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Guide to the use of Weather and Climate Information (WCI) for agricultural practices over selected districts of SNNP and Tigray, National Regional States Ethiopia
Second series

National Meteorollogical Agency (NMA) of Ethiopia

November 2017

Cover Page: cover page photos are taken at Mekan Kebele Farmers Association, Endamahoni district of Tigray National Regional State of Ethiopia (left) and at Shendoloiyo Farmers Association, Boricha district of SNNPR (middle and right). Left picture shows how the farmer *(Mr. Desta Abadi)* keeps records of daily rainfall from plastic rain gauge and use the information to make decisions on his Wheat farm. Middle and right pictures show comparison of Haricot bean plantation performance between experimental which use weather and agricultural meteorology information (middle) and control, non-user of climate information (right) farms.

Photo taken by Mr. Kassa Fekadu (September 13-15, 2017)

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Disclaim

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Guide to the use of Weather and Climate Information (WCI) for agricultural practices over selected districts of SNNP and Tigray National Regional States, Ethiopia

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Guide to the use of Weather and Climate Information (WCI) for agricultural practices over selected district of SNNP and Tigray National Regional States, Ethiopia

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List of Abbreviations and Acronyms

AAS	Agro Meteorological Advisory Services
AWS	Automatic Weather Station
CFS	Climate Forecast System
CRGE	Climate resilient green economy
ECMWF	European Center for Medium-Range Weather Forecasts
ENACTS	Enhancing National Climate Services
ENSO	El Nino Southern Oscillation
ET	Evapotranspiration
ETo	Reference Evapotranspiration
FAO	Food and Agricultural organization
GDD	Growing degree days
GHG	Greenhouse gases
GMT	Global Mean Time
GTP	Growth and Transformation Plan
IOD	Indian Ocean dipole
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
ITCZ	Inter-Tropical Convergence Zone
JAS	July, August September
LGP	Length of growing period
LLJ	Low Level Jet
LRF	Long Range Forecast
MI	Moisture Index
NDVI	Normalized Difference Vegetation Index
NMA	National Meteorological Agency
NOAA	National Oceanic and Atmospheric Agency
PET	Potential Evapotranspiration
PON	Percent of Normal Analysis
QBO	Quasi-biennial Oscillation
RH	Relative Humidity
RMSC	Regional Meteorological Service Centers
RF	Rainfall
SOI	Southern Oscillation Index
SST	Sea Surface Temperature
SPI	Standard precipitation index

SWI	Soil Water Index
TC	Tropical Cyclone
TV	Television

THI	Temperature Humidity Index
TEJ	Tropical Easterly Jet
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World health organization
WMO	World Meteorological Organization
WRSI	Water Requirement Satisfaction Index

Forward

This is the second district climate guide series. The first climate guide has been prepared for five Tigray districts under Irish Aid Project Phase I (Kinfe et al., 2015). This second district climate guide explains climate of three additional districts in Tigray and three districts in SNNPR. Feedbacks from the first climate guide have been used as input to improve the content of this guide. Such climate guide has to be prepared and published for all districts of Ethiopia as a continuation of this series.

The National Meteorological Agency (NMA) of Ethiopia has given a responsibility to establish meteorological stations all over Ethiopia, collect data analyze, interpret meteorological and climate information and forecast weather, and issue early warnings. It also provides applied meteorological services specialized for agriculture, water, health and air navigations. Meteorological services have been delivered for the last 60 years at different capacities. Currently, NMA set an ambitious vision of "the provision of world class meteorological service by 2022" with its eleven Regional Meteorological Service Centers and over 996 staffs. NMA strived to improve its services and reach the level of customer satisfaction.

Customers of climate services always request location specific information that is tailored to their specific use. Such service requires an extensive representative monitoring stations, modern and advanced computational capacity, and above all, highly experienced and qualified professionals. NMA in its 5-year GTP-II plan tried to address some of these demands by expanding modern observational systems, such as automatic weather stations, starting of Post Graduate Program in Meteorology in collaboration with Ethiopian Water Technology Institute and accredited training center for meteorological technicians.

On the other hand, the state of grass root service, particularly for the Ethiopian farmers, through the provision of plastic rain gauges and farmers training on the interpretation and use of weather and climate information has shown promising results. An increase of agricultural productivity, between 10% and 44% has been recorded in Irish Aid phase I pilot project districts (Project Evaluation Report, 2015). Based on such localized service experience, this phase II project which was funded by the Irish Aid and technically supported by World Meteorological Organization (WMO) has been implemented in eight selected districts of Tigray National Regional State and three districts in SNNPR of Ethiopia. This climate users' manual is part of the activities of the project that aim to help agricultural extension officers, local authorities, progressive farmers and intermediaries so they can interpret weather and climate information and understand about climate of the selected Districts.

I am confident that NMA will continue to scale-up such localized grass-root and tailored climate services to other parts of Ethiopia. The ultimate goal of NMA in this respect is therefore to consolidate experiences of such endeavours, in order to establish full-fledged grass root climate services that satisfy the end users need and enhance agricultural productivity. By doing so, NMA will address the pillars of the Global Framework on Climate Services-GFCS in Ethiopia.

Fetene Teshome

Director General
National Meteorological Agency

Preface

The major aspects that influence the agricultural potential and constraints at a particular locality over the tropics chiefly include the availability of soil moisture at the different stages of the crop growing period. Moreover various experiences have clearly indicated that the agricultural productivity largely depends on how far farm level managements have succeeded in using weather and climate information for enhancing agricultural production. Thus the need for a locally specific climate guide is due to the understanding that the development of an agro- meteorological advisory system for a particular area is considered to be more effective when integrated with the agro-climatic constraints and potentialities of a particular area are clearly found. Moreover effective use of this guideline can be used to identify basket of recommendations for identified weather and climate scenarios that can be exhibited in the crop growing season in the identified areas.

The major objective of this Climate guideline is to support the decision making process at farm level over the specified areas using the presented information about the agro-climatic potentials and constraints presented in the guideline for each specified pilot District. Thus it is expected that agricultural development agents should understand well the Climate guideline so that they can use it as one important tool to build the capacity of the small holder farmers in enhancing the agricultural production at farm level using the opportunities and the potentials and to minimize agricultural loss due to the identified weather and climate constraints. This then can help to develop more the making of a modern farmer who would use weather and climate information for the improvement of farm level management so as to maximize agricultural production.

Finally this guideline can also be used as a resource material during the orientation of agricultural development agents and subject matter specialists who are new to the given area in enhancing their understanding about the weather and climate potentials and constraints, about the characteristics of the crop calendar and can also be used as a reference in the preparation of extension advisory. And also as a training document for enhancing agricultural development programs and projects over the given specified area. Thus it is hoped that with feedback from agronomists, agricultural development agents, educators and farmers is crucial in the improvement of this guideline to become more-friendly to the farmers in their efforts to increase farm level agricultural production.

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Chapter One: Introduction

For the past several decades, the National Meteorological Agency (NMA) of Ethiopia has been providing a wide range of weather and climate services for various socio-economic applications. The agricultural sector has been the main user of the information NMA disseminates which includes weather and climate assessment summary and predictions with agro-meteorological applications at different space and time scale; daily, ten-daily, monthly, seasonal and two-seasons. However, there are several issues that have hampered the effective and efficient communication and use of weather and climate information at various levels, in particular farm level. First, location specific products that are tailored to the need of end users have been lacking. Despite the recent improvement in quality of various NMA products, addressing farm level climate risk management requires even higher resolution and location-specific information. Second, the capacity of users at all levels including small holder famers is limited to uptake weather and climate information. Better understanding, interpretation and utilization of existing meteorological and climate information by end users could help make informed decisions to cope with anticipated climate risks. Third, reaching last mile end users has been identified as a challenge. Dissemination through information intermediaries including agricultural extension services and media has not always been ensured. Fourth, institutional linkages need to be strengthened with stakeholders working on food security and climate adaptation issues.

This climate information users' guide is part of a project entitled "Improvement of Agro Meteorological Information for Small Scale Agricultural Production over Tigray and SNNPR of Ethiopia" which is implemented by NMA in collaboration with the World Meteorological Organization (WMO) and Irish- Aid. The objective of the project was to improve agricultural production and food security in the regions through improved weather, climate and agro-meteorological service by strengthen the capacity of NMA to produce and disseminate more localized weather information to the regions and enhance institutional linkages between Regional Meteorological Service Centers, Bureau of Agriculture and key stakeholders. Six districts selected from both regions namely, Asegede Tsimbila, Sahreti Samre, and Endemehoni from Tigray region and Alaba Special District Special District, Shebedino and Borecha Districts are selected from SNNPR region as project implementation sites. The purpose of this guide is to enhance the understanding of the use and application of climate and agro-climate information for farm level decision making. The guide would enable a more systematic approach for capacity development for extension services and small holder farmers. The guides will explain how different types of weather and climate information provided by NMA can be utilized by different end users for decision makings in various situations. The development of these materials is built on NMA's experience in roving seminars and training for trainer's initiatives. This guide will also be used as a resource material to train the development agents, agricultural extension professionals and progressive farmers. It also gives detailed knowledge on the climate resources of the selected districts to help farmers make farm level decision on their agricultural practices.

The second Chapter of this guide discuss about the climate of Tigray and SNNPR regions based on main meteorological systems that affect the weather and climate of both regions. The third Chapter explains weather forecast and climate prediction in general with basics of interpretation and understanding. Chapter four and five presents detailed climate of the selected pilot districts and mainly discusses on the characteristics of rainfall under different ENSO episodes. It also explains the details of agro-meteorological characteristics of each pilot district. Chapter six defines basic terminologies and finally, we present our recommendation and concluding remarks in Chapter seven.

Chapter Two: Climate Pattern of the Project Area

2.1. Weather and climate system affecting Ethiopia

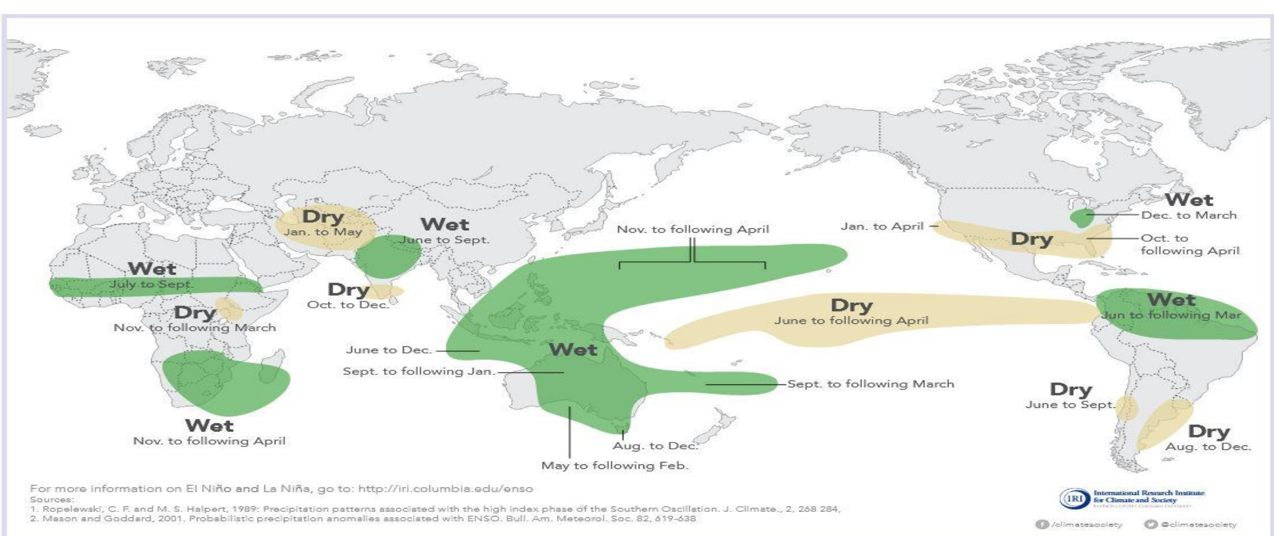
Seasonal and annual rainfall variations in Ethiopia as well as the neighboring areas of the region are associated with the macro-scale pressure systems and monsoon flows (Haile 1987; Hastenrath, 1991). Bekuretsion (1987) has indicated that the weather and climate of Ethiopia arises from the influence of tropical weather systems, like the Inter-tropical Convergence Zone (ITCZ), the monsoon, easterly waves, quasi-stationary subtropical anticyclones of both northern and southern hemisphere. The interactions between the tropical and extra-tropical weather systems produce major active weather over Ethiopia, especially during the months of February to May (Northern Hemisphere Spring). The main weather bearing systems for the Ethiopian climate and seasonal performance can be described as follows.

During the northern hemisphere winter (October – January) the winds to the tropics originates either from the Saharan anticyclone or from the ridge of high pressure extending into Arabia from the large high over central Asia (Siberia) which brings dry air masses. During this time Much of Ethiopian regions predominantly falls under the influence of warm and cool northeasterly winds the dry season (Bega). From February to May, the Arabian high moves towards the northern Arabian Sea and pushed over the water body, it causes a moist southeasterly air current to flow towards Ethiopia (Camberlin et al, 2002; NMSA 1996). Occasionally, there are also frontal lows that either originate from the Mediterranean area or originate within the Atlantic Ocean and are swept through from west to east, this produce excess rainfall over Ethiopia small rainy season (Belg) season over east, central and south part of the region. Over the remaining month (June – September) the northward propagation of ITCZ as well as the formation of heat lows over the Sahara and Arabian landmasses are dominant features (Korecha et al, 2007; NMSA 1996). Formation of subtropical high pressure systems over the Azores, St. Helena, and Mascarene, the position and strength of these systems, especially the St. Helena and Mascarene, influence the moisture flux and the rainfall over Ethiopia during main rainy season (Kiremt) (Kassahun, 1987). A boundary zone defined by the confluence of Atlantic/Congo and Indian Ocean air streams extends northwards along western part of Ethiopia. The rainfall activity increasing significantly in most part of the nation when the

St. Helena and Mascarene high pressure system are strong and decreases significantly when they are weak. Tropical Easterly Jet (TEJ), which is located at the boundary of the southern and northern Hadley Cells at around 200mb, is among the systems that are most influential to the circulations in Africa (Camberlin 1997) and its formation enhances the rainfall over Ethiopia (Kassahun, 1987).

2.1.1. Influence of ENSO

Ethiopian seasonal rainfall variability is highly influenced by remote ocean characteristics at central Pacific Ocean, among many other things, undulated by characteristics of Indian Ocean. El Nino is the warming of the water body along the west coast of South America, along the Peru cost. However, the name El Nino represents all sea-surface warming in equatorial Pacific Ocean. El Nino is also associated with changes in sea-level pressure at locations across Pacific between Darwin (Australia) and Tahiti. When pressure is high in around Tahiti, it is low at Darwin, and vice versa. This process is known as the Southern Oscillation. The two processes, one in the ocean, El Nino and the other in the atmosphere, the Southern Oscillation interacts to form a phenomenon known as El Nino/Southern Oscillation (ENSO). When the sea surface temperature in the equatorial central Pacific cooler than normal it is known as La Nina. The opposite event (warming of equatorial central Pacific as compared to its normal) is known as EL-Nino When the sea surface temperature along equatorial Pacific Ocean is neither warm nor cold as compared to the long term average, the event is known as ENSO-Neutral. In general the impact of El Nino is opposite in some location to that of La Nina. In Ethiopia for example, El Nino in Kiremt is associated with deficient rainfall in some areas, where as La Nina is mostly associated with wet rainfall activity during Kiremt season (figure 1). Nevertheless, not all El Nino or La Nina is alike as a result of other continental and regional factors such as Indian Ocean Dipole (IOD). Therefore, close follow up of the seasonal advisor issued from NMA on a regular basis for each and every specific season is instrumental.



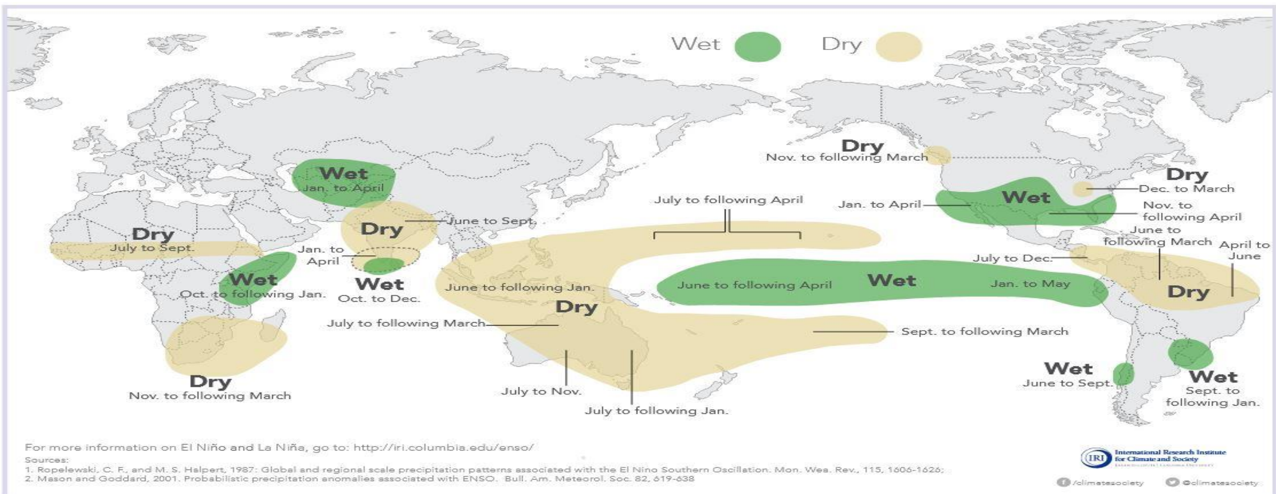


Figure 1: IRI Tele-connection of ENSO with regional rainfall performance during El-Nino (upper panel) and La-Nina (lower panel) (www.IRI.colombia.edu)

The IOD also known as the Indian Nino is an irregular oscillation of sea- surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean . A positive phase sees greater-than-average sea-surface temperatures and greater precipitation in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean which tends to cause droughts in adjacent land areas of Indonesia and Australia (www.bom.gov.au). The negative phase of the IOD brings about the opposite conditions, with warmer water and greater precipitation in the eastern Indian Ocean, and cooler and drier conditions in the west. In general IOD together with ENSO influence the seasonal rainfall variability of Tigray and SNNPR regions.

