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

National Meteorological Agency (NMA) of Ethiopia

February 2015

Cover Page: cover page photos are taken on September 15, 2015 at Ganta Afeshom district of Tigray National Regional State of Ethiopia. Both wheat farm plots used the same agricultural inputs except weather and climate information was continuously utilized as an additional input by the farmer (upper photo). As a result, an excess yield of seven quintal per hectare was registered with climate information user (top) as compared to non-user (bottom).

Photo taken by Tesfaye Gebretsadikan

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Disclaim

This guide was developed under the project entitled "Improvement of Agro-meteorological Information for Small Scale Agricultural Production in the Tigray Region", funded by the Irish Aid and with a technical support of WMO. The Irish Aid and WMO were not involved in the designing of the Guide and do not necessarily obliged to support the views included in this document.

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

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Forward

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 Meteorological Branch Directorates and over 850 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 plan tried to address some of these demands by expanding modern observational systems, such as automatic weather stations, career structure 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 in agricultural productivity. Based on such localized service experience, this project which was funded by the Irish Aid and technically supported by World Meteorological Organization (WMO) has launched implemented in five selected Woredas (districts) of Tigray Regional State 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 climate information and understand about climate of the selected Woredas.

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 endeavors, 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 Woreda. 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.

Table of Contents

Chapter One: Introduction

For the past several decades, the National Meteorological Agency (NMA) of Ethiopia has provided a wide range of weather and climate services for various socio-economic applications. The agricultural sector has been identified as the main user of information that NMA continuously disseminates which includes summary of weather and climate assessment and predictions with agro-meteorological applications for various space and time scales. However, there are several issues that have hampered the effective and efficient communication and use of weather and climate information at various levels, particularly on farm level. In the first place, location specific products that are tailored to the need of end users have been lacking. Despite the recent improvement in the quality of various NMA products, addressing farm level climate risk management requires even higher resolution and location-specific information. Secondly, 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 in order to cope with anticipated climate risks. Thirdly, reaching last mile end users has been identified as the main challenge. Disseminating through intermediaries including, agricultural extension services and media has not yet been ensured. Fourthly, institutional linkages need to be strengthened with stakeholders working on food security and climate adaptation issues.

This users' guide is part of a project entitled "Improvement of Agro Meteorological Information for Small Scale Agricultural Production in Tigray-Ethiopia" which is implemented by NMA in collaboration with the World Meteorological Organization (WMO) and Irish-Aid. The objective of the project is to improve agricultural production and food security in Tigray Regional State through improved weather, climate and agro-meteorological service by strengthen the capacity of NMA to produce and disseminate more localized weather information to Tigray region and enhance institutional linkages between Regional Meteorological Branch Office, Bureau of Agriculture and key stakeholders. Five Woredas namely, Kola Tenben, Tahitai Koraro, Raya Azebo and Kilite Awlalo and the sixth contingency Woreda, Endamehone, has been selected as project implementation sites. The purpose of this guide is therefore to enhance the understanding of the use and application of climate and agro-climate information for farm level decision making. The guide also enables a more systematic approach for capacity development for extension services and small holder farmers. The guide explains 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 being built on NMA's experience in roving seminars and training for trainers initiatives conveyed since 2010. This guide can 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 selected districts to help farmers making farm level decision on their agricultural practices.

This Guide has six chapters, including this chapter. The second chapter of this guide describes about climate of Tigray and major meteorological systems that influence weather and climate of the region. The third chapter explains weather forecast and climate prediction in general with basics of interpretation and understanding. Chapter four deals with detailed climate of the selected pilot Woredas and it also characterizes rainfall of the region under different ENSO episodes. It further explains the agro-meteorological characteristics of each pilot Woreda. Chapter five defines basic terminologies while in the last portion of this guide recommendation and concluding remarks are presented. Training module for the farming community is annexed at the end of this guide.

Chapter Two: Climate of Tigray

2.1 Seasons and seasonal classifications over Tigray

Over high and mid-latitudes, seasons are regulated by temperature patterns and classified as winter, spring, summer and autumn, while in low latitudes they are categorized as wet and dry seasons. In the case of Tigray, the seasons are classified into three periods based on rainfall patterns and meteorological systems. Hence, based on the mean rainfall distributions, the rainfall regimes are delineated and the types of seasons in Tigray are identified.

The eastern and most of the southern half of the Region (identified by letter A in Figure1) has two rainy seasons and one dry period. The two rainy seasons 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* where as western and central part of Tigray, which is identified by the letter B in Figure1, has one rainfall peak (Tesfaye, 1986 and Abebe, 1987). In this region, the length of rainy period (June to September) suppressed due to the meridional migration of the ITCZ (Inter-Tropical Convergence Zone).

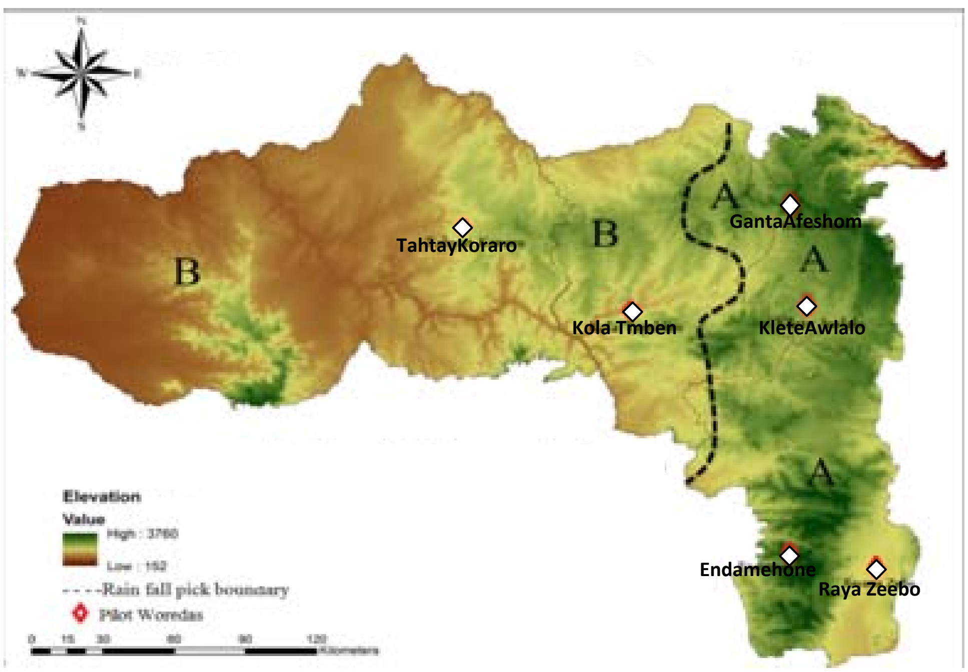

Figure 1: Rainfall patterns of Tigray, area marked with 'A' has Bimodal rainfall pattern Kiremt (JJAS), Belg (MAM) and areas with letter 'B' has uni-modal rainfall pattern, Kiremt (JJAS).

2.2 Weather system affecting Tigray

Seasonal and annual rainfall variations in Tigray as well as the neighboring areas of the region are associated with the macro-scale pressure systems and monsoon flows (Tesfaye1986, 1987; Hastenrath, 1991). Kassahun (1987)has also indicated that the weather and climate of Ethiopia arise 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 tropical and extra-tropical weather systems produce major active weather over the Tigray region, especially during the months of February to May (Northern Hemisphere Spring). The main weather bearing systems for *Bega, Belg* and *Kiremt* seasons, respectively are discussed below.

2.2.1 *Bega* synoptic systems

During *Bega* (the dry season) the region predominantly falls under the influence of warm and cool northeasterly winds. These dry air masses originate either from the Saharan anticyclone or from the ridge of high pressure extending into Arabia from the large high over central Asia (Siberia), as depicted on Figure 2. However, occasionally northeasterly winds are interrupted when migrating low pressure systems originating in the Mediterranean are a move southwards and interact with the tropical systems resulting into unseasonal rains over pocket places of east and south east Tigray. Occasionally the development of the Red Sea Convergence Zone (RSCZ) during *Bega* also produces rains over northeastern Ethiopia (Pedgley,1966).

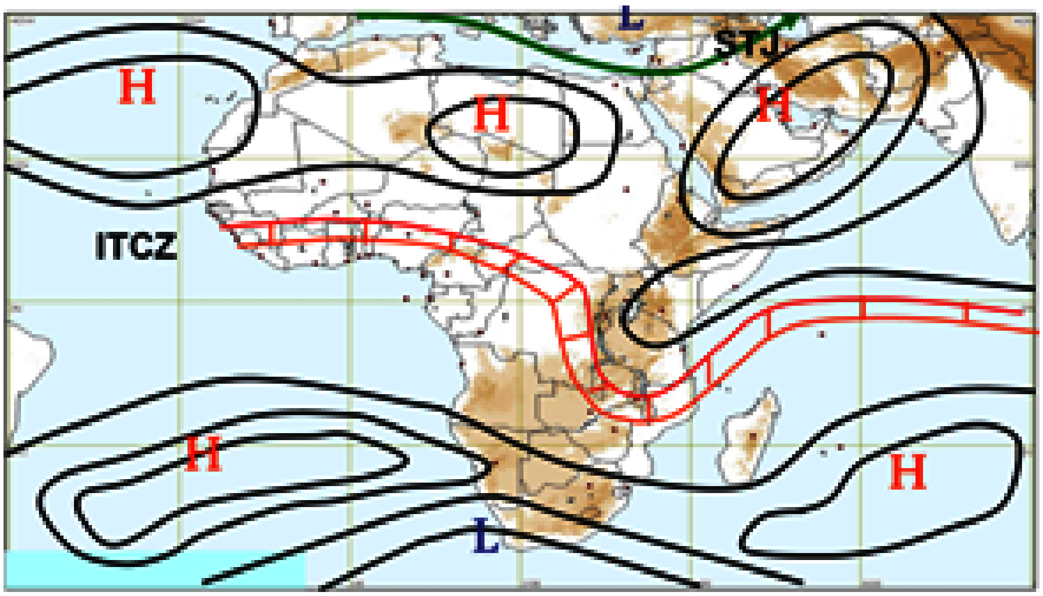

Figure 2: Prevailing Synoptic systems during Bega season (Courtesy of NMSA, 1996)

2.2.2 Belg synoptic systems

During Belg (the small rainy season) which spans from February to May, the Arabian high pressure system moves towards the northern Arabian Sea (see figure 3).When it is pushed over the water body, it causes a moist south easterly air current flow towards Ethiopia (Camberlin et al, 2002; NMSA1996). Occasionally, there are also frontal lows that either originate from the Mediterranean area or originate within the Atlantic Ocean and sweep from west to east. These occur in association with a cold front, the intensity of which depends on the temperature contrast ahead and behind the front. As it reaches east of Mediterranean Sea, the surface front splits into two: one front over the Arabian low land and the other over the Sudan low land (Gizaw, 1968). Once the surface fronts reach the high grounds they interact with the equatorial systems and produce abundant rains over the pocket center, east and south, parts of Tigray and the escarpments. Sometimes when the low-level westerly trough penetrates along the Rift Valley, the rainfall activity lingers for some days low land south Tigray neighbors to western Afar region. Other dominate future of the region is RSCZ (Red Sea Convergence Zone) it brought more rainfall for the north east and south highland of Tigray.

The relationship between the Ethiopian rainfall during *Belg* and the tropical cyclones over the southwest Indian Ocean indicates that low/high frequency of the cyclones resulted in excess/deficit rainfall (Shanko et al, 1998). The same to Tigray region low frequency of cyclone produces excessive rainfall and high frequency of cyclone produces less rainfall, during *Belg* (MAM) season over east and south part of the region. The formation of intenseandfrequenttropicaldisturbancesoverthesoutheastIndianOcean, which occurs during rainy seasons induce deficient rains over *Belg* and *Kiremt* rainfall benefiting regions of Ethiopia (Bekele, 1992).

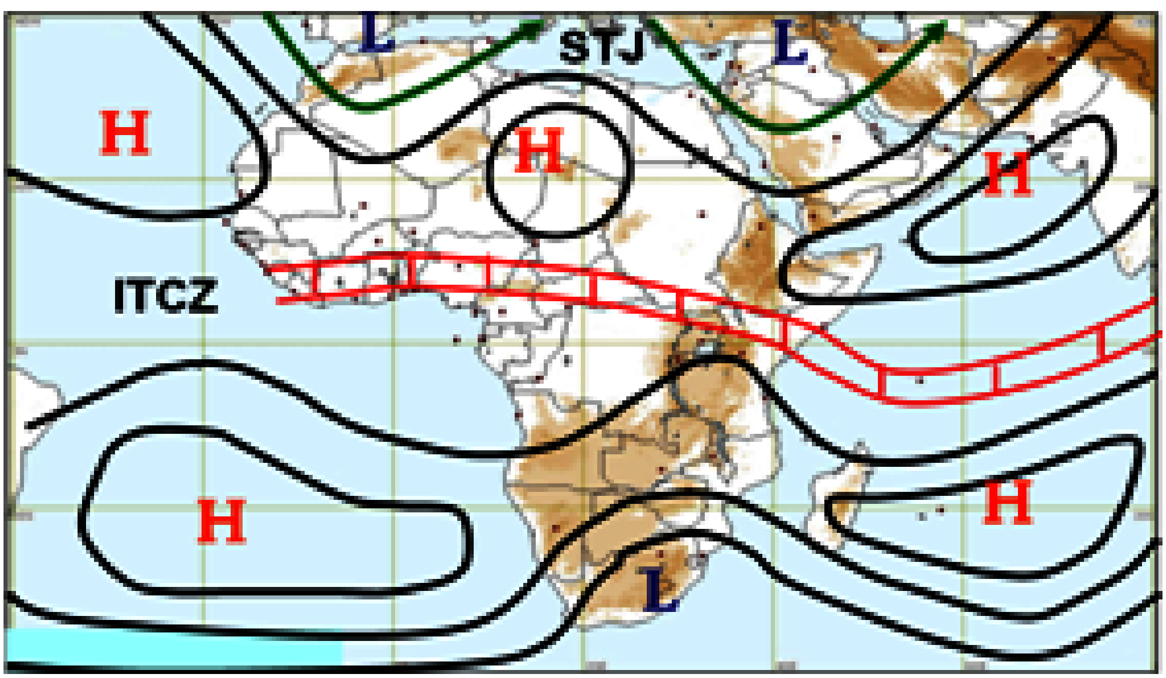

Figure 3: Typical Synoptic Weather system during Belg season (Courtesy of NMSA, 1996)

2.2.3 *Kiremt* synoptic systems

Kiremt (JJAS) is the main rainy season over the region. Main synoptic systems that trigger weather during the season include the northward propagation of ITCZ as well as the formation of heat lows over the Sahara and Arabian landmasses (Korecha and Barnston, 2007). ITCZ attains its peak position of 15^{o}N and 15^{o}S during July and January, respectively (Asnani,2005).Air flow is dominated by zones of convergence in the low pressure systems accompanied by the oscillatory of ITCZ extending from West Africa through Ethiopia towards India (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 (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 increases significantly in most part of Tigray and decreases significantly when the St. Helena high pressure is weak or the boundary is displaced westwards because these two high pressure systems have significantly contribution in pushing moisture from large water body toward the northern region.

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 mostly influence circulations in Africa (Camberlin1997) and its formation enhances rainfall over Ethiopia (Kassahun,1987). When the TEJ strengthens the intensity and distribution of rainfall enhances almost in all part of Tigray, when the TEJ weakens, the rainfall decreases and dry spell occurs.

