Training Manual for the Farming Community on the Use of Weather, Climate and Agrometeorological Information in Ethiopia

December, 2017

Training Manual for the Farming Community on the Use of Weather, Climate and Agro-meteorological strict Climate Information in Ethiopia, Published in November 2017 by the National Meteorological Agency (NMA), P.O. Box 1090, Tel: 251-11-5512299, Fax: 251-11-5528713,
Web site: http://www.Ethiomet.gov.et

Disclaim

This Training manual was developed under the project entitled "Improvement of Agro-meteorological Information for Small Scale Agricultural Production in the SNNP & Tigray Regions", 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.

Training Manual for the Farming Community on the Use of Weather, Climate and Agro-meteorological Information in Ethiopia

Prepared by

Tsegaye Ketema[1]
Asaminew Teshome[2]
Aderajew Admasu[3]

National Meteorological Agency
P.O. Box 1090
Addis Ababa, Ethiopia
Web: http://www.ethiomet.gov.et

December 2017

[1]tsegayeketema@gmail.com; [2] asmin2met@gmail.com; adomean71@gmail.com[3]

Training Manual for the Farming Community on the Use of Weather, Climate and Agro-meteorological Information in Ethiopia

Reviewed by

Fetene Teshome[1]
Kassa Fekadu[2]
Kinfe Hailemariam[3]
Henok Hailu[4]

National Meteorological Agency
P.O. Box 1090
Addis Ababa, Ethiopia
Email: nmsa@ethionet.et
Web: http://www.ethiomet.gov.et

[1]fetenekoket@yahoo.com ; [2]K_fekadu01@hahoo.com ; [3]kinfe_hm@yahoo.com ;

Acknowledgements

This Guide was developed under the project entitled "Improvement of Agro-meteorological Information for Small Scale Agricultural Production in the SNNP and Tigray National Region States of Ethiopia", funded by the Irish Aid with a technical support of WMO. National Meteorological Agency is highly grateful to the Irish Aid and WMO for financial and technical support of the preparation of this Guide. Besides, NMA is indebted to acknowledge technical and reviewer teams.

Contents

List of Figures

Forward

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

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

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

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

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

Fetene Teshome

Director General
National Meteorological Agency

Preface

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

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

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

List of Acronyms

AAS Agro Meteorological Advisory Services

AWS Automatic Weather Station

CFS Climate Forecast System

CRGE Climate resilient green economy

ECMWF European Center for Medium-Range Weather Forecasts

ENACTS Enhancing National Climate Services

ENSO El Nino Southern Oscillation

ET Evapotranspiration

ETo Reference Evapotranspiration

FAO Food and Agricultural organization

GDD Growing degree days

GHG Greenhouse gases

GMT Global Mean Time

GTP Growth and Transformation Plan

IOD Indian Ocean dipole

IPCC Intergovernmental Panel on Climate Change

IPM Integrated Pest Management

ITCZ Inter-Tropical Convergence Zone

JAS July, August September

LGP Length of growing period

LLJ Low Level Jet

LRF Long Range Forecast

MI Moisture Index

NDVI Normalized Difference Vegetation Index

NMA National Meteorological Agency

NOAA National Oceanic and Atmospheric Agency

PET Potential Evapotranspiration

PON Percent of Normal Analysis

QBO Quasi-biennial Oscillation

RH Relative Humidity

RMSC Regional Meteorological Service Centers

RF Rainfall

SOI Southern Oscillation Index

SST Sea Surface Temperature

SPI Standard precipitation index

SWI Soil Water Index

TC Tropical Cyclone

TV Television

THI Temperature Humidity Index

TEJ Tropical Easterly Jet

UNFCCC United Nations Framework Convention on Climate Change

WHO World health organization

WMO World Meteorological Organization

WRSI Water Requirement Satisfaction Index

Module 1: Introduction to weather and climate

The purpose of this module is to familiarize participants with the key weather and climate concepts. At the end of this module, participants should be able to:

1- Define and distinguish between weather and climate
2- Describe the type of Meteorological stations and Meteorological Instruments
3- Know how meteorological observation made
4- Introduce meteorological data and its interpretation

1.2. Definition of climate and weather

Weather refers to the behavior of the atmosphere on a day-to-day basis in a given area. The components of weather parameters are daily air temperature, relative humidity, air pressure, sunshine, cloud cover, visibility, wind and rainfall. Describing these parameters for a location defines the weather for that locality. We talk about changes in weather in terms of the near future: "How hot is it right now?" "What will it be like today?" and "Will we get a cloudy and sunny this week?"

Climate is refers to the weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location. We talk about climate change in terms of years, decades, and centuries.

No.	Weather	Climate
1	Weather is the condition of the atmosphere in a specific	While climate is the average weather conditions over a place and it mostly takes place after 30 year of time.
2	Weather may involve just one condition of the atmosphere	While climate includes all the conditions of the atmosphere such as temperature, precipitation, wind, humidity, cloud and pressure.
3	Weather occurs in a place within a short period of time	Climate takes place over longer period of time
4	Weather is what you get on a daily basis;	Climate is what you expect over long time
5	Weather changes within a short time	The overall changes and variations of a climate are very stable and may take decades or centuries
6	The scientific study of weather is called meteorology and meteorologist studies weather	The scientific study of climate is called climatology; a climatologist climate

