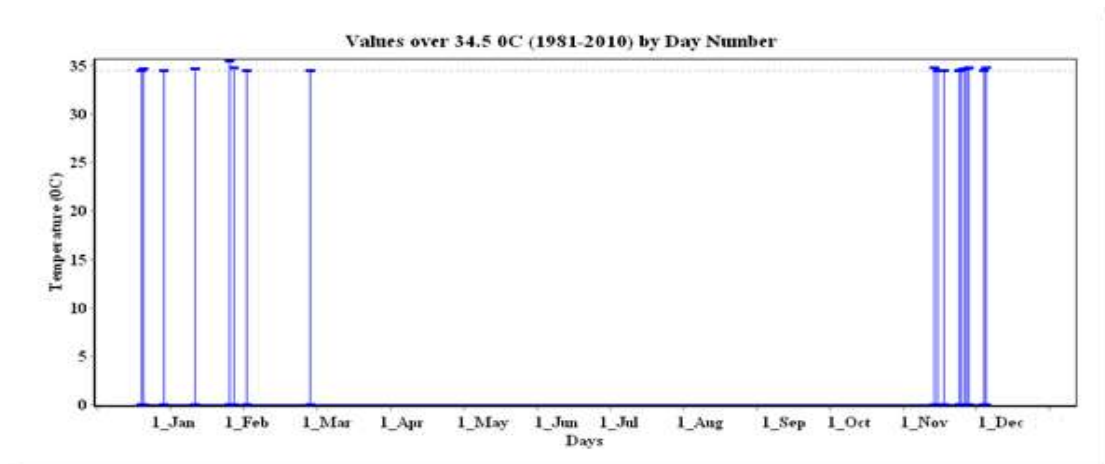

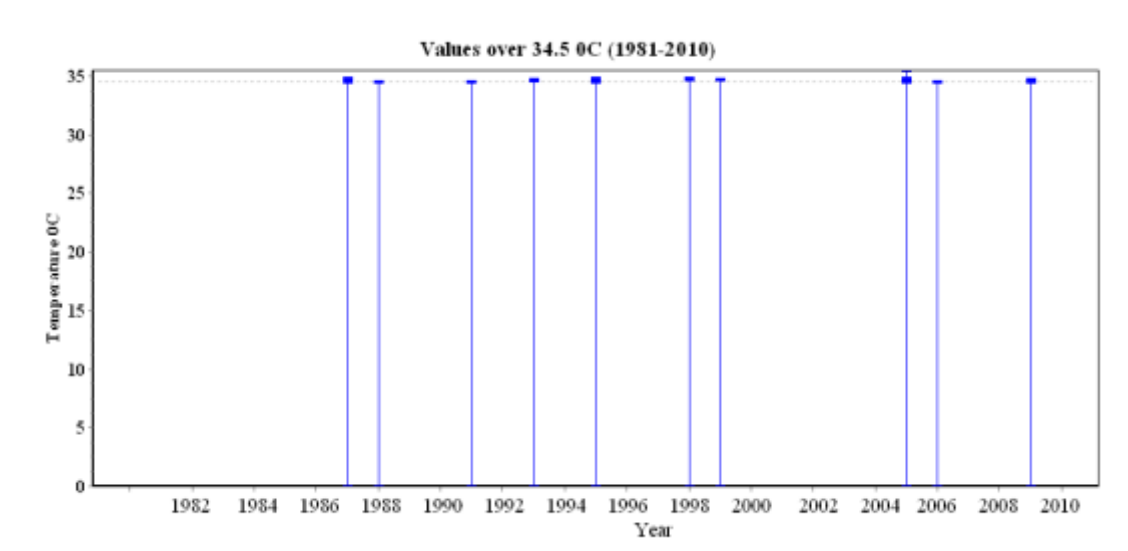Figure 20: Temperature values exceeding 34.50C by day number in the study site