2.2. Climate and seasonal classification of Tigray and SNNPR regions

In high and mid-latitudes, seasons are classified as winter, spring, summer and autumn, while in low latitudes they are categorized as wet and dry seasons. In the Ethiopia, the seasons are classified into three periods based on annual rainfall patterns and basic meteorological systems. Hence, different scientists based on the mean annual and mean monthly rainfall distributions, the rainfall regimes are delineated and the types of seasons in Tigray and SNNPR are identified.

In Tigray eastern and most of the south half of the Region (identified by letter A in Figure 2(a)) has two rainy periods and one dry period. The two rainy periods are locally known as Kiremt (June to September) and Belg (February to May). The annual rainfall distribution over this region shows two peaks corresponding to the two rainy seasons, separated by a relatively short "dry" period. The dry period, which covers the rest of the year (October to January), is known as Bega. The western and central part of Tigray, which is identified by the letter B in Figure 2 (left panel), has one rainfall peak during the year (Haile, 1987). In this region, the length of the rainy period (June to September) decreases due to the meridional migration of the ITCZ (Inter-Tropical Convergence Zone). The same too the region SNNPR has three different rainfall regimes as shown below (Figure 2 (right panel)).

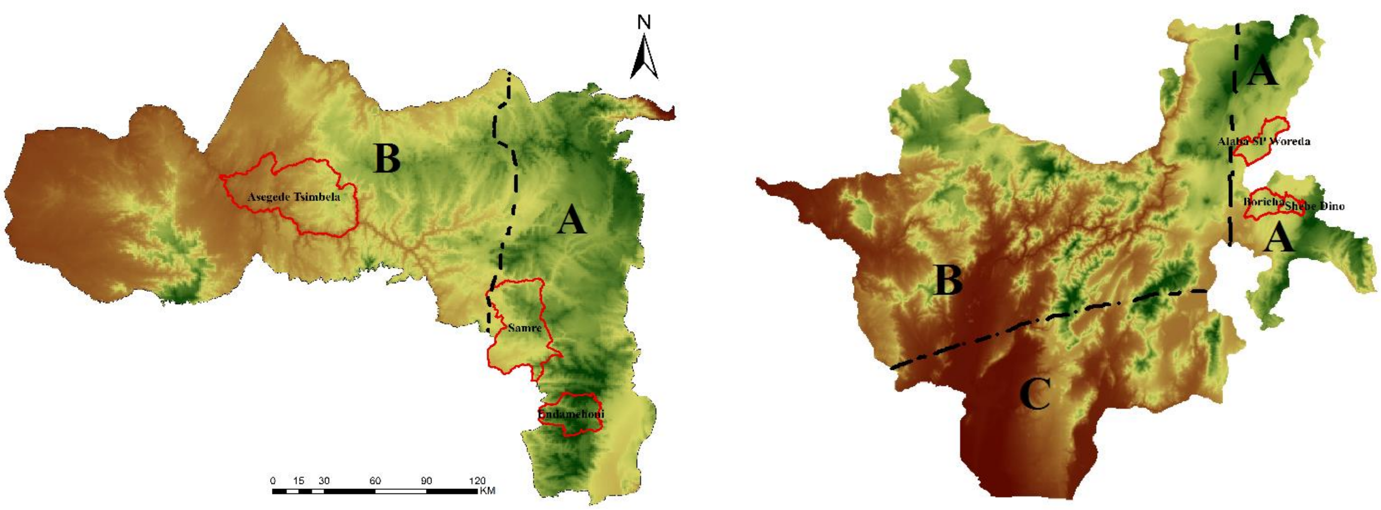


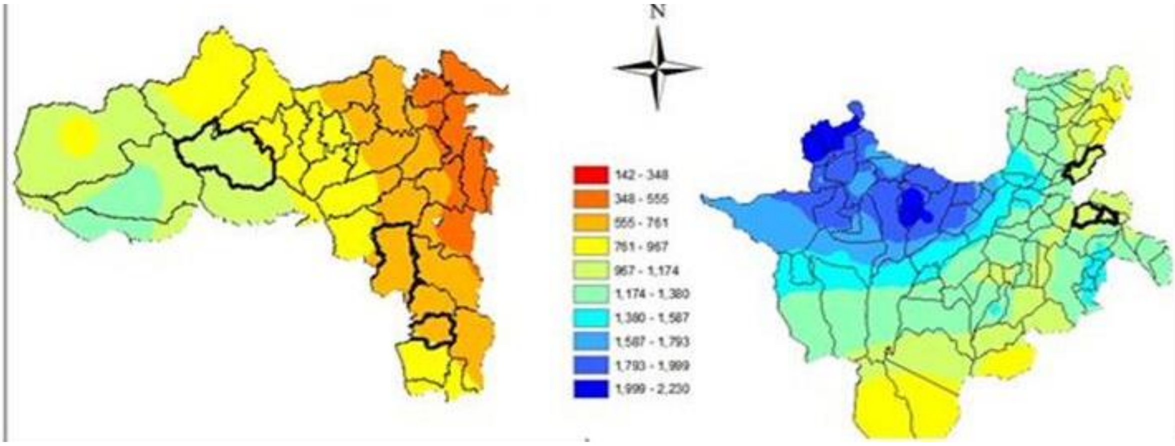
Figure 2: Rainfall pattern of Tigray (left) and SNNPR (right), area marked with 'A' has Bi-modal rainfall pattern Kiremet *(JJAS) and Belg (MAM), areas with letter 'B' has uni-modal rainfall pattern, Kiremt (JJAS)and Area with letter 'C' Bimodal type two Belg (MAM) and Bega (OND) (Adapted from Haile, 1987).*

Rainfall pattern produced based on 1983-2014 data from ENACT data set for selected districts of SNNPR shows mono-modal in the northern SNNPR and bimodal rainfall pattern in the southern SNNPR (Figure 3).

Figure 3: Monthly climatological rainfall performance of SNNPR.

2.2.1. Meso-scale system and topographic impact on local climate of SNNPR and Tigray

Meso scale system can be described as a weather systems that is even smaller than synoptic scale and its extent is horizontal dimensions generally range from around 2 kilometers to several hundred kilometers (www.meteor.iastate.edu). The effects of topography on the climate of any given region are powerful. Mountain ranges create barriers that alter wind and precipitation patterns. Mountains play an important role in precipitation patterns. Topographic barriers such as mountains and hills force prevailing winds up and over their slopes. As air rises, it also cools. Cooler air is capable of holding less water vapor than warmer air. As air cools, the water vapor is forced to condense, depositing rain on windward slopes. This creates an effect known as a rain shadow on their leeward (protected) sides, where the air contains very little moisture. Most part of Tigray and SNNPR regions are mountainous and the effect of topography is high (figure 4). However, details of local effect need further study.



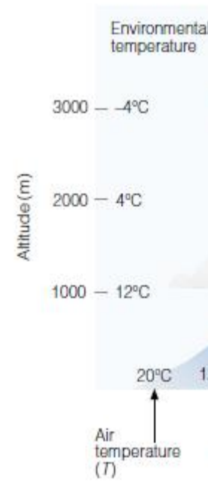


Figure 4: Schematic diagram of impact of mountain in producing excess rainfall in the windward side of a mountain and lesser rainfall on the leeward side of a mountain

2.2.2 Rainfall distribution over Tigray and SNNPR

In general, the mean annual rainfall distribution of Tigray increases from east of the region towards west. For the western half of Tigray, it also increases from north to the south. The mean annual rainfall ranges from less than 600mm over eastern and southern border of Tigray to in excess of 1200mm over southern part of the western half of the region (see figure 5 left panel).

Figure5: Mean annual total rainfall distribution in mm over Tigray (left) and SNNPR (right). Pilot District with bold District Boundary

Kiremt (June to September) is the main rainy season for Tigray with rainfall ranging from 300 to over 1000mm. Kiremt contributes 50% to 90% of the annual rainfall over the major rainfall areas of the region. As we can see the figure 6 below in Kiremt rainfall decreasing as we go from west to east.

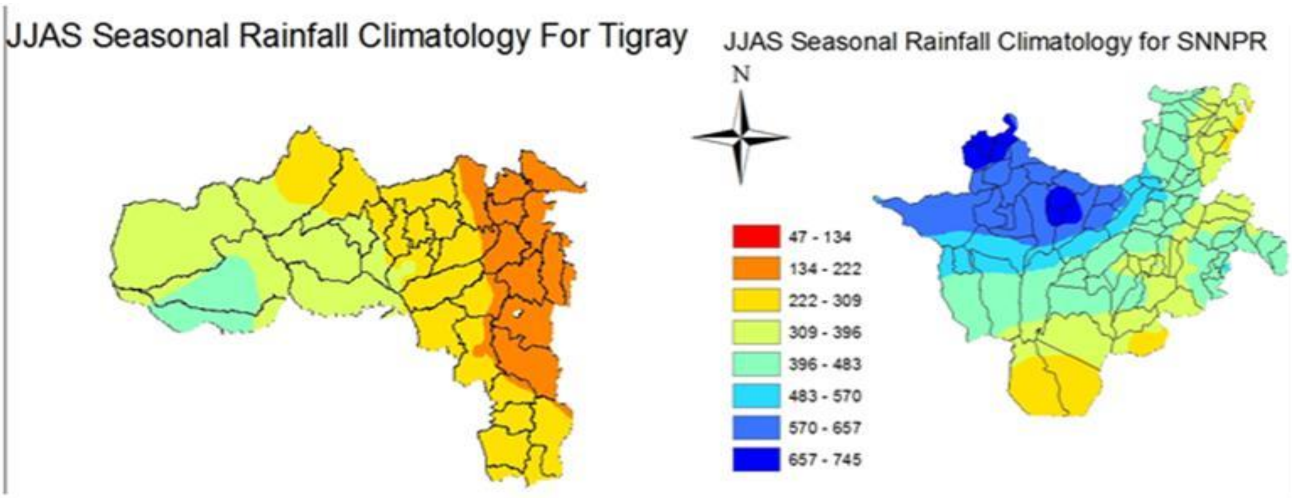


Figure 6:.Mean Kiremt (June-September) total rainfall over Tigray (left) and SNNPR (right)

2.3.3 Kiremt Onset

Kiremt onset can be defined as the first wet-spell of the year at least three days total 20mm or more, provided there were no sequences of eight or more dry less than 0.1 mm days in the subsequent 30 days) of the area of interest. In Tigray region onsets of Kiremt differ (June 01-July 10) from place to place especially when we go from west to east. The onset is earlier in the west of the region than the other parts and the onset variability is almost one week to four weeks over eastern, central and western parts of the region (figure 7).

Figure 7: Mean Kiremt onset date over Tigray (adopted from Segele, 2002)

2.3.4 Kiremt cessation

Kiremt cessation is the first day of a dry-spell less than 0.1mm/day of at least 20 days duration that occurred after onset. In Tigray region, there is late cessation in the west part of the region and an early cessation in eastern, central and southern of the region. The variability is about one month in the west, east and south of the region (figure 8).

Figure 8*:* Mean Kiremt cessation date for Tigray (adopted from Segele, 2002)

Chapter Three: Weather and Climate Forecast

3.1 Weather and climate forecast

The terminologies of weather and climate are often confusing for many common users of climate information. The simplest way of describing their difference is that weather is the day to day activities of the atmosphere while climate is the long term average of weather parameters like rainfall, and temperature to behave in a defined place and time.

Weather and climate plays an important role almost in all aspects of the life on earth. The country's economy mainly depends on rain fed agricultural activities. Hence, accurate and timely forecasting has got wide implications ranging from increasing the agricultural production to reducing the damage to life and property. Currently, weather forecasting services are rendered to agricultural, farmers, water, construction, investors and health sectors etc. Weather Forecasting is implies that giving a statement of anticipated/expected meteorological condition for a specified place and time based of local, regional and global systems. There are several different forecasting techniques that can be used to prepare a forecast.

3.2. Techniques of weather forecasting

3.2.1 Qualitative methods (subjective): These types of forecasting methods are based on judgments, opinions, intuition, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations mostly used for short range and now casting forecast based on past weather events of cloud coverage, wind speed and direction, temperature etc. Examples of qualitative forecast description could be heavy fall, light rain, snow, moderate, and cold, warm.

3.2.2. Quantitative methods (objective): These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations. They are used for Numerical Weather Prediction and medium and long range forecast. Mostly they described in amount. (e.g., 60 mm rainfall, 20 ^{o}C maximum temperature, -2 ^{o}C minimum temperature)

3.2.3 Persistent method: This method assumes that the conditions at the time of the forecast will not change i.e. Tomorrow's weather is same as today's weather or Today's weather will occur tomorrow also (at the same location). –Predicts for immediate future using current information

3.2.4. Trends method: The trends method involves determining the speed and direction of movement of air masses, fronts, pressure systems, clouds, precipitation and the likely location features in the future. It applies if a phenomenon is in steady state, or is moving at constant speed, Today's weather will occur tomorrow (at a nearby location).

Rate = distance/ time

3.2.5. Statistical method: This type of forecast is done by expecting average values. Correlation regression analysis is done by associating the changes in weather variables with changes in other variables located nearby or far away or associating one variable with another variable identify predictor Example El Nino- rainfall association

Probability analysis, calculates the chance of occurrence of a weather variable from historical data. Example:

- What is the chance to get 10 mm rainfall at Fiche town on June 1st?

3.2.5. Analogue method (pattern recognition): Identify existing features on a weather chart that resemble those that occurred in the past. Weather prediction is based on the assumption that, the weather will behave the same way as it did in the past for similar conditions. This method is useful method for longer-term forecasts (10 days - months). National Meteorological Agency highly relies on this technique to produce seasonal forecasts.

3.2.6. Numerical weather prediction (NWP): it is the process of obtaining an objective forecast of the future state of the atmosphere by running a numerical model on a high capacity computer. It uses physical laws to formulate mathematical equations governing the changes in atmosphere to project present state to future. It is objective method.

3.3 Weather and climate prediction and their characteristics

Weather forecasting produces only for short to medium range from one to ten days whereas climate prediction is for longer periods. The forecast accuracy is highly dependable on time segments and hence in general short range forecast is accurate than long range climate prediction.

3.4 Seasonal climate prediction: Seasonal climate prediction in Ethiopia provides climate information from one to four months and the prediction includes rainfall outlook, agro-met advisory, hydro-met and bio-meteorological services and other climate parameters.

In Ethiopia we have three season's based on rainfall and temperature these are Bega (October to January), Belg (February to May) and Kiremt (June to September).

During Bega dry and cold weather condition prevailed over much of the nation, except in the South and South-eastern Ethiopia, where Bega is the second rainy season. Belg is the short rainy season for northeast, east, central and southern highland while, main rainy season for south and southeast portions and Kiremt is main rainy season across much of the Ethiopia except south and southeast of the country. The basic approach for climate prediction is based on selection of analogous years based on the ENSO episode. In addition, the characteristics of the regional oceans such Indian Ocean, Atlantic Ocean and Arabian Sea have key role in determining the variability of the seasonal climate within a given ENSO episode. Thus, the influence of the regional systems and other local effect are considered in each specific seasonal prediction. The seasonal forecast is given in a probability of three categories (terciles), with the value which define the probability of being above normal, normal or below normal as compared to the long term climatology.

3.4.1 Interpretation of tercile probabilities in climate prediction

Terciles are used to represent three broad sectors of the probability distribution that are equally likely, climatologically. For each location and season, the terciles correspond to actual temperature or precipitation ranges, based on the set of historical observations. In using tercile forecasts, users need to know the ranges (i.e. the two main cutoff values that define the terciles) to which the terciles refer for the location/season of concern. The cut of are based on the long term climatology. Without any forecast clues, the probability that any of the three outcomes will occur is one-third, or 33.3%, which means that if the situation could be "rerun" many times, each outcome would occur one out of three times. However, with forecast clues, such as the presence of an El Nino, a La Nina, or other climate event, the probabilities of the terciles might no longer be equal, so that the probability of one (or two) of them would be greater than 33.3% and the remaining one(s) less than 33.3%. This deviation from the climatological, equal chance 33.3% (below normal), 33.3% (normal) and 33.3% (above normal) represents a forecast, because it suggests increases and decreases in the likelihoods of occurrence of terciles relative to the likelihoods reflected in the long-term observations. Forecasts are expressed in terms of the likelihood of terciles because of the typically large amount of uncertainty in the forecasts. This uncertainty makes the forecasting of exact temperatures, or amounts of precipitation, misleading, since large errors are often likely. (Such errors would not be as large, however, as the errors that would result from random guessing, or from always forecasting the climatological average.) The use of tercile probabilities provides both the direction of the forecast relative to climatology, as well as the uncertainty of the forecast. For example, suppose a forecast calls for precipitation probabilities of 20% for the dry tercile, 35% for the middle tercile, and 45% for the wet tercile. Since the wet tercile is above 33.3% and the dry tercile is below 33.3%, this forecast suggests that above normal precipitation is more likely than it usually is, and below normal is less likely than usual.

3.4 Interpretation of forecasts and forecast variability.

3.4.1. Definition of the probability terciles categories

Category information for precipitation forecast:

Seasonal forecast are categorized by three rainfall percent of normal; namely above normal, normal and below normal. When the forecast indicates above normal, the seasonal precipitation forecast is above average compared to its long term climatological mean by 125% while normal condition is between 125% and 75% and below normal condition is below 75%

For example; if a station A has long term mean rainfall of 1000mm for a given season and its actual observed rainfall value is 1251 mm, then the observed rainfall is categorized as above normal (1251mm/1000mmX100%=125.1%). On the other hand if the actual observed rainfall amount is 800mm; then it lies under the normal category where as if the actual observed rainfall amount is 600mm then it lies under below normal category.

3.4.3. Probability of precipitation

A **probability of precipitation (POP)** is a formal measure of the likelihood of precipitation that is often published from weather forecasting models. Its definition varies.

In NMA weather forecasting, POP is the probability of occurrences that more than 1/100th of mm of precipitation (rain) will fall in a single spot, averaged over the forecast area. For instance, if there is a 100% probability of rain covering one side of a region, and a 0% probability of rain on the other side of the region, the POP for the city would be 50%. A 50% chance of a rainfall covering the entire region would also lead to a POP of 50%.