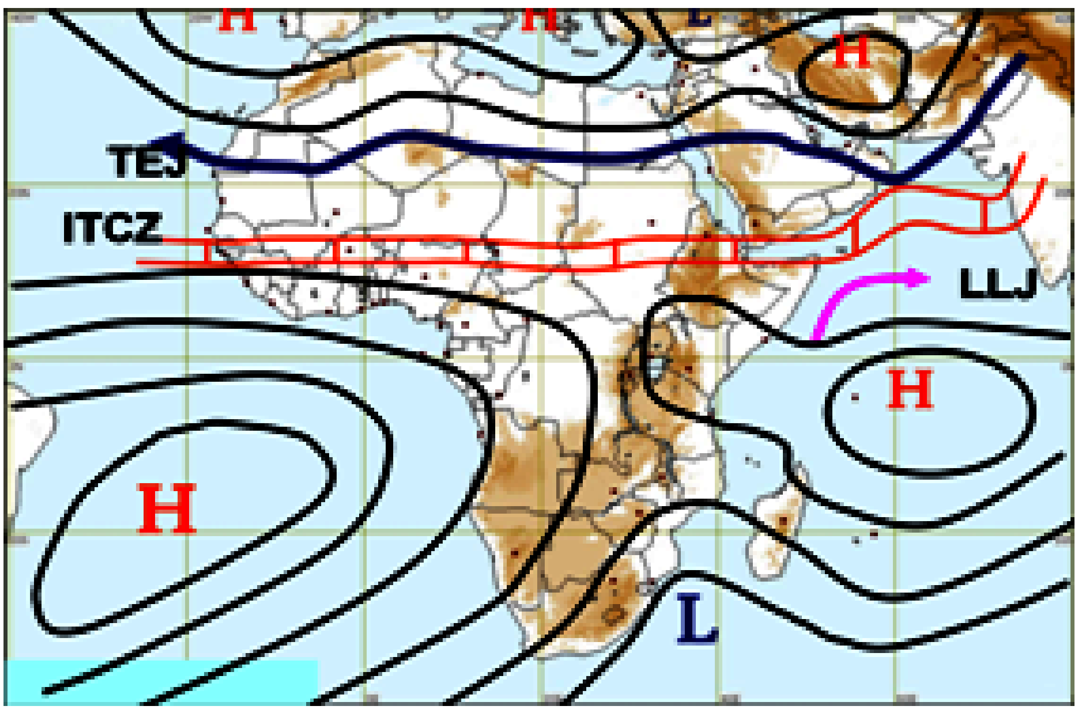

Figure 4: Typical Synoptic Weather system during Kiremt season (Courtesy of NMSA, 1996)

2.2.4 Rainfall patterns under ENSO episodes

Ethiopian seasonal rainfall variability is highly influenced by remote ocean particularly central Pacific Ocean, among many other things while subsequently undulated by Indian Ocean. El Niño is the warming of the water along the west coast of South America, along the Peru cost. However, the name El Niño represents all sea-surface warming in equatorial Pacific. El Nino is also associated with changes in sea-level pressure at locations across Pacific between Darwin (Australia) and Tahiti (central Pacific Ocean). When pressure is high around Tahiti, it usually low at Darwin, and vice versa. This process is known as the Southern Oscillation. The two processes, one in the ocean, El Niño and the other in the atmosphere, the Southern Oscillation interacts to form a phenomenon known as El Niño/Southern Oscillation (ENSO). When the sea surface temperature in the central Pacific cools it is known as La Niña. When the sea surface temperature along equatorial Pacific, neither warm nor cold compared to the long term average, the event is known as ENSO-Neutral. In general the impact of El Niño is opposite in some location to that of La Nina. In Ethiopia for example, El Nino is associated with deficient rainfall during *Kiremt* season in some areas, where as La Nina is mostly associated with wet *Kiremt*. The effect of ENSO events over selected Woredas are presented in chapter four to give users a general idea of the expected rainfall distribution in both ENSO episodes. Nevertheless, not all El Niño or La Niña events are alike as a result of other continental and regional factors such as Indian Ocean Dipole (IOD). Therefore, close follow up of the seasonal advisories issued from NMA on a regular basis for each and every specific season is highly recommended.

The Indian Ocean Dipole (IOD) is an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer/colder than the eastern part of the ocean. A positive phase associated to warmer sea-surface temperatures and greater rainfall in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean which tends to cause droughts over Indonesia and Australia regions. The negative phase of the IOD brings about the opposite conditions, with warmer water and excessive rainfall in the eastern Indian Ocean, and cooler and drier conditions in the west. In general, IOD together with ENSO influence seasonal rainfall patterns of Tigray region.

2.2.5 Impacts of meso scale systems and topography on local climate

Meso scale systems can be described as small weather systems with horizontal dimensions generally ranging from 2 kilometers to several hundred kilometers. They affect climatic patterns over the localized regions. On the other hand, the effect of topography on the climate of any given region is powerful. Mountain ranges create barriers that modify wind and rainfall patterns. Mountains also play an important role on rainfall. Hence, 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, this water vapor is forced to condense, depositing rain on windward slopes. This creates an effect known as a rain shadow on the leeward (protected) side of mountain, where the air contains very little moisture (Figure 5). As most parts of Tigray are characterized by complex mountains, the effect of topography is very significant in affecting local climate features of the region.

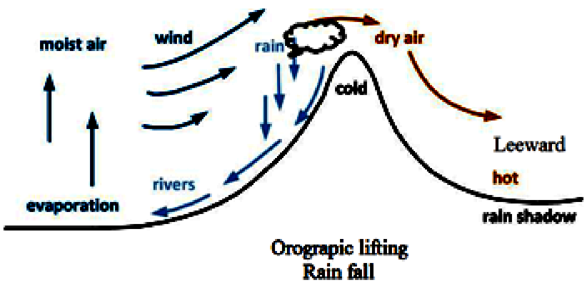

Figure 5: Orographic effect on local climate (Adopted from Whiteman, C. David (2000)).

Tigray is located at the northern limit of the central highlands of Ethiopia. The landform is complex composed of highlands with the range of 2300-3200m, lowland plains with an altitude range of 500-1500m, mountain peaks as high as 3935m and high to moderate relief hills 1600-2200m above mean sea level. Thus Tigray has diversified agro-ecological zones each with distinct soil, geology, vegetation cover and other natural resources.

2.3 Climate of Tigray

2.3.1 Climate classification

According to Koppen Climate Classification, Tigray has four types of climate (Gonfa, 1986). North western, central north tips and the eastern strip of Tigray is characterized by Hot semi-Arid climate (Bsh) with a mean temperature between 18 to 27^{o}C and mean annual rainfall between 410 to 820 mm. The rainfall is highly variable from year to year. Such regions are intermediate between the hot arid and the humid climate (see figure 6). Central Tigray has Tropical rainy climate (Aw) type with mean temperature of the coldest month above 18^{o}C and 680 to 1200mm of rainfall (see Figure 6). A narrow strip extending from south to north, west of the hot semi-arid trip of eastern strip Tigray has Warm Temperate (Cwb) type climate with a distinct dry month during winter and mean temperature of the coldest month below 18^{o}C.

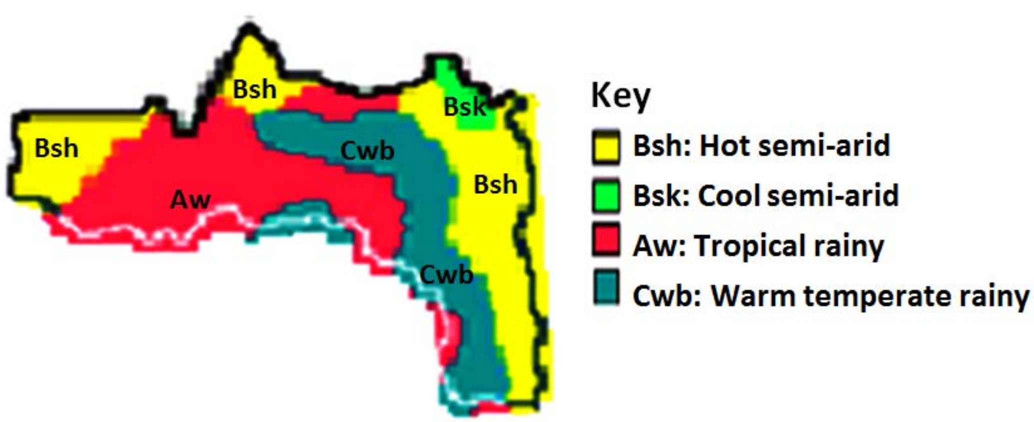

Figure 6: Climate classification of Tigray (reproduced from Lemma Gonfa, 1986)

2.3.2 Rainfall distribution over Tigray

Mean annual rainfall distribution over Tigray increases from east to west of the region. The mean annual rainfall totals 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 7). Over western half of Tigray where there is better rainfall activity, the rain decreases as one move from north to south.

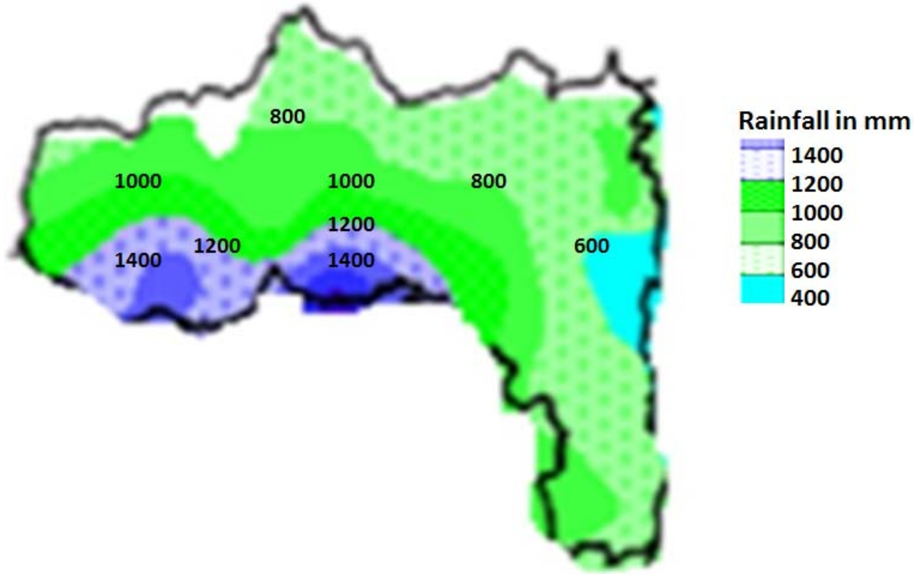

Figure 7: Distribution of mean annual rainfall totals over Tigray

Kiremt (June to September) is the main rainy season for Tigray with rainfall ranging from 300 to 1000mm. Figure 8 below shows *Kiremt* rainfall decreases towards the east.

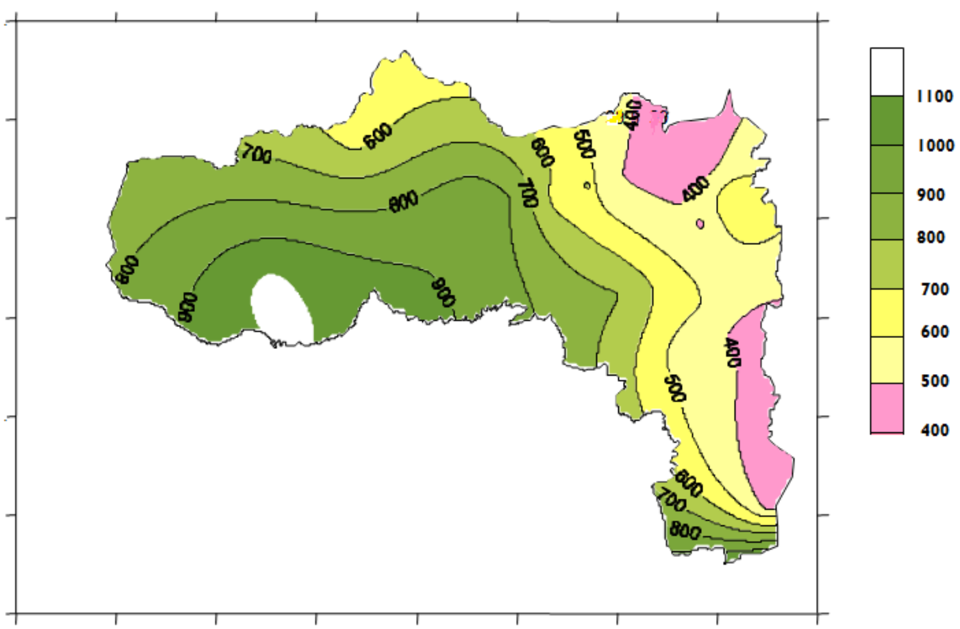

Figure 8: Mean Kiremt (June-September) total rainfall in mm over Tigray

2.3.3 Onset of *Kiremt* season

Onset of *Kiremt* season is defined the time when the first wet-spell of the year occurs at least with three days total rainfall amount of 20mm or more, provided there were no sequences of eight or more dry days[1], in the subsequent 30 days of the area of interest. In Tigray region onsets of *Kiremt* differ from place to place (Figure 9). The earliest onset is on 01 June and the late onset is on 10 July. The onset is earlier in the west of the region than over other parts and the onset variability is almost one week to four weeks over eastern, central and western parts of the region (Figure 9).

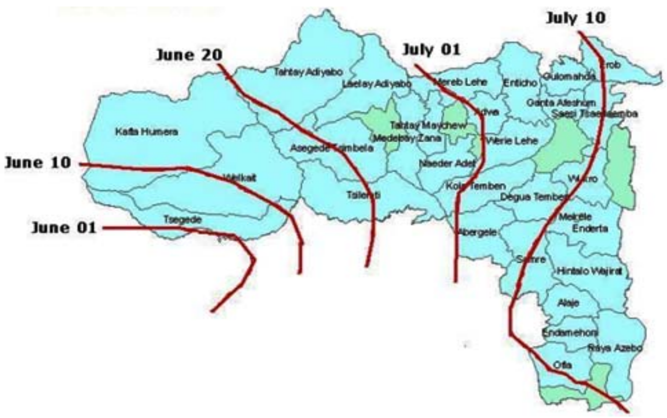

Figure 9: Mean onset date of Kiremt season over Tigray (reproduced from Segele and Lamb, 2005)

2.3.4 Cessation of *Kiremt* season

Cessation of *Kiremt* rain is declared when the first day of a dry-spell with duration of at least 20 days occurred after the seasonal rainfall activity. In Tigray region, *Kiremt* rain usually delays in the west part of the region while early withdraw very early cessation from eastern, central and southern of the region (Figure 10). Normal cessation date of *Kiremt* rains generally varies by about one month in the west, east and south of the region.

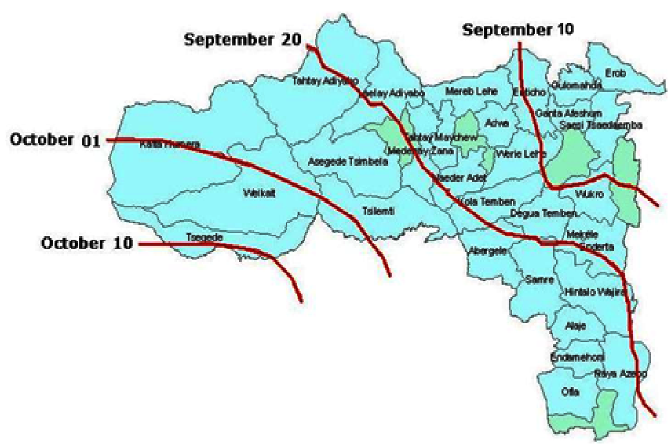

Figure 10: Mean cessation date of Kiremt season over Tigray (reproduced from Segele and Lamb, 2005)

[1] Dry days are days with rainfall amount less than 0.1 mm

Chapter Three: Weather and Climate Forecast

3.1 Weather and Climate forecast

Difference between weather and climate is often confusing for many common users of climate information. The very easy way of describing their difference is that weather is what one actually experienced whereas climate is what one expects at a given place and time. WMO operational definition for climate is a 30 year average of a climate parameter such as rainfall or temperature including variability and extremes at a particular place and time

Weather and climate plays an important role almost in all aspects of life on earth. Particularly, for the country's economy mainly depends on rain fed agricultural activities. Hence, accurate and timely forecast has got wide implications ranging from increasing the agricultural production to reducing the damage to life and property. Currently, NMA has provided various types of weather and climate forecasts tailored to agriculture, water, energy, health sectors and etc.

There are several different methods that can be used to prepare weather forecast. The method a forecaster chooses depends upon the level of his/her understanding the physics, the amount of information available, compatibility of the format the forecast is presented, and the degree of accuracy or confidence needed in the forecast.

3.2 Types of forecasting methods

3.2.1 Qualitative method (subjective): This type of forecasting method is based on individual judgments, opinions, intuition, or personal experiences. It is generally subjective in nature. Besides, it does not rely on any rigorous mathematical computations. Some of the examples of qualitative forecast description include heavy fall, light rain, snow, moderate, cold, warm and etc.

3.2.2 Quantitative method (objective): This type of forecasting method is based on mathematical (quantitative) models, and is objective in nature. It relies heavily on mathematical computations. This type of forecasting technique mainly used for Numerical Weather Prediction, short range, medium and long range forecast. Mostly the quantitative forecast products can be described in amount (e.g., 60mm of rainfall, 20^oC maximum temperature and -2^oC minimum temperature).

3.3 Weather and climate prediction and their characteristics

It is well known that weather forecasts are usually fairly accurate in terms of predicting significant weather features for a few days. It is known that the accuracy of weather forecasts decreases as the lead time increases. For instance, weather forecast for 4 days into the future often should be revised and updated every day in order to keep up its accuracy.
At seasonal lead times, there is very difficult to get usable skill in forecasting on which day or locality will have rainfall, storms, temperature extremes, frontal passages, and so forth. This is consistent with the rapid drop-off of skill after several days, discussed above. However, there is nonetheless some skill in predicting anomalies in the seasonal average or climate anomalies. This

skill of the forecast is presented regardless of timing of the major weather events within the period. The total rainfall, for example, may be predicted to be higher than the climatologically average due to a greater-than-normal expected frequency of a specific atmospheric circulation pattern that is conducive to rainfall at the location in question. Again, the timing of the rainfall events remains unknown. Forecasts of the likelihood of enhanced or suppressed rainfall or lower or higher temperatures than the average, over the course of a season have a level of accuracy that is far from perfect but noticeably above the level of random chance. This level of skill for seasonal averages or totals may be useful for sectors impacted by climate variability, such as energy production, agriculture, health, and others. Much of the skill in predicting departures from normal seasonal totals or averages, often associated with atmospheric circulation patterns, has its origin in the slowly changing conditions at the earth's surface that can influence the climate. The most important surface condition affecting climate is the sea surface temperature (SST), and particularly the SST in the tropical zones. SST can be used to predict seasonal climates some months in advance, mainly over the tropical regions.