Figure 21: Temperature values exceeding 34.5^{0}C by years in the study site

4.3   THE IMPACT OF LOCAL CLIMATIC RISK TO BIOMASS AND CROP YIELD

Below is result on the impact of local climatic risk to biomass and crop yield. The figure below (Figure 22) shows the effect of local climatic risk (planting date variability) to groundnut yield and biomass production in kilograms. The Figure indicates different yield and biomass production at different planting dates. More yield and biomass production is observed in Def_22 and Def_33 compared to Def_11 and Def_44. High risk is observed in Def_44 when there is no yield and biomass production (yield and biomass production is zero).
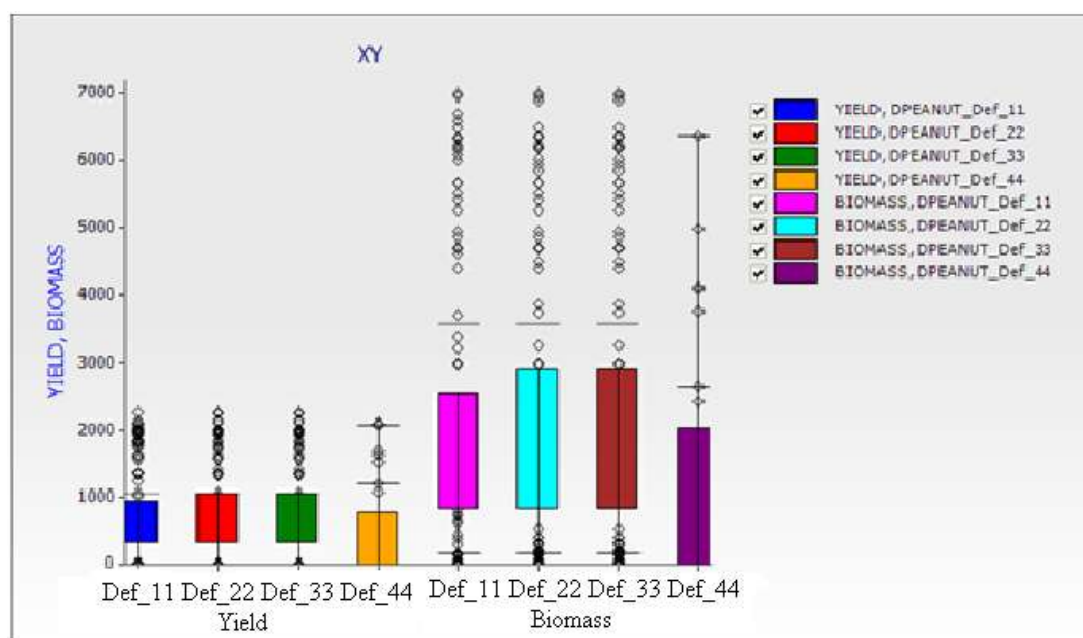

Figure 22: The relationship between planting date variability and groundnut, biomass production

4.4   OPTIONS TO MINIMIZE LOCAL CLIMATIC RISK USING CLIMATIC DATA

This section required to provide results of the third objective on options to minimize local climatic risk using climatic data. The details are found in the following sub-sections.

1. *Percentage risk reduction of crop failure or replanting*

Figure 23 is the bar chart showing the length of the seasons for two definitions, Def_11 and Def_22. The percentage risks reduction of crop failure or replanting is calculated on how many times the length of the season for Def_22 is longer than Def_11.Figure 23 shows nine years of Def_22out of 30 years is longer than Def_11. The risk reduction is calculated as a ration of number of years of Def_22 is longer than Definition_11, multiplied by 100. For this study the risk reduction observed is (9/30)*100=30%.
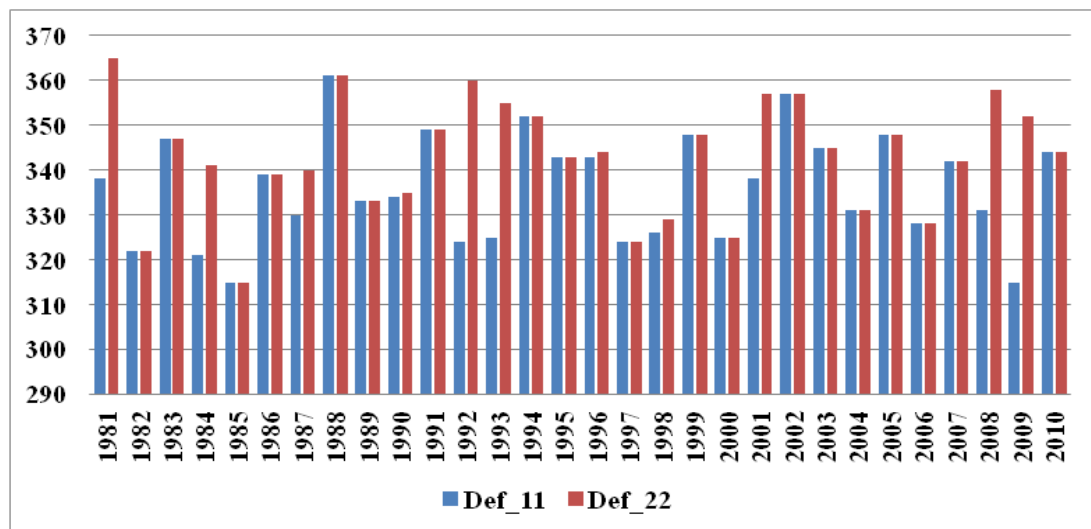
Figure 23: A plot of length of the season for Def_11 and Def_22 against years (1981-2010)

The Figure below (Figure 24) is a bar chart showing the length of the seasons for Def_ 22 and Def_. This plot also shows eight years of Def_44 out of 30 years is greater than Def_33. The risk reduction is calculated as a ratio of number of years Def_44 is longer than Definition_33, multiplied by 100. For this study the risk reduction observed is (8/30)*100= 26.7 %.