Note that the POP measure is meaningless unless it is associated with a period of time. NMA forecasts commonly use POP defined over 24-hour periods (POP24)

Mathematical definition of **Probability of Precipitation** is defined as:

PoP = CxA

C = the confidence that precipitation will occur somewhere in the forecast area.

A = the percent of the area that will receive measurable precipitation, if it occurs at all.

For example, a forecaster might be 50% confident that under the current weather conditions precipitation will occur, and that should rain happen to occur, it will happen over 80% of the area. This results in a PoP of 40 %:(0.5 x 0.8) x 100 = 40%

So, most of the time, the forecaster is expressing a combination of degree of confidence and areal coverage. The NMA explains this as follows: "Chance of rain 40 percent" means there is a 40 percent chance that rain will occur *at any given point* in the area. Another way to express "Chance of rain 40 percent" is that *on average* for *all of the points* in the area during the specified time period (usually 24-hour periods), chance that rain will occur is 40%.

Terms typically in weather forecasts based on POP:

- **0%** – No mention of precipitation
- **10%** – No mention of precipitation, or isolated/slight chance
- **20%** – Isolated/slight chance
- **30%** – (Widely) scattered/chance
- **40%** or **50%** – Scattered/chance
- **60%** or **70%** – Numerous/likely
- **80%**, **90%** or **100%** – showers and thunderstorms

3.4.4 Rainfall intensity characteristics.

Rain classification	Definition and description over 24 hours
Very light rain	Less than 0.9 mm
Light Rain	1mm to 10mm
Moderate rain	10mm to 30mm
Heavy rain	30mm and above

3.5. Numerical Weather Prediction (NWP)

Numerical Weather Prediction is a quantitative forecast which uses the high performance computers to solve governing mathematical equations of the state of the atmospheric circulation. In NWP the forecast is expressed directly in amount at specific area as area and point forecast. As we see in figure 9 and 10, the NWP model forecast for rainfall and temperature is quantitative forecast we can see where how much rainfall or temperature will be happened for the place. Figure 9 the upper panel describes daily total rainfall of the country while figure 9 the bottom panel discusses daily air temperature pattern while figure 10 shows that specific point forecast.

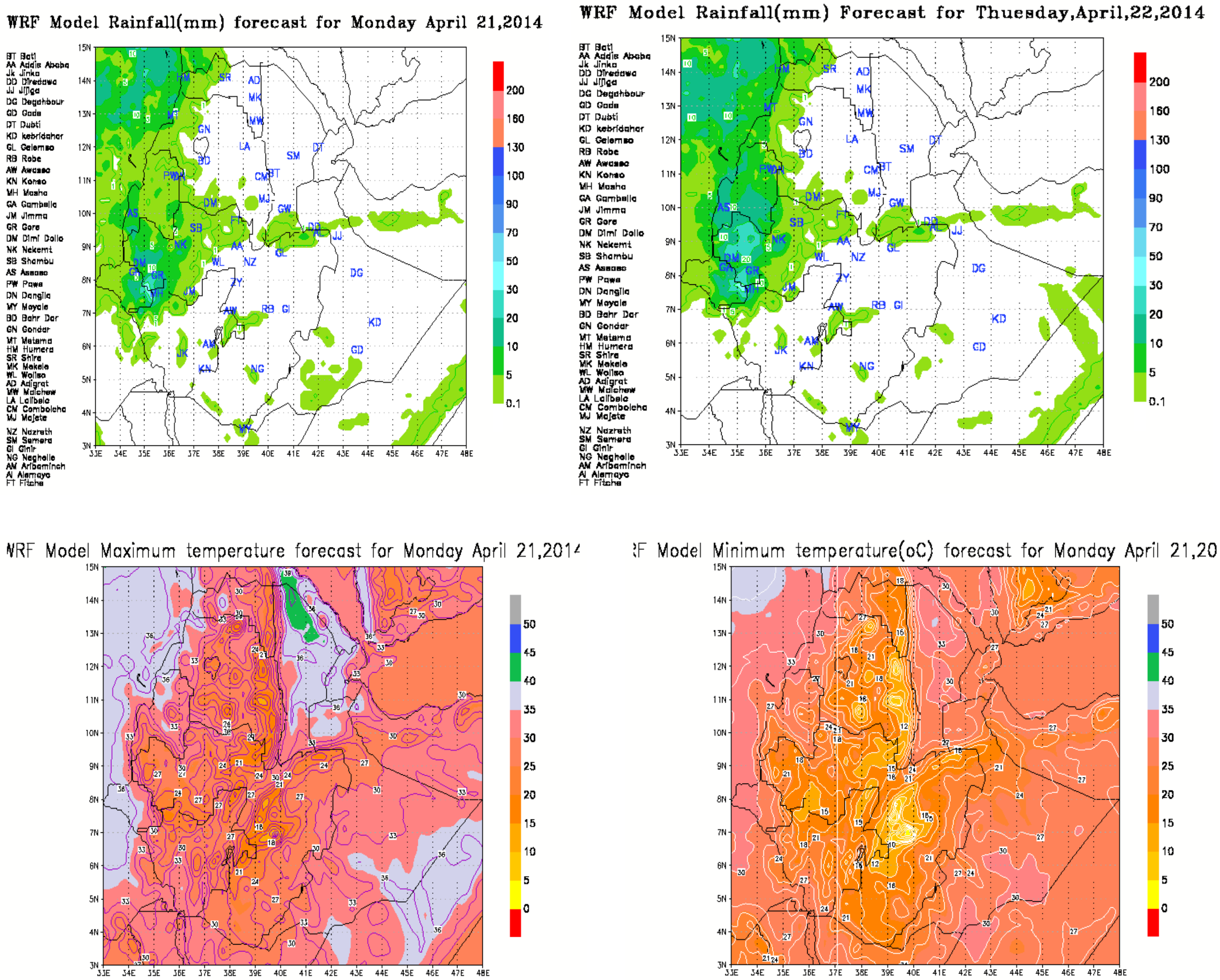


Figure 9: Example of rainfall and minimum maximum Temperature NWP area forecast.

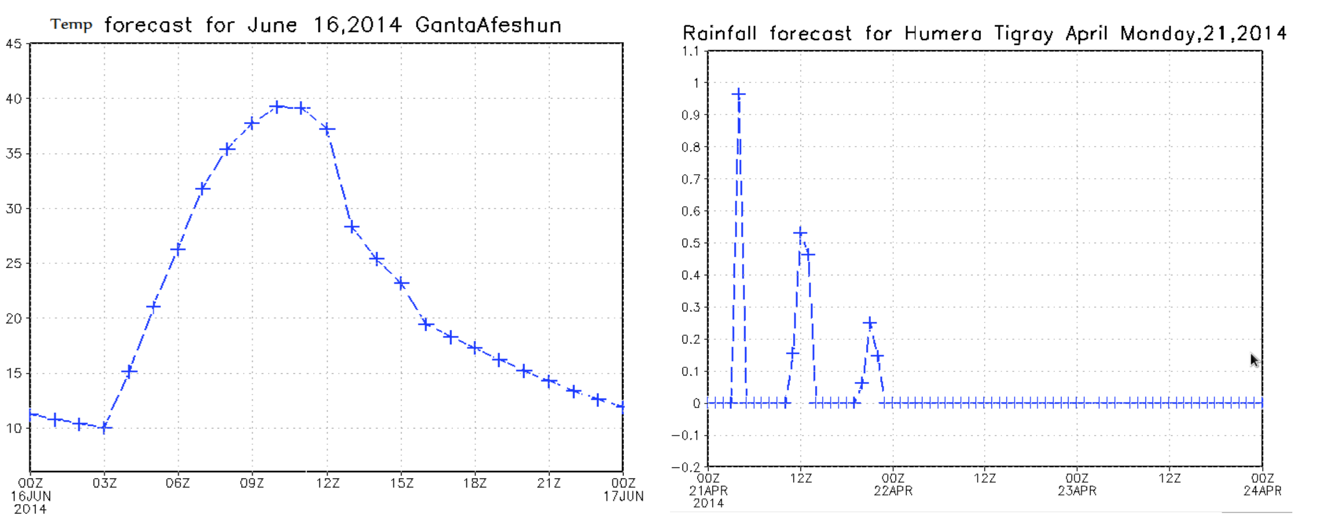


Figure 10: Example of point forecast for rainfall, minimum and maximum temperature using NWP

Chapter Four: Climatic and agro-climatic resources of Tigray pilot Districts

4.1 Introduction

The development of agro-meteorological guideline requires the investigation and the identification of the crop growing period and the opportunities and the risks associated with crop cultivation regarding the availability of moisture for crop growth. The advisories regarding fertilizers application, protection against crop pests and diseases can be undertaken only through the identification of the crop growing period which will be the basis for understanding the dominant crop calendar. Thus the agro-meteorological advisories are based on first identifying the characteristics of the crop growing period which would be the basis for advisories regarding the planting window, the type of crops to be cultivated, coping mechanisms on crop pests and diseases for the area and application of fertilizers with a brief supplemental note to the agronomic researcher. Thus, detailed agro-meteorological analysis has been carried out for the three selected districts of Tigray in this chapter. The ENSO episode climatology for each district given under this chapter is believed to give a guide to end-users what type of rainfall distribution is expected, once NMA declare the expected ENSO phase for the upcoming season.

4.1.1 Pilot District selection

The project funding Irish Aid has a long standing history to provide technical assistance to enhance agricultural production and to address the food security issue in Tigray. The project intends to enhance the resilience of small holder farmers to climate shocks more effectively by bringing synergy to the on-going Irish Aid efforts and other relevant interventions. Thus, the site selection has been carried out based on the following criteria: (i) Availability of weather stations and that of more consistent historical climatological data for producing good products for the end-user communities (ii) Existing interventions to enhance agricultural productions and to avert, mitigate and transfer climate risks. In particular, Districts where Irish Aid funded projects are on-going are priorities. (iii) Diversity of agro-climatological zones represented. (iv)Consideration of both livestock and crop areas to be represented. (v) Existence of operational Automatic Weather station (AWS) near-real time monitoring of the weather. Accordingly, three Districts namely Asegede Tsimbela, Samre and Endamehoni has been selected as a project site (figure 11).

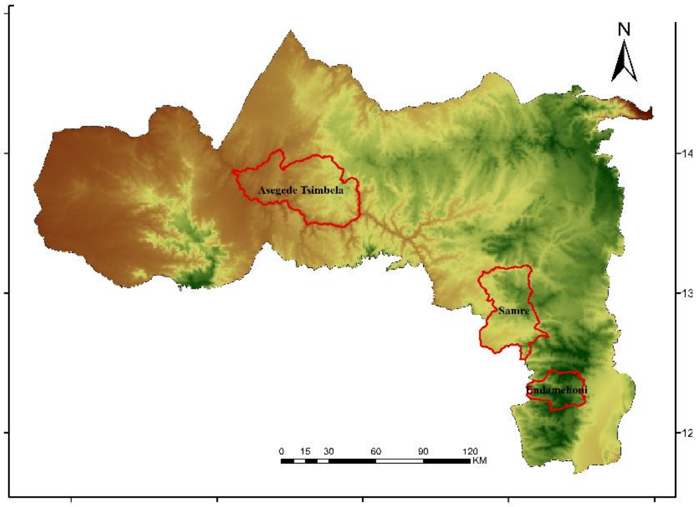


Figure 11*:* Location of Pilot Districts

4.1.2. Data and methodology

Data

The data used for District level detailed analysis were blended and gridded data of dekadal rainfall and temperature from 1983-2014 at 4km by 4km spatial resolution (Dinku et al, 2013). For the District climate analysis spatial average of the gridded data has been used by extracting the NMA map room tools (WMO, 2011)

Methodology

- Simple statistical analysis over different ENSO episode has been deployed for each pilot District to present the climate characteristics under each ENSO episode as a reference. In addition, analysis and computation of normalized anomaly for variability and trend in the time series has been used. Climatological mean for the year 1983 to 2014 is used for normal.

- The computation of dekadal rainfall at different probabilities was computed in Microsoft Excel worksheet, where the probability of exceedance was computed by sorting the time series data in a descending order and by assigning Rank (R) for each value and where **P=100xR/(n+1)**, n being the number of the years, it is considered that for large number of years, this value would approach the true value
- LGP is the difference between starting and end of rainfall of particular season.
- Reference Evapo-transpiration was computed based on the use of the maximum and minimum temperature data, with other data estimated. Here Crop-wat8 and Agromet shell models were also

used to compute and compare the results with those stations having all the necessary data of maximum and minimum temperature, relative humidity, sunshine hour, wind speed.

- The start and end of the crop growing period in each Districts was determined using Ms- Excel worksheet and defined as the time when the amount of rain and half of ETo become equal.

4.1.3. Results on length of crop growing period for the selected Districts

The computation of the length of the crop growing period at different probability levels of 80%, 50% and 20% were used so as to develop agro-meteorological advisory systems that can be used with the different agro-climatic variations, that farmers can expect, both temporal and spatial. Analysis of dekadal characteristics of crop growing period can help the assessment of the risk of undertaking of different agricultural activities, such as planting, fertilizer application, weeding etc.

Thus dekadal rainfall at 20%, 50% and 80% probability level has been computed at dekadal basis and the ratio of this value to the dekadal reference evapo-transpiration has been computed for this purpose. The 20% probability level greatly corresponds to the case which farmers usually call a good year which for this purpose occurs once in five years this probability level shows us the best scenario that the farmers can expect over a given area. The 50% probability level indicates the case which the farmers face once in roughly two years and thus also includes risks which the farmer has to take on fifty-fifty basis. The 80% probability level indicates the dependable crop growing period which shows the scenario of minimum risk.

Crop growth analysis over the selected Districts shows that the crop growing period attains the longer period over Asegede Tsimbla (100 to 110 days) and Endemehone (90 to 100) and the shorter over Samre with 60 to 70 days. Thus the identification of the best crop for the area should take into account this characteristic. The next important point is how to minimize planting failure and in this respect the planting window based on the determination of the planting time at different probability level is undertaken. Here in this case, the maximum variability in the planting window is found over Samre from July third dekad to August third dekad, which the farmers should take into account so as to minimize planting failure, by avoiding false start of the rains, where as planting risk failure over the rest of the selected Districts is smaller. These agro-climatic characteristics are given for each selected District in the next chapter.

4.1.4. Recommended advisories on fertilizer application for the selected Districts

The skilful use of fertilizer application is greatly dependent on our knowledge of the moisture condition that is existing at the time of fertilizer application.

The check lists for the application of fertilizers that should be communicated to the farmers should be the following:-

- Never apply fertilizers during dry spells.
- Never apply fertilizers during heavy rainfall days.
- Avoid applying fertilizers during times of high water logging occasions, especially if the soil is fully saturated with moisture, the soil will not absorb the fertilizer solution.
- The best time of the application of fertilizer is when there is sufficient water to make the fertilizer solution that is during moderate rainfall conditions, with no water logging where the soil is not saturated.

The actual application of fertilizer should be based on the above check lists. Thus as there is ample rainfall activity during the month of July and as the problem of water logging is exhibited during the month of August, the month of July can be considered as the best month for fertilizer application. However the exact timing is the function of local agro-ecological and agronomic factors, and the actual weather condition that is expected over a few days and thus information on short term forecast of two to three days is important which should be available to the farmers, when they intend to apply fertilizers.

Application of Fertilizers during the month of August may be necessary for crops such as Teff which are usually planted during this month. Thus the application of fertilizer during the month of August should take into account the week when the problem of water logging is minimal and when the problem of heavy rainfall events and hail storms is minimal. Probably the first half of August may be more favorable, which still has to be implemented by taking into account local agro-ecological features and short range forecast.

The most suitable time for fertilizer application is during the time when there is minimum risk of dry spells, minimum risk of heavy rainfall activity, and when there is minimum risk of water logging. A table on dekadal rainfall at different probability levels is given here to support decision making process.

4.1.5. Supplemental note for agronomic researchers in the selected Districts

Among the cultural practices, sowing date and fertilizer application are the major limiting factors to achieve production potential of the crop. Research over different parts of the world has shown that maximum productivity of crops can be achieved by the proper combination of a given soil moisture level, a given rainfall amount (or else a given amount of irrigation water) with the timing of fertilizer application. These research works also indicate that yields were mainly limited by the timing of sowing/ planting and proper fertilizer application. These variables, soil moisture amount, daily rainfall amount, temperature and a given amount of fertilizer are usually the functions of the crop type and the local agro-ecological characteristics including the soil type. The magnitude of nitrogen loss from denitrification is dependent on temperature, soil texture, soil organic matter, and moisture status of the soil. Denitrification occurs at soil moisture tensions near saturation, with rapid changes in the rate of gaseous nitrogen emissions during wetting and drying cycles. The great value attached to this type of research is that it can increase the effectiveness of the applied fertilizer to the optimum level. This type of research thus should be supported with data coming from an automatic weather station equipped also with soil moisture measurement instrument, so as to identify the optimum efficiency of fertilizer application and communicate the technology to the farmers.

4.1.6. Major crop pests and diseases in the selected Districts

The occurrence of crop pests and diseases is closely linked with the interaction of the weather favorable to the crop pests and diseases and also the susceptibility of the particular crop growth stage for the crop pests and diseases. Over highland parts of the selected Districts, wheat rust is considered as one important problem during high rainfall and high humidity years with an extended period of cloudiness. Thus care should be taken over the highlands during wet years to identify the best method of the prevention of wheat rust. Over lowland areas, the common pests attacking crops are shoot fly which affects Teff, the **Stalk Borer** which affects sorghum and aphids and rodents that attack barley and wheat. As sorghum is a drought tolerant crop cultivated over the area protection of this crop against the widespread damage of Stalk borer should be considered as one important component of the agro-meteorological advisory system, during rainfall deficient years. Stalk Borer occurs usually during moisture deficient years with high temperature being the other factor. Thus coping mechanisms during rainfall deficient years should also address simultaneously the problem of Stalk Borer.