3.4 Seasonal Forecast

Seasonal forecasts provide information about the long-term period from months up to a year. In Ethiopia, there are three season as classified to represent distinct nature of rainfall and temperature. These are *Bega* (October to January), *Belg* (February to May) and *Kiremt* (June to September). During *Bega* season, dry and cold weather conditions prevail over much of Ethiopia, except in the South and South-eastern Ethiopia, where *Bega* is the second rainy season. Belg on the other hand, is the short rainy season for northeast, east, central and southern highland while it is the main rainy season for south and southeast portions of the country. In contrast *Kiremt* is the main rainy season across much of Ethiopia except south and southeast of the country. NMA has started seasonal prediction since the 1987. In seasonal climate prediction, NMA has adopted analogue methods, which relies on ENSO indices. In addition, the characteristics of the regional oceans such Indian Ocean, Atlantic Ocean and Arabian Sea have key roles in determining the variability of the seasonal climate within a given ENSO episode. Thus, the influence of the regional systems and other local effects are considered in each specific seasonal prediction. The seasonal forecast is given tercile probabilities of three categories with the value which define the probability of being above normal, normal or below normal as compared to the long term climatology. For instance, tercile rainfall probability for *Kiremt* 2014 has shown in Figure 11.

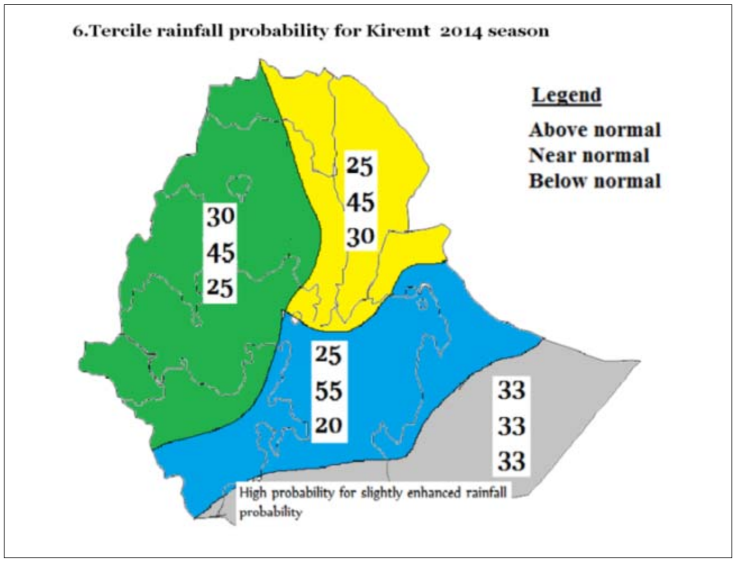

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Figure 11: Tercile rainfall probabilistic forecast for Kiremt (JJAS) 2014

3.4.1 The meaning of tercile probabilities in climate forecasts

Terciles are used to represent three broad sectors of probability distribution that are equally likely, or climatologically. For each location and season, terciles correspond to actual temperature or rainfall 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 off are based on long term climatology.

Without any forecast clues, the probability that any of the three outcomes occur is one-third, or 33.3%, which means that if the situation run iteratively for 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 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 rainfall, 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 uncertainty of the forecast. For example, suppose a forecast calls for rainfall probabilities of 20% for dry tercile, 35% for normal 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 rainfall is more likely than it usually is, and below normal is less likely than usual. Note, however, that there is much uncertainty implied in the forecast. Even though it is in the direction of above-normal rainfall, the probability for above normal rainfall is still less than 50%. And the probability of below normal rainfall is still 20%, implying that one time out of 5 cases of this climate situation, below normal rainfall would be expected. It is clear that even though this forecast shows a tilt of the odds toward wetness relative to the climatological probabilities, there is much uncertainty in the outlook.

3.5 Interpretation of forecasts and forecast variability.

3.5.1 Definition of tercile probability

Seasonal climate forecasts can be categorized as below normal, near normal and above normal. The threshold used to define the category is 0.43 times the inter-annual seasonal standard deviation of the variable (i.e. temperature or rainfall). This choice makes the category equi-probable (same probability) on average.

Tercile categories for temperature forecast are expressed in the following format:

- When the forecast indicates **above normal**, the seasonal temperature forecast is warm when compared to the 30 seasons of the 1981-2010 periods. One third of the season in that period is as warm as the forecast.
- When the forecast indicates **below normal**, the seasonal temperature forecast is cold when compared to the 30 seasons of the 1981-2010 period. One third of the seasons in that period is as cold as the forecast.
- When the forecast indicates **near normal**, this is forecast in all other cases. This means that the forecast anomaly is weak and the forecast temperature is close to its 30 year average.

Tercile categories for rainfall forecast are expressed in the following format:

- When the forecast indicates **above normal**, the seasonal rainfall forecast is wet when compared to the 30 seasons of the 1981-2010 period. One third of the seasons in that period were as wet as the forecast.
- When the forecast indicates **below normal**, the seasonal rainfall forecast is dry when compared to the 30 seasons in the 1981-2010 period. One third of the seasons in that period were as dry as the forecast.
- When the forecast indicates **near normal**, this is forecast in all other cases. This means that the forecast anomaly is weak and the forecast rainfall is close to its 30 year average.

3.5.2 Interpretation of weather and climate maps

Utilizing maps for particular purpose, for instance map showing rainfall anomaly forecast, is done through the same steps, except that you have interpret anomaly forecast map with respect to, climatology and threshold maps.

Examples

1. If rainfall climatology for the area of interest is 300mmand the threshold value is 30 mm, above, below and near normal categories are defined in terms of the following values:
   - **Above normal**: rainfall forecast to be equal to or greater than 330 mm (in water equivalent).330mm = 300mm + 30mm.
   - **Below normal**: rainfall forecast to be equal to or less than 270mm (in water equivalent.270mm = 300mm – 30mm.
   - **Near normal**: rainfall forecast to be between 270 and 330 mm (in water equivalent).

3.5.3 Probability of precipitation

Probability of precipitation **(POP)** is a formal measure of the likelihood of rainfall 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 city, and a 0% probability of rain on the other side of the city, 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 rainfall will occur somewhere in the forecast area.

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

For example, a forecaster might be 50% confident that under the current weather conditions rainfall will occur, and that rain could occur, it will happen over 80% of the area. This results in a PoP of 40 %:(0.5 x 0.8) x 100 = 40%.In this regard, most of the time, the forecaster expresses a combination of degree of confidence and areal coverage. In the case of NMA, "Chance of rain of 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 of 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 included in weather forecasts based on POP are:

- **0% –** No mention of rainfall
- **10% –** No mention of rainfall, 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

3.5.4 Rainfall intensity characteristics.

At a given period of time, rainfall pattern can be expressed in terms of its intensity. That is it is expressed as amount of rainfall occurs within a shorter/longer period of time (few minutes to hours). It can be therefore classified according to rainfall values and the time it elapse as follows;

Rain classification	Rainfall amount recorded within 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

3.6 Numerical Weather Prediction (NWP)

Numerical Weather Prediction is an example of quantitative forecast. It depends on the level of computing facilities. In NWP, the forecast is expressed directly in amount at specific place as area or point forecast. For example, NWP forecast depicted in Figure 12 and 13 represent rainfall and temperature forecast in terms of numerical values. This type of quantifiable weather forecast has a lot application. For examples it is very useful for fertilizer application, pre and post harvesting activity and etc.

It is also user oriented forecast. One can read from the map (Figure 12) how much temperature is forecasted for Mekelle and any other particular place. As we can see from the Figures12 and 13, 29^{o}C maximum and 15^{o}C minimum temperature is forecasted for Mekelle, Expected rainfall at Humera is about 0.8 mm in 24 hours.

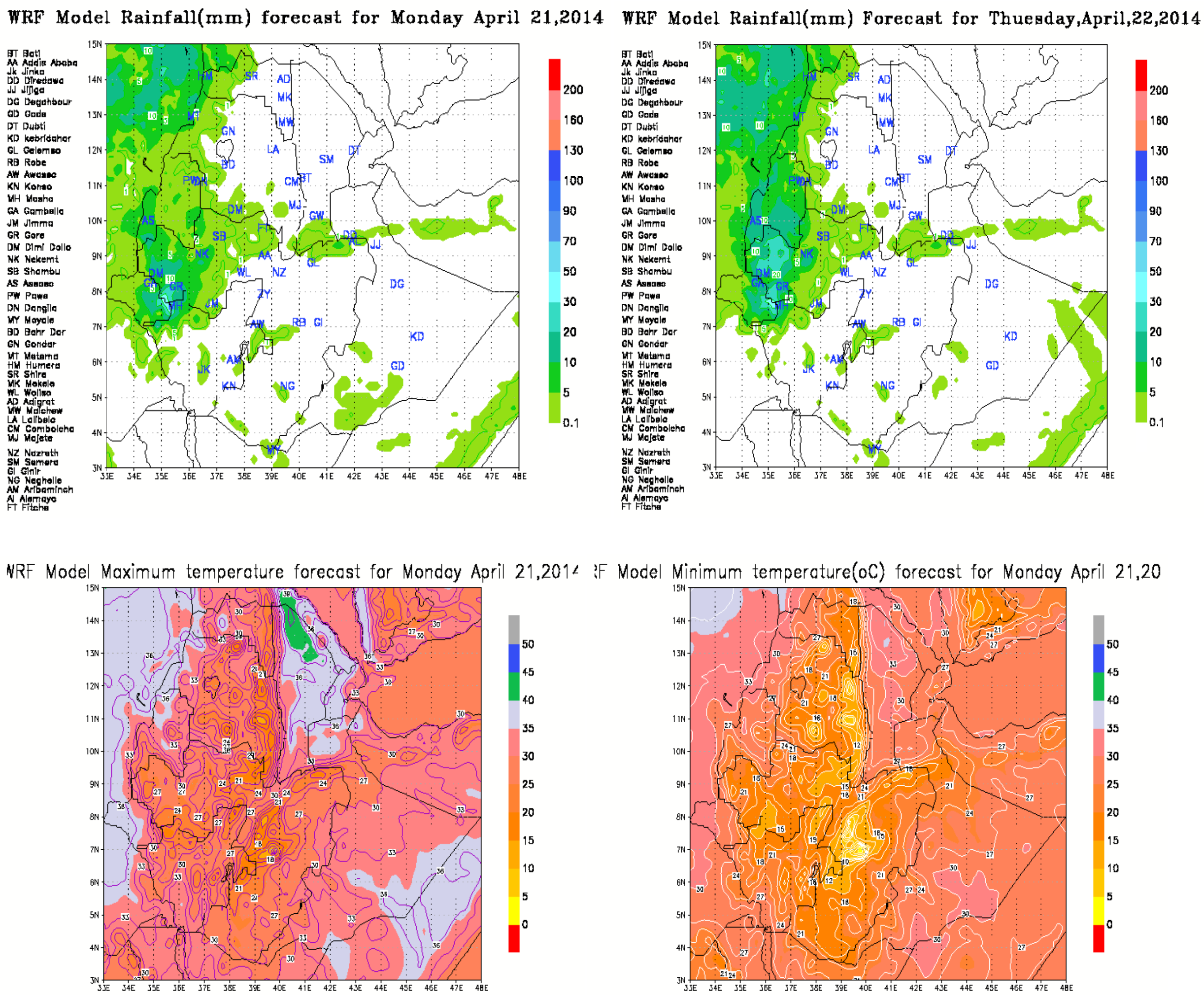

Figure 12: Example of rainfall and minimum and maximum Temperature as forecasted using WRF model.

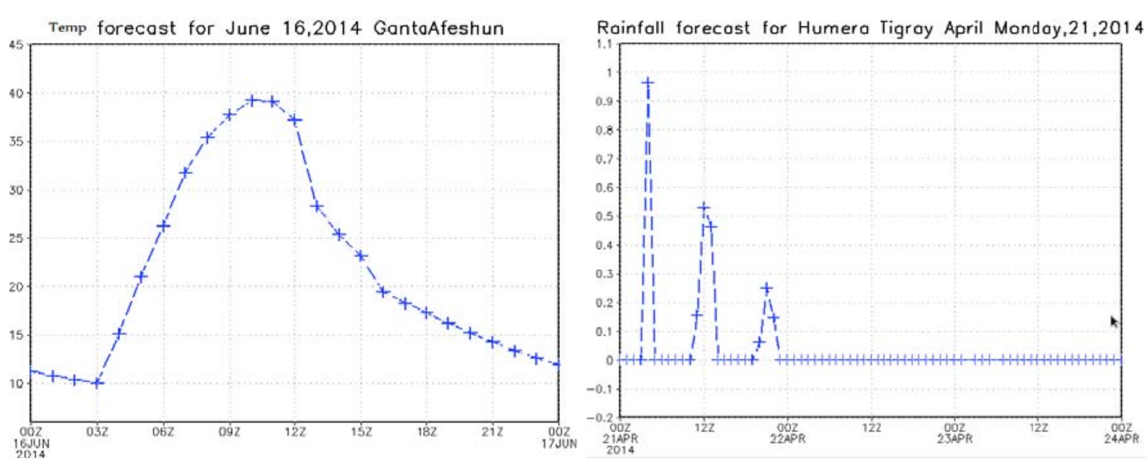

Figure13: Example of point for rainfall and minimum maximum Temperature forecast using NWP

3.7 Application of Plastic Rain gauge for farm level planting date decision

(a) Plastic Rain gauge

(b) Installation Arms

Figure 14: (a) Photograph representing plastic rain gauge with graduated scale. (b) Installed plastic rain gauge at a farm site

3.7.1 Description of plastic Rain gauge

This type of plastic rain gauge was designed to e install it at farm sites where farmers can monitor daily rainfall and apply for day to day agricultural practices. This apparatus has a capacity of 150 mm of rainfall depth, cylindrical and conic shape with a diameter of 11.5 cm at the top and height of 15.5 cm. The conic part has a height of 11.5 cm and a capacity of 25 mm of rainfall. The gauge has a sticker on it to enable farmers can read digitally at a level of 0.1 mm graduation. The gauge has to be installed at the height of 1-1.5 meter above the ground where there is no shed of any barriers and flow of droplets of water into the gauge. Besides, it should be installed in such a way that its upper circular part is horizontally leveled.

3.7.2 Usage of plastic rain gauge

Collection of rainfall from the gauge should start after the heralding news from the National Meteorological Agency on the onset of rainfall for that particular farm. The measurement of rainfall using the plastic rain gauge may be once, twice or more in a day, depending on the seasonal rainfall pattern. The data collected within 24 hours, from previous day 9am local time to next day 9 am local time has to be added to get one day rainfall of the previous day. Then summation of daily rainfall will be made on ten-daily (dekadal) basis. Based on the observed cumulative rainfall, for two consecutive dekads the planting date can be decided by the farmers themselves. Rainfall threshold value of twenty millimeters in each dekad is adequate for sowing or planting of crop. The rainfall amount of 20 mm + 20mm in the two consecutive dekads is believed to be sufficient for the emergence of seedlings by recharging the upper top sub soil. Then after, different agricultural practices could takes place following the emergence of crops.

Different agricultural inputs could be applied based on the crop water balance computation and the weather forecasts. Crop status can also be monitored by comparing the actual crop water balance with the normal based on the rainfall amount from the gauge.

3.7.3 Seasonal forecast and crop selection

The seasonal climate outlook is given based on analogue method by considering how climate will change in subsequent season based on global and regional atmospheric Oceanic predictors as indicated in the previous section. Farmers or Das are recommended to install plastic rain gauges. On the basis of the rainfall records from the plastic rain gauges, planting/sowing of crops will takes place on the basis of twenty-twenty mm of rainfall record for two consecutive dekads. The agricultural inputs application highly depend the rainfall records from the plastic rain gauges and the crop water balance.

Chapter Four: Climatic and agro-climatic resources of pilot Woredas

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 selected Woderas of Tigray in this chapter. The ENSO episode climatology for each Woreda 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 episode for the upcoming season.

4.1.1 Pilot Woreda selection

Irish Aid, who is the funding Agency of this project, has a long standing history to provide technical assistance, in order to enhance agricultural production and 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, Woredas 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, five Woredas namely Kola Tembien, Tahtayt Koraro, Kilete Awlalo, Genta Afeshom and Raya Azebo, has been selected as a project site and Endamohone Woreda being selected as contingency site (Figure 15).

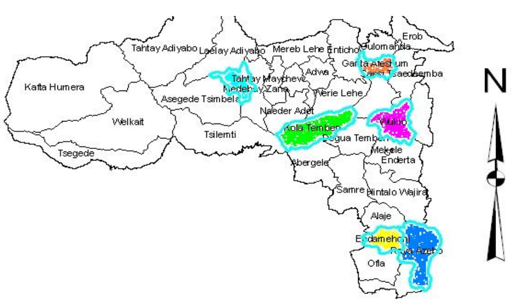

Figure 15: Map showing Pilot Woredas in Tigray Regiona

4.1.2 Data and Methodology

4.1.2.1 Data

The data used for Woreda level detailed analysis were blended and gridded data of dekadal rainfall and temperature from 1983-2012 at 10 km by 10 km spatial resolution obtained from NMA. NMA map room tools (Dinku et al, 2011, 2013) has been used for extracting Woreda level spatial average climate analysis of the gridded data. Other atmospheric systems such as synoptic scales circulations, onset and cessation date of seasons are adopted from various literatures (NMSA, 1996).

4.1.2.2 Methodology

In this study, we calculate grass reference evapo-transpiration, length of growing period, the start and end of the crop growing season. Available scientific computation methods are adopted as outlined below.