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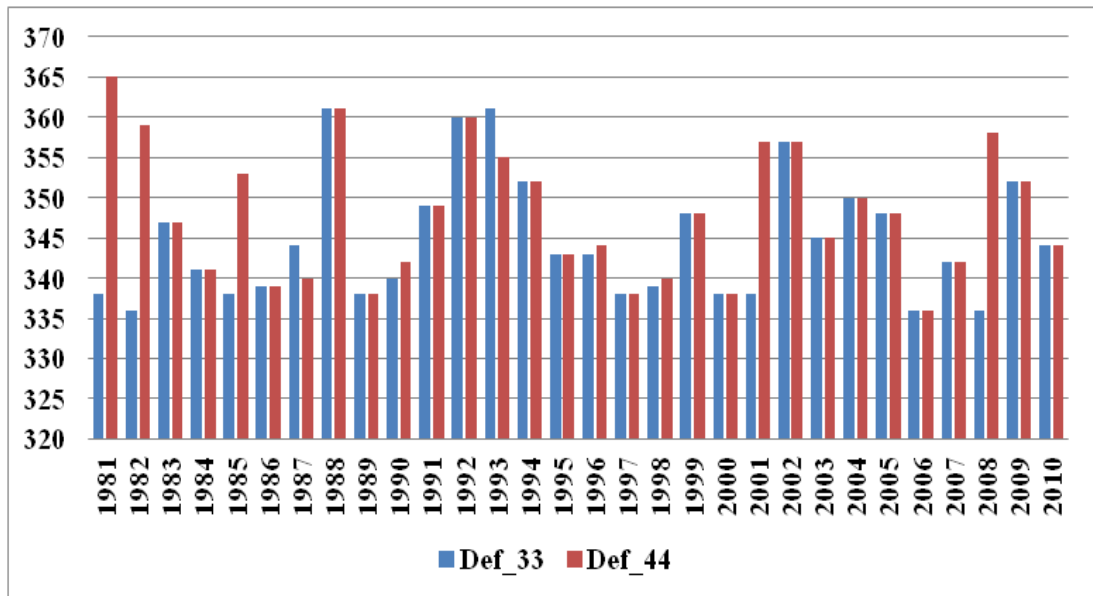
Figure 24: A plot of length of the season for Def_33 and Def_44 against years (1981-2010)

2. *Box plot and standard error mean*

The Figures below (Figures 25 and 26) show box plot for planting date and length of the seasons respectively. In Figure 25, the box plot for Def_33 is shorter indicating less variability compared to the rest of the boxes.

Figure 26 below shows Def_33 has shorter box than the rest of the Definitions indicating less variability.
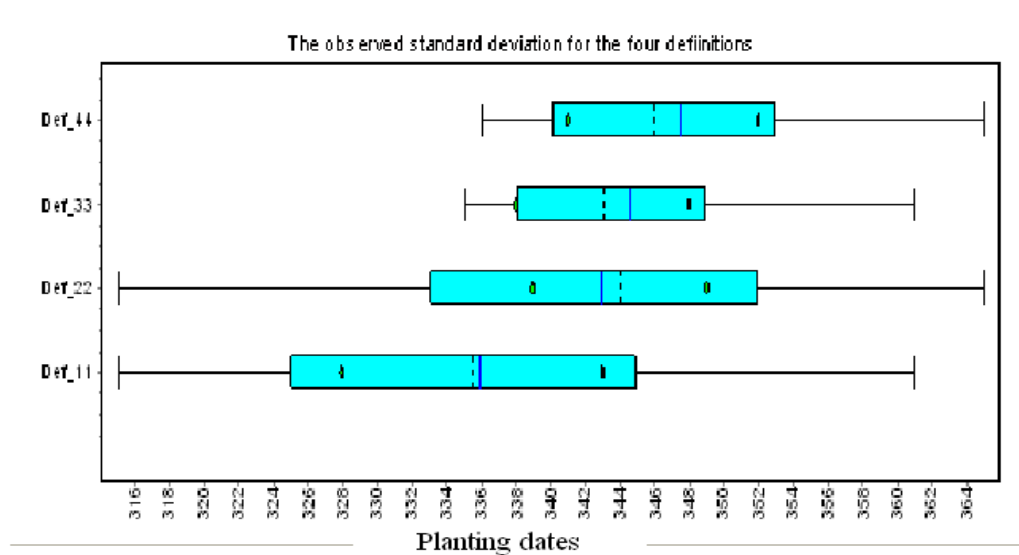
Figure 25: A plot of standard deviation of planting dates (Def_11, Def_22, Def_33 and Def_44).