4.1.7. Management of soil and water in the selected Districts

The improvement of the effectiveness of soil moisture conservation and the use of rain water harvesting, can be very important to minimize loss of production through the problem of deficient soil moisture. This is in part explained due to the high variability of the rainfall during the month of September in the Kiremt season, especially for districts with high rainfall variability and shorter cropping season such as Samire. Thus moisture conservation through the use of various combinations of applications should also be considered as one important area of research. The application of rain water harvesting schemes during the month of August for counteracting the problem of rainfall deficiency during the month of September should be one important area of research. Soil moisture conservation can also be very important for keeping soil moisture reserve after the completion of the Kiremt crop growing period. As different climate change scenarios have indicated, the increased likelihood of an increase in the rainfall during the northern hemisphere autumn months in October-November months can also be beneficial to cultivate some crops based on soil moisture reserve, Especially for clay soil types, which have large capacity for soil moisture storage. Management of soil means that of replenishing soil nutrients that have been used during previous seasons, and increasing the quality of the soil in its water holding capacity.

In the next sections, major agro-climatic characteristics of the three selected Districts are given which the agricultural development agents and the agricultural researchers should use in combination with the meteorological forecasts and agro-meteorological advisories in the implementation of this pilot project.

4.2. Detailed District level climate and agro climatic analysis

4.2.1. Climatic and agro-climatic resources of AsegedeTsimbla

4.2.1.1 Climate analysis for Asegede Tsimbla

Asegede Tsimbla has uni-modal rainfall pattern with a mean annual rainfall 1070.9mm and 14.9% coefficient of variation, which is low. The Kiremt season has coefficient of variation of 12.3% and the variability of Kiremt seasonal rainfall over the District is strongly influenced by ENSO events. Kiremt mean rainfall is 78.73 mm per decade. However, Kiremt rainfall averaged over El Nino years is 82.2 mm per decade; this is above the long term mean. On the other hand, Kiremt rainfall averaged over La Nina years is 78.9 mm per decade. Moreover, the maximum Kiremt dekadal mean rainfall in El Nino years does not exceed 131.9mm where as Kiremt dekadal mean during La Nina years can exceed 110 mm (see table 1). As we can see from the graph that, the peak seasonal dekadal rainfall during La Nina years is well below 115mm, where as in El Nino years it could reach well above to 130 mm (see figure 11). However seasonal onset and cessation are not significantly impacted by ENSO events (Table 2). Normalized anomaly rainfall shows a slight decreasing trend (figure 11) while the normalized temperature anomaly shows a general increasing trend (figure 12).

ENSO	No of yrs	A	B	C	D	E	F
El-Nino	10/32	1	5	4	32.	82.2	131.9
Neutral	12/32	8	2	2	35.3	75.8	105.2
La-Nina	10/32	3	3	4	33.5	78.9	111.4
All Years	32/32	12	10	10	33.8	78.7	115.5

Table 1: Kiremt rainfall statistics for Asegede Tsimbla based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal mean maximum rainfall in mm)

ENSO	**Onset Decade**	**Cecession Decade**
Neutral	June 2nd decade	Sep 2nd decade
El-Nino	June 2nd decade	Sep 2nd decade
La-Nina	June 2nd decade	Sep 2nd decade
All Years	June 2nd decade	Sep 2nd decade

Table 2: Onset and secession date variation on ENSO episode, Asegede Tsimbla

Climate analysis for Asegede Tsimbla District Based on ENSO episode

4.2.1.2 Agro-Climatic Characteristics of Asegede Tsimbla

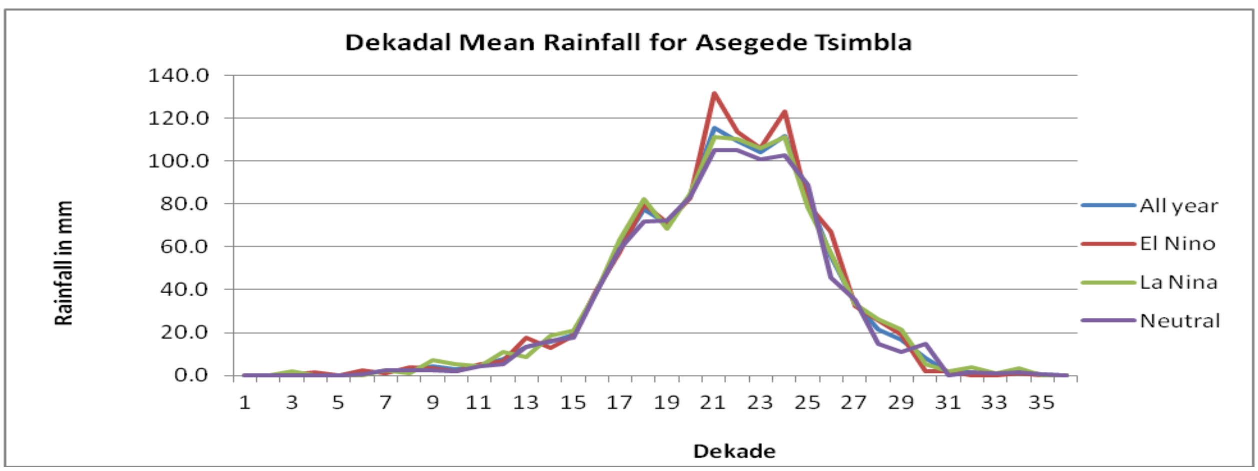


Figure12:Mean decadal rainfall of Asegede Tsimbla District for 1983-2014(averaged for all years, averaged for only La Nina year’s solid lines, averaged for El Nino year’s and averaged for only ENSO neutral years.

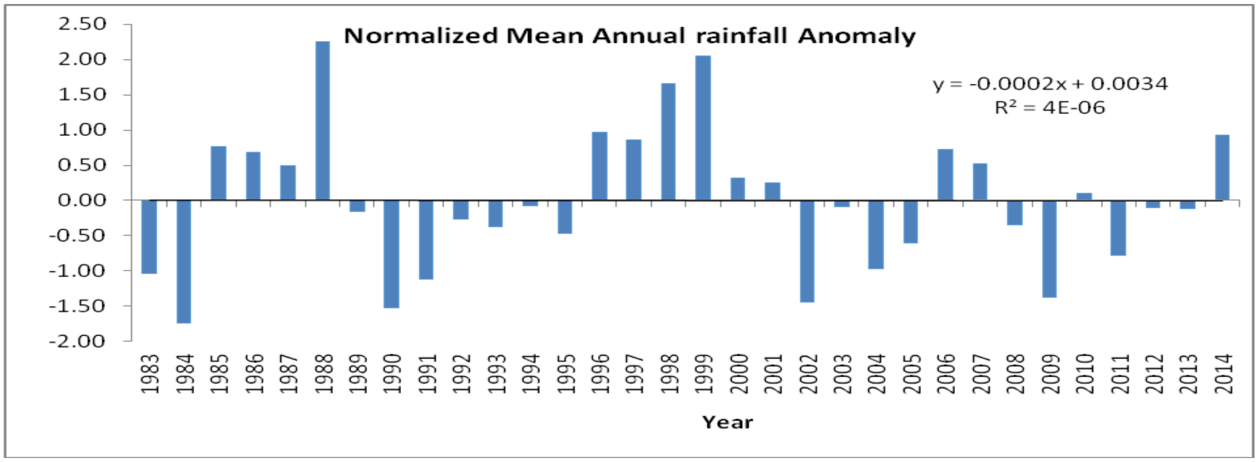


Figure12: Standardized mean annual rainfall anomaly over Asegede Tsimbla District

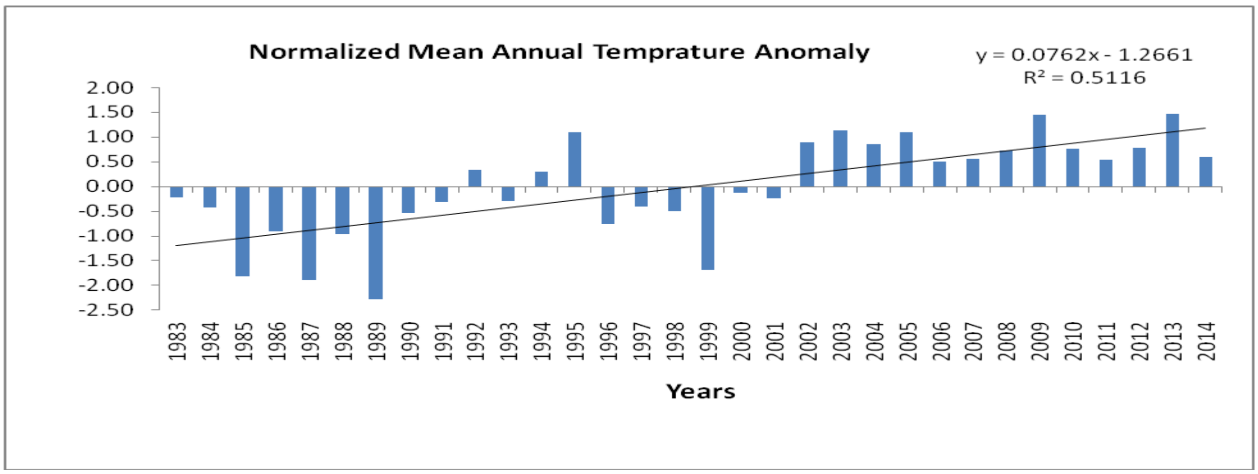


Figure13: Standardized mean annual Temperature anomaly over Asegede Tsimbla District

4.2.1.2.1 Identification of crop types for AsegeTsimbla

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 70 to 120 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

4.2.1.2.2 Planting Windows for Aseged Tsimbla

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used two criteria. The first criterion is when the ratio of the decadal rainfall to the decadal reference evapo-transpiration is greater or equal to 0.5 and the other criterion we used is the first dekad when the rainfall is greater than 20 mm of rainfall and by integrating the two criteria. It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. Planting time with 80% assured success is computed to be the June third dekad, where as if we consider on a fifty-fifty basis, the second dekad of June is recommended. However if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would be May 2nd dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from May 2nd dekad to the third dekad of June (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be July first dekad, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important.

4.2.1.2.3 Cessation of the crop growing period for Asegede Tsimbla

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be September second dekad. The 50% probability level shows that the cessation can sometimes extend up to September second dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years this may still extend up to September 1st dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

Percent of probability	50% prob	**80%** prob	20% prob
Planting window based on rainfall to half of ETo (RR >ETO/2)	June 2nd	June 3rd	May 2nd
Cessation based on rainfall to half of ETo (RR < Eto/2)	Sep 2nd	Sep 2nd dekad	Sep 1st
LGP	100 to 110 days	90 to 100 days	120 to 130

Table 3*:* Characteristics of planting window, cessation of crop growing period and LGP at different probability level

Decade	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
50% prob	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	91	92	84	60	123	136	82	144	83	79	16	21	0	0
80% Prob	0	0	0	0	0	0	0	0	0	0	0	2	14	13	18	41	41	111	32	84	130	82	84	83	56	81	19	0	14	0
20% Prob	0	0	0	0	0	0	9	0	21	25	16	4	22	45	27	21	10	98	105	87	86	80	118	128	108	35	28	0	0	0

Table 4*:*Dekadal rainfalls expected at different probability level for Asegede Tsimbla

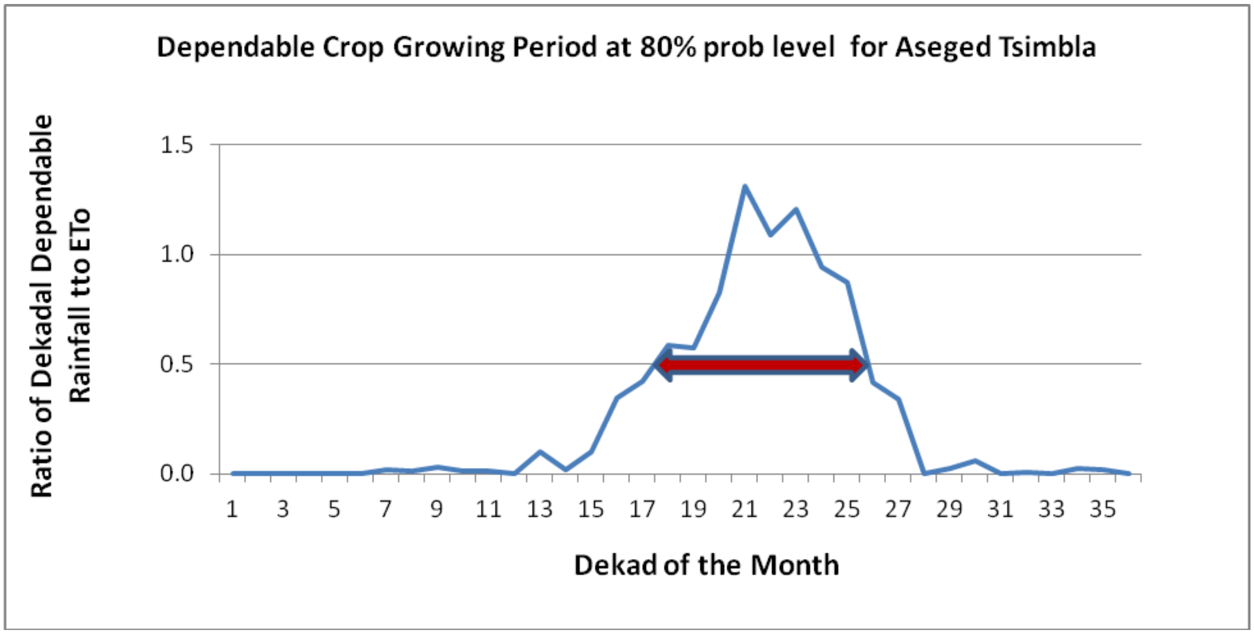


Figure14*:* Dependable crop growing period for Asegede Tsimbla 80% probability

4.2.5 Climatic and Agro-climatic resources of Samre

4.2.5.1. Climate analysis for Samre

Samre has bimodal rainfall pattern with a mean annual rainfall 615.5mm and 23.7 % coefficient of variation, which shows moderately high year to year rainfall variability. The Kiremt season has coefficient of variation of 26.2%, which is moderately high. Like others, Samre also is strongly influenced by ENSO events. The Kiremt mean rainfall is 44.6 mm per decade. However, the Kiremt rainfall averaged over El-Nino years is 46.8mm per decade, which is above the long term mean. On the other hand, Kiremt rainfall averaged over La Nina years is 43.0mm. Moreover, the maximum Kiremt dekadal mean rainfall in El Nino years does not exceed 96.2mm, where as Kiremt dekadal mean during La-Nina years could reach 85.3 mm (see table 5). As we can see from the graph on figure 15, the peak seasonal dekadal rainfall during El Nino years is well Above 95 mm; where as in other years could reach below to 85mm.

This District is also one of the Belg benefiting areas with mean rainfall is 6.1mm per decade and 78.5 % coefficient of variation, which is shows very high year to year rainfall variability. Belg rainfall averaged over El-Nino years is 68.7mm. During El Niño the rainfall enhanced in Kiremt season while in Belg season it's weakened. Regarding long term trend, this District has a temperature increasing trend, which unexpected with global warming, where as rainfall show a decreasing trend (see figure 16and 17).

Season	ENSO	No of Years	A	B	C	D	E	F
Kiremt	El Nino	10/32	4	4	2	2.3	46.8	96.2
	Neutral	12/32	6	3	3	3.8	44.0	83.5
	La Nina	10/32	3	4	3	2.7	43.0	85.3
	All Years	32/32	13	11	8	3.3	44.6	82.0
Belg	ElNino	10/32	3	4	3	0.3	5.7	11.5
	Neutral	12/32	5	3	4	0.0	5.6	18.3
	La Nina	10/32	6	2	2	0.4	5.1	11.8
	All Years	32/32	14	9	9	0.3	6.1	14.2

Table 5*:* Kiremt and Belg rainfall statistics for Samre based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal maximum rainfall in mm)

ENSO	**Onset Decade**	**Cecassion Decade**
Neutral	Jul 2nd decade	Sep 2nd decade
El-Nino	July 2nd decade	Sep 2nd decade
La-Nina	Jun 2nd decade	Sep 2nd decade
All Years	July 1st decade	Aug 3rd decade

Table 6*:* Onset and secession date variation on ENSO episode for Samre District

Climate analysis for Samre District Based on ENSO episode

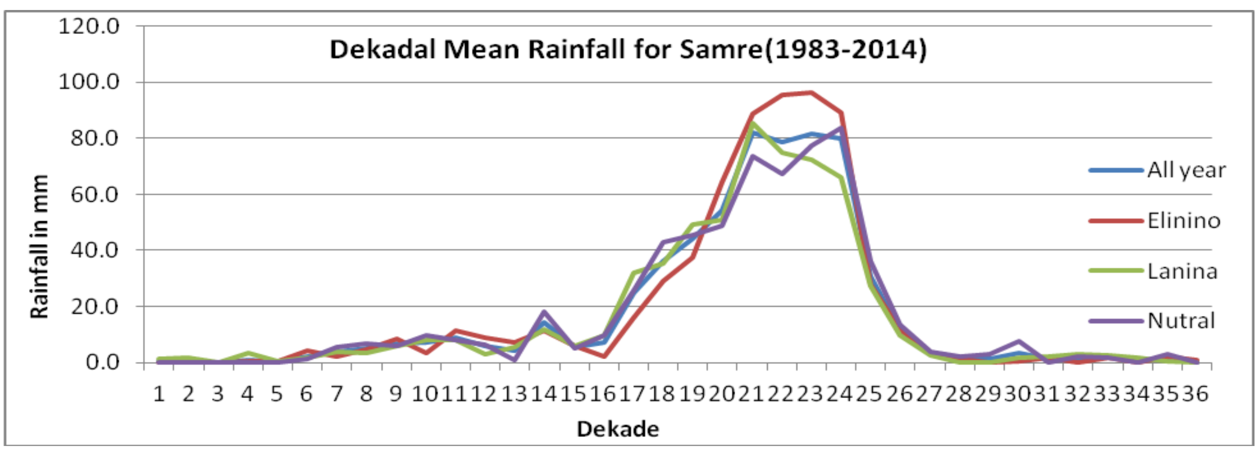


Figure15: Mean Dekadal rainfall of Samre District for 1983-2014 (averaged for all years, averaged for only La Nina years, averaged for El Nino years and averaged for only ENSO neutral year.