Simple statistical analysis over different ENSO episode has been applied to each pilot Woreda climate data to present the climate characteristics under each ENSO episode. In addition, analysis and computation of normalized climate anomalies has been done to examine the level of their variability and trend in the time series. Climatological means are computed based on 1983-2012 years.

Dekadal rainfall values at different probabilities are computed using MS Excel, where the probability of expedience was computed **P=100xR/(n+1)**, where n being the number of the years, it is considered that for large number of years, this value would approach the true value. Besides, the computation of Length of the crop growing period (LGP) is based on onset and cessation dates of rainy season.

Grass reference evapo-transpiration was computed using maximum and minimum temperature data and estimated relative humidity, wind speed and sun shine hour data. In this analysis Crop-wat8 and Agromet shell software were selected to compute and compare the results with those stations having complete data for calculating grass reference evapotranspiration, maximum and minimum temperature, relative humidity, sunshine hour, wind speed. The start and end of the crop growing period was defined in accordance with the following major criteria:-

- The start of the crop growing period is the dekad that satisfies both conditions in which dekadal RF/Dekadal ETo > 0.5 and Dekadal Rainfall > 20 mm
- The end of growing season is considered to be the first dekad where dekadal RF/Dekadal ETo < 0.5

4.1.3 Results on Length of Crop Growing period for the selected Woredas

Computation of the length of the crop growing period at 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 at various temporal and spatial scales. Analysis of dekadal characteristics of crop growing period can help for the assessment of risk of undertaking different agricultural activities, such as planting, fertilizer application, weeding etc.

Dekadal rainfall totals at 20%, 50% and 80% probability level are computed at dekadal basis. 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 when farmers usually call a good year which for this purpose occurs once in five years. This probability level shows 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. On the other hand, 80% probability level indicates the dependable crop growing period which shows the scenario of minimum risk.

Crop growth analysis over the selected Woredas shows that the crop growing period attains the maximum value over Tahtay Koraro and Kola Temben (90 to 100 days) and the minimum value is found over Raya Azebo with 40 to 60 days. The Woredas have crop growing period in between the two extremes. 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 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 Ganta Afeshum from June third dekad to July second dekad, which the farmers should take into account so as to minimize planting failure, by avoiding false start of the rains, whereas planting risk failure over the rest of the selected Woredas is smaller. These agro-climatic characteristics are given for each selected Woreda in the next chapter.

4.1.4 Recommended advisories on fertilizer application for the selected Woredas

The skillful use of fertilizer application is greatly dependent on our knowledge of moisture condition that exists 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 for the application of fertilizer is when there is sufficient water to make the fertilizer soluble 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. However, for the planning of fertilizers, we can use dekadal rainfall probability at 80% probability level which is given for all selected Woredas on the next chapter.

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.

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 second dekad of July can also be recommended in general, but for crops planted in the beginning of August like Teff, 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.

4.1.5 Supplementary note for agronomic researchers in the selected Woredas

Among the cultural practices, sowing date and fertilizer application are the major limiting factors to achieve production potential of crops. 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 nitrogen (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.

4.1.6 Major crop pests and diseases in the selected Woredas

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 Woredas, 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, the 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 Woredas

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. 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 selected Woredas 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 Woreda level climate and agro climatic analysis

4.2.1 Climatic and Agro-climatic resources of Kola Temben Woreda

4.2.1.1 Climate

Kola Temben has uni-modal rainfall pattern with mean annual rainfall of 813.5 mm and 21.8% coefficient of variation, which is moderate. The *Kiremt* season has coefficient of variation of 22.7% and the variability of *Kiremt* seasonal rainfall over the Woreda is strongly influenced by ENSO events. *Kirem*t mean rainfall is 55.2 mm per dekad. However, *Kiremt* rainfall averaged over El Niño years is 48.4mm per dekad, which is below the long term mean. On the other hand, *Kiremt* rainfall averaged over La Niña years is 59.2 mm per dekad. Moreover, maximum *Kiremt* dekadal mean rainfall in El Niño years does not exceed 76.1 mm where it exceeds 110 mm in the case of La Niña years (Table 1). As it can be seen from the graph peak seasonal dekadal rainfall during El Niño years is well below 80 mm, where as in other years it reaches up to 100 mm (see

Figure 16). Seasonal onset and cessation dates are also impacted by ENSO events (Table 2). With an El Niño the *Kiremt* season shows a shift by a dekad with early onset and early cessation. Normalized anomaly rainfall shows a general decreasing trend (Figure 17a) while the normalized temperature anomaly shows an increasing trend (Figure 17b).

Table 1: Kiremt rainfall statistics* for Kola Temben Woreda based on ENSO episode

ENSO Phase	No. of Years	A	B	C	D	E	F
El-Niño	7/30	3	4	0	8	48.4	76.1
Neutral	14/30	4	5	5	9.9	58.0	100.6
La-Niña	9/30	2	3	4	8.3	59.2	110.4
All Years	30/30	9	12	9	8.0	55.2	110.4

*** 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***

Table 2: Onset and cession date of Kiremt season based on different ENSO phases over Kola Temben Woreda

ENSO Phase	Onset Dekad	Cessation Dekad
El-Niño	June 1st dekad	Sep 1st decad
Neutral	June 2nd dekad	Sep 2nd decad
La-Niña	June 2nd dekad	Sep 2nd decad
All Years	June 1st dekad	Sep 2nd decad

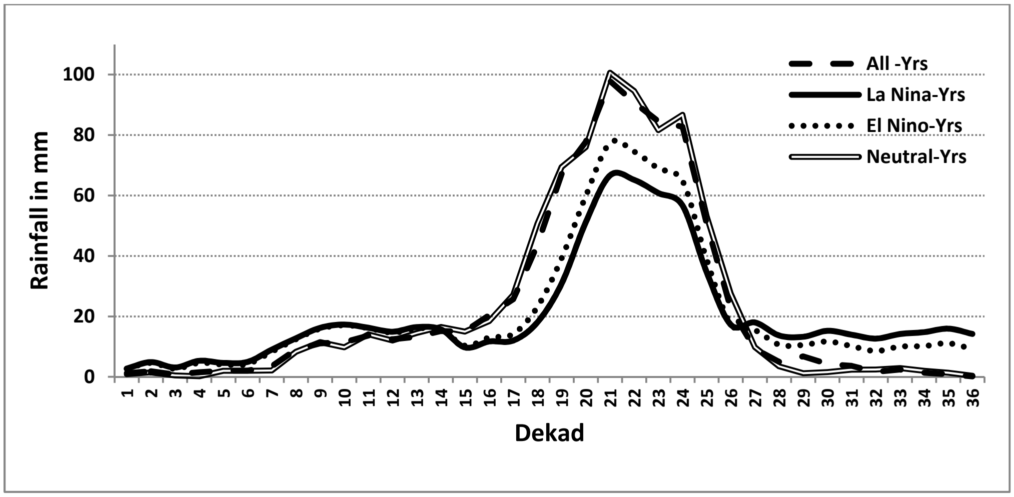

Figure 16: Mean dekadal rainfall of Kola Temben Woreda for 1983-2012 averaged for ENSO and non-ENSO episodes

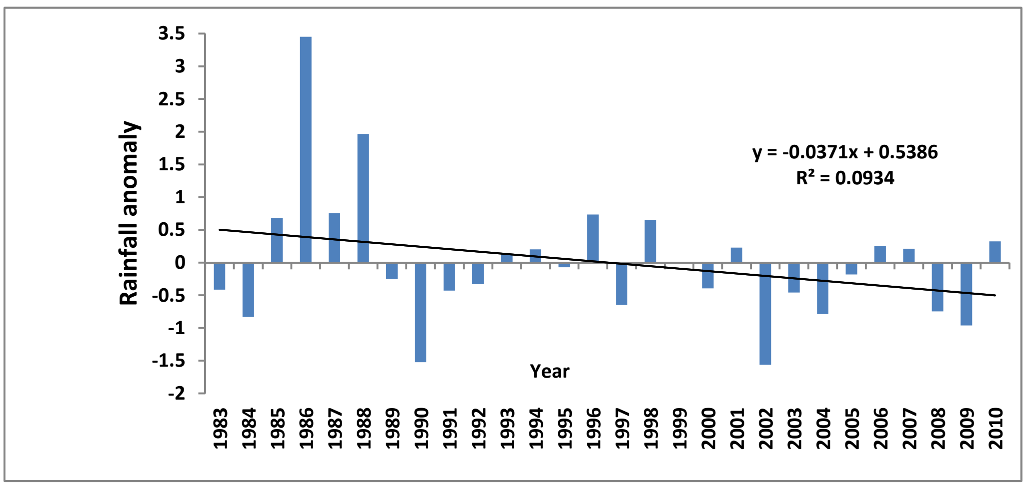

Figure 17 a: Standardized annual rainfall anomaly over Kola Temben Woreda

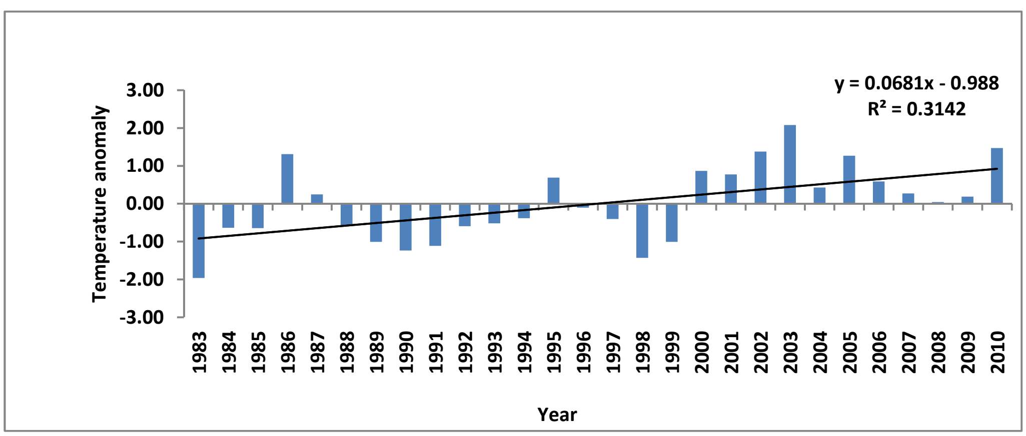

Figure 17 b: Standardized annual temperature anomaly over Kola Temben Woreda

4.2.1.2 Agro-Climatic Characteristics of Kola Temben Woreda

4.2.1.2.1 Identification of crop types

The computation of the crop growing period at different probability levels show 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

Agro-meteorologists have identified a planting window (Table 3) that 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 purpose, we employed two criteria as explained below. The first criterion is when the ratio of the dekadal rainfall to the decadal reference evapo-transpiration is greater or equal to 0.5 and the other criterion adopted here is the first dekad when rainfall total is greater than 20 mm 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% probability level (Figure 18) assured success is computed to be 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 3rddekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from May 3rddekad 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, whereas 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

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 (Figure 18). 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 3rddekad. 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 (Table 3 and 4).

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

Event	Probability Level		
	50%	**80%**	20%
Planting window based on rainfall to ETo ratio (RR/ETo> 0.5) >0.5	June 2nd Dekad	June 3rd Dekad	May 3rd Dekad
Planting window based on 20mm rain threshold (RR>20mm)	June 2nd Dekad	June 3rd Dekad	May 2nd to 3rd Dekad
Cessation based on rainfall to ETo ratio (RR/ETo<0.5)	Sep 2nd Dekad	Sep 1st Dekad	Sep 2nd to Sep 3rd
LGP	80 to 90 days	70 to 80 days	100 to 120 days

Table 4: Dekadal rainfall totals expected at different probability level for Kola Temben

Dekad/ Probability Level	**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%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**6**	**9**	**8**	**9**	**8**	**10**	**8**	**11**	**21**	**41**	**68**	**70**	**87**	**85**	**86**	**83**	**50**	**22**	**7**	**2**	**0**	**0**
80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**5**	**0**	**1**	**2**	**1**	**11**	**26**	**46**	**58**	**69**	**66**	**56**	**55**	**33**	**7**	**1**	**0**	**0**	**0**
20%	**1**	**2**	**1**	**0**	**2**	**2**	**7**	**13**	**20**	**23**	**27**	**21**	**27**	**28**	**25**	**35**	**41**	**57**	**85**	**98**	**124**	**118**	**110**	**107**	**67**	**36**	**15**	**10**	**8**	**7**

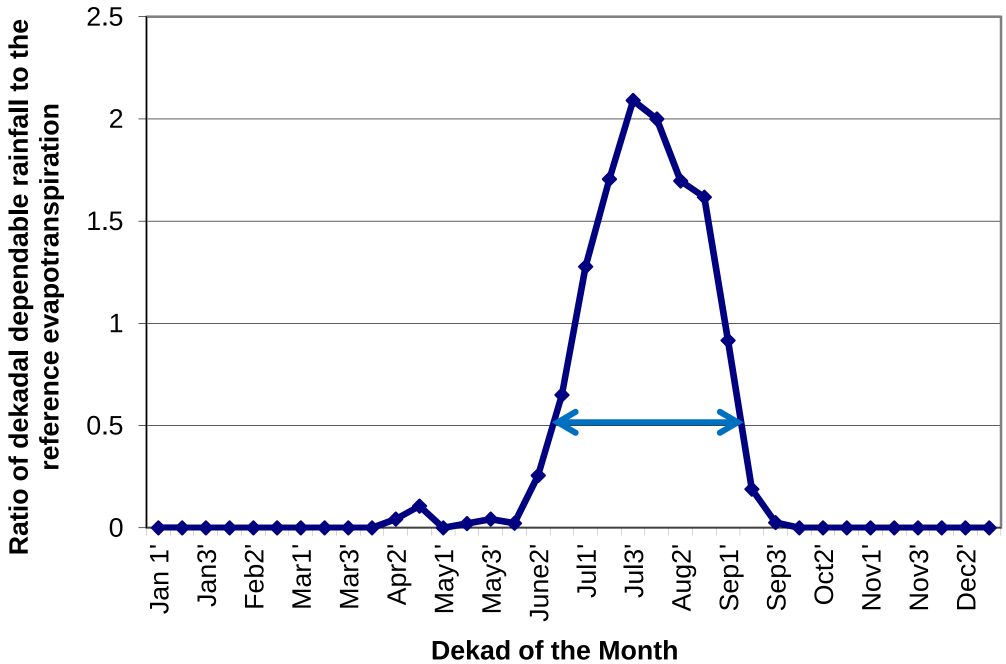

Figure 18: Dependable crop growing period for Kola Temben at 80% probability level

4.2.2 Climatic and Agroclimatic resources of Tahtay Koraro

4.2.2.1 Climate

Tahtay Koraro has uni-modal rainfall pattern with mean annual rainfall of 993.2 mm and 19.2% coefficient of variation, which shows lower year to year rainfall variability. The *Kiremt* season has coefficient of variation of 19.8%, which is strongly influenced by ENSO events. The rainfall statistics under different ENSO episode is summarized in Table 5. The *Kiremt* mean rainfall is 68.6 mm per dekad. However, *Kiremt* rainfall averaged over El Niño years is 61.5 mm per dekad, which is below the long term mean. On the other hand, *Kiremt* rainfall averaged over La Nina years is 72.4 mm (Table 5). Moreover, the maximum *Kiremt* dekadal mean rainfall for El Niño years does not exceed 92.3 mm, whereas *Kiremt* dekadal mean during La Niña years reaches 118 mm (Figure 19). As it can be seen from the graph in Figure 18, the peak dekadal rainfall during El Niño years is well below 95 mm; where as in other years it reaches up to 120 mm.

Seasonal onset and cessation are also impacted by ENSO events; with an El Niño *Kiremt* season shows a slight shift by two dekads with early onset and three dekad with early cessation (see Table 6). Figure 20a and Figure 20b shows a decreasing rainfall trend, whereas temperature doesn't show clear trend in either increasing or decreasing direction.