Figure 26 below also is a box plot of standard variation of seasonal length for Def_11, Def_22, Def_33 and Def_44
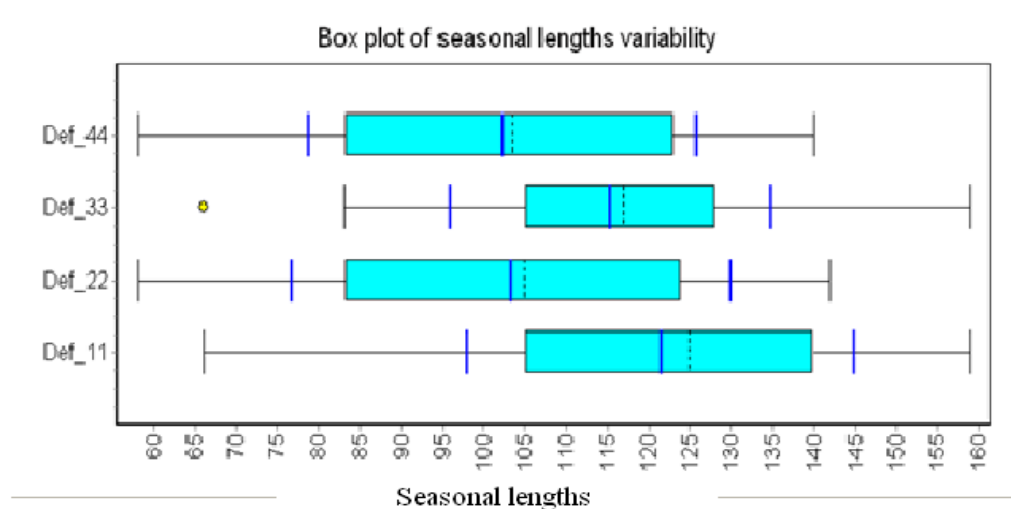
Figure 26: A plot of standard variation of seasonal length (Def_11, Def_22, Def_33, and Def_44)

Figure 27 below is the standard error mean for the four definitions. The smaller the standard errors mean the more accurate to the true value. From this Figure Def_33 observed to be the low standard error mean compared to the rest of the definitions.