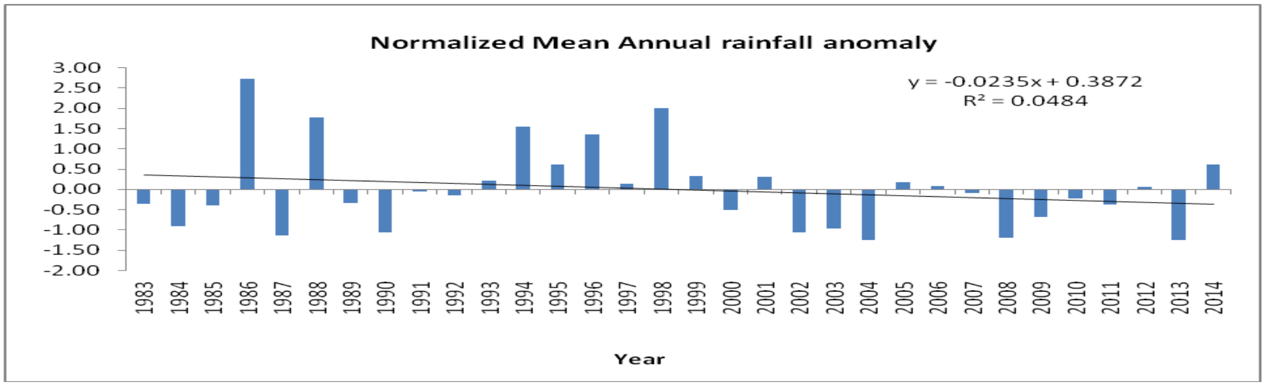


Figure16*:* Standardized mean annual rainfall over Samre District

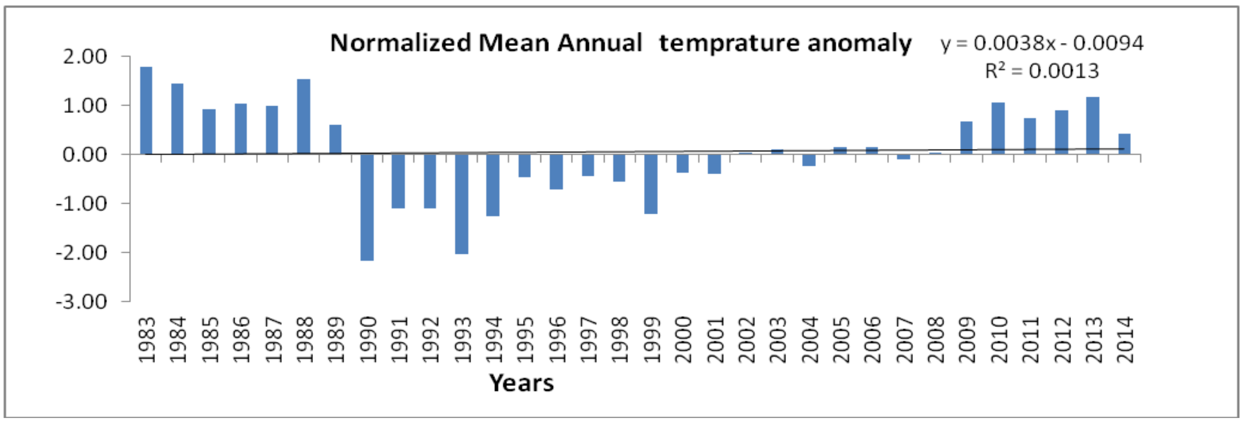


Figure 17: Standardized mean annual Temperature anomaly over Samre District

4.2.5.2 Agro-Ccimatic characteristics of Samre

4.2.5.3 Crop growing period at different probability levels for Samre

Analysis of temperature and rainfall shows that the dependable growing period at a probability level of 80% is assured only for the Kiremt season for the Samire District. The most dependable months for moisture availability for crops with minimum variance are July and August, where as the month of August shows the probability of water logging occurring, which greatly depends on the type of the soil and the topography. For soil type of clay, this indicates that proper drainage management is important for the month of August. The 80% probability level called the dependable growing period for Samre with minimum risk shows that the growing period comprises the time period of July
3rd decade to August third dekad, adding up to 50 days. The 50% probability level called the median or the mean length of crop growing period with a 50% risk, or the case in which the farmer expects good climatic conditions once in two years comprises the time period July second dekad to August third dekad, adding up to 60 days. The 20% probability level called the best scenario that the farmer can expect in the inter annual variability of the rainfall shows an interesting feature where, the farmer can get the opportunity of cultivating medium cycle crops. The length of the crop growing period from July first dekad to the August third dekad, comprising about 70 days. It is important to note this scenario occurs occasionally only, once in five years. However, with the correct information that farmers can get from meteorological forecast, farmers can get a good harvest by utilizing these conditions.

4.2.5.4 Identification of crop types for Samre

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 50 to 70 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

4.2.5.5 Planting Windows for Samre

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used criteria. The start and end of the crop growing period in each Districts was determined using excel work sheet and defined as the time when the amount of rain and half of ETO become equal.

It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. Planting time with 80% assured success is computed to be the third dekad of July, where as if we consider on a fifty-fifty basis, the second dekad of July is recommended. Similarly, if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would still be July first dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from July first dekad to the second dekad of July (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be the beginning of July, which the farmer must adjust

Based on the actual weather conditions in the given year, where forecast information would be very important

4.2.5.6 Cessation of the crop growing period for Samre

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be August 3rd dekad. The 50% probability level shows that the cessation can sometimes extend up to the end of August third dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years this may still extend up to the August third dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

	50% prob	**80% prob**	**20% prob**
Planting window based on rainfall to half of ETo(RR>ETO/2)	July 2nd	July 3rd dekad	July 1st dekad
Cessation based on rainfall to half of ETo (RR <Eto/2)	Aug 3rd dekad	Aug 3rd dekad	Aug 3rd Dekad
LGP	60 days	50 days with no humid period	70 days

Table 7*:* Characteristics of planting window, cessation of crop growing period and LGP for samre at different probability level

Decade	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
50% prob	0	4	0	3	0	0	0	15	2	0	3	12	48	0	0	0	0	15	21	60	65	10	73	88	23	0	0	13	0	2
80% Prob	0	0	0	0	0	0	0	0	15	5	0	0	0	0	0	0	39	39	28	36	87	63	45	46	27	1	0	0	0	0
20% Prob	0	0	0	0	1	0	0	11	46	8	18	16	0	20	0	0	0	13	57	66	11	66	13	70	30	0	5	0	0	3

Table 8 : Dekadal rainfalls expected at different probability level for Samre

Crop Growing Period at 80% probability level at Samre

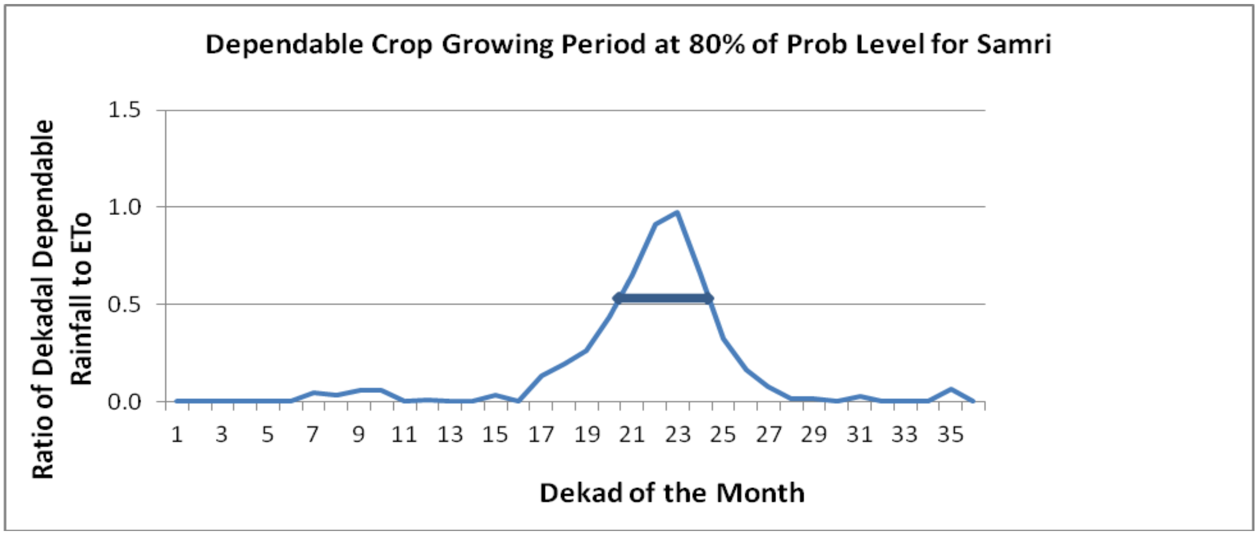


Figure18*:* Dependable crop growing period for Samre 80% probability

4.2.6 Climatic and Agro-climatic resources of Endamohone

4.2.6.1 Climate analysis for Endamohone

Endamohone has bimodal rainfall pattern and has mean annual rainfall 757.7mm and 19.9% coefficient of variation, which shows relatively lower inter-annual variability. However, the Kiremt season has higher rainfall variability with 26.7% coefficient of variation. The variability of seasonal rainfall over the District is strongly influenced by ENSO events. Kiremt mean rainfall is 44.5mm per decade. Kiremt rainfall averaged over El Nino years is 37.0mm per decade, which is below the mean from all 30 years. On the other hand, Kiremt rainfall averaged over La Nina years is 53.0mm. Moreover, the maximum Kiremt decadal mean rainfall during El Nino years does not exceed 76.6mm where as Kiremt dekadal mean during La Nina years could reach 115.2 mm (see table 9). As we can see from the graph in figure 30, the peak seasonal dekadal rainfall during El Nino years is well below 80mm, where as in other years could reach up to 120mm.

This District is also one of the Belg benefiting areas and Belg season with a mean rainfall is 11.5 mm per decade wand 42.1% coefficient of variation. Belg rainfall averaged over El Nino years is 14.0mm per decade. In general the annual rainfall variability is less while the Belg rainfall is high variable hence this District more vulnerable to drought in Belg.

Season	ENSO	No of Years	A	B	C	D	E	F
Kiremt	El-Nino	7/30	6	0	1	8.0	37.0	76.6
	Neutral	14/30	6	5	3	10.7	43.6	85.1
	La-Nina	9/30	1	2	6	6.7	53.0	115.2
	All Years	30/30	13	7	10	6.7	44.5	115.2
Belg	El-Nino	7/30	1	3	3	3.7	14.0	32.7
	Neutral	14/30	7	3	4	4.2	9.0	16.5
	La-Nina	9/30	5	1	3	3.4	11.5	21.7
	All Years	30/30	13	7	10	3.4	11.5	32.7

Table 9*:* Kiremt rainfall statistics for Endamohone based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal maximum rainfall in mm)

ENSO	**Onset Decade**	**Secession Decade**
Neutral	June 3rd decade	Sep 1st decade
El-Nino	July 1st decade	Sep 1st decade
La-Nina	July 1st decade	Sep 1st decade
All Years	July 1st decade	Sep 1st decade

Table 10*:* Onset and secession date variation on ENSO episode for Endamohone District

Climate analysis for Endamohone District Based on ENSO episode

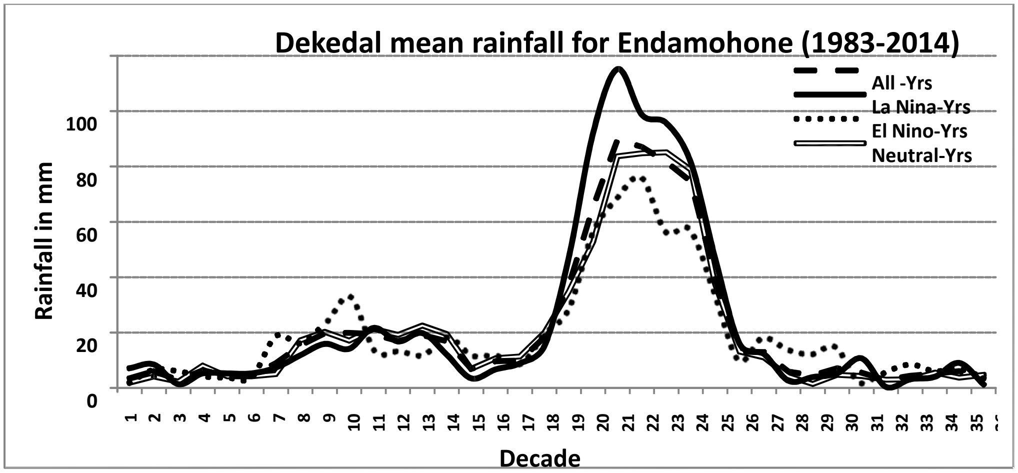


Figure19: Mean dekadal rainfall of Endamohone District for 1983-2012 (averaged for all years dashed line, averaged for only La Nina years solid lines, averaged for El Nino years dotted line and averaged for only ENSO neutral years doubled line)

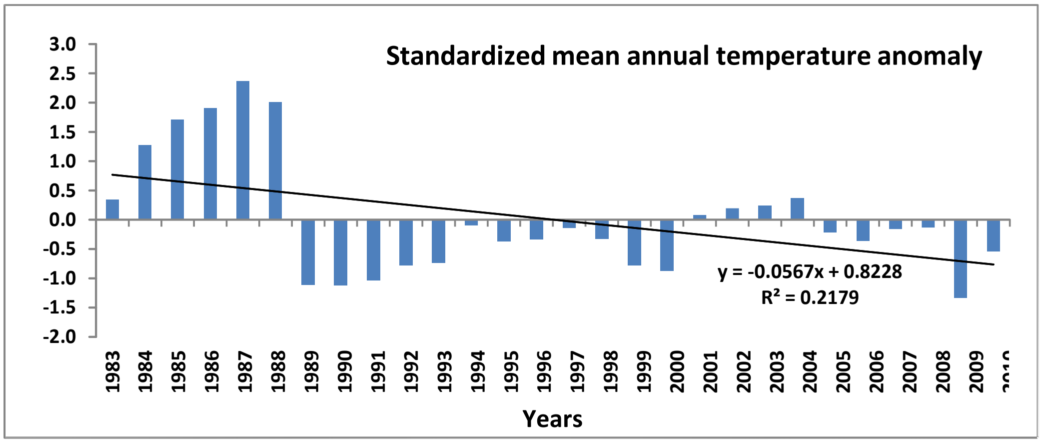


Figure20*:* Standardized mean annual temperature anomaly over Endamohone District

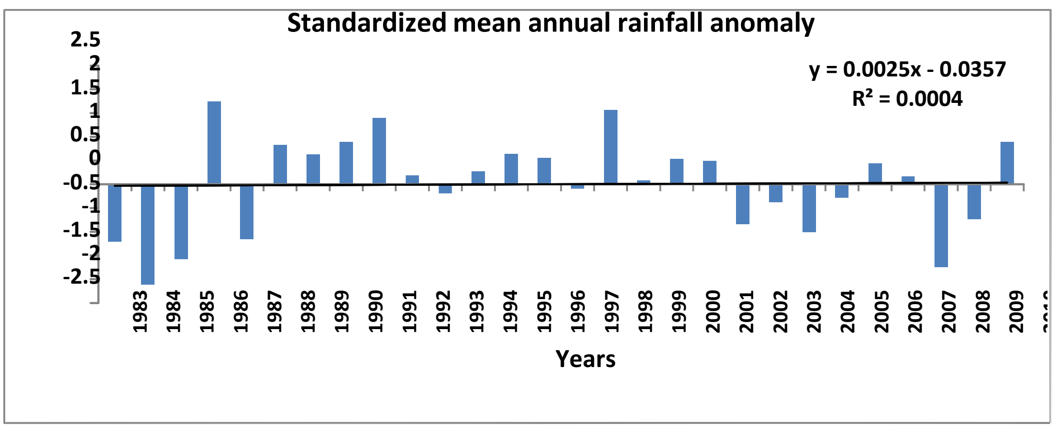


Figure 21 *:* Standardized mean annual rainfall anomaly for Endamohone District

4.2.5.2Agro-Climatic Characteristics of Endamohone

4.2.5.3 Crop growing period at different probability levels for Endamohone

Analysis of temperature and rainfall shows that the dependable growing period at a probability level of 80% is assured only for the Kiremt season for the given area. The most dependable months for moisture availability for crops with minimum variance are July and August, where as the month of August shows the probability of water logging occurring, which greatly depends on the type of the soil and the topography. For soil type of clay, this indicates that proper drainage management is important for the month of August. The 80% probability level called the dependable growing period for Endamohone with minimum risk shows that the growing period comprises the time period of July 2nd dekad to August third dekad, adding up to 50 to 60 days. The 50% probability level called the median or the mean length of crop growing period with a 50% risk, or the case in which the farmer expects good climatic conditions once in two years comprises the time period march third dekad to August third dekad, adding up to 160 to 170 days. The 20% probability level called the best scenario that the farmer can expect in the inter annual variability of the rainfall shows an interesting feature where, the farmer can get the opportunity of cultivating medium cycle crops. The length of the crop growing period from may first dekad to the August third dekad, comprising about 120 to 130 days. It is important to note this scenario occurs occasionally only, once in five years. However, with the correct information that farmers can get from meteorological forecast, farmers can get a good harvest by utilizing these conditions.

4.2.5.4 Identification of crop types for Endamohone

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 50 to 170 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

4.2.5.5 Planting Windows for Endamohone

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used the criteria. The start and end of the crop growing period in each Districts was determined using excel work sheet and defined as the time when the amount of rain and half of ETO become equal. It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. Planting time with 80% assured success is computed to be the second dekad of July, where as if we consider on a fifty-fifty basis, the third dekad of March is recommended. Similarly, if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would still be May first dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from July first dekad to the second dekad of July (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be the beginning of July, which the farmer must adjust, based on the actual weather conditions in the given year, where forecast information would be very important.