Table 5: Kiremt rainfall statistics* for Tahtay Koraro based on ENSO episode

ENSO Phase	No. of Years	A	B	C	D	E	F
El-Niño	7/30	5	2	0	18.3	61.5	92.3
Neutral	14/30	3	6	5	25.1	72.0	101.1
La-Niña	9/30	3	2	04	23.9	72.4	118.3
All Years	30/30	11	10	9	24.3	69.7	101.8

**** 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***

Table 6: Onset and cession date of Kiremt season based on different ENSO phases, Tahtay Koraro Woreda

ENSO Phase	Onset Dekad	Cession Dekad
El-Niño	June 1st dekad	Sep 2nd dekad
Neutral	June 1st dekad	Sep 3rd dekad
La-Niña	June 1st dekad	Sep 3rd dekad
All Years	June 1st dekad	Sep 3rd dekad

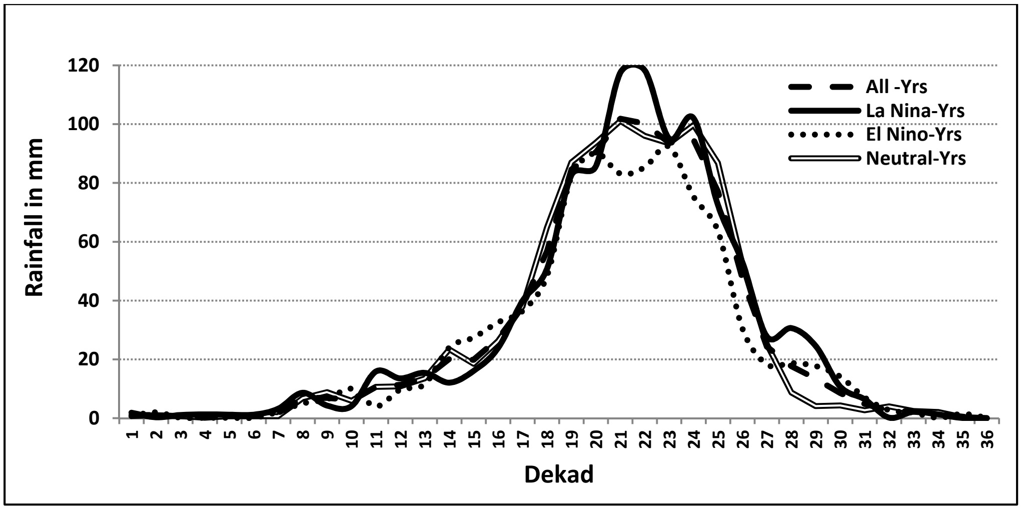

Figure 19: Mean dekadal rainfall of Tahtay Koraro Woreda for 1983-2012 averaged for all ENSO and non-ENSO episodes

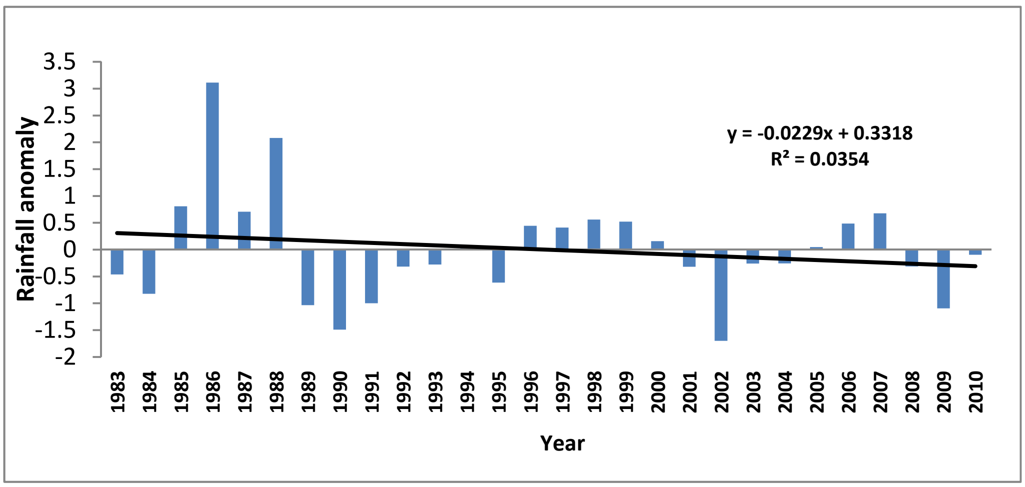

Figure 20a: Standardized annual rainfall anomaly over Tahtay Koraro Woreda

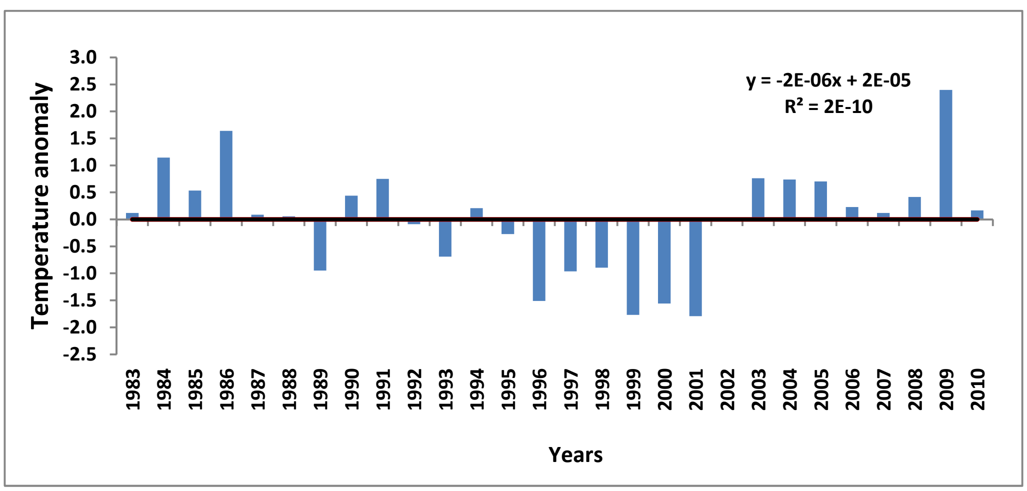

Figure 20b: Standardized annual temperature anomaly over Tahtay Koraro Woreda

4.2.2.2 Agro-Climatic Characteristics of Tahtay Koraro

4.2.2.3 Identification of crop types

Computation of crop growing period at different probability levels shows that the baskets of crops that 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.

4.2.2.4 Planting Windows

Agro-meteorologists have identified planting windows (Table 7) that 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 study, two criteria are adopted as explained below. The first criterion is when the ratio of the dekadal 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 rainfall total is greater than 20 mm 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% (Figure 21) 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 first dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from May first 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, whereas 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 June third dekad, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important.

4.2.2.5 Cessation of the crop growing period

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 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 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 (Table 8).

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

Event	Probability Level		
	50%	80%	20%
Planting window based on rainfall to ETo ratio (RR/ETo> 0.5) >0.5	June 1st Dekad	June 3rd Dekad	May 1st Dekad
Planting window based on 20mm rain threshold (RR>20mm)	June 1st Dekad	June 3rd Dekad	May 1st Dekad
Cessation based on rainfall to ETo ratio (RR/ETo<0.5)	Sep 3rd Dekad	Sep 2nd Dekad	Sep 3rd Dekad
LGP	100 days	90 days	110 days

Table 8: Dekadal rainfall expected at different probability levels for Tahtay Koraro Woreda

Dekad/ Probability Level	**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%	0	0	0	0	0	0	0	0	3	3	7	8	9	13	13	24	41	52	80	88	101	93	93	95	73	47	24	12	5	4
80%	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	9	16	36	59	68	66	75	66	66	51	24	13	2	0	3
20%	1	1	0	0	0	0	3	11	13	12	19	19	27	35	39	43	53	70	108	107	125	117	114	116	97	63	34	27	17	12

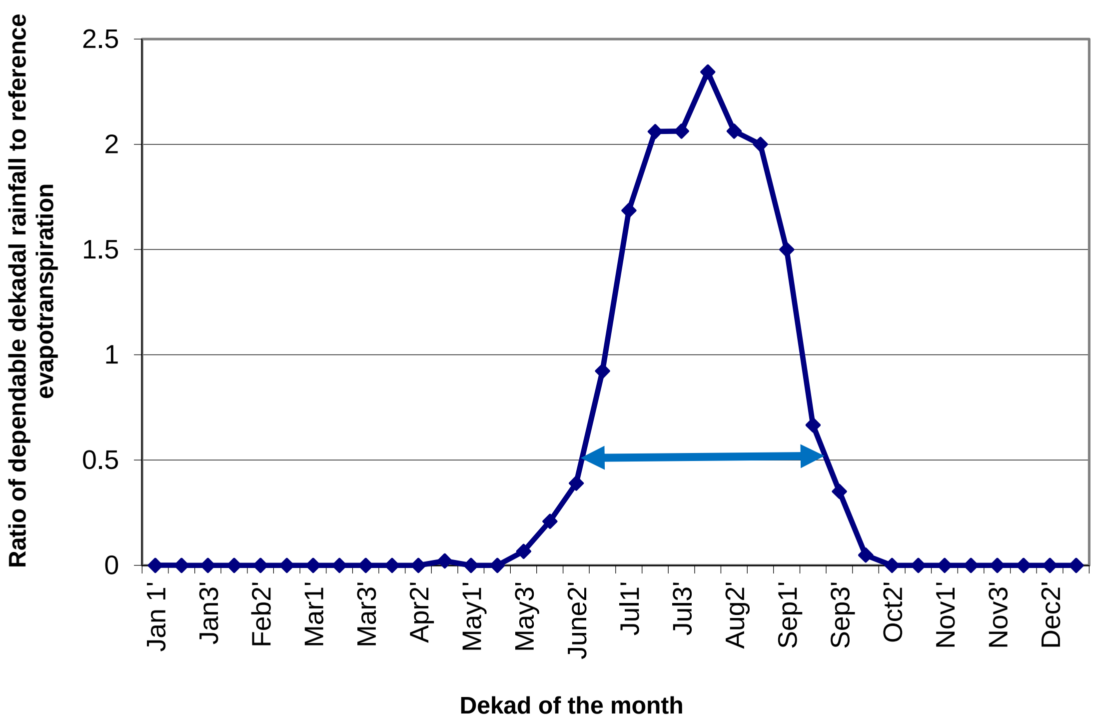

Figure 21: Dependable crop growing period for Tahtai Koraro at 80% probability level

4.2.3 Climatic and Agro-climatic resources of Kilte Awlalo Woreda

4.2.3.1 Climate

Statistical summary of rainfall characteristics for *Belg* and *Kiremt* over Kilete Awlalo under the three phases of ENOS is presented in Table 9. According to the summarized data, Kilte Awlalo has bimodal rainfall patterns with *Kiremt* and *Belg* are the main and short rainy season, respectively. It has mean annual rainfall of 587.5 mm with coefficient of variation 26.8%, which shows moderately high annual variability. The variability of seasonal rainfall over the Woreda is strongly influenced by ENSO. *Kiremt* season has coefficient of variation of 32.5%, which is very high and vulnerable to drought (Hare, 1983). During *Kiremt* season, mean rainfall is 35.5 mm per dekad. However, when it is averaged over El Niño years, the value becomes 28.2mm per dekad, which is below the long term mean. On the other hand, *Kiremt* rainfall averaged over La Niña years is 41.4mm. Moreover, the maximum *Kiremt* dekadal mean rainfall in El Niño years does not exceed 56.4mm, whereas *Kiremt* dekadal mean during La Niña years reaches 87.1 mm (Table 10). As we can see from Figure 22, the peak seasonal dekadal rainfall during El Niño years is well below 60 mm, whereas during non El Niño years it increases to 90mm. This Woreda receives very light rain during *Belg* of about 9.9 mm per dekad with a coefficient of variation of 57.9%, which is extremely high. As it can be seen from Figure 24, *Belg* dekadal rainfall total peak hardly exceeds 20mm.

Table 10 shows that during that *Kiremt* rainfall starts earlier during ENSO neutral years as compared to the other two phases, while cessation is similar in all cases. Figure 23a and 23b shows a clear increasing trend of temperature and a slight decrease of rainfall over time.

Table 9: Kiremt rainfall statistics* for Kilte Awlalo (Wukro) based on ENSO episode

Season	ENSO Phase	No, of Years	A	B	C	D	E	F
Kiremt	El-Niño	7/30	6	1	0	4.0	28.2	56.4
	Neutral	14/30	4	6	4	7.1	36.9	72.4
	La-Niña	9/30	1	3	5	2.7	41.4	87.1
	All Years	30/30	11	10	9	2.7	35.5	87.1
Belg	El-Niño	7/30	2	3	2	0.0	9.5	21.1
	Neutral	14/30	6	6	2	3.4	10.6	17.6
	La-Niña	9/30	2	3	4	3.3	9.5	18.8
	All Years	30/30	10	12	8	0.0	9.9	21.2

**** 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***

Table 10: Variation of onset and cessation date under various ENSO episodes for Kilte Awlalo Woreda

ENSO Phase	Onset Dekad	Cession Dekad
Neutral	June 3rd dekad	Sep 1st dekad
El Niño	July 1st dekad	Sep 1st dekad
La-Niña	July 1st dekad	Sep 1st dekad
All Years	June 3rd dekad	Sep 1st dekad

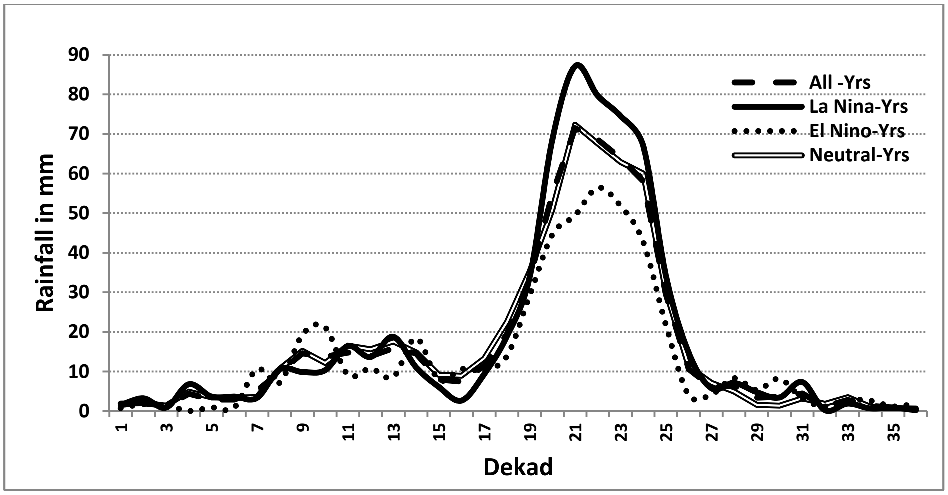

Figure 22: Mean dekadal rainfall of Kilte Awlalo Woreda for 1983-2012 (averaged for all ENSO and non-Episode years

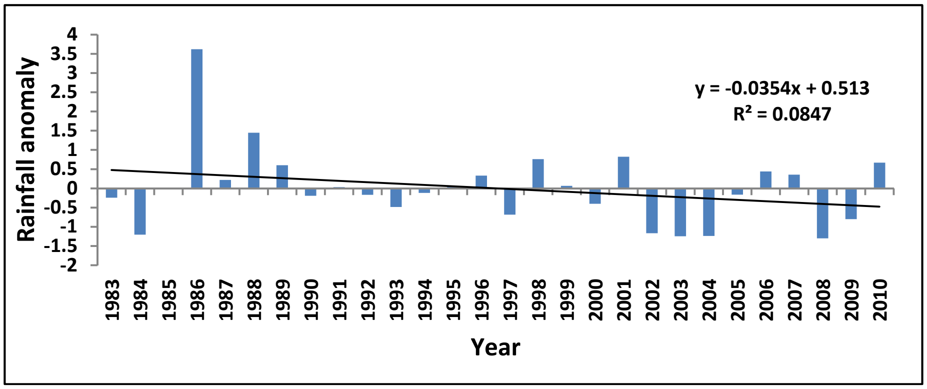

Figure 23a: Standardized annual rainfall anomaly over Kilte Awlalo Woreda

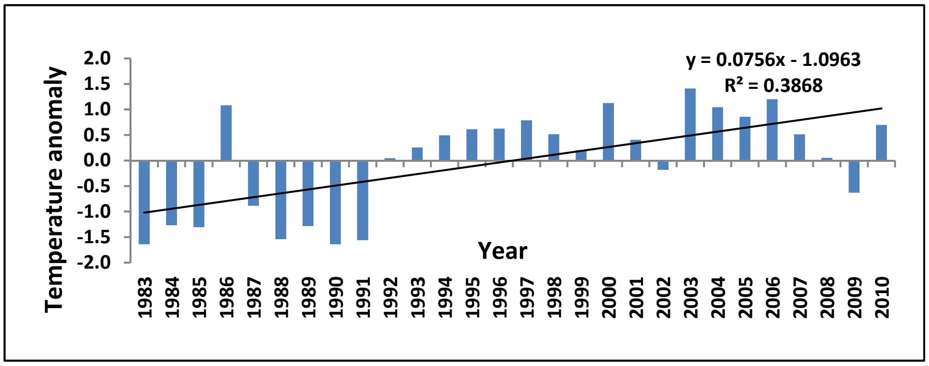

Figure 23b: Standardized annual temperature anomaly over Kilte Awlalo Woreda

4.2.4 Agro-Climatic Characteristics of Kilte Awlalo

4.2.4.1Crop growing period at different probability levels

Analysis of grid data of temperature and rainfall produced by the National Meteorological Agency, by merging satellite estimate and ground observation 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, whereas the month of August shows the probability of water logging occurs, 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 Kilte Awlalo with minimum risk shows that the growing period comprises the time period of July 2nddekad to September first dekad, adding up 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 July first dekad to September first dekad, adding up to 60-70 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 crop growing period extends from June third dekad to the September second dekad, comprising about 80-90 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, they can get a good harvest by utilizing these condition.

4.2.4.4 Identification of crop types

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 80 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.

4.2.4.5 Planting Windows

We can come up with a planting window (Table 11) 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 criteria 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% (Figure 24) assured success is computed to be the second dekad of July, where as if we consider on a fifty-fifty basis, the first dekad of July is recommended. However if we consider the 20% probability level, which usually occurs in 20% of the years, the earliest planting time would be June third dekad. Thus we can consider the decision making process of the farmer to determine the planting time, starting from June third 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, whereas 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 first half of July, which the farmer must adjust based on the actual weather conditions in the given year, where forecast information would be very important

4.2.4.5 Cessation of the crop growing period

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 the end of September 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 September second 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 (Table 12).