Def_11 Standard error of mean = 2.2211	Def_22 Standard error of mean = 2.5007
Def_33 Standard error of mean = 1.4013	Def_44 Standard error of mean = 1.5949
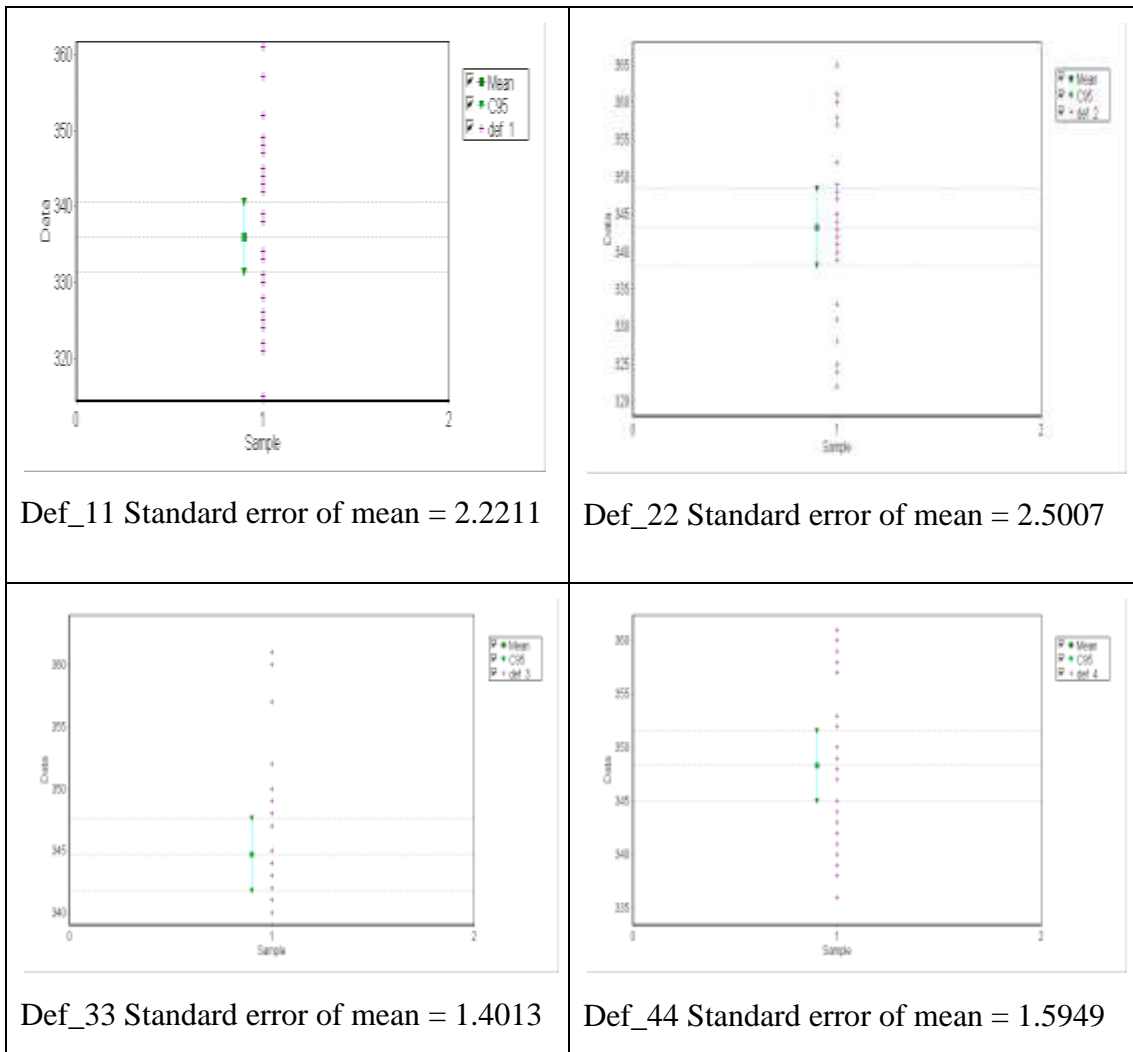
Figure 27: A plot of the standard error mean for Def_11, Def_22, Def_33, and Def_44

3. *Daily data display*

The Figures below (Figure 28, 29 and 30) daily data display for Dodoma

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meteorological station from 1981 to 1990, 1991 to 2000 and 2001 to 2010 respectively. Insignificant false start of rainfall is observed in Figure 28 and significant false start of the seasons is observed in Figures 29 and 30. In both Figures it is observed that little or no rainfall is recorded in the 1st of November in all three decades. Also the false start of rain in October is always followed by the dry spell for Figures 29 and 30 respectively. The lengths of the season observed shorted in the recent decades compared to previous decade. For example in 1981 to 1990 rainfall ended in late may, but in decade starting 1991 to 2010 rainfall ended early just in April. The Figure below, Figure 28 shows daily data display of rainfall from 1981 to 1990.