4.2.5.6 Cessation of the crop growing period for Samre

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be August 3rd dekad. The 50% probability level shows that the cessation can sometimes extend up to the August third dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years this may still extend up to the August third dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

	50% prob	**80% prob**	**20% prob**
Planting window based on rainfall to half of ETo (RR>ETO/2)	March 3rd	July 2nd dekad	May 1st dekad
Cessation based on rainfall to half of ETo (RR <Eto/2)	Aug 3rd dekad	Aug 3rd dekad	Aug 3rd Dekad
LGP	160 to 170 days	50 to 60 days with no humid period	120 to 130 days

Table 11 *:* Characteristics of planting window, cessation of crop growing period and LGP for Endamohone at different probability level

Decade	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
50% prob	0	0	0	0	0	0	0	0	63	12	20	28	31	0	0	0	13	36	53	76	120	97	36	56	28	0	6	0	0	22
80% Prob	0	7	0	0	0	0	0	11	0	12	0	15	4	0	0	0	16	22	0	81	38	128	53	50	1	11	0	25	0	0
20% Prob	0	0	0	0	0	0	0	0	7	0	27	0	59	0	0	0	0	5	53	57	149	143	114	58	20	18	25	16	0	0

Table 12*:* Dekadal rainfalls expected at different probability level for Endemhone

Crop Growing Period at 80% probability level at Endemehone

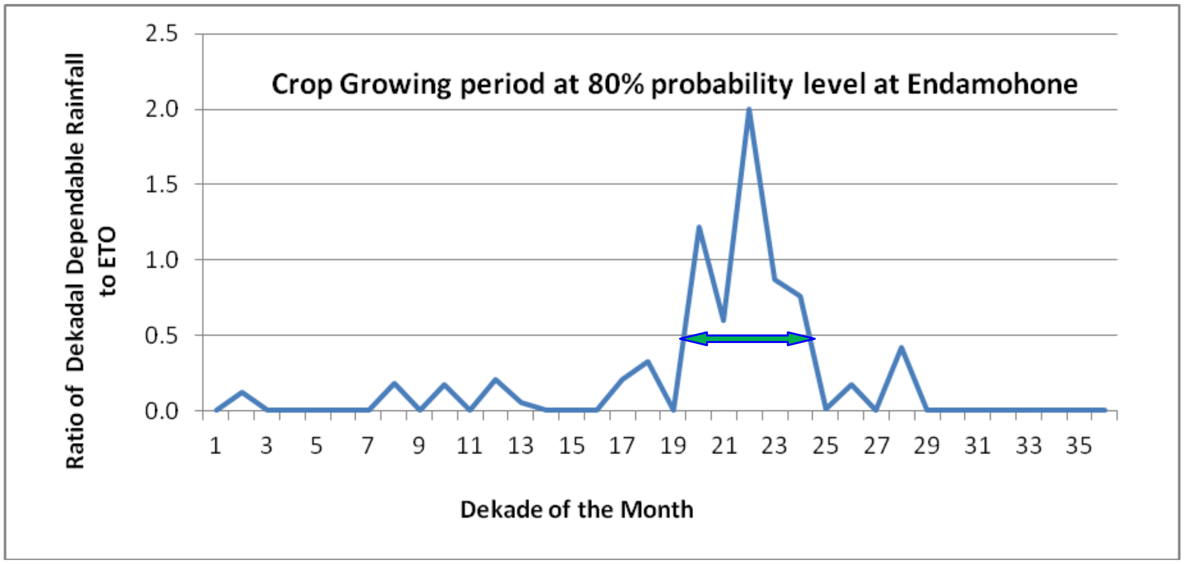


Figure22*:* Dependable crop growing period for Endamohone 80% probability

CHAPTER Five: Climatic and Agro-Climatic Resources of Pilot SNNPR Districts

5.1 Introduction

The development of agro-meteorological guideline requires the investigation and the identification of the crop growing period and the opportunities and the risks associated with crop cultivation regarding the availability of moisture for crop growth. The advisories regarding fertilizers application, protection against crop pests and diseases can be undertaken only through the identification of the crop growing period which will be the basis for understanding the dominant crop calendar. Thus the agro-meteorological advisories are based on first identifying the characteristics of the crop growing period which would be the basis for advisories regarding the planting window, the type of crops to be cultivated, coping mechanisms on crop pests and diseases for the area and application of fertilizers with a brief supplemental note to the agronomic researcher. Thus, detailed agro-meteorological analysis has been carried out for the selected Districts of SNNPR and Tigray in this chapter. The ENSO episode climatology for each District given under this chapter is believed to give a guide to end-users what type of rainfall distribution is expected, once NMA declare the expected ENSO phase for the upcoming season.

5.1.1 Pilot District selection

The project funding Irish Aid has a long standing history to provide technical assistance to enhance agricultural production and to address the food security issue in SNNPR and Tigray. The project intends to enhance the resilience of small holder farmers to climate shocks more effectively by bringing synergy to the on- going Irish Aid efforts and other relevant interventions. Thus, the District selection has been carried out based on the following criteria: (i) Availability of weather data and that of more consistent historical climatological data for producing good products for the end-user communities (ii) Existing interventions to enhance agricultural productions and to avert, mitigate and transfer climate risks. In particular, Districts where Irish Aid funded projects are on-going are priorities. (iii) Diversity of agro- climatological zones represented. (iv) Consideration of both livestock and crop areas to be represented. (v) Mobile network (GPRS) coverage to enable monitoring via automatic weather station. Accordingly, three Districts from the SNNPR region has been selected as a project site; namely Alaba Special District , Shebedino and Boricha from SNNPR region.

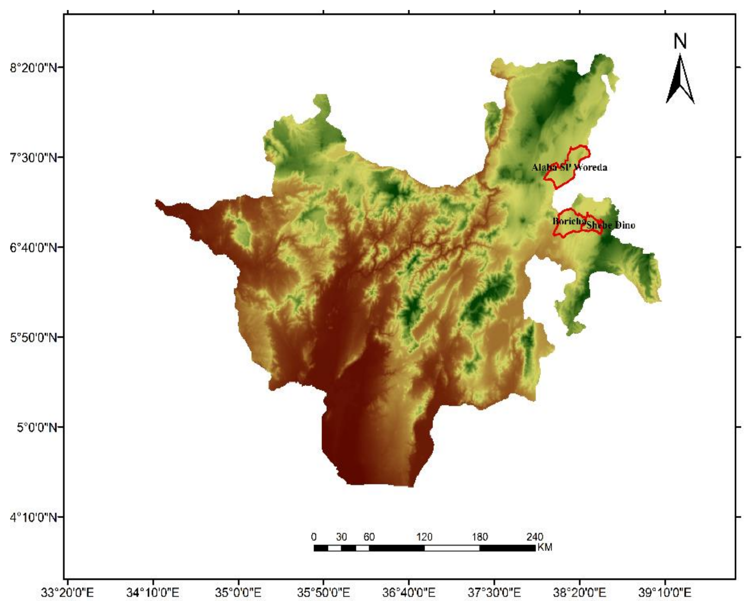


Figure23*:* Map showing Pilot Districts of SNNPR regions

5.1.2. Data and Methodology

Data

The data used for District level detailed analysis were blended and gridded data of dekadal rainfall and temperature from 1983-2014 at 10km by 10km spatial resolution (Dinku et al, 2013). For the

District climate analysis spatial average of the gridded data has been used by extracting the NMA map room tools (WMO bulleting No. 62)

Methodology

- Simple statistical analysis over different ENSO episode has been deployed for each pilot District to present the climate characteristics under each ENSO episode as a reference. In addition, analysis and computation of normalized anomaly for variability and trend in the time series has been used. Climatological mean for the year 1983 to 2012 is used for normal.

- The computation of dekadal rainfall at different probabilities was computed in excel work sheet, where the probability of exceedance was computed by sorting the time series data in a descending order and by assigning Rank for each value and where **P=100xR/(n+1)**, n being the number of the years, it is considered that for large number of years, this value would approach the true value

- The computation of the LGP (Length of the crop growing period is based on the FAO Methodology.

- Reference Evapo-transpiration was computed based on the use of the dekadal mean maximum and minimum temperature data. In this study Throntwise model was used to estimate the potential Evapo-transpiration of each selected Districts.

- The start and end of the crop growing period in each Districts was determined using excel work sheet and defined as the time when the amount of rain and half of ETo become equal.

5.2. Results on Length of Crop Growing period for the selected Districts in SNNPR region

The computation of the length of the crop growing period at different probability levels of 80%, 50% and 20% were used so as to develop agro-meteorological advisory systems that can be used with the different agro-climatic variations, that farmers can expect, both temporal and spatial. Analysis of dekadal characteristics of crop growing period can help the assessment of the risk of undertaking of different agricultural activities, such as planting, fertilizer application, weeding etc.

Thus dekadal rainfall at 20%, 50% and 80% probability level has been computed at dekadal basis and the ratio of this value to the dekadal reference evapo-transpiration has been computed for this purpose. The 20% probability level greatly corresponds to the case which farmers usually call a good year which for this purpose occurs once in five years this probability level shows us the best scenario that the farmers can expect over a given area. The 50% probability level indicates the case which the farmers face once in roughly two years and thus also includes risks which the farmer has to take on fifty-fifty basis. The 80% probability level indicates the dependable crop growing period which shows the scenario of minimum risk.

Crop growth analysis over the selected Districts in SNNPR region shows that the crop growing period attains the maximum value over Shebedino (90 to 120 days) and Borich (90 to 110 days) and the minimum value is found over Alaba Special District with 60 to 90 days. Thus the identification of the best crop for the area should take into account this characteristic. The next important point is how to minimize planting failure and in this respect the planting window based on the determination of the planting time at different probability level is undertaken. Here in this case, the maximum variability in the planting window is found over Shebedino from June third dekad to July third dekad, which the farmers should take into account so as to minimize planting failure, by avoiding false start of the rains, where as planting risk failure over the rest of the selected Districts is smaller. These agro-climatic characteristics are given for each selected District in the next chapter.

5.1.4. Recommended advisories on Fertilizer Application for the selected Districts

The skilful use of fertilizer application is greatly dependent on our knowledge of the moisture condition that is existing at the time of fertilizer application.

The check lists for the application of fertilizers that should be communicated to the farmers should be the following:-

- Never apply fertilizers during dry spells.
- Never apply fertilizers during heavy rainfall days.
- Avoid applying fertilizers during times of high water logging occasions, especially if the soil is fully saturated with moisture, the soil will not absorb the fertilizer solution.
- The best time of the application of fertilizer is when there is sufficient water to make the fertilizer solution that is during moderate rainfall conditions, with no water logging where the soil is not saturated.

The actual application of fertilizer should be based on the above check lists. Thus as there is ample rainfall activity during the month of march and as the problem of water logging is exhibited during the month of April, the month of July can be considered as the best month for fertilizer application. However the exact timing is the function of local agro-ecological and agronomic factors, and the actual weather condition that is expected over a few days and thus information on short term forecast of two to three days is important which should be available to the farmers, when they intend to apply fertilizers. However for the planning of fertilizers, we can use the dekadal rainfall probability at 80% probability level which is given for all the selected Districts on the next chapter.

Application of Fertilizers during the month of April may be necessary for crops such as Maize which are usually planted during this month. Thus the application of fertilizer during the month of April should take into account the week when the problem of water logging is minimal and when the problem of heavy rainfall events and hail storms is minimal. Probably the first dekad of April may be more favorable, which still has to be implemented by taking into account local agro-ecological features.

The most suitable time for fertilizer application is during the time when there is minimum risk of dry spells, minimum risk of heavy rainfall activity, and when there is minimum risk of water logging. Moreover, it is not advisable to use fertilizer application after the soil is fully saturated since that can lead to water logging with a given rainfall activity. Moreover there should be enough soil moisture to facilitate the formation of the fertilizer solution so that it can be absorbed by the plant. Fertilizer Application in the first dekad of April can be recommended in general, but for crops planted in the beginning of April like Maize, care should be taken in the determination of the best time for fertilizer application, where short term forecasts of heavy rainfall events should be monitored. A table on dekadal rainfall at different probability levels is given here to support decision making process.

5.1.5. Supplemental note for agronomic researchers in the selected Districts

Among the cultural practices, sowing date and fertilizer application are the major limiting factors to achieve production potential of the crop. Research over different parts of the world has shown that maximum productivity of crops can be achieved by the proper combination of a given soil moisture level, a given rainfall amount (or else a given amount of irrigation water) with the timing of fertilizer application. These research works also indicate that yields were mainly limited by the timing of fertilizer application. These variables, Soil moisture amount, daily rainfall amount, temperature and a given amount of fertilizer are usually the functions of the crop type and the local agro-ecological characteristics including the soil type. The magnitude of N loss from de nitrification is dependent on temperature, soil texture, soil organic matter, and moisture status of the soil. De nitrification occurs at soil moisture tensions near saturation, with rapid changes in the rate of gaseous N emissions during wetting and drying cycles. The great value attached to this type of research is that it can increase the effectiveness of the applied fertilizer to the optimum level. This type of research thus should be supported with data coming from an automatic weather station equipped also with soil moisture measurement instrument, so as to identify the optimum efficiency of fertilizer application and communicate the technology to the farmers.

5.1.6. Management of soil and water in the selected Districts

The improvement of the effectiveness of soil moisture conservation and the use of rain water harvesting, can be very important to minimize loss of production through the problem of deficient soil moisture. This is in part explained due to the high variability of the rainfall during the month of May in the Belg season and during September in the Kiremt season. Thus moisture conservation through the use of various combinations of applications should also be considered as one important area of research. The application of rain water harvesting schemes during the month of April/August for counteracting the problem of rainfall deficiency during the month of May/ September should be one important area of research. Soil moisture conservation can also be very important for keeping soil moisture reserve after the completion of the crop growing period. Management of soil means that of replenishing soil nutrients that have been used during previous seasons, and increasing the quality of the soil in its water holding capacity.

In the next sections, major agro-climatic characteristics of the three selected Districts are given which the Agricultural Development Agents and the Agricultural Researchers should use in combination with the meteorological forecasts and agro-meteorological advisories in the implementation of this Pilot project.

5.2. Detailed District level climate and agro climatic analysis

5.2.1. Climatic and Agro-climatic resources of Alaba Special District

5.2.1.1 Climate analysis for Alaba Special District

Alaba Special District has bi-modal rainfall pattern with a mean annual rainfall 1009.3mm and 16.0% coefficient of variation, which is low. The Kiremt season has coefficient of variation of 15.6% with a mean seasonal rainfall of 517.9mm. While the Belg long mean seasonal rainfall is 378.2mm with coefficient of variation of 29.6, which is moderately high. The variability of both Kiremt and Belg seasonal rainfall over the District is positively influenced by ENSO events. Kiremt and Belg dekadal mean rainfall over Alaba Special District is 43.3 and 31.5mm respectively. However, Kiremt rainfall averaged over El Nino years is 47.5mm per decade and which is a little far above the long term mean by about 4mm per dekad. On the other hand, Kiremt rainfall averaged over La Nina years is 41.7mm per dekad, which is below the climatological mean rainfall of the area. Thus, during the ENSO episodes, the selected District has somewhat experienced a wetter condition during El Nino phase and parched condition during La Nina Neutral phase. Moreover, the maximum Kiremt dekadal mean rainfall in El Nino years might exceed 76mm where as Kiremt dekadal mean rainfall does not exceed 60mm during La Nina and Neutral years (see table 1). According to the graph in figure 16, the peak seasonal dekadal rainfall during El Nino years could reach up to 70mm, where as in the case of La Nina and Neutral ENSO phase it is well below 60mm per dekad. When we look at to the seasonal onset and cessation of the growing period we understand that they are impacted by ENSO events (Table 2). With an El Nino the Kiremt season shows a shift by a dekad with late onset and late cessation. Normalized anomaly rainfall shows a general decreasing trend (figure 16) while the normalized temperature anomaly shows a general increasing trend (Figure 17).

ENSO Kiremt	No of yrs	A	B	C	D	E	F	ENSO Belg	A	B	C	D	E	F
El-Nino	10/32	2	1	7	29.3	47.5	73.6		1	4	5	16.8	37.5	59.4
Neutral	12/32	4	5	3	25.5	42.6	59.8		4	4	4	14.7	32.4	53.6
La-Nina	10/32	4	3	3	30.7	41.7	56.0		5	3	2	1.2	25.6	46.9
All Years	32/32	10	9	13	29.0	43.3	64.0		10	11	11	12.6	31.5	62.6

Table 13*:* Kiremt and Belg rainfall statistics for Alaba Special District based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal maximum rainfall in mm)

ENSO	**Onset Dekad**	**Cessation Dekad**
Neutral	June 3rd dekad	Oct 1st dekad
El-Nino	June 3rd dekad	Oct 2nd dekad
La-Nina	June 2nd dekad	Sep 3rd dekad
All Years	Jun 2nd dekad	Oct 1st dekad

Table 14*:* Onset and secession date variation on ENSO episode, Alaba Special District

Climate analysis for Alaba Special District Based on ENSO episode

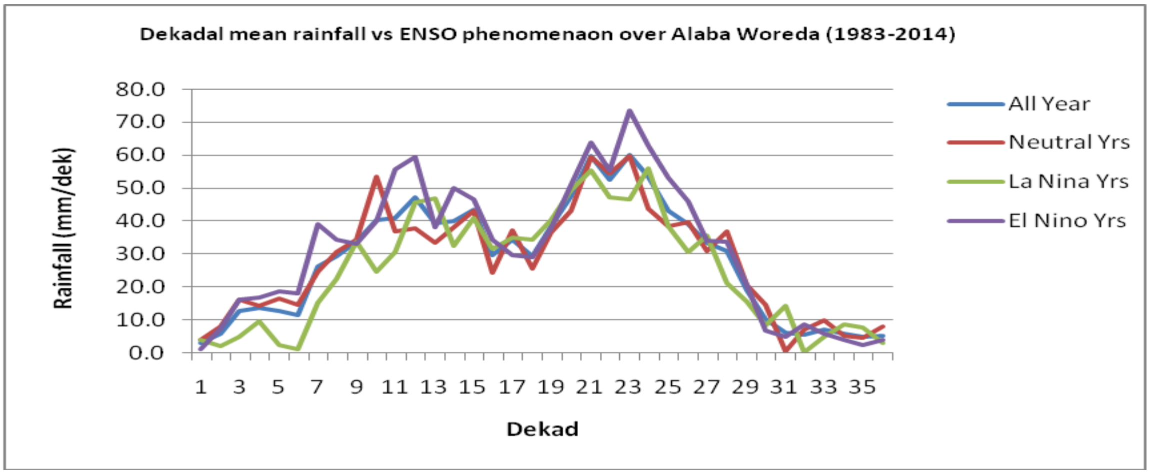


Figure24: Mean dekadal rainfall of Alaba Special District for 1983-2014 (averaged for all years, averaged for only La Nina years, averaged for El Nino years and averaged for only ENSO neutral years)