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

Event	Probability Level		
	50%	**80%**	20%
Planting window based on rainfall to ETo ratio (RR/ETo> 0.5) >0.5	July 1st Dekad	July 2nd Dekad	June 3rdDekad
Planting window based on 20mm rain threshold (RR>20mm)	June 3rd to July 1st Dekad	July 2nd Dekad	June 3rdDekad
Cessation based on rainfall to ETo ratio (RR/ETo<0.5)	Sep 1st Dekad	Sep 1st Dekad	Sep 2nd Dekad
LGP	60-70 days	60 days	80 to 90 days

Table 12: Dekadal rainfall expected at different probability level for Kilte Awlalo

Dekad/Probability Level	**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%	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**5**	**8**	**9**	**12**	**11**	**14**	**11**	**1**	**4**	**9**	**17**	**32**	**49**	**68**	**63**	**59**	**53**	**28**	**8**	**1**	**3**	**0**	**0**
80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**4**	**0**	**0**	**0**	**0**	**1**	**3**	**12**	**38**	**44**	**46**	**33**	**22**	**17**	**0**	**0**	**0**	**0**	**0**
20%	**2**	**3**	**2**	**1**	**3**	**3**	**9**	**15**	**24**	**29**	**27**	**21**	**29**	**21**	**18**	**17**	**20**	**32**	**49**	**76**	**93**	**90**	**91**	**84**	**41**	**14**	**10**	**12**	**7**	**4**

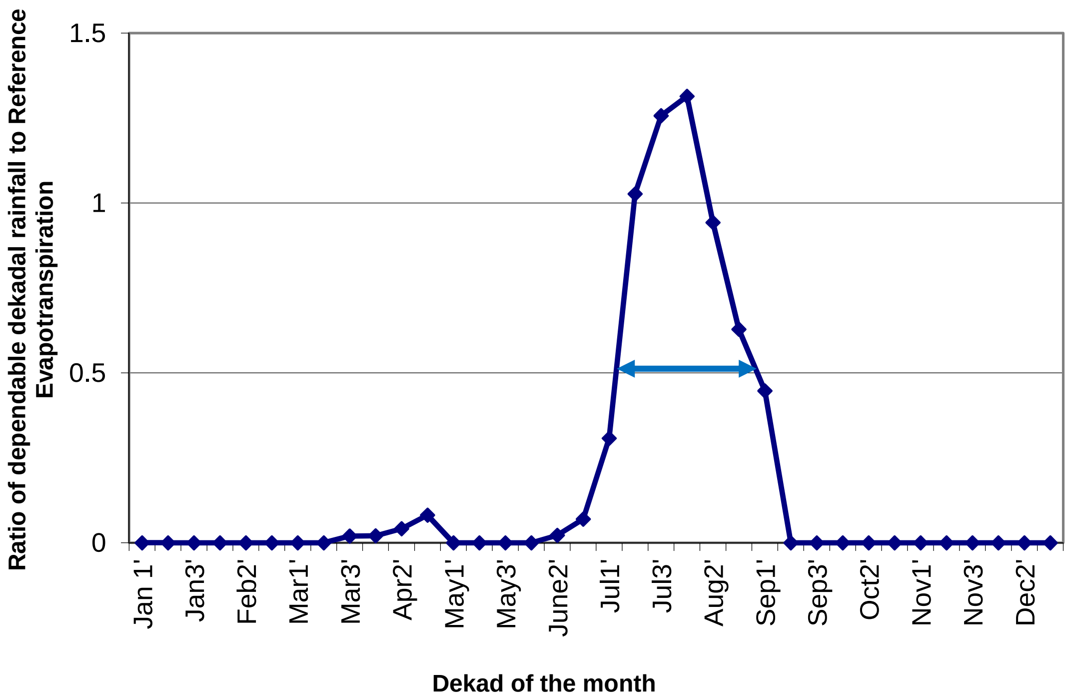

Figure 24: Dependable crop growing period for KileteAwlalo 80% probability

4.2.5 Climatic and Agro-climatic resources of Ganta Afeshom

4.2.5.1 Climate

Genta Afeshom has bimodal rainfall pattern with a mean annual rainfall of 615.2mm and coefficient of variation 33.4%. Thus, its year to year rainfall variability is high and vulnerable to drought. The variability of seasonal rainfall over the Woreda is strongly influenced by ENSO events. The *Kiremt* season has coefficient of variation of 39.2% and the *Kiremt* mean rainfall is 36.3 mm per dekad. However, the *Kiremt* rainfall averaged over El Niño years is 28.0mm per dekad, which is below the long term mean. On the other hand, *Kiremt* rainfall averaged over La Nina years is 40.5 mm. Moreover, the maximum *Kiremt* dekadal mean rainfall in El Niño years does not exceed 52.9 mm whereas *Kirem*t dekadal mean during La Niña years could reach 81.3 mm (Table 13). As we can see from the graph on Figure 25, the peak seasonal dekadal rainfall during El Niño years is well below 55 mm, where as in other years it could reach up to 85 mm.

This Woreda is also receiving light rains during *Belg* with mean dekadal rainfall 9.9 mm and 63.7% coefficient of variation. Thus, *Belg* rainfall is extremely variable and non-dependable. *Belg* rainfall averaged over El Niño years is 9.0 mm whereas over La Niña years are 11.0 mm which is above the other ENSO episodes (Table 14). Figure 26a and 26b shows a decrease rainfall trend with time, but no significant trend for temperature.

Table 13: Kiremt rainfall statistics for Gantan Afeshom based on ENSO episode*

Season	ENSO Episode	No. of Years	A	B	C	D	E	F
Kiremt	El-Niño	7/30	4	3	0	3.9	28.0	52.9
	Neutral	14/30	4	5	5	6.5	40.4	78.0
	La-Niña	9/30	3	1	5	5.4	40.5	81.3
	All Years	30/30	11	9	10	3.9	36.3	81.3
Belg	El-Niño	7/30	0	4	3	0.0	9.0	21.6
	Neutral	14/30	9	3	2	1.4	9.8	18.6
	La-Niña	9/30	4	2	3	4.2	11.0	20.6
	All Years	30/30	13	9	8	0.0	9.9	21.6

**** 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)***

Table 14: Onset and secession date variation on ENSO episode for Ganta Afeshom Woreda

ENSO Episode	Onset Dekad	Secession Dekad
El Niño	July 1st dekad	Sep 1st dekad
Neutral	June 3rd dekad	Sep 1st dekad
LA-Niña	June 3rd dekad	Sep 1st dekad
All	July 3rd dekad	Aug 3rd dekad

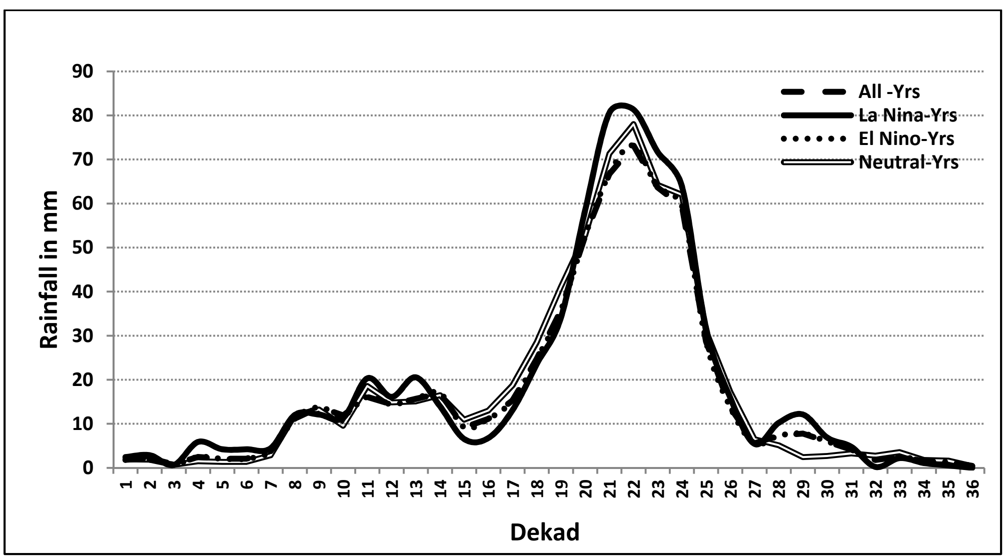

Figure 25: Mean dekadal rainfall of Ganta Afeshom Woreda for 1983-2012 averaged for ENSO and non-ENSO years

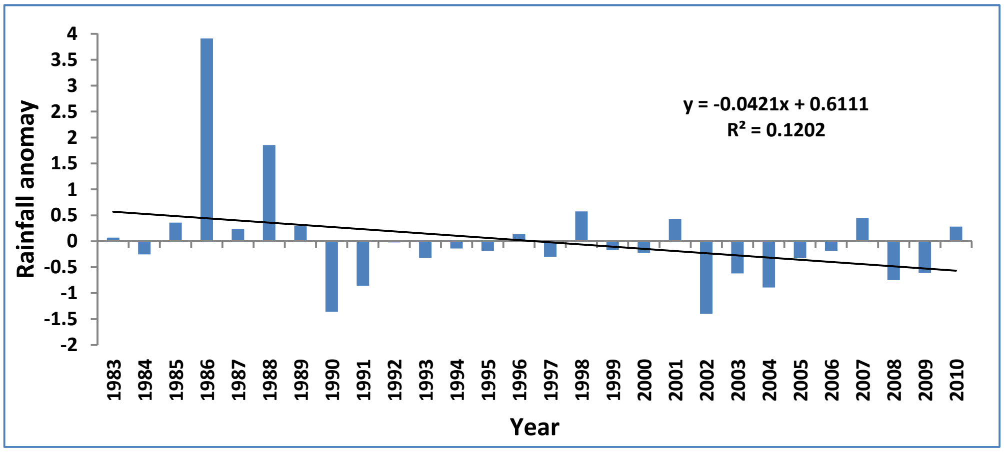

Figure 26a: Standardized annual rainfall over Ganta Afeshom Woreda

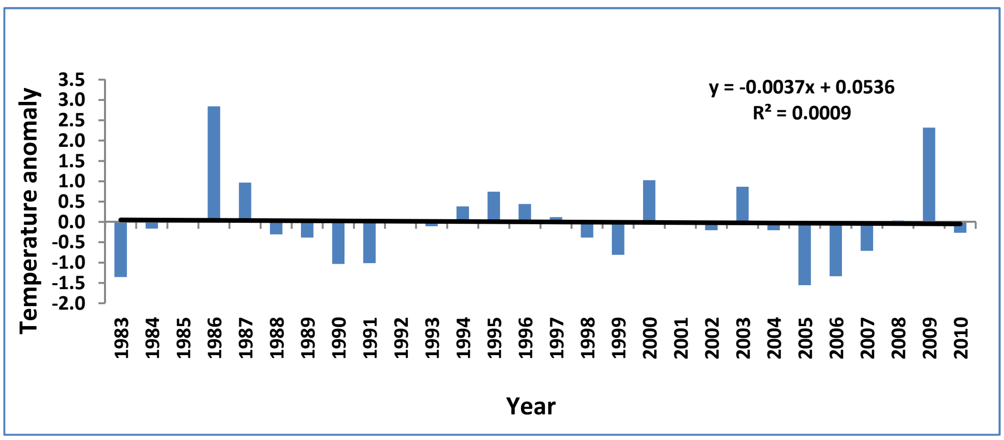

Figure 26b: Standardized annual Temperature anomaly over Ganta Afeshom Woreda

4.2.5.2 Agro-Climatic Characteristics of Ganta Afeshom

4.2.5.3 Crop growing period at different probability levels

Analysis of grid data of temperature and rainfall produced by National Meteorological Agency, by merging satellite estimate and ground observation shows that the dependable growing period at 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; whereas the month of August shows the probability of water logging occurrences, 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 Genta Afeshom with minimum risk shows that the growing period comprises the time period of July 2nd dekad to September 1st 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 June third dekad to September 1st dekad, adding up to 80 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 extends from June 2nd dekad to September 1st dekad, comprising about 90 to 100 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, they can get a good harvest by utilizing these conditions.

4.2.5.4 Identification of crop types

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 80 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

We can come up with a planting window (Table 15) 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% (Figure 27) 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 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 June second dekad.

Thus we can consider the decision making process of the farmer to determine the planting time, starting from June second 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, whereas 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

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/September first dekad. The 50% probability level shows that the cessation can sometimes extend up to the end of September 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 September second 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 (Table 16).

Table 15: Characteristics of planting window, cessation of crop growing period and LGP for Ganta Afeshom at different probability level

Event	Probability Level		
	50%	**80%**	20%
Planting window based on rainfall to ETo ratio (RR/ETo > 0.5) >0.5	June 3rd Dekad	July 2nd Dekad	June 2nd Dekad
Planting window based on 20 mm rain threshold (RR >20mm)	June 3rd Dekad	July 2nd Dekad	June 2nd Dekad
Cessation based on rainfall to ETo ratio (RR/ETo < 0.5)	Sep 1st Dekad	Aug 3rd to Sep 1st Dekad	Sep 2nd Dekad
LGP	80 days	50 days	90 to 100 days

Table 16: Dekadal rainfall expected at different probability level for Ganta Afeshom

Dekad/ Probability Level	**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%	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**8**	**11**	**8**	**10**	**14**	**13**	**10**	**3**	**8**	**11**	**22**	**38**	**49**	**60**	**64**	**59**	**55**	**26**	**11**	**4**	**5**	**0**	**0**
80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**0**	**3**	**4**	**2**	**1**	**1**	**0**	**2**	**8**	**17**	**27**	**39**	**51**	**42**	**28**	**16**	**3**	**0**	**0**	**0**	**0**
20%	**2**	**2**	**2**	**1**	**1**	**1**	**6**	**14**	**22**	**21**	**27**	**22**	**26**	**27**	**21**	**18**	**20**	**37**	**52**	**78**	**84**	**94**	**87**	**86**	**35**	**22**	**10**	**13**	**9**	**10**

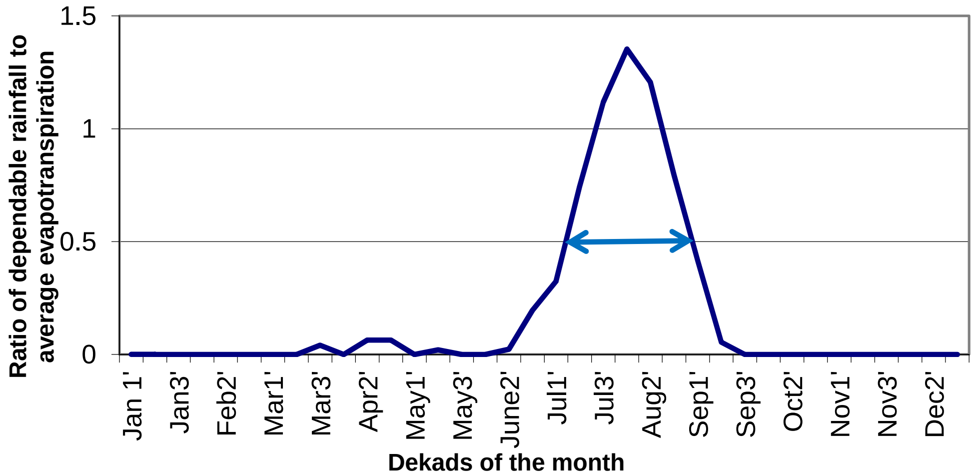

Figure 27: Dependable crop growing period for Ganta Afesom at 80% probability level

4.2.6 Climatic and Agro-climatic resources of Raya Azebo

4.2.6.1 Climate

Raya Azebo has bimodal rainfall pattern with a mean annual rainfall 678.7 mm and 22.3 % coefficient of variation, which shows moderate year to year rainfall variability. The *Kiremt* season has coefficient of variation of 33.9%, which is high and thus prone to drought during *Kiremt*. Like others, Raya Azebo also is strongly influenced by ENSO events (Table 18). The *Kiremt* mean rainfall is 33.0 mm per dekad. However, the *Kiremt* rainfall averaged over El-Niño years is 24.8mm per dekad, which is below the long term mean. On the other hand, *Kiremt* rainfall averaged over La Nina years is 42.8 mm. Moreover, the maximum *Kiremt* dekadal mean rainfall in El Niño years does not exceed 48.7 mm, whereas *Kiremt* dekadal mean during La-Niña years could reach 99.3 mm (see Table 17). As we can see from the graph on Figure 28, the peak seasonal dekadal rainfall during El Niño years is well below 50 mm, whereas in other years could reach up to 100 mm.

This Woreda is also one of the *Belg* benefiting areas with mean rainfall is 15.8mm per decade and 42.2 % coefficient of variation, which is shows very high year to year rainfall variability. *Belg* rainfall averaged over El Niño years is 16.4 mm. During El Niño the rainfall a little bit enhanced in *Belg* season while in *Kiremt* season it weakened. Regarding long term trend, this Woreda has a temperature decreasing trend, which unexpected with global warming, where rainfall doesn't show distinct trend (see Figure 29a and 29b).