Figure 28: Daily data display of rainfall from 1981 to 1990

Figure 29: Daily data display of rainfall from 1991 to 2000

Figure 30: Daily data display of rainfall from 2001 to 2010

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CHAPTE 5: DISCUSSION, CONCLUSION, RECOMMENDATIONS

5.1   DISCUSSION

1. *Observed local climatic risk*
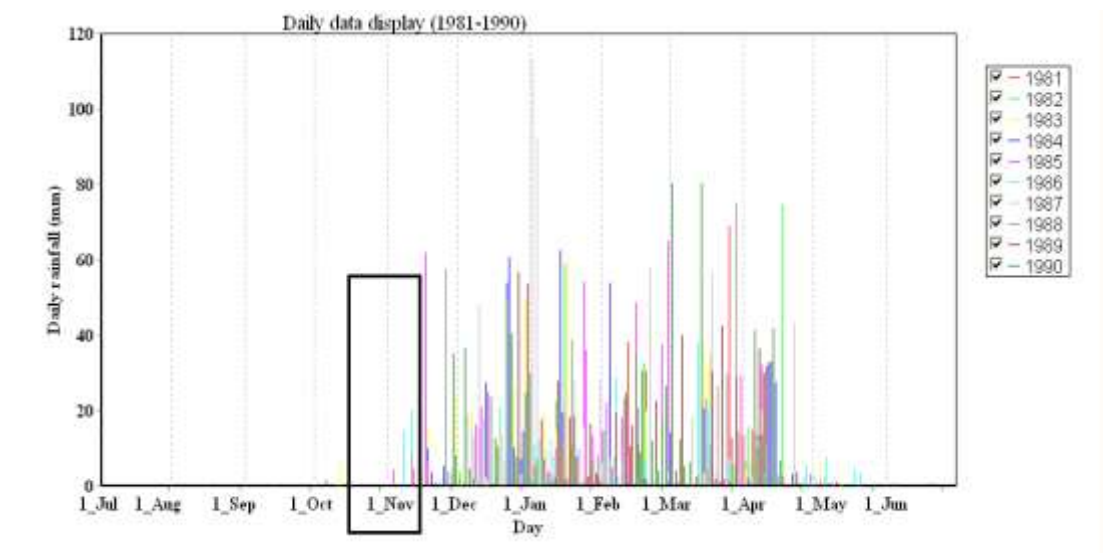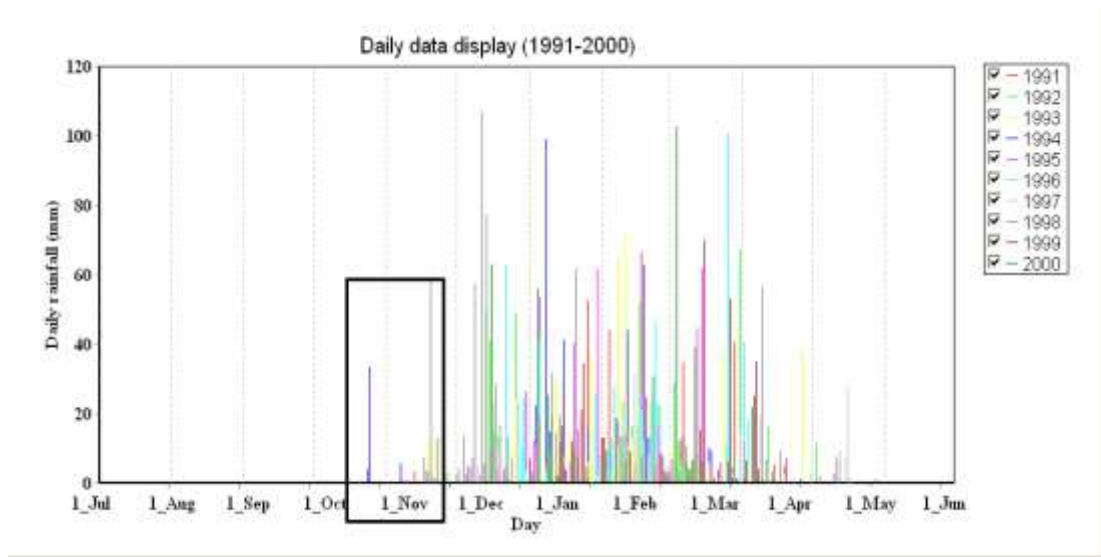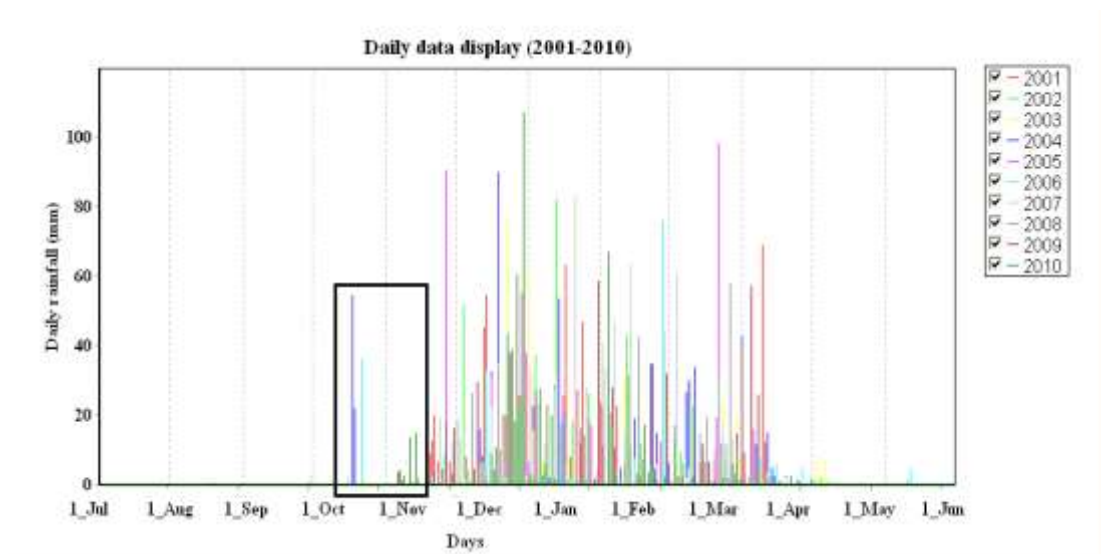
Climate variability is the major risk beyond farmers control in rain-fed agriculture system in rural areas due to randomness of the weather events, especially in tropical regions (Hansen, Sato & Ruedy 2011). Climate variability often denotes deviation of climatic statistics over a given time, for example years from long term statistic that relate to corresponding calendar period. It is measured by the use of statistics such as the trends of events by R-squared and standard deviation (World Meteorological Organisation 2013). Climate variability identified as a major challenge in the analysis of planting date, raindays, seasonal length and dry spell; Figures 7 to 19 showed the details. For example, in planting date variability, Figures7 to 10, the R-squared value is far from one indicating that there is no clear trend of planting dates on yearly basis.