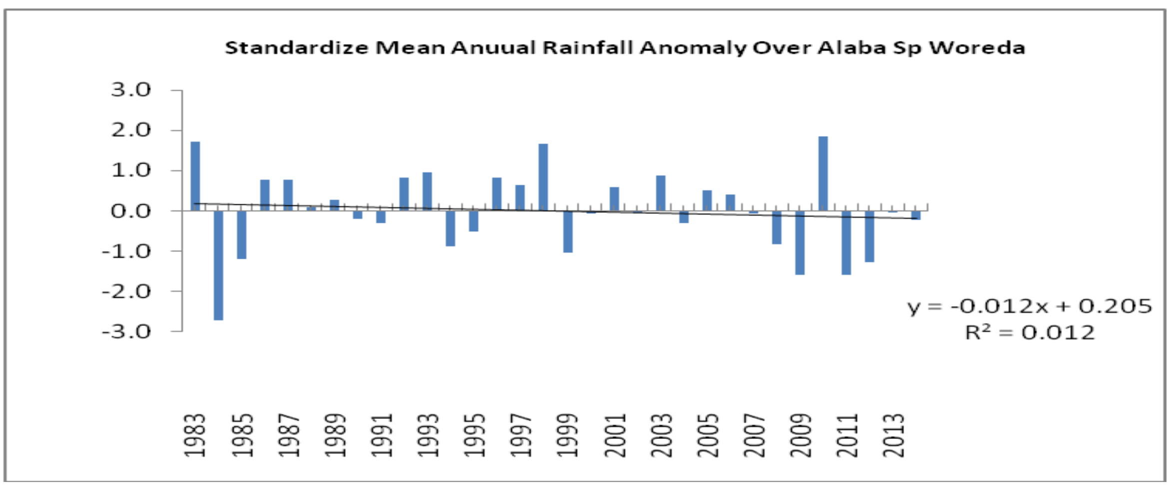


Figure25: Standardized mean annual rainfall anomaly over Alaba Special District

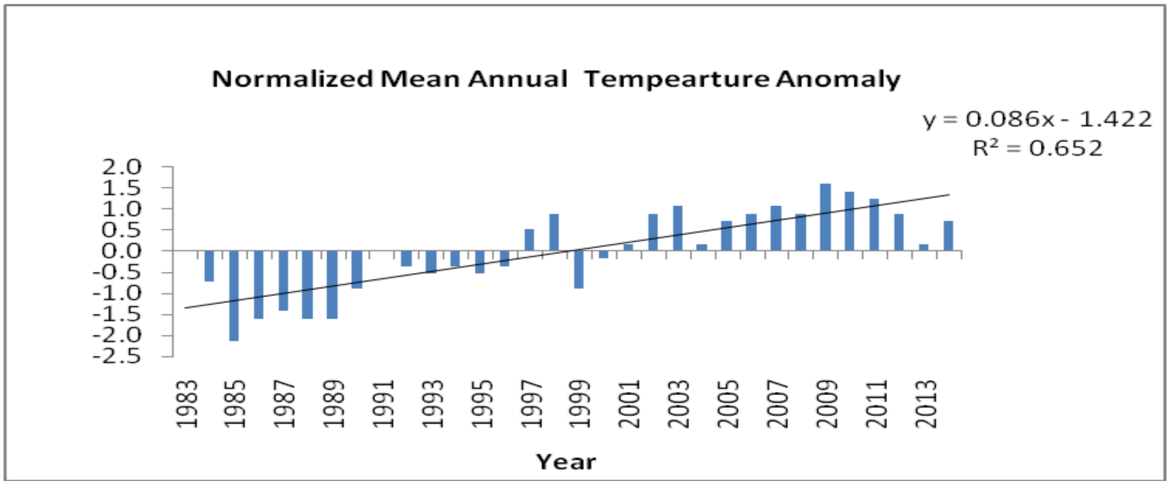


Figure26*:* Standardized mean annual temperature anomaly over Alaba Special District

5.2.2.2 Agro-Climatic Characteristics of Alaba Special District

5.2.2.3. Identification of crop types for Alaba Special District

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 60 to 90 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

5.2.2.4. Planting Windows for Alaba Special District

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used the criteria which states that the start and end of the crop growing period is determined by considering the time when the amount of mean dekadal rainfall is equal to half of mean dekadal ETo in the growing season. It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. For Meher crops planting time with 80% assured success is computed to be the June third dekad, where as if we consider on a fifty-fifty basis, the second dekad of June is recommended. However if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would be May 3rd dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from May 3rd dekad to the third dekad of June (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be July first dekad, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important.

5.2.2.5. Cessation of the crop growing period for Alaba Special District

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be September first dekad. The 50% probability level shows that the cessation can sometimes extend up to September second dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years this may still extend up to the end of September third dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

	50% prob	**80%** prob	20% prob
Planting window based on rainfall to half of ETo (RR>ETo/2)	June 2nd	June 3rd	May 3rd
Cessation based on rainfall to half of ETo (RR<ETo /2)	Sept 3rd	Sept 1st	Sept 3rd
LGP	110 days	100 days	130 days

Table 15 *:* Characteristics of planting window, cessation of crop growing period and LGP for Alaba Special District at different probability level

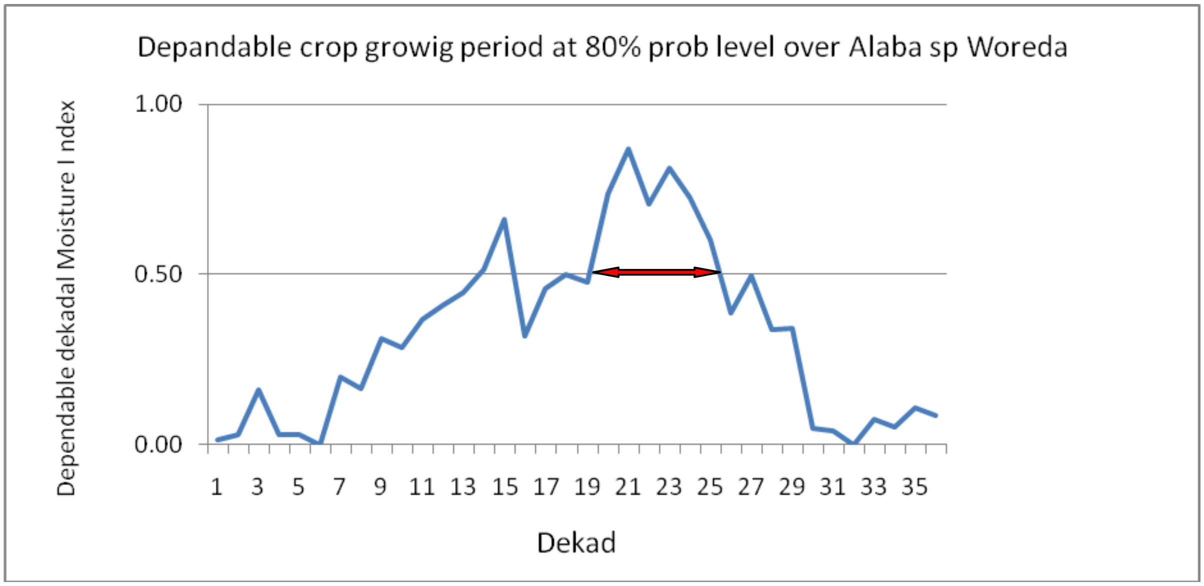


Figure27: Dependable crop growing period for Alaba Special District at 80% probability level

5.2.1. Climatic and Agro-climatic resources of Shebedino District

5.2.1.1 Climate analysis for Shebedino District

Shebedino is characterized by bi-modal rainfall pattern **in the course of** a mean annual rainfall of 1204.5mm with 15.3% coefficient of variation, which is low. The Kiremt mean seasonal rainfall is 517.6mm with coefficient of variation of 20.0% which is still low. While the Belg long mean seasonal rainfall is 473.4mm with coefficient of variation of 24.6, which is moderately high. The variability of both Kiremt and Belg seasonal rainfall over the District is not significantly manipulated by ENSO events with respect to long term mean value. Kiremt and Belg dekadal mean rainfall over **Shebedino** is 43.1 and 39.5mm respectively. However, Kiremt rainfall averaged over El Nino years is 42.9mm per decade and which is almost equal with the long term mean. On the other hand, Kiremt rainfall averaged over La Nina years is 45.9mm per dekad, which is a little far above the climatological mean rainfall of the area. When we look at to the mean values, the selected area exhibited insignificant variation during ENSO events. On the other hand, when we evaluate the number of dry and wet years in ENSO condition, more dry years was observed during El Nino and Neutral years than their counterpart phase, La Nina. Moreover, the maximum Kiremt dekadal mean rainfall in La Nina years might exceed 88mm where as Kiremt dekadal mean rainfall does not exceed 65mm during El Nino and Neutral years (see table 1). According to the graph in figure 16, the peak seasonal dekadal rainfall during La Nina years could reach up to 90mm, where as in the case of El Nino and Neutral ENSO phase it is well below 75mm per dekad. When we look at to the seasonal onset and cessation of the growing period we understand that they are somewhat impacted by ENSO events (Table 2). With an La Nina the Kiremt season shows a shift by three dekad with early onset and normal cessation. Normalized rainfall anomaly shows a general decreasing trend (figure 16) while the normalized temperature anomaly shows a general increasing trend (Figure 17).

ENSO Kiremt	No of yrs	A	B	C	D	E	F	ENSO Belg	A	B	C	D	E	F
El-Nino	10/32	5	2	3	29.3	47.5	62.0		1	6	3	15.3	43.1	73.8
Neutral	12/32	6	3	3	27.0	41.0	52.0		5	1	6	16.9	40.2	55.1
La-Nina	10/32	2	4	4	27.8	45.9	88.5		6	1	3	4.5	34.9	67.3
All Years	32/32	13	9	10	29.0	43.3	64.0		12	8	12	12.6	39.5	62.6

Table 16: Kiremt and Belg rainfall statistics for Shebedino based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal maximum rainfall in mm)

ENSO (Kiremt)	**Onset Dekad**	**Cessation Dekad**	**Belg Season**	**Onset Dekad**	**Cessation Dekad**
Neutral	June 3rd dekad	Oct 2nd dekad		Mar 3rd dekad	Jun 1st dekad
El-Nino	Jul 2nd dekad	Oct 2nd dekad		Mar 3rd dekad	Jun 1st dekad
La-Nina	June 2nd dekad	Oct 2nd dekad		Mar 3rd dekad	Jun 2nd dekad
All Years	Jul 2nd dekad	Oct 2nd dekad		Mar 3rd dekad	Jun 2nd dekad

Table 17*:* Kiremt and Belg season onset and secession date variation on ENSO episode, Shebedino

Climate analysis for Alaba Special District Based on ENSO episode

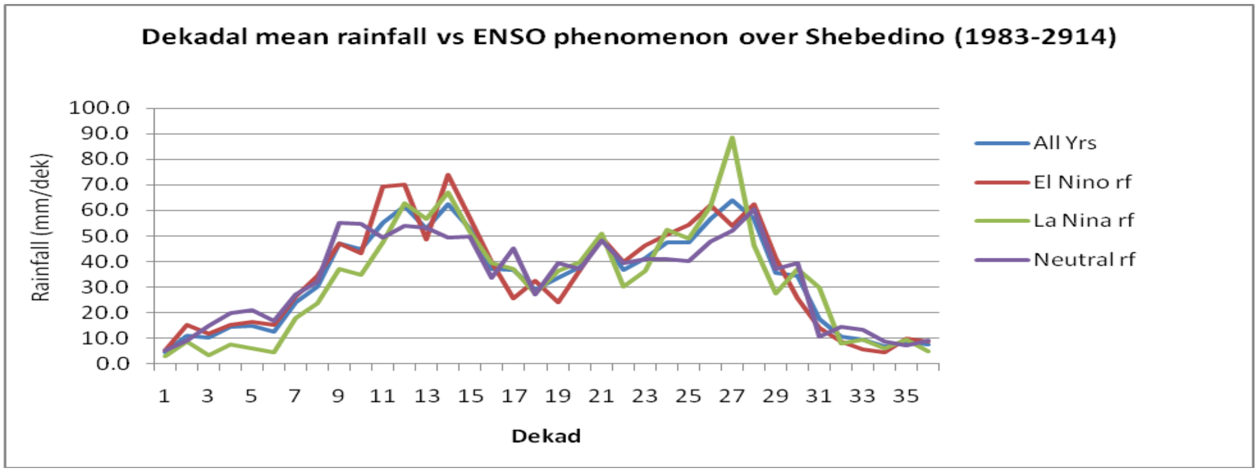


Figure28: Mean dekadal rainfall of Shebedino for 1983-2012 (averaged for all years, averaged for only La Nina years, averaged for El Nino years and averaged for only ENSO neutral years)

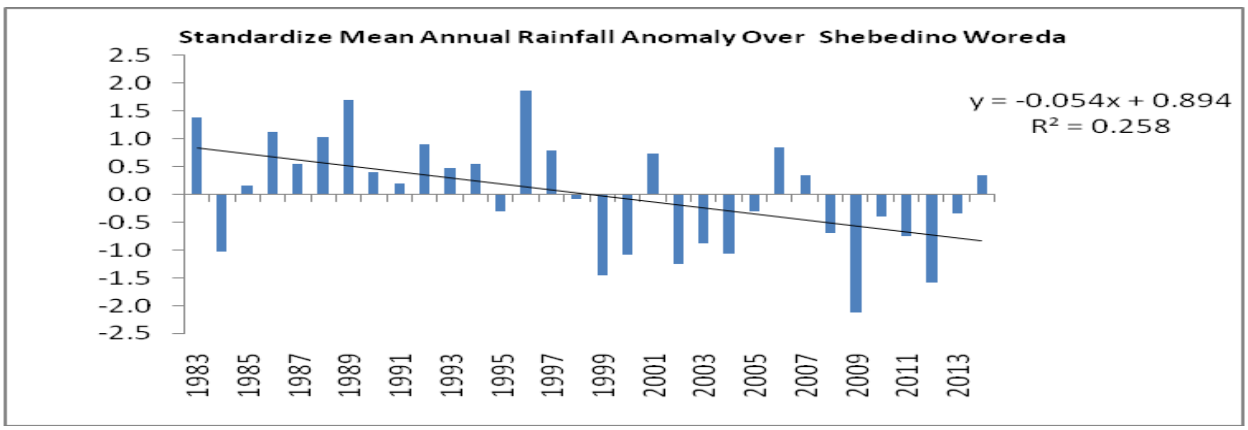


Figure29: Standardized mean annual rainfall anomaly over Shebedino

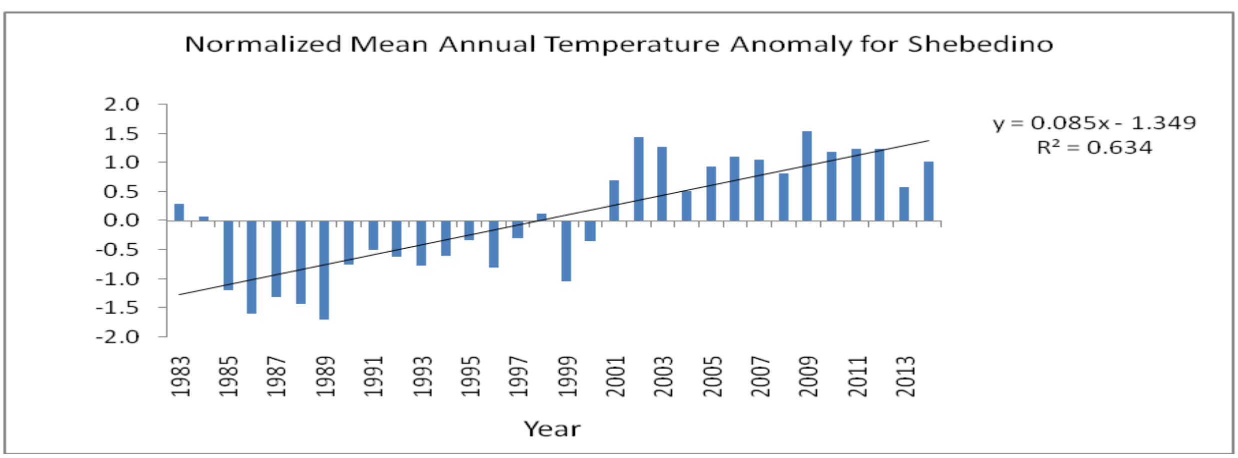


Figure30: Standardized mean annual temperature anomaly over Shebedino

5.3.1.2 Agro-Climatic Characteristics of Shebedino

5.3.1.2.1 Identification of crop types for Shebedino

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 90 to 120 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

5.3.1.2.2 Planting Windows for Shebedino

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used the criteria which states that the start and end of the crop growing period is determined by considering the time when the amount of mean dekadal rainfall is equal to half of mean dekadal ETo in the growing season. It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. Planting time with 80% assured success is computed to be the June third dekad, where as if we consider on a fifty-fifty basis, the first dekad of June is recommended. However if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would be May 3rd dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from May 3rd dekad to the third dekad of June (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be July first dekad, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important.