Table 17: Kiremt rainfall statistics* for Raya Azebo based on ENSO episode

Season	ENSO Episode	No of Years	A	B	C	D	E	F
Kiremt	**El-Niño**	7/30	6	0	1	1.6	24.8	48.7
	Neutral	14/30	4	7	3	2.4	31.3	69.1
	La-Niña	9/30	2	1	6	1.3	42.8	99.3
	All Years	30/30	12	8	10	1.3	33.0	99.3
Belg	**El-Niño**	7/30	1	3	3	4.7	16.4	38.3
	Neutral	14/30	6	3	5	5.9	16.7	26.4
	La Niña	9/30	5	2	2	3.7	14.5	25.3
	All Years	30/30	12	8	10	3.7	15.9	38.3

**** 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)***

Table 18: Onset and secession date variation on ENSO episode for Raya Azebo Woreda

ENSOEpisode	Onset Dekad	Cession Dekad
El Niño	July 1st dekad	Sep 1st dekad
Neutral	July 1st dekad	Sep 1st dekad
La-Niña	July 1st dekad	Sep 1st dekad
All Years	July 1st dekad	Sep 1st dekad

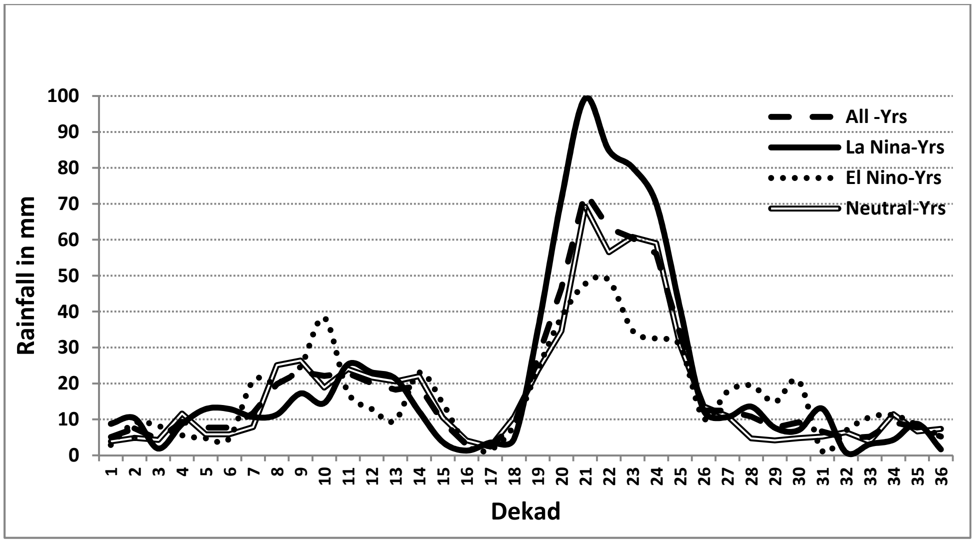

Figure 280: Mean dekadal rainfall of Raya Azebo Woreda for 1983-2012 (averaged for all ENSO and non-ENSO years

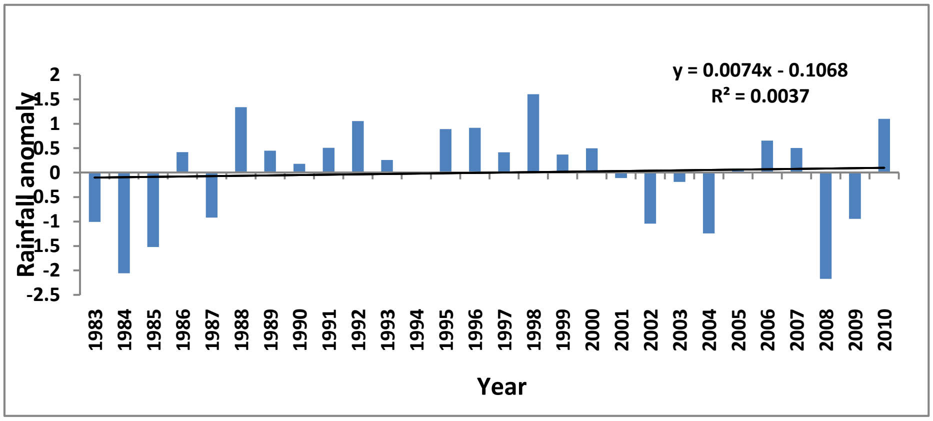

Figure 29a: Standardized mean annual rainfall anomaly over Raya Azebo Woreda

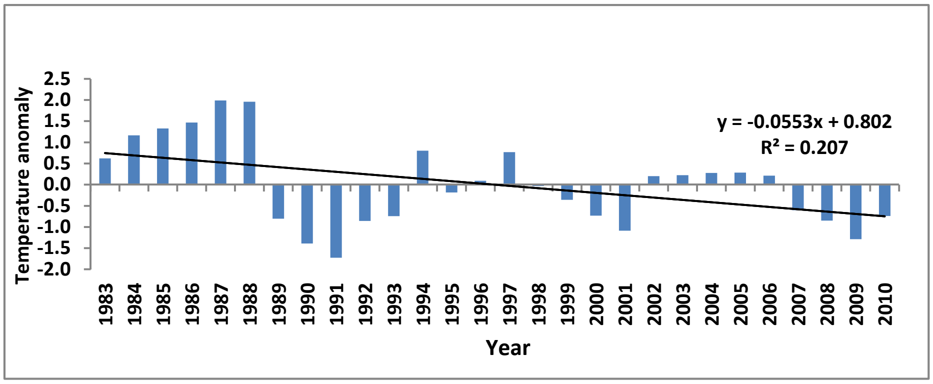

Figure 29 b: Standardized annual Temperature anomaly over Raya Azebo Woreda

4.2.6.2 Agro-Climatic Characteristics of Raya Azebo

4.2.6.3 Crop growing period at different probability levels

Analysis of grid data of temperature and rainfall produced by the National Meteorological Agency, by merging satellite estimate and ground observation 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, whereas the month of August shows the probability of water logging occurrences, 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 Raya Azebo with minimum risk shows that the growing period comprises the time period of July 2nddekadto August third dekad, adding up to 40 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 first dekad to September first dekad, adding up to 60 days. The 20% probability level called the best scenario that the farmer can expect an inter-annual variability of the rainfall shows an interesting feature. Thus the farmer can get the opportunity of cultivating medium cycle crops. The length of the crop growing period extends from July first dekad to September 2nddekad, 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, they can get a good harvest by utilizing these conditions.

4.2.6.4 Identification of crop types

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 40 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.

4.2.6.5 Planting Windows

We can come up with a planting window (Table 19) 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% (Figure 30) assured success is computed to be the second dekad of July, where as if we consider on a fifty-fifty basis, the first 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, whereas 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

4.2.6.6 Cessation of the crop growing period

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 September 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 September second 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 (Table 20).

Table 19: Characteristics of planting window, cessation of crop growing period and LGP for Raya Azebo at different probability level

Event	**Probability Level**		
	50%	**80%**	**20%**
Planting window based on rainfall to ETo ratio (RR/ETo> 0.5) >0.5	July 1st Dekad	July 2nd Dekad	July 1st Dekad
Planting window based on 20mm rain threshold	July 1st Dekad	July 2nd Dekad	July 1st Dekad
Cessation based on rainfall to ETo ratio (RR/ETo<0.5)	Sep 1st Dekad	Aug 3rd Dekad	Sep 2nd to Sep 3rdDekad
LGP	60 days	40 days with no humid period	70 days

Table 20: Dekadal rainfall expected at different probability level for Raya Azebo

Dekad/Probability Level	**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%	**0**	**3**	**1**	**1**	**0**	**0**	**8**	**15**	**19**	**17**	**17**	**20**	**15**	**9**	**2**	**0**	**0**	**4**	**23**	**44**	**82**	**68**	**47**	**55**	**30**	**9**	**9**	**8**	**2**	**0**
80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**8**	**8**	**5**	**1**	**0**	**0**	**0**	**0**	**1**	**25**	**27**	**38**	**26**	**20**	**15**	**1**	**1**	**0**	**0**	**0**
20%	**12**	**14**	**8**	**18**	**14**	**14**	**19**	**34**	**46**	**44**	**40**	**32**	**25**	**39**	**22**	**5**	**8**	**15**	**45**	**61**	**106**	**86**	**101**	**90**	**52**	**22**	**20**	**22**	**13**	**10**

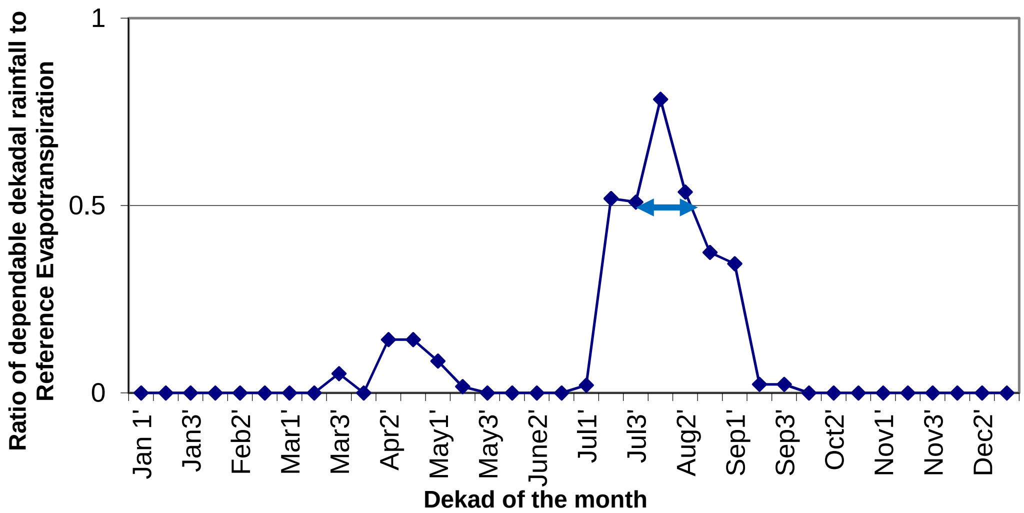

Figure 30: Dependable crop growing period for Raya Azebo 80% probability

4.2.7 Climatic and Agro-climatic resources of Endamohone

4.2.7.1 Climate

Endamohone has bimodal rainfall pattern and has mean annual rainfall 757.7 mm 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 Woreda is strongly influenced by ENSO events (Table 22). *Kiremt* mean rainfall is 44.5 mm per dekad. *Kiremt* rainfall averaged over El Nino years is 37.0 mm per dekad, which is below the mean from all 30 years. On the other hand, *Kiremt* rainfall averaged over La Niña years is 53.0 mm. Moreover, the maximum *Kiremt* decadal mean rainfall during El Niño years does not exceed 76.6mm whereas *Kiremt* dekadal mean during La Niña years could reach 115.2 mm (see Table 21). As we can see from the graph in Figure 31, the peak seasonal dekadal rainfall during El Niño years is well below 80 mm, where as in other years could reach up to 120 mm.

This Woreda 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 Niño years is 14.0 mm per dekad. In general the annual rainfall variability is less while the *Belg* rainfall is high variable hence this Woreda more vulnerable to drought in *Belg*.

Figure 32a and 32b shows a general decrease of temperature over time, while rainfall shows no trend in either increases or decrease direction.

Table 21: Kiremt rainfall statistics for Endamohone based on ENSO episode*

Season	ENSO Episode	No of Years	A	B	C	D	E	F
Kiremt	**El-Niño**	7/30	6	0	1	8.0	37.0	76.6
	Neutral	14/30	6	5	3	10.7	43.6	85.1
	La-Niña	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-Niño**	7/30	1	3	3	3.7	14.0	32.7
	Neutral	14/30	7	3	4	4.2	9.0	16.5
	La-Niña	9/30	5	1	3	3.4	11.5	21.7
	All Years	30/30	13	7	10	3.4	11.5	32.7

**** 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)***

Table 22: Onset and secession date variation on ENSO episode for Endamohone Woreda

ENSO Episode	Onset Dekad	Secession Dekad
El Nino	July 1st dekad	Sep 1st dekad
Neutral	June 3rd dekad	Sep 1st dekad
La-Nina	July 1st dekad	Sep 1st dekad
All Years	July 1st dekad	Sep 1st dekad

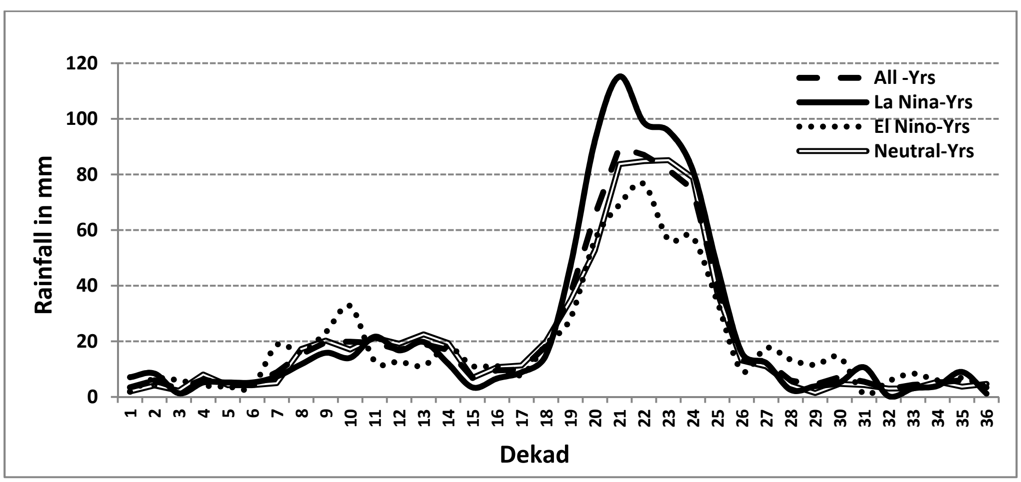

Figure 31: Mean dekadal rainfall of Endamohone Woreda for 1983-2012 averaged for all ENSO and non-ENSO years

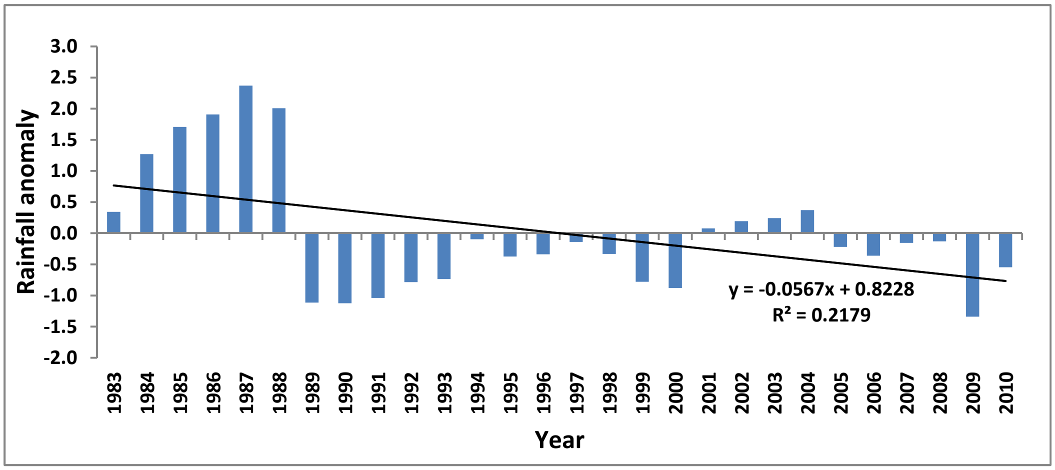

Figure 32a: Standardized annual temperature anomaly over Endamohone Woreda

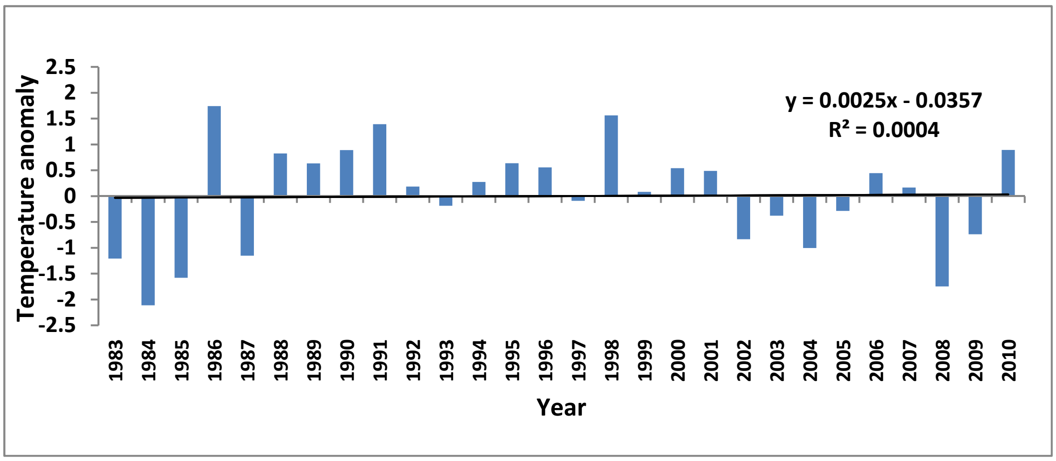

Figure 32b: Standardized annual rainfall anomaly for Endamohone Woreda

Chapter 5: Terminology and Definition

Weather is the state of the atmosphere at any particular time and place.
Climate is the accumulation of daily and seasonal weather events over a long period of time.

Climate variability is variation of mean status of climate and some other statistics (standard deviation and occurrence of extreme value) on seasonal and longer time-scales.

Climatological Normal is the average of climatological data calculated from 30 years data (WMO standard).

Climatology is the description and scientific study of climate in all its aspect. Often the term used to refer to the observed distribution of a meteorological parameter, or set of parameters, over a number of years (typically a 30-year period)

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

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. influence a region or part of a country. Due to revolution of earth around the sun, Ethiopia has three seasons. Based on the mean monthly rainfall distributions, the rainfall regimes are delineated and the types of seasons in Ethiopia are identified as:

***Kiremt*:** is the main rainy season that spans from June to September

***Bega*:** is mainly a dry season except over some parts of the county and spans from October to January. In *Bega*, it is cold in early morning and in the night. Frost occurs at some high grounds at some localities.