Table 1: Difference between weather and climate

1.2. Meteorological observations

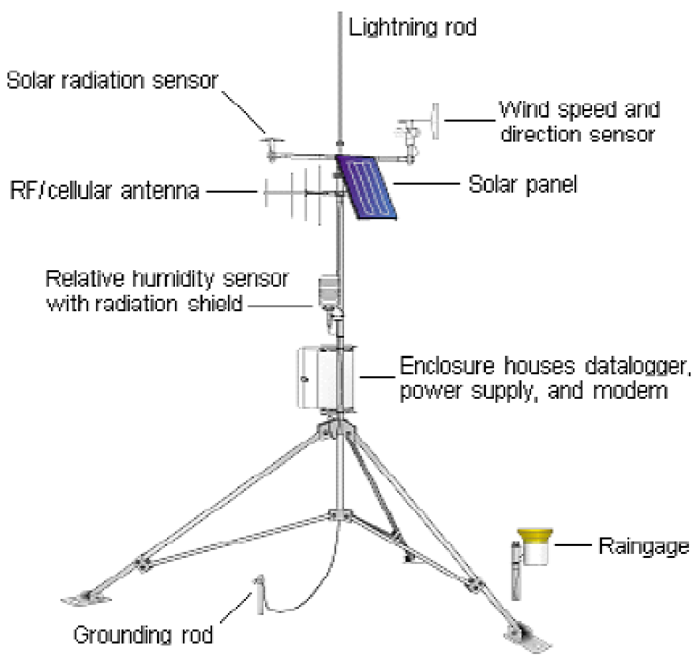
In Ethiopia Meteorological data observation started, due to the missionaries in the 19th century and they established the first Meteorological stations and explores, in 1890 and 1896. During the five years (1936-1941) Italian invasion 192 Meteorological stations were established in various locations of Ethiopia. Beginning 1951around 495 aeronautical and climatological stations were established to address the need of aviation operations and other economic sectors. After the establishment of the National Meteorological Services Agency (NMSA) in 1980, the total numbers of manned (Surface based) meteorological stations substantially increased to 1244 and in the recent years the National Meteorological Agency established different types of Meteorological stations which is operated by trained experts and automated station. Hence currently NMA have 1300 manned Meteorological stations and 250 Automatic weather stations.

Synoptic Stations

Surface observations are the key to generating good surface analyses, although good surface analyses incorporate a variety of data sources to accurately depict the physical processes occurring in the atmosphere at that given time. Meteorological observations and records are made for national and international data exchange purposes. The main synoptic hours of observation are at 0000, 0600, 1200 and 1800 GMT. The intermediate Synoptic hours of Observations are at 0300, 0900, 1500 and 2100 GMT. Additional routine observations are taken every hour for 24 hours a day at full GMT hours. There are 18 such synoptic stations in Ethiopia. Observations and records at each schedule hour are made for the following meteorological parameters:

- Air Temperature, dry bulb (^oC) , Wet bulb (^oC) , Dew Point Temperature (^oC)
- Relative Humidity (%)
- Total precipitation (24 hour mm), rainfall intensity (mm/time)
- Amount of cloud, Type of cloud (octas) , Height of cloud base
- Present weather and past weather (i.e. in the last hour)
- Horizontal visibility (kms)
- Wind Direction and Speed(degree and knots or m/sec) at 10ms
- Wind Speed (m/sec) at 2ms
- Pressure (mm of mercury)
- Intensity of solar radiation wm^2
- Sunshine Duration (hour)
- Evaporation (mm)
- Soil Temperature at different depth (i.e. 5, 10, 20, 30, 50 and 100 cm in ^oC)

Principal or Indicative Stations (First class stations): Meteorological observations are made for various activities including for climatological purposes at these stations. Observations are taken every three hours in the following order 0300, 0600, 0900, 1200, 1500 GMT. Except Horizontal visibility, Pressure, Station level pressure, Mean sea-level pressure and Pressure tendency .Ordinary Stations (third class stations): At these stations, three meteorological elements are observed and recorded. They are maximum air temperature of the day, minimum air temperature of the day and total rainfall amount in 24 hours. Observations are taken at 0600 and 1500 GMT .Precipitations Stations (Fourth class stations): These are stations at which only the total rainfall amount in 24 hours are observed. Observations are taken at 0600 GMT daily.



- **Conventional Weather Station:**

- Synoptic Stations (Second Class stations)
- Principal or Indicative Stations (1st class stations)
- Precipitations Stations (Fourth class stations)
- Ordinary Stations (third class stations)

Automatic Weather Station: AWS are unmanned stations which provide meteorological information in a timely and on a continuous fashion. Getting more information on the atmosphere, more frequently and from more locations are useful. The distributions of AWS in Ethiopia as of 201? are shown in Fig 3.1 below. AWS could contain different sensors, but the commons are the following instruments: for measuring various meteorological parameters:

- Thermometer for measuring air temperature
- Hygrometer for measuring humidity
- Rain gauge for measuring rainfall
- Anemometer for measuring wind speed
- Wind vane for measuring wind direction
- Pyranometer for measuring Solar radiation
- sunshine duration sensor for measuring sunshine hours
- Leaf witness for measuring moisture of the leave's

Figure 1: Conventional weather station (left) and automatic weather station (right) for measuring weather variables