5.3.1.2.3 Cessation of the crop growing period for Shebedino

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be September 2^{nd} and which is consider as less risk with short growing period. The 50% probability level shows that the cessation could sometimes extend up to October first dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years and this might still extend up to October third dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

	50% prob	**80%** prob	20% prob
Planting window based on rainfall to half of ETo (RR>ETo/2)	June 1^{st}	June 3^{rd}	May 3^{rd}
Cessation based on rainfall to half of ETo (RR<ETo /2)	Oct 1^{st}	Sept 2^{nd}	Nov 1^{st}
LGP	130 days	100 days	170 days

Table 18: Characteristics of planting window, cessation of crop growing period and LGP at different probability level

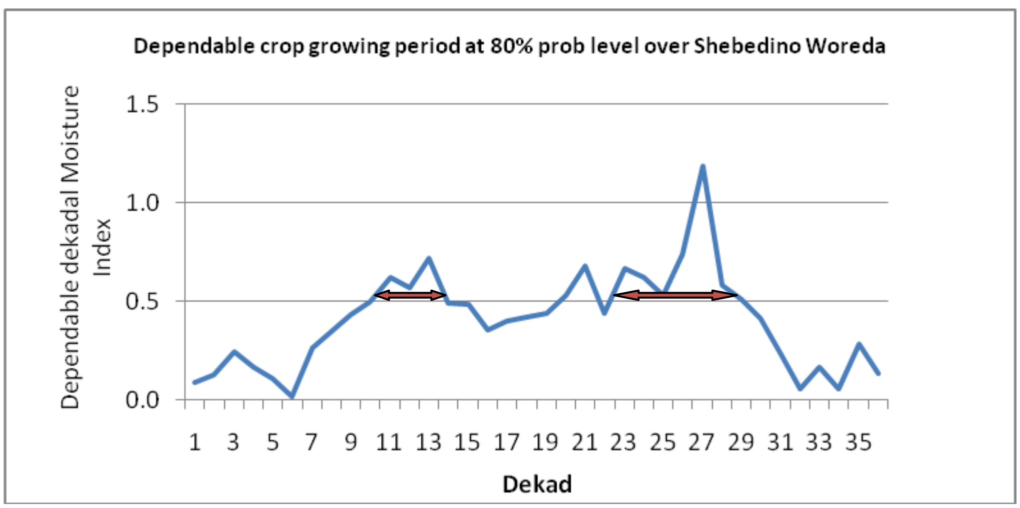


Figure31: Dependable crop growing period for Shebedino District at 80% probability level

5.2.2 Climatic and Agro climatic resources of Boricha

5.2.2.1 Climate analysis for Boricha

Boricha has Bi-modal rainfall pattern with mean annual rainfall of 1397.5mm with 15.2% coefficient of variation, which shows lower year to year rainfall variability. The mean Kiremt and Belg season rainfall is 470.3mm and 580.5 with coefficient of variation of 28.3 and 19.3% respectively. It implies that the Kiremt season rainfall pattern is more variable than the Belg season rainfall over the selected District. However, the variability in both seasons is not strongly influenced by ENSO events. The Kiremt and Belg rainfall statistics under different ENSO episode is summarized in table 3a and b. The Kiremt mean rainfall is 39.3mm per decade. However, the Kiremt rainfall averaged over El Nino years is 43.9mm per decade, which is a little far above the long term mean. On the other hand, Kiremt rainfall averaged over La Nina years is 41.9mm, which is still a little far above the long term average value. Moreover, the peak Kiremt and Belg dekadal mean rainfall during ENSO phenomena does not show significant variation when it compares with the long term mean value.

ENSO/Kir	No of Years	A	B	C	D	E	F	ENSO Belg	A	B	C	D	E	F
El-Nino	10/32	3	1	6	23.6	43.9	74.5		3	1	6	10.4	51.9	102.6
Neutral	12/32	9	0	3	25.5	39.3	74.1		9	0	3	10.1	48.4	91.8
La-Nina	10/32	6	0	4	26.2	41.9	78.4		6	0	4	2.5	45.3	100.6
All Years	32/32	18	1	13	25.5	39.3	74.1		18	1	13	10.1	48.4	91.8

Table 19*:* Kiremt (a) and Belg (b) rainfall statistics for Boricha District based on ENSO episode (A: Number of years with below normal rainfall, B: Number of years with normal rainfall, C: Number of years with above normal rainfall, D: Dekadal mean minimum rainfall in mm, E: Dekadal mean rainfall in mm and F: Dekadal maximum rainfall in mm)

Kiremt and Belg Seasonal onset and cessation are also impacted by ENSO events. In an El Nino year the Kiremt season shows a shift by two dekad with late onset and one decade with early cessation. While in the case of La Nina, it shows no change with onset and a shift by two dekad with late cessation. However, in an El Nino year the Belg season shows a shift by one dekad with late onset and cessation (see table 4). Figure 19 and 20 shows that annual rainfall and temperature illustrate an increasing trend over Boricha District.

ENSO/Kiremt	Onset (dekad)	End date (dekad)
El Nino	Jul 3rd dekad	Oct 3rd dekad
Neutral	Jul 1st dekad	Oct 2nd dekad
La Nina	Jul 1st dekad	Nov 1st dekad
All Years	Jul 1st dekad	Oct 2nd dekad
ENSO/Belg		
El Nino	Apr 1st dekad	Jul 3rd dekad
Neutral	March 3rd dekad	Jun 2nd dekad
La Nina	March 3rd dekad	Jun 2nd dekad
All Years	March 3rd dekad	Jun 2nd dekad

Table 20 *:* Kiremt/Belg season onset and end date variation on ENSO episode, Boricha District

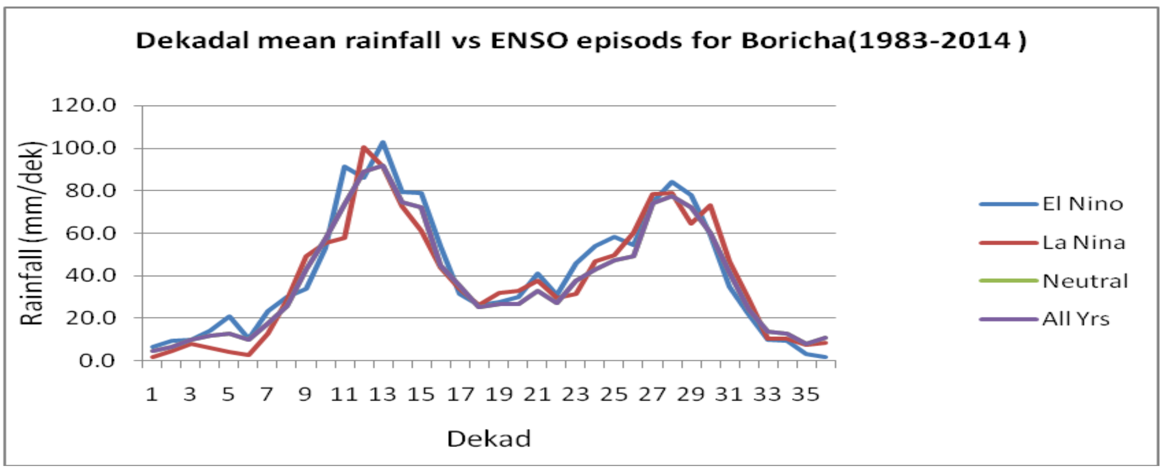


Figure 32 *:* Mean dekadal rainfall of Boricha District for 1983-2012 (averaged for all years, averaged for only La Nina year's, averaged for only El Nino years and averaged for only ENSO neutral years)

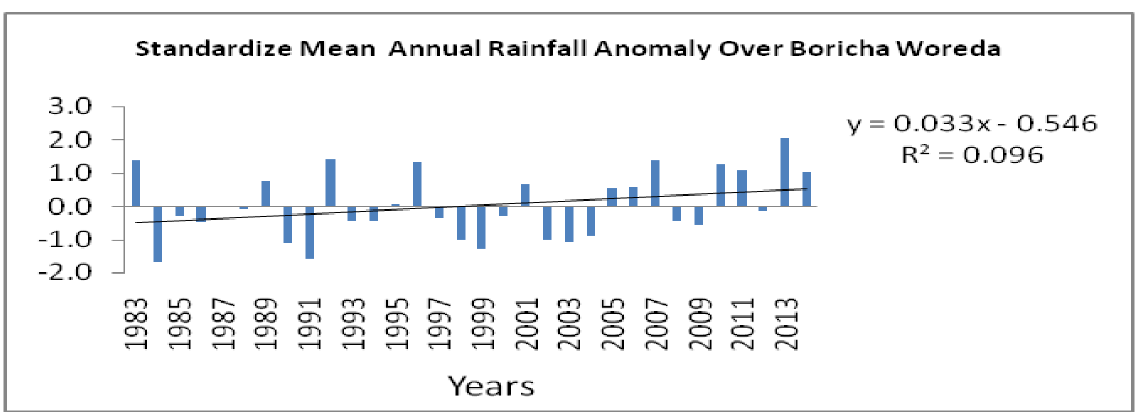


Figure33*:* Standardized mean annual rainfall anomaly over Boricha District

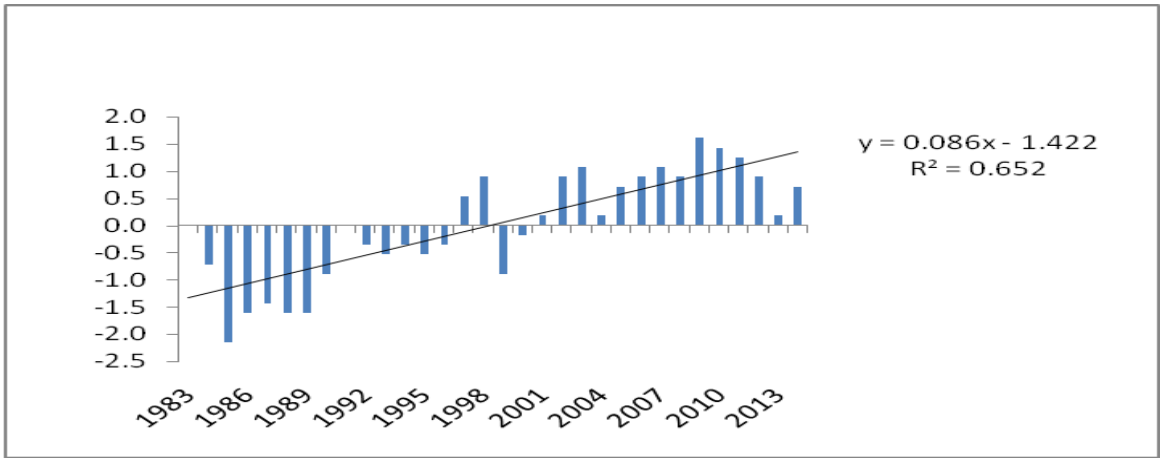


Figure34: Standardized mean annual Temperature anomaly over Boricha District

5.2.2.2 Agro-Climatic Characteristics of Boricha

5.2.2.3. Identification of crop types for Boricha

The computation of the crop growing period at different probability levels shows that the baskets of the crops which the farmer should cultivate must have crop growing period extending from 90 to 110 days. However, it is important to note that soil moisture reserve can extend the length of the crop growing period from one to two weeks.

5.2.2.4. Planting Windows for Boricha

We can come up with a planting window to support the decision of the farmer when to plan planting by the computation of the beginning of the crop growing period at different probability levels. For this, we have used the criteria which states that the start and end of the crop growing period is determined by considering the time when the amount of mean dekadal rainfall is equal to half of mean dekadal ETo in the growing season. It is known that there are different types of decisions taken by the farmer in his agricultural activity. The first and the most important is the determination of the planting time. For Meher crops planting time with 80% assured success is computed to be the June third dekad, where as if we consider on a fifty-fifty basis, the first dekad of June is recommended. However if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would be May 3rd dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from

May 3rd dekad to the third dekad of June (the so called planting window). The advantage of earlier planting is in the maximization of crop yield but with a higher planting risk, where as late planting means the minimization of risk but with the problem of decrease in the crop growing period. Thus the best scenario for planning activities would then be July first dekad, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important.

5.2.2.5. Cessation of the crop growing period for Boricha

The computation of the cessation of the crop growing period is very important to undertake activities in coping with the problem of moisture stress at the end of the crop growing period. The most probable scenario is given by the 80% probability level, and here we observe the cessation of the crop growing period to be October third dekad. The 50% probability level shows that the cessation can sometimes extend up to November first dekad, where as if we consider the best scenario at 20% probability level which occurs once in five years this may still extend up to the end of November third dekad. It is important to note the importance of moisture conservation during the crop growing season so that crop will not suffer from moisture stress during the time of grain formation.

	50% prob	**80%** prob	20%
Planting window based on rainfall to half of ETo (RR>ETo/2)	June 1st	June 3rd	May 3rd
Cessation based on rainfall to half of ETo (RR<ETo /2)	November 1st	October 3rd	Novemb
LGP	100 days	90 days	110 days

Table 21 : Characteristics of planting window, cessation of crop growing period and LGP for Boricha at different probability level

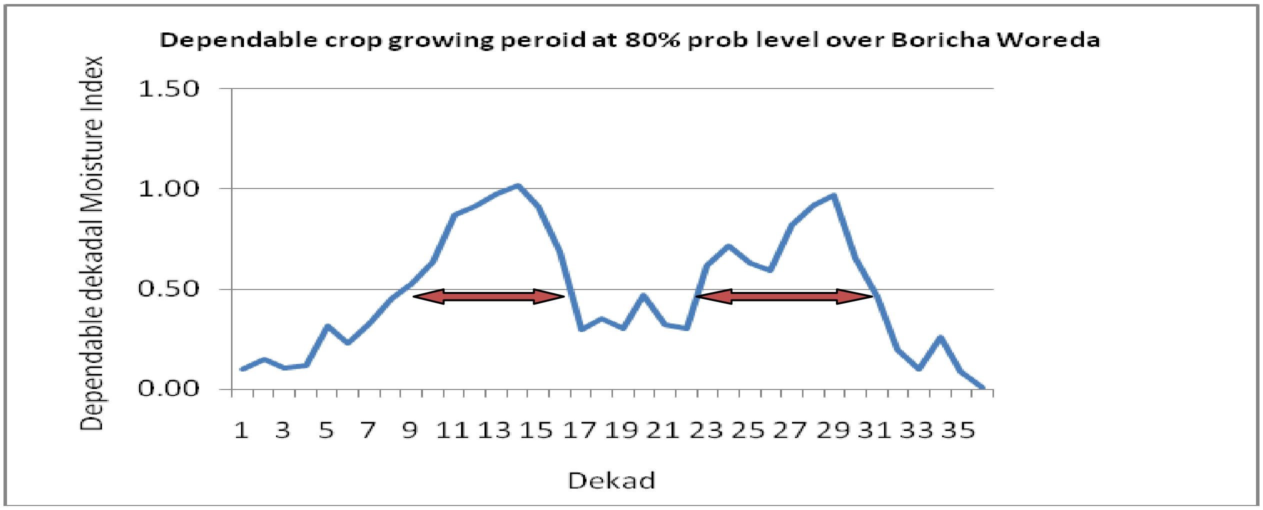


Figure 35 : Dependable crop growing period for Belg and Kiremt season over Boricha District at 80% probability level

Chapter 6: Terminology and Definition

Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy.

Climate is the pattern of variation in temperature, humidity, atmospheric pressure, precipitation, atmospheric particles count and other variables in a given region over long periods.

Climate variability is variation of mean status of climate and some other statistics on seasonal and longer time-scales.

Climatological Normal is the average of climatological data calculated from 30years periods (WMO Standard)

Climatology is a science that focuses on the study of climate over a period of time. It is the study of cause, variations, distribution and types of climate.

Climate product: The end result of a process of synthesizing climate science and data.

Climate anomaly is the departure of the value of climatic element from its normal value.

Climate Change: The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: “A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use”.

Season is a period when an air mass characterized by homogeneity in temperature, humidity, wind, rain fall etc which influence a region or part of a country. Due to revolution of earth around the sun Ethiopia has 3 seasons and different climate zones according to elevation. Due to revolution of earth around the sun, Ethiopia has 3 seasons and different climate zones according to elevation. Based on the mean monthly rainfall distributions, the rainfall regimes are delineated and the types of seasons in Ethiopia are identified as:

Kiremt: June-Sep is the summer season

Bega: Oct-Jan is the dry season with frost in morning especially in January

Belg: Feb-May is the autumn season with occasional showers.

Drought: Drought is a temporary abnormality from normal climatic conditions. In practice, drought is defined in a number of ways that reflect various perspectives

- **Meteorological Drought:** based on the degree of dryness: Standardized Precipitation Index (SPI)
- **Agricultural Drought:** insufficient amount of moisture held in the soil to support the growth of plants for food: Normalized Difference Vegetation Index (NDVI)
- **Hydrological Drought:** decrease of underground and surface water levels in reference to long

term period: Standardized Water level Index (SWI

Flood: Flooding is the unusual presence of water on land to a depth which affects normal activities. Flooding can arise (occur) from:

- Overflowing rivers (river flooding),
- Heavy rainfall over a short duration (flash floods)
- An unusual inflow of sea water onto land (Ocean flooding can be caused by storms such as hurricanes.

Weather forecast: A weather forecast is simply a scientific estimate of future weather condition. Weather condition is the state of the atmosphere at a given time expressed in terms of the most significant weather variables. The significant weather variables being forecast differ from place to place.

Climate prediction : Climate forecast is forecasting of weather condition over long time range climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate is different from weather, in that weather only describes the short-term conditions of these variables in a given region. The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation.

Now casting weather forecast: - it very short time forecasting 30min to 1hours time range forecast mostly it use full for post harvesting activity in Agriculture and much more application in filed like sport and aviations and the forecast is generated from Numerical Weather Prediction, satellite and Radars know NMA is used Numerical weather prediction and satellite based now casting forecast service.

Sort-range weather forecasting: Beyond 12hours and up to 72 hours (three days) description of weather parameters. Mostly use for fertilizers applications in Agriculture activity.

Dekadal forecast: It is part of Medium-range weather forecast which has average of 10 days.

Example.3 during April 1-10/2014 SNNPR, Gambela, much of Oromia, southern and eastern Amhara, Southern Tigray, Afar and northern Somali will receive light to heavy rainfall.

Monthly forecast: Extended-range weather forecasting it is description of weather parameters usually averaged and expressed as a departure from climate values for that period.

E.g., for the coming month, South Tigray, much of eastern Tigray, are expected to have normal to above normal rainfall. Beside, parts of west Tigray and will receive near normal rainfall. On the other hand, some portions of central Tigray will receive light rainfall.

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Glossary

ENAC T:
ENSO: El-Nino and Southern Oscillation
ETo: Grass Reference Evapo Transpiration
IOD: Indian Ocean Dipole
IRI: International Research Institute
JJAS: June–July–August–September
LGP: Length of Growing Period
MAM: March- April – May
NMA: National Meteorological Agency
NMSA: National Meteorological Services Agency
OND: October- November -December
TEJ: Tropical Easterly Jet