The results are consistent with study done by Semenov & Porter (1995) on climate variability and modelling of crop yields in UK and Frace using crop model for winter wheat. The study analysed sensitivity to changes in mean and climatic variable and found that changes in climate variability have a more profound effect to yield and associated risks than changes in mean climate. This means for planting date there is no clear cut or fixed date that farmers is advised to plant. For example, if farmers had enough rainfall for the past two years and anticipate will continue to be enough for the next two years, the decision could change into maladaptation if rainfall could fall below the average (Prabhakar & Srinivasan 2009).

A farmer may opt to plant at different dates but each date has got its own risk. For example, if he or she decided to plant early, (Def_11) the dates may be followed by a dry spell. A farmer may also decided to plant late, he/she may still followed by other risks such as shortened season. It is better to learn and understand risks associated with variability to identify dates with minimum risk. For this study Def _33 to has minimum variability (Figure 11) and is measured by observing minimum standard deviation (Table 1) of 7.8 or one week compared to the rest of the definitions. Inaction to identify planting dates that lead to minimum risk could create impact to crop yield (Jones 2012) .

In planting dates variability, signals of rising trend observed. For example Figure 22 showed that in recent years (2000-2010) farmers planted late compared to previous years (1991-2000). This is interpreted as signal another risk known as seasonal shift. This risk may differ from one definition to another and could be linked with slowing changing in climate as seen in Figures 7 to 10 (Intergovernmental Panel on Climate Change 2007).

This study also analysed raindays variability for the four definitions and found variability in number of raindays do not change much across definitions. This creates another climate ambiguity about climatic risks (Prabhakar & Srinivasan 2009). Figures 11 to 14 showed the details. The measure of raindays variability is shown in Table 2. There are no much changes in the numbers of raindays across definitions. This means a farmer may observe the same raindays between two definitions but differ by dry spell or seasonal length.

Signals of falling trend of seasonal length observed at local area. Figures 15 to 18 showed the details. For example, in Figure 17, the length of the season for Def_33 showed a falling trend in the length of the season. This could be interpreted as decreased in length of the season by at least ten days in recent years compared to the previous years. The shortened season is associated with decreased in number of days for grain filling before crops reach mature. This means that groundnuts may

not get enough time for filling hence decreased production observed in recent years (2000-2010) compared to previous years. The standard deviation for seasonal length showed deviation of up to three weeks from the mean. Def_33 observed to have lower standard deviation compared to the rest of definitions and this is interpreted as more accurate definition compared to other definitions.

The longest dry spell lengths for January were also determined in this study. The trend line for Figure 19 showed insignificant relationship among years as measured by the R-squared being far from one. Increasing trends on the longest dry spell observed and is interpreted as increased risk in recent years compared to previous years. The recent observed risk of about two weeks of no rainfall could significantly affect crop yields if no other interventions put in place.

Temperature extreme was also determined in this study (Figure 20). This study observed extreme temperature of 34.5oC (usually not common) coincide with the growing season (from November to March). This could add heat stress to plants hence reducing yields. Also Figure 21 showed shortened period on the occurrences of extreme temperature in recent years compared to previous year. The interpretation of this event is that in recently extreme temperatures are occurring frequently compared to the previous years (1981-1986).

2. *Impact of local climatic risks to biomass and crop yield*

The impact of local climatic risk to groundnut production was observed in this study. The box plot (Figure 22) showed that the different planting dates produced different yields. More yields were observed in Def_22 and 33 compared to Def_11 and 44. This could be interpreted as a that when a farmer plant early he/she could be faced by dry spell risk hence reduce yield and if the farmer decided to plant late he/she could be faced by shorter season hence reduce yield sometimes to minimum (zero).

3. *Options to minimize local climatic risk using climatic data*

Many studies related to risk management ended by listing options to minimize local climatic risks. This study attempted to show how to minimize local climatic risks using climatic data. The percentage of risk reduction of crop failure or replanting was determined. The result showed that the risk can be reduced by up to 30% by just understanding and apply weather and climate information of local area. For example, for this study (Figure 23 and 24) showed that for a farmer who plant late and considering dry spell is having a longer seasons than a farmer who plant early and do not consider dry spell. When a farmer is having longer seasons, there is a change of having enough time for groundnuts filling hence more crop production.