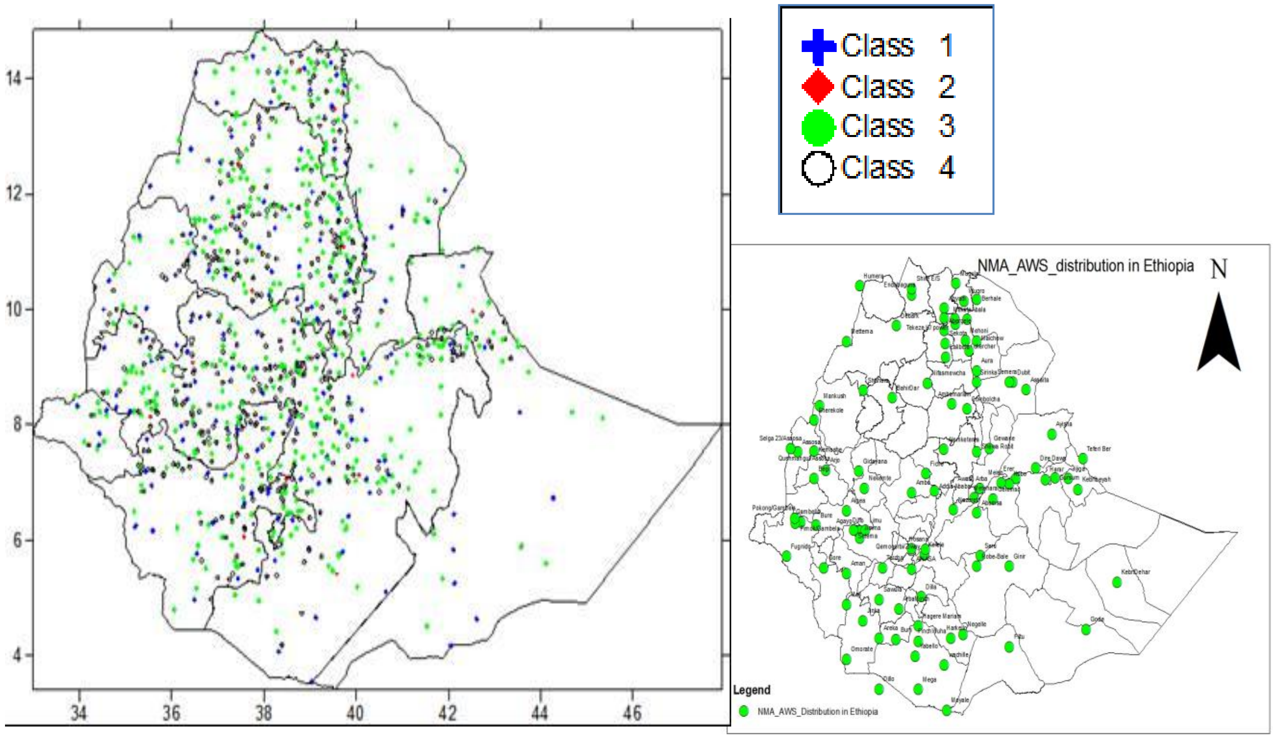


Figure 2: Meteorological manual Stations and AWS distributions

Upper Air stations

Upper air observation is one of the main observations of the atmospheric condition upto 35 km and performing analysis on different upper-air levels provides a very useful view of the atmosphere.

A surface location from which upper-air observations are madefor the following elemnts:

- Tempreture (^{o}C)
- Humidity (%)
- Wind speed and direction. (degree and knots or m/sec)
- Pressure and other parametres are derived from these elements

Advantage of Upper air analysis

- Locating pressure systems
- Locating moist and dry areas
- Analyzing surface and upper-level weather
- Evaluating wind, temperature, pressure, moisture, dry and jet stream patterns

Meteorological weather satellite

Satellite images are images captured by satellites at 15minutes regular intervals and used by meteorologists to forecast the now-cast weather by using the available channels to identify upper level circulations, jet streams, fronts, shear lines, leeside perturbations-mountain waves/turbulence, cloud and topographic features. The three types of satellite imagery displayed on Weather zone are infrared images, visible images and water vapor images of cloud. Satellites are polar orbiting, covering the entire Earth asynchronously, or geostationary, hovering over the same spot on the equator.

Weather radar, is a type of radar used to locate precipitation, calculate its motion, and estimates its type (rain, snow, hail etc.). Modern weather radars are mostly pulse-Doppler radars, capable of detecting the motion of rain droplets in addition to the intensity of the precipitation. Weather radar is one of the most imporatant remote sensing weather observing system.

Figure 3:The new weather radar stationed in shahura, Amhara region

Importance of meteorological information for different socio-economic development of the country

Weather and climate information has multiple benefits for different categories of users in the agriculture, aviation, natural resources management, health, manufacturing, infrastructure, and services development such as tourism. There is an increasing demand for climate information in pastoral system, water, energy sectors, risk management and long-term planning.

Farmers, for example, can plan and decide when and what to plant, experts, policy makers and other climate information users can make informed decisions (ClimDev-Africa, http://www.climdev-africa.org/cop21/climate-information-services-supporting-africas-development). A climate forecast of unwanted rain for the Bega season in most part of Ethiopia during October and November would alert farmers and decision-makers to harvest crops before their crop fields become wet.

Agricultural activities are highly dependent on weather, climate and water availability, and unexpected departures from anticipated climate normal can be best managed using early warnings of weather and climate. Integration and delivery of improved climate forecast information into decision making systems will help design of national development strategies and program

Generally, weather and climate information are prepared to save lives and livelihoods, and to tell how the present state of the atmosphere is changing. The knowledge about the future weather is extremely important to many operational and development activities.

Discussion questions

- Differentiate the difference between weather and climate?
- List some of the Meteorological observation instruments and elements?
- What is the application of meteorological data in your area?

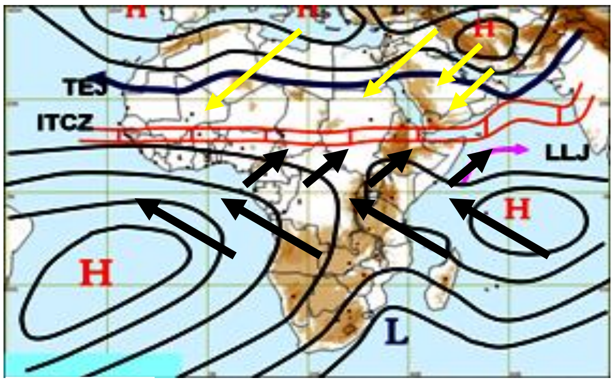
2. Season and climate of Ethiopia

The purpose of this module is to familiarize participants with the key season and climate of Ethiopia. At the end of this module, participants should be able to:

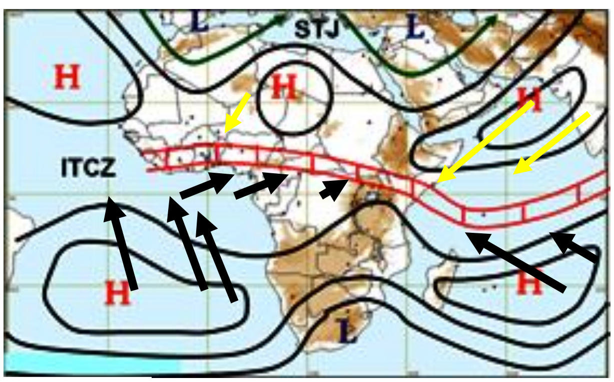
1. Understanding existing seasonal classifications
2. Identifying the main governing weather producing systems in each season
3. Differentiating and familiarizing each rainfall regime
4. Understanding seasonal rainfall distribution during Kiremt, Bega and Belg seasons

2.1. Seasons of Ethiopia (Belg, Kiremt, Bega) and mean climate system

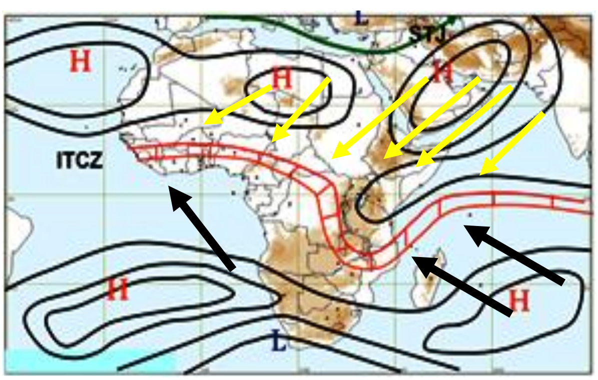
In Ethiopia seasons are classified based on the annual rainfall amount and temperature distribution. So, there are three seasons namely the Belg (short rain), Kiremt (main rain) and Bega (dry for most portions the nation). The rainy season in Ethiopia is associated with a change in the predominant wind direction; northeast wind prevails during the dry season and westerly to southwesterly winds during the rains. As a result the dry season prevails during October, November, December and January which is related to the strengthen of the northerly wind from the continental air mass. During each seasons different climate systems commonly prevails over the area at different time of the year.



Kiremt



Belg



Bega

H-High Pressure **STJ**-Subtropical Jet
L-Low Pressure **LLJ**-Low Level Jet
ITCZ- **N.E** **S.E**

Kiremt Systems: The ITCZ is the main rain producing components of all season. The ITCZ starts its northwards migration before the onset of Belg and Kiremt and keeps its movement to the north till it attains its northern limit at the end of June or beginning of July. During this time in normal years most of the country excluding the southern and southeastern regions receives rainfall. At the beginning of September, the ITCZ resumes its southwards movements and leaves Ethiopia in December. The Southern hemisphere anticyclones both the St. Helena and the Mascarene are the main moisture source to Ethiopia. The LLJ indicates the strength of cross equatorial flow from southern hemisphere to the northern. At medium and upper troposphere levels northwards displacement of anticyclones are observed. At upper troposphere the TEJ is dominant in good years (top left picture).

Belg Systems: In the northern hemisphere the sub-tropical anticyclone (the Sahara and Arabian) bring dry air to Ethiopia at the beginning of the season. At the middle and end of the Belg season the deep penetration of extra-tropical low pressure systems to the Middle East and the formation and propagation of the Mediterranean depression forces the Arabian anticyclone to shift to the Arabian Sea. These low pressure systems (extra-tropical and Mediterranean) occasionally interact with tropical air masses. At the middle and end of the season the penetration of upper air troughs to the tropics are more pronounced (middle left picture)..

Bega Systems: The Arabian and Sahara anticyclones intensify and bring cold-dry warm-dry weather to Ethiopia respectively. Sometime if the depression forms over the Mediterranean Sea or Europe and moves eastward and interacts with the tropical air mass rain occurs in Ethiopia. Although tropical depressions rarely form over the Arabian Sea, sometimes they move to the horn of Africa and bring untimely unwanted rain over the regions. Generally during Bega season, anticyclones mostly dominate Ethiopia (bottom left picture).

Figure 4: The main Synoptic systems which is common in each season

2.4. Rainfall regime

In Ethiopia, the pattern and character of rainfall varies in different parts of the country. There are some regions, which experience three seasons (tri-modal type) with two rainfall peaks (where one peak is more prominent than the other), while some regions have three seasons with two distinct rainfall peak (bi-modal type). There are still some regions, which have two seasons with single rainfall peak (mono-modal type) as shown in the Figure below.

Areas under region A are characterized by three distinct seasons and are locally known as Bega (October to January), Belg (February to May) and Kiremt (June to September). The rainfall pattern in region A has two distinct peaks during a year.

Areas under region C cover the southern and south-eastern parts of the country are characterized by two distinct rainfall peaks with dry season in between, where the first wet season is from March to May and the second is from October to January.

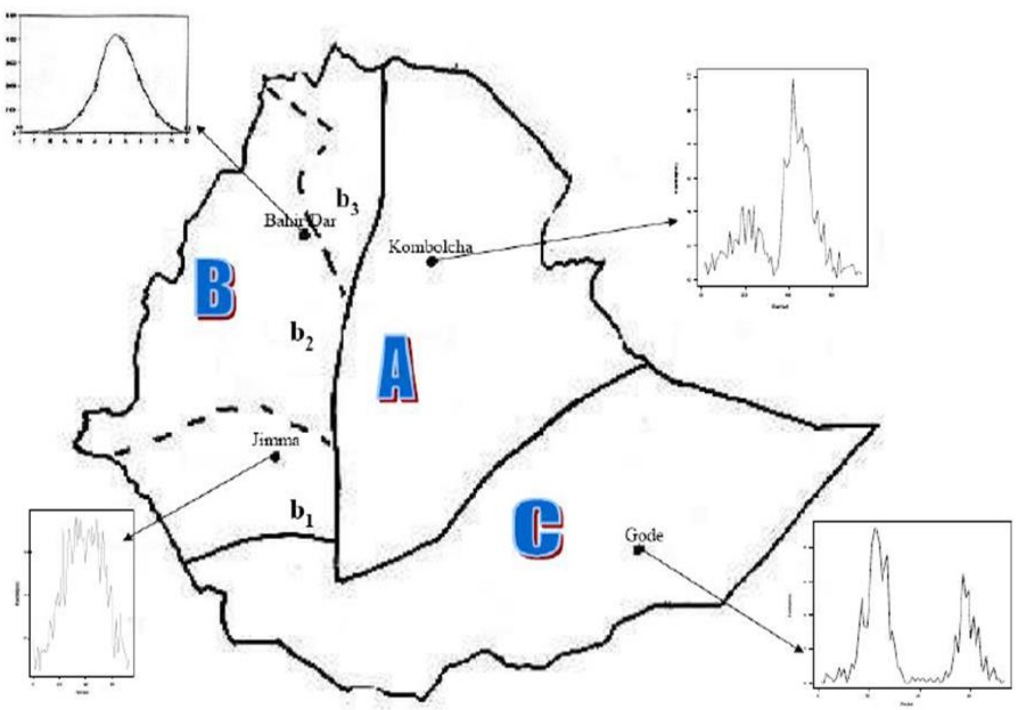


Figure 5: Rainfall regimes over Ethiopia (after Tesfaye Haile)

Areas characterized by region B are characterized by single rainfall peak during a year, where two distinct seasons, one being wet and the other dry are encountered. Mean monthly rainfall pattern shows that the south-western, western and north-western parts of the country are under their wet season during February/March to October/November, April/May to October/ November and June to September, respectively.

2.5. Seasonal distribution of rainfall and temperature over Ethiopia

The National Meteorological Agency, considering the dominant regional atmospheric circulations and the rainfall patterns across the three major rainfall regimes over the country uses the following seasonal classifications for operational monitoring and forecasting of the weather over the country.

October to January (Bega):- predominantly called Bega (dry season) over areas in region A, also part of the long dry season over north-western parts of the country of region B, whereas over the western and south-western parts of the country of the region B, denotes the time when the long rainfall season comes to an end to be followed by a medium to short dry season during the same period. During the first half of this season, south and south-eastern parts of the country of region C get their short rain season due to the south ward retreating Inter Tropical Convergence Zone. Year to year variability of the weather during this season are largely related to intensities of the occurrences of west-ward moving depression over the Arabian Sea, intensities of the Siberian high pressure systems and its extensions and the Saharan high pressure system which may affect the variability in the cloudiness and minimum temperature values over the central, eastern, western, south-western and north-western parts of the country. North-eastern parts of the country and adjoining areas can sometimes get some rain during January due to east ward moving northern hemisphere mid latitude systems coupled with Red Sea Convergence Zone. More over global tele-connection patterns such as ENSO also can have influence on abnormal weather conditions such as un-seasonal rainfall activities over areas where this season is considered normally as a dry season.

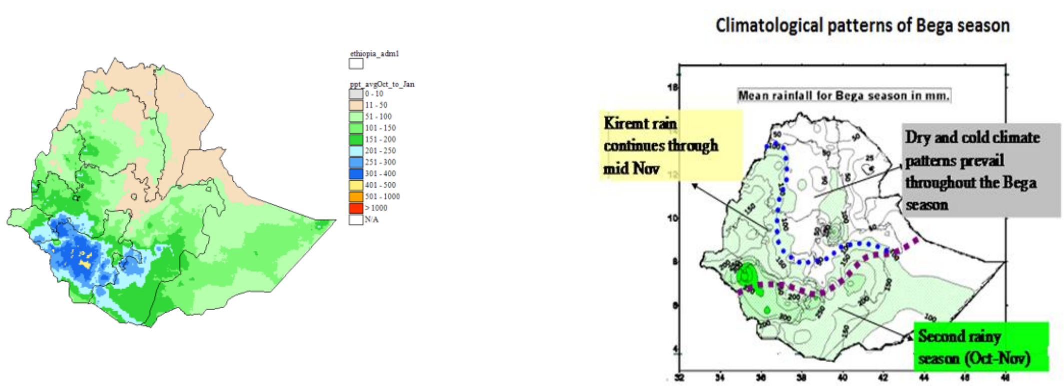


Figure 6: The mean climatological records of rainfall (left) and the most benefitted areas during Bega

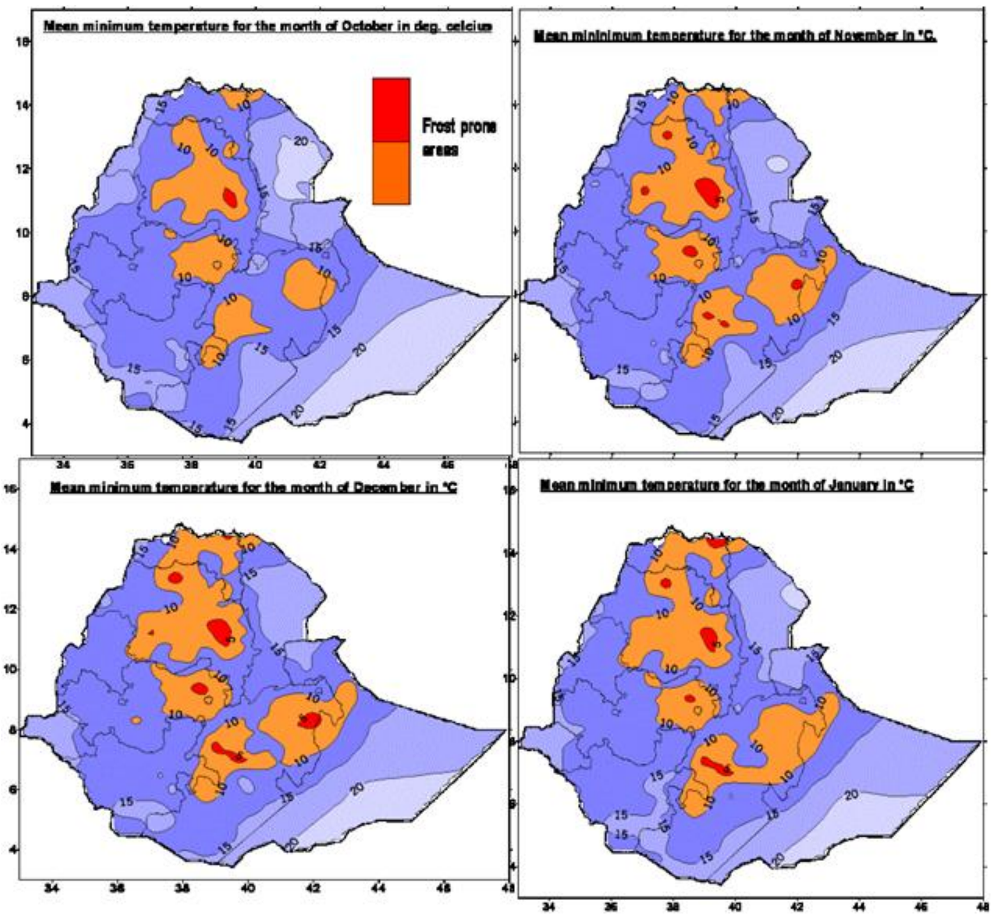


Figure 7: Climatological Minimum Temperature Distribution during of Bega

February to May (Belg):- predominantly called Belg or small rainy season over areas in region A, whereas over the south-western parts of the country region B, it denotes the start of the long rainy season. Over the western parts of the country of region B also the rainy season starts during March/April. However over the north-western parts of the country of region B, this season is predominantly dry except for the month of May. Southern and south-eastern parts of the country of region C are expected to get their long rainy season during this time starting in March and peaking in April.

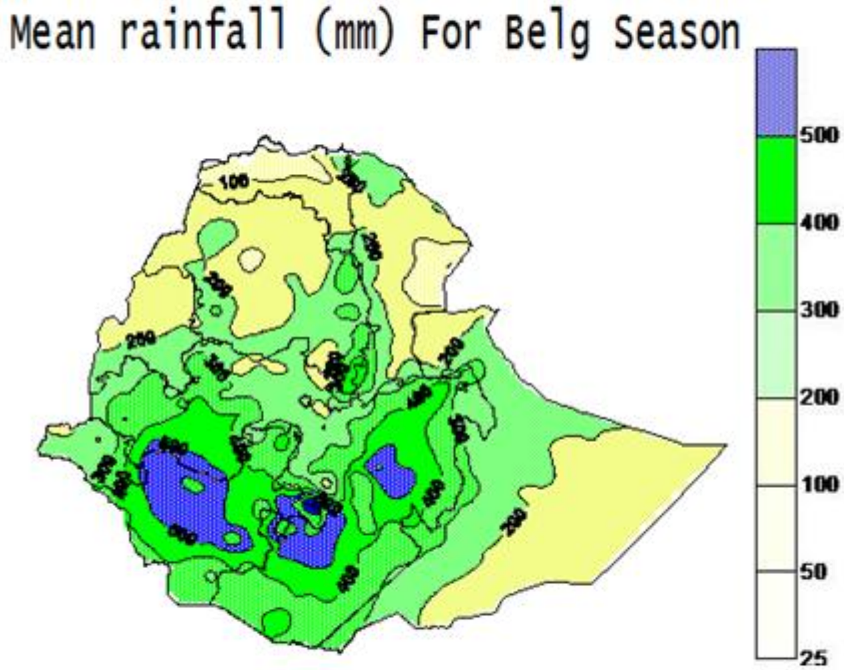


Figure 8: Climatological rainfall distribution during of Belg

June to September (Kiremt):- Predominantly called Kiremt season which is considered as the main rainy season in which about 85% to 95% of the food crops of the country are produced. The magnitude of rainfall is higher as compared to the other seasons for many parts of the country. It is to be noted that this rainfall season is not experienced over the southern and south-eastern lowlands of the country due to divergence field of the wind originating from the Indian Ocean over these areas. Thus, we have to note that there are variations in the timing of rainfall season and rainfall peaks over different parts of the country. One method of identifying the mean timing of the rainfall seasons and the rainfall peaks is by computing mean dekadal (for more professional work, pentad i.e. five days mean values are used) and monthly values of rainfall amount and rainy days and by studying the dekadal or the monthly rainfall pattern.

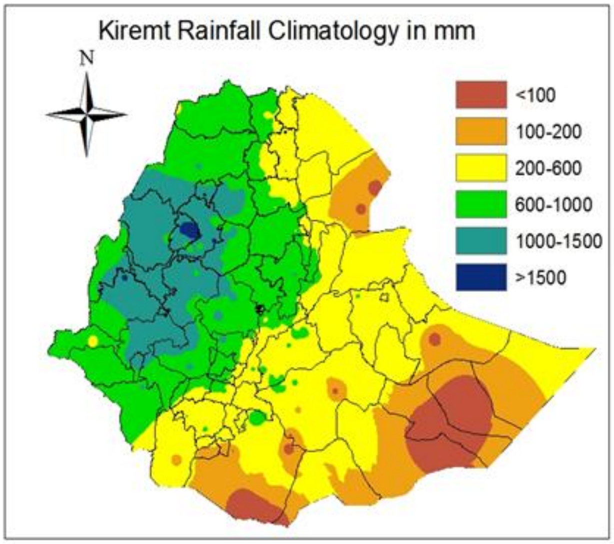


Figure 9: Climatological Rainfall distribution during of Kiremt

The major drawback of producing mean Climatological maps over Ethiopia is that of the problem of associated with uneven station distribution, problems of data continuity and data uniformity. The unevenness of the station distribution network has long been a major problem in the amount of the completeness of information that can be conveyed about the different parts of the country. In general there is a tendency of the station network to be denser along the roads and over the highlands whereas this distribution is very sparse over the lowlands, though in recent years this has shown some improvement. The completeness of the information on climatology of a place is in general reasonable according to the World Meteorological Organization.

2.6. Climate extremes

An adequate knowledge of the climate of a place can be an important tool for planning of various economical activities. Moreover, monitoring of variability's of climate and climatic extremes such as drought and flood need knowledge of the climatology of an area, this means the long-term mean value of climate parameters such as temperature and rainfall within their degree of variability or deviation from the mean. These are abnormal manifestations of weather that potentially cause loss of lives and livelihoods. Climate change is often associated with increased frequency and intensity of strong weather events (climate extremes). Drought and flooding are the two common weather extremes in almost all parts of Ethiopia. The 2015 El Nino driven drought and the 2006 and 2007 floods can be good examples of weather extremes in recent past. There are various forms of climate extremes in Ethiopia and other parts of the globe such as cyclones, typhoons, tornados, frost, etc.

Drought: is a general deficit of moisture below the norm and is explained in its three variants: meteorological (deviation of precipitation below the normal), hydrological (deviation of surface and underground water volumes below the normal) and agricultural (variation of soil moisture for crop and pasture development below the normal). Based on the hydrologic cycle, prolonged occurrence of meteorological drought will subsequently bring in hydrologic and agricultural droughts. It is primarily caused by deficit or no rainfall and is worsened by poor soil moisture holding capacities, low underground water storage potentials, and poor agricultural and land management practices. Rainfall deficits are governed by large scale atmospheric and oceanic processes and, to a certain extent, by local factors such as altitude, vegetation cover, and the relative position of a certain geographical area within a country in reference to major rain producing systems.

Flooding: is excess flow of water over land and occurs as a result of excess rainfall: However, it is important to note that land surface conditions such as soil properties and vegetation cover do affect the intensity and severity of flood waters. That is, a land with good vegetation cover is highly likely to be less affected than a land with poor or no vegetation cover while the rainfall amount and other factors remain the same. The same applies to lands with different soil properties.

Drought hazard measurements could vary depending on the types of droughts being dealt. For example, the magnitude of meteorological drought is often measured by standardized precipitation Index (SPI) method or by classifying percent deviations of rainfall observations from the long term average.

1. SPI is a measure of meteorological drought or wet conditions that tells the number of standard deviations a particular rainfall observation is above or below its long term average (climatological normal).

For example, if the RF observation "x" in time "t" is less than 1 standard deviation from the long term average, it might be categorized as moderate drought. If it is 1.5 or 2 standard deviations below the norm, it is classified as severe drought, etc.

When RF observations are above the mean, they represent wet conditions to an extent of flooding.

The Standardized Precipitation Index (SPI) is calculated with the following equation.

$SPI=(X_{ij} - X_{im})/\delta$

Where, SPI is the Standardized precipitation Index, X_{ij} is the seasonal precipitation at the ith rain-gauge station and jth observation, X_{im} is its long-term seasonal mean and δ is its standard deviation.

Plenary discussion

- Characteristics and causes of drought and flooding (both large scale and local factors);
- Which climate extremes are common in respective areas?
- What can be done to address the two climate extremes?

2.7. Measure of climate variability

Climate variability: refers to the variation in the state of climate variables such as temperature or rainfall for a relatively shorter time horizon (often one month to 10 years). For example, the annual rainfall of a certain location varies from year to year without showing significant changes in its long term mean. In this case we say climate variability but not climate change. Nevertheless, we should also be cognizant of the fact that climate variability can be observed with or without climate change. Figure10 helps to illustrate the differences among weather, climate variability and climate change across time scales.

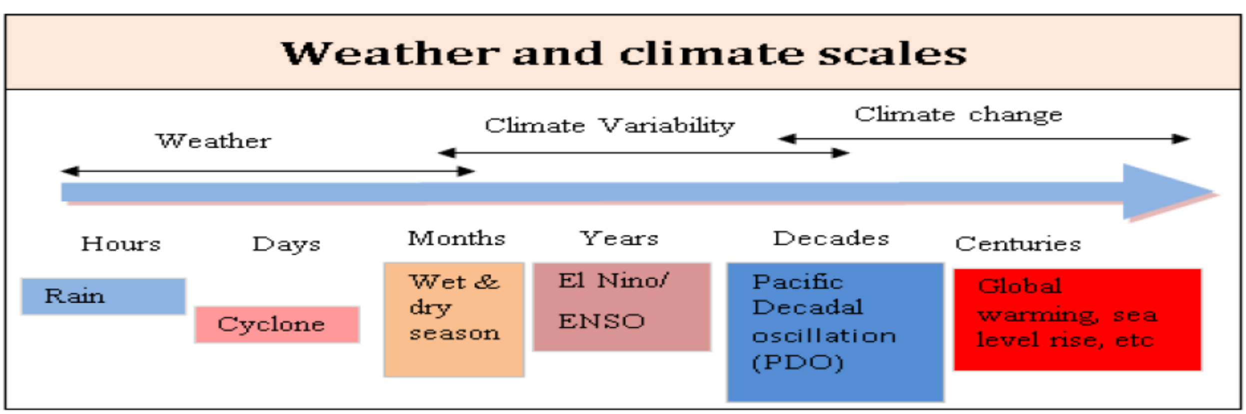


Figure 10: weather, climate variability and climate change across time scales

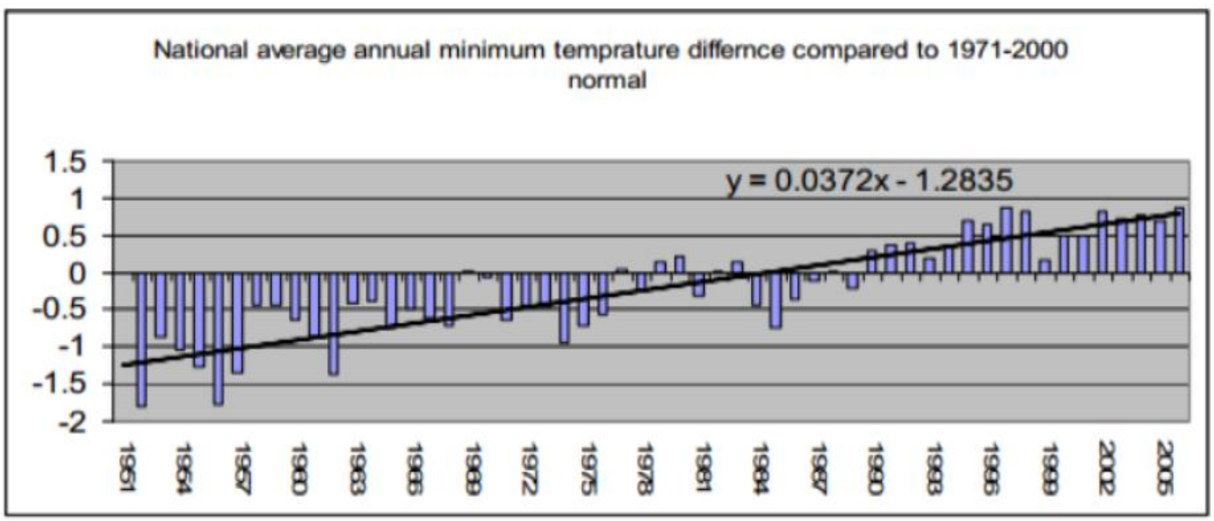
This climate signals (Climate Change and Climate Variability) can be measured by different scientific statically measures like mean, standard deviation, coefficient of variation and Anomaly of the records from the long term records of a specific parameters. As a result climate change can be measured by the long term mean value of trends of the data. Climate variability measured by the coefficient of variability, standard deviation of a group of records and Anomaly of the records.

Standard Deviation is a measure of how spread out numbers is. Its symbol is σ (the Greek letter sigma) the formula is easy and it is the square root of the Variance. So now you ask, "What is the Variance?" Variance The Variance is defined as: The average of the squared differences from the Mean.

The "**Population** Standard Deviation": $$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

The "**Sample** Standard Deviation": $$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

The Following climate analysis can identify the difference between climate change and climate



variability; sourced from National meteorological agency climate analysis of Ethiopia in 2007.

Figure 11:warming trend in minimum temperature by a value of about 0.37 oC over the past 55 years (NMA, 2007)

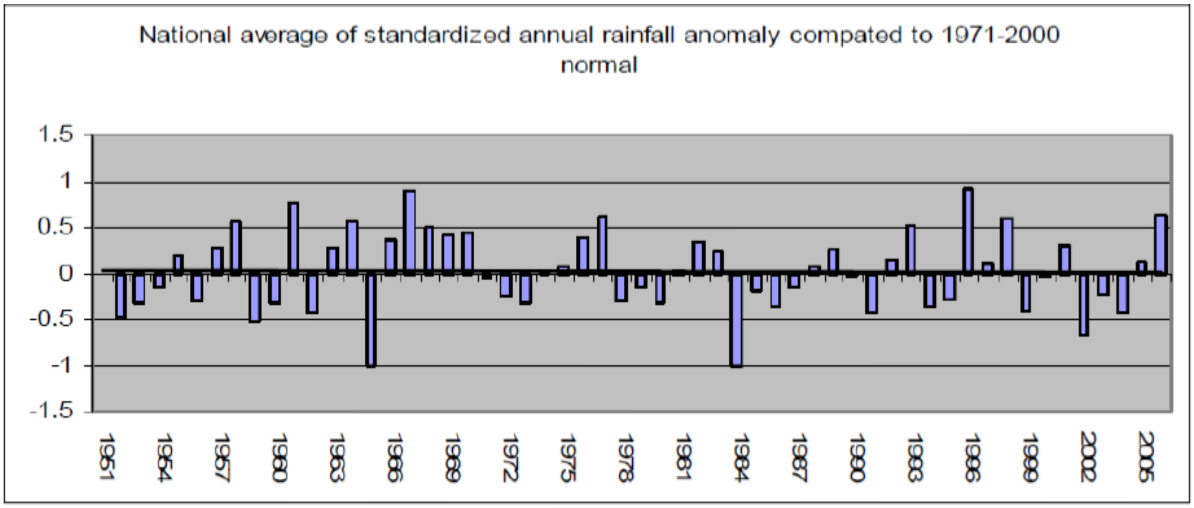


Figure 12: Year to year variability of annual mean rainfall and there is no significant trend in the mean annual rainfall (Source: National Meteorological Services Agency, 2007)

The minimum temperature record during the 1960th up to 1970th it shows negative standardized anomaly whereas after 1980th up to 2000 the minimum temperature had positive standardized anomaly this shows the running mean of the data show increasing trend as shown by the black solid line in the above figure. this indicates there is a climate change signal on last thirty years.

Unlike the Minimum Temperature the annual rainfall doesn't show a fixed trend line which show either increasing or decreasing trend from the analysis date but it rather shows the variability of rainfall records from year to year. We can see there is high rainfall variability which can refer as climate variability of ethiopia for the last 30 years. We can quitify the magnitude of the variability by computing the coeffient of variation.

Section Exercise

- How can we describe our local climate in the past two/three decades?
- How do you describe about the equation in Figure above?
- What is the existing climate variability evidence in your local area?

2.8. Definition and computation of local climatology

Ethiopia is