***Belg*:** is the short rainy season that spans from February to –May and it is characterized by hot days.

Drought: is a period of abnormally dry weather sufficiently long enough to cause serious effects on agriculture and other activities in the affected area. In practice, drought is defined in a number of ways that reflect various perspectives

- **Meteorological Drought –** a lack of precipitation over a large area and for an extensive period of time

- **Soil Moisture Drought –** a reduction in soil moisture due to a shortfall in precipitation, coupled with high evaporation rates
- **Hydrological Drought –** a reduction in stream flow, reservoir and lake levels, and groundwater levels and recharge
-

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.

Climate prediction: Climate prediction is an outlook of the climate 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.**

Now casting weather forecast: - it a very short time forecasting from 30 min to 3 hours ahead.

Short-range weather forecasting: weather forecast from 12 hours up to 72 hours (three days) a head.

Dekadal forecast: is a forecast of 10 days and part of medium-range weather forecast.

Medium-range weather forecast is a forecast from 72 to 240 h ahead

Monthly forecast: is an outlook for one month. It is usually expressed as a departure from climate normal values.

El Niño An extensive ocean warming that begins along the coast of Peru and Ecuador. Major El Nino events occur once every 2 to 7 years as a current of nutrient-poor tropical water moves southward along the west coast of South America.

La Niña A condition where the central and eastern tropical Pacific Ocean turns cooler than normal.

Inter Tropical Convergence Zone (ITCZ) a belt of high rainfall near the equator. It is formed by the vertical ascent of warm, moist air converging from the north and south. It is usually found a few degrees to the north of the equator but moves north and south with the seasons

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Annex I

Training module for the farming community

on

The understanding, interpretation, access and use of weather and climate information for agriculture

Main contents included in the module

- Introduction
- Purpose of the training program
- Goal
- Objectives
- Duration
- Training strategy
- Language
- Trainee
- Trainers
- Training material
- Feedbacks
- Evaluation and Certification:
- **Module 1:** Introduction to weather and climate
    - Content ; Method; Learning Outcomes
- **Module 2:** Climate and climatology of Ethiopia
    - Content ; Method; Learning Outcomes
- **Module 3:** Climate Change
    - Content ; Method; Learning Outcomes
- **Module 4:** Weather and Climate forecast
    - Content ; Method; Learning Outcomes
- **Module 5:** Agro-meteorology
    - Content ; Method; Learning Outcomes
- **Module 6:** Agronomic application of weather and climate information
    - Content ; Method; Learning Outcomes
- **Module 7:** Accessing and choosing weather and climate information
    - Content ; Method; Learning Outcomes
- Resources required
- Acknowledgements

Introduction

Agriculture is the most important sector in the economy of Ethiopia, contributing over 40 percent to GDP, 80 percent of exports, and occupies 80 percent of the labor force. Around 75% of Ethiopia's 87 million people are dependent on agriculture, which is almost entirely rain-fed and small scale; coffee, and more recently flowers, are the only major commercial crops. Production however is also overwhelmingly of a subsistence nature, and a large part of commodity exports are provided by the small agricultural cash-crop sector. Livestock is also important in the Ethiopian agricultural sector. However most of pastoralists are also operating at subsistent scale. Therefore both farmers and pastoralists are highly dependent on climatic resources for their livelihoods. Ethiopia is highly vulnerable to natural disasters of hydrological and meteorological origin including drought and flood, but its capacity to cope with such events is very limited. Therefore the national capacity needs to be enhanced to better cope with climate risks. While a holistic climate risk management approach should be emphasized, sustainable robust climate service is a prerequisite for effective climate risk management. Communication of seasonal forecasts, weather warnings and advisories to rural farmers would enable them to make informed decisions on their farming operations and to achieve improved productivity while risks associated with erratic climate conditions could be reduced.

Weather and climate are some of the biggest risk factors impacting on farming performance and management. More effective approaches to delivery of climate and weather information to farmer may need the incorporation of a more participatory and cross disciplinary approaches. Given the current concerns with climate variability, change and its impacts on crop productivity, there is an urgent need to educate the agricultural extension officers and farmers about weather and climate, and its use.

The National Meteorological Agency have many recent experiences under different project including Rockefeller in teaching farmers and development agent's on weather and climate, which is found to be more effective. Thus, under this Irish-Aid and WMO supported project, an attempt is made to standardize the training by preparing this module. The target group of this module is mainly to agricultural development agents, subject matter specialist and model farmers who have some level of education. However, the same module could be customizing to farmers as well.

Purpose of the training program

Educate on basics of the science of weather and climate, understand and use of weather and climate information and enhance climate service at a farm level for agricultural decision making.

Goal

This is to achieve the following goals:

- Mainstreaming weather and climate information into agricultural and pastoral activity as part of the agricultural extension service package
- Enhance the effective usage of localized and tailored climate service to enhance agricultural productivity

Objectives

The main objective of this module is:

- Attain practical experience on different meteorological monitoring, data analysis, interpretation and application for agriculture
- To enhance the capacity of development agent (DA), subject matter specialist (SMS) and farmers to understand, interpret, access and effectively use weather and climate information to make informed agricultural decision to explore the positive impact and minimize the risks associated with weather and climate
- Improve agricultural practices based on localized and tailored weather and climate information and advisories.
- Standardize the training given to farming community on the understanding, use and access of climate and weather information to enable the technical competence of government extension officers and other relevant stakeholders.
- To help the agricultural research and technology experiments with climate smart interventions.
- To make DA and farmers become more self reliant in dealing with weather and climate issues as the same affect agricultural production on their farms and through getting them better informed about effective weather/climate risk management

Duration

Each module could take a full day with practical exercise and group discussions well undertaken. Thus, the full package could take one week. In case of financial and time constraints, each module could be squeezed into a half day so that the whole training program could be completed in 3 to 4 days. The training program could also be carried in a one day sandwich program with only PowerPoint presentation as orientation seminar.

Training Strategy

The training will be given in cities of the eleven Meteorological Branch Directorate in a form of Training of Trainers (TOT) targeting development Agents (DA) Subject Matter Specialist (SMS) and selected model farmers. Farmers training are preferred to be conducted at FTC level. However, such training could be arranged at NMA branch level to enhance experience sharing among different localities. All the modules will be delivered with a lecture presentation followed by a practical exercise using data from local stations. It should be interactive involving the entire trainee through the practical demonization and group discussion. Each module includes 25% theoretical and 75% practical exercise, case studies, individual and group works, instructional games, application tools, station visit and on farm activities, such as installation of plastic rain gauge, station observation, etc. Use of local data and sample climate services and their interpretation makes the trainee more interactive and attracted to the training program.

Language

English presentations with Amharic explanations will be used for training of trainers (TOT) trainings as most of the DA's and SMS have at least college level education. When the training is given mainly to the farmers, presentations will be prepared in Amharic and explanation discussion will be in both Amharic (the Federal working language) and the regional languages (Afan Oromo, Tigrigna, etc). Interpreters should be arranged for local farmer training sessions. Definitions of important terms in Amharic follows English definitions should be prepared.

Trainee

For the TOT, DA, SMS and model farmers of the targeted area will be selected by the local Agricultural and Rural Development Bureau based on their role and effectiveness in agricultural extension work. Trainings are most effective when done with a small to medium size group of trainees with a common goal and a willingness to learn together. 20-30 farmers that are community members and can be clustered together for the training will be advisable.

Trainers

Trainers for TOT training could be given by professionals from the NMA head quarter or branch directorate, while for farmers training a combined team of selected DA's and NMA branch directorate experts could be involved. In both case, professionals form regional agricultural and rural development office will be participating specifically to address module 6. Priority will be given to trainers with better training performance evaluation from previous similar programs.

Training material

Training material for each module should be prepared based on the data and climatology of the localities and region where the training is conducted. Printed teaching material should be provided to the trainee during the training. Meteorological data from NMA archive will be used for the training practical exercises. Details lesson plan covering the entire content of each module should be prepared in advance and shared with the trainee. The training material will be standardized in the future from the accumulated practical teaching experience.

Feedbacks

Trainee feedback will be gathered from all the training events and compiled to help continuous revision of this module. Feedback from experts from the ministry of Agriculture, Agricultural Transformation Agency and other stakeholders will also be used in the continuous revision of the module. NMA will revise this module on a yearly basis to fit to the need and requirement of the trainee and stakeholders.

Evaluation and Certification

Both trainee and trainers will be evaluated on their performance. Trainers will be evaluated both in practical exercises, case study works, and group work and written tests. A certificate will be awarded on a successful completion of the training program. Trainers will be evaluated by the trainees based on the effective method of module delivery, their communication skill, coverage of the module and meeting of the learning outcomes via a standardized evaluation form.

Module 1: Introduction to weather and climate

Content

- Definition of climate and weather
- Meteorological observations (instruments, station exposure, type of stations, observation standards, visual observations, station visit, etc)
- Introduction to data processing and quality control
- Meteorological elements and their interpretation (definition and understanding of basic parameters; rainfall, maximum temperature, minimum temperature, humidity, sunshine hours, evaporation, wind, hail, storm, dust storm, frost, fog, lightening, etc)
- Importance of meteorological data for different socio-economic development of the country

Method

- Power point presentations
- Station visit and onsite explanation with practical exercise in measuring different climate parameters, feel the meaning of the values and recording formats
- Do simple calculation and interpretation exercise on the most recent data of different weather parameters of the locality (graphic and tabular presentation)
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

By the end of this module, the trainee will be able to:

- Understand how meteorological observations are done
- Identify station types, and meteorological parameters to agricultural activities and the data type they generate
- Explain the meaning of basic meteorological parameters
- Define and differentiate between weather and climate
- Manipulate and interpret basic climate data
- Know the importance of the local station for national, regional and global climate analysis and national developmental decision making

Module 2: Climate and climatology of Ethiopia

Content

- Seasons of Ethiopia (*Belg*, *Kiremt*, *Bega*) and mean climate system
- Discuss on the Indigenous local seasonal classification
- Physiographic and climate , climate classifications
- Rainfall regime
- Seasonal distribution of rainfall and temperature over Ethiopia and locality
- Drought, flood and other climate extremes
- Climate variability (Mean, STD, CV, anomaly, etc)
- Definition and computation of local climatology

Method

- Power point presentations
- Hand on exercise on computing and plotting climatology of the localities
- Group discussion on the sources of moisture for different seasons and their interpretation
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

By the end of this module, the trainee will be able to:

- Understand Ethiopian seasons and drivers of the seasons
- Differentiate the local physiographic and associated climate as compared to the national one
- Identify basic climate drivers that affect the locality (e.g., mountain, lake, geographic location to basic climate system such as ITCZ, etc)
- Identify the rainfall pattern of Ethiopia, the locality and the seasonal rainfall and temperature distribution
- Define drought, flood and extreme events (heat wave, cold stress, strong wind, heavy fall, etc)
- Analyze rainfall and temperature climatology of their localities
- Able to plot and interpret climatology graph and rainfall patterns using local station data

Module 3: Climate Change

Content

- Definition of climate change
- Cause of climate change
- Observed climate change in the world, Ethiopia and in the locality
- Future climate projections and possible impacts on Agriculture
- Climate change adaption and mitigation options and importance of climate services
- Discuss indigenous knowledge and traditional coping strategies to climate variability that can be scaled up to climate change adaptation
- Climate change perception group discussion: guiding question- How do you perceive climate change in your region or village? What agricultural impact observed? What adaptations option you propose? Comparison between farmers' perspective and scientific projections
- International, regional and national initiatives on climate change (such IPCC, UNFCCC, CRGE, etc)

Method

- Power point presentations
- Hand of exercise on climate trend analysis on local data
- Discussion on climate change perception among DA's or farmers
- Group discussion on possible adaptation options to local agriculture
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

By the end of this module, the trainee will be able to:

- Describe climate change, it causes and its main effects.
- Explain observer and projected climate change signals in the world and localities
- Describe how climate change is affecting the local agriculture, the country and community
- Differentiate between climate change adaptation and mitigation
- List potential adaptation options to climate change for agriculture
- Describe key global, regional and national climate change initiatives

Module 4: Weather and Climate forecast

Content

- Forecast types in space and time resolution
    - Probabilistic vs. deterministic forecast and interpretation with examples and exercise
- Understanding probabilistic climate forecasts
- Interpretation of weather and climate forecast
    - Normal, below normal and above normal
- ENSO and IOD
- Seasonal analog and its application
- Define and explain, seasonal onset, secession , number of rainy days, heavy fall
- Exercise on sample weather and climate forecast to verify proper interpretation and use
- Managing forecasting limitation and uncertainty
- Indigenous knowledge of weather and climate forecast as compared to the scientific methods
- Present and discuss the most recent seasonal predication of *Kiremt*, *Bega* or *Belg* to the trainee

Method

- Power point presentations
- Hands on training on the downscaling, interpretation and utilization for forecast to the localities
- Hands on training on probabilistic games
- Computational exercise of onset an secession date
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

At the end of this module, trainees are expected to:

- Describe how important climate forecast for agricultural practices decision making
- Distinguish between El Niño and La Niña phenomena, IOD and their implication in local rainfall
- Identify the type of forecast and when to use which type to minimize climate risk
- Understand the probability forecast and how to address forecast uncertainty
- Differentiate scientific forecast with indigenous one
- Able to interpret issued forecast and make decision on agricultural activity
- Aware to contest the impact of drought, flood and other climate extremes

Module 5: Agro-meteorology

Content

- Basic agro-meteorological terms (e.g., dry spell, wet spell, water logging, etc) and agro-climatic zone of Ethiopia
- Phonological observation and its application
- Crop-water balance and moisture balance for pasture (WRSI, WatBal, etc)
- Installation, data collection and application for plastic rain gauge (20mm-20mm, 40mm, etc)
- Interpretation and use of agro meteorological advisory (Agro-meteorological bulletins)
- Introduction to better climate risk management including weather index insurance and its application.
- Malaria prevalence and climatic favorability
- Interpretation and use of satellite images on vegetation
- Crop calendar, LGP

Method

- Power point presentations
- Computation of WRSI using MS-Excel or calculator
- Hands on training on farm level decision based on different agro-met advisories
- Games for sensitizing of agricultural risk and insurance
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

At the end of this module, trainees are expected to:

- Understand and describe key agro-meteorological parameters and phonological observation
- Describe agro-climatic zone of Ethiopia and their localities
- Understand the moisture requirement of crop or pasture at its different stages and tools to monitor the moisture status
- Describe crop calendar, length of growing period and NDVI images
- Demonstrate the installation and data collection using plastic rain gauge
- Make decision using data from plastic rain gauge and forecast issued
- Understand advisories on agro-meteorological bulletins and make farm level decision
- Appreciate weather index insurance and its application.

Module 6: Agronomic application of weather and climate information

Content

- Cropping system in Ethiopia and their dependency on rainfall
- Application of weather and climate forecast for different agricultural practices: land preparation, sowing/seed bed, weeding, planting, harvesting, transplanting, fertilizer application (split), etc
- Use of weather and climate information for fertilizer and chemical applications
- Weather and climate impact monitoring (flood, drought, water logging, land slide, pest outbreak, etc)
- Mitigation practices on negative impacts of weather and climate
- Climate risk copping strategies (e.g, water harvesting, pest and disease management, etc)
- Preparation of climate related Disaster Risk and Risk Management Plan
- Integrating the use of technology with weather and climate information
- Impact of extreme climate (high temperature, cold stress, drought, flood, etc) in livestock

Method

- Power point presentations
- On farm practice: illustrate with practical exercises how farmers take strategic and tactical decision on their farm using the weather and climate information and early warning advisories. Give an agro-meteorological advisory with a potential risk and let the trainee exercise what and how they take decision.
- Group discussion on different climate based agronomic advisory (case study work: based of specific agro-met alert, warning issued by NMA, flood, dry spell, flood, etc)
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

At the end of this module, trainees are expected to:

- Identify the major crops and describe the cropping systems in their perspective areas
- Describe the cropping calendar of local crop varieties
- Describe how to apply given agro-meteorological advisor to agronomic decision such as water harvesting, application fertilizer and pesticides, etc
- Differentiate strategic and tactical decisions on farm based on agro-meteorological advisory and warnings
- Explain the climate-related risks at each stage of crop growth
- Identify climate-related risks and prepare a risk management plan for crops and livestock

Module 7: Accessing and choosing weather and climate information

Content

- Sources and formats of weather and climate information and selecting the best source of climate information for different application
- NMA website and its use
- SMS based information dissemination
- Feedback on disseminated weather and climate information, its format and the channels
- Communication of climate and weather forecast and risks
- Sources of climate information and useful contacts (At the national level, at the regional level)

Method

- Power point presentations
- Demonstration of sample climate information extraction/access and its use/application
- Group discussion on the understanding, format, options of disseminated weather information
- Prepare list of questions for the trainee to respond or discuss in group to check it they grasp the lesson covered.

Learning Outcomes

At the end of this module, trainees are expected to:

- Identify reliable sources of climate information for different agricultural decision making
- Identify the preferred climate information communication format and timing
- Share experience among the trainee on access to climate information and ways to share weather and climate information
- Identify the key considerations for communicating weather and climate forecast information

Resources Required

- Facilitators
- Trainers: Meteorologists and agronomist
- Flipcharts and markers
- Poster materials
- Projector and laptop