Box plot and standard error mean plots for planting dates and seasonal length also drawn in this study to show options to minimize climatic risks using climatic data. Figure 25 showed that Def_33 has got shorter box compared to the rest of definitions. The box for Def_33 showed the smaller range and is interpreted as lower variability compared to other definitions hence more accurate compared to the longer boxes for other definitions. The plot for seasonal length (Figure 26) also reported smaller variability for Def_33; imply more accuracy for this definition compared to the rest of the definitions. The minimum standard error (Figure 27) is observed in Def_33 (1.403) compared to the rest of definitions hence more accuracy for Def_33 compared to other definitions.

Decadal daily data display was done in this study as a way to show who to identify false start of the seasons hence minimizing climatic risks. Figures 28, 29, and 30 showed little or no rainfall on the first day of November. False start of the season is well observed in Figure 29 and 30. For example in Figure 30, rainfall was fallen in late October of about 50 mm per day followed by a length of dry spell till sevenths of November. The false start of rainfall is well observed in recent decade (Figure 30) compared to previous decades. Also the lengths of the seasons observed

shorted in recent decades compared to previous decades. For example, in 1981 to 1990 rainfall ended in late may, but in decade starting 1991 to 2010 rainfall ended early just in April. The risk of dry spell and shortened season could be avoided by just understanding patterns of rainfall and climatology of the local area.

5.2   GENERAL DISCUSSION

Climate risk management is the new concept, increasing seen as the way forward to deal with climate variability to promote sustainable development (Taylor 2007). In this study the key input to climate risk management at local area is centred on the understanding of local climatic risks, realizing the impact and looking a way forward to deal with these risks.

In this study the local climatic risks have manifested in various ways such as planting date, raindays, seasonal lengths, and dry spell variability including extreme temperatures. This study observed various unique risks at different stages of crop development that demonstrates absence of one solution to existing risks at local area. For example, the risk of dry spell and the planting date variability could be identified and managed differently. The dry spell variability could be managed by for example, supplementing irrigation (using on farm water harvesting technique) and planting date variability by selecting planting dates with minimum standard deviation. All these provide different adaptation options to different climatic risks.

It is a reality that most farmers in rural areas are poor with limited capacity for intervention, and sometimes it is impractical for example, recommending supplementary irrigation. The extension officers should advice farmers on for example, productive planting dates, but the advice could be challenged by the fact that crop production is multi-disciplinary industry, hence joint effort is required to optimistic achievements.

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5.3   CONCLUSION

Rain-fed crop production is dominant farming system is rural areas and will continue to support the majority of an increasing population. Understanding local climatic risks is one of many adaptation options to increase crop yield in rain-fed rural areas with minimum financial capital. This study found that local climatic risks are very unique and affect crops at various stages of development. Climatic risks if not well known are potential to decrease yield hence compromise efforts of increasing crop production by farmers and other key stakeholders such at crop researcher, extension officers and insurance companies. This study also showed that the effect of climatic risks can be minimized by planting crops with planting date with minimum variability, for example by using box plots and daily data display.

Acknowledgement of this reality is essential, but application of weather and climate information to crop yield are still not well understood by farmers especially in rain-fed rural community. Also enough extension officers are still a challenge in many rural communities thus limiting the use of climate information to rural areas.

5.4   RECOMMENDATIONS

This study is recommended to researchers, extension officers and crop insurance companies dealing with local farmers to manage local climatic risks at local area. The researchers can add knowledge on the understanding of full risks available in the local area. The extension officer can work together with local farmers to communicate and manage local risks, The insurance companies can improves their insurance indexes by considering multiple climatic risks that affect crops production with the aim to compensate farmers when multiple risks occurs (Taylor 2007).

Based on results of this study, the following recommendations are proposed for future research on sustainable crop production:

1. This study was centred on single station climate data analysis (one station). There is a need for multiple stations analysis on climatic risks and interactions to study the impact of spatial climatic risks;

2. The study on the analysis of the impact of individual risks should be done for each crop because each crop is impacted different by different risks. This could help to identify priorities to handle climatic risks;

3. This study used climatic data to show how to minimize climatic risks. There is a need for further study on other interventions on how to minimize climatic risks and improve yield for example, by the use of manure and supplementary irrigation to minimize dry spell that affect crops at various growing stages at local environment, and

4. There is a need for further studies on communicating local climatic risks with stakeholder with the aim to update new interventions to minimize climatic risks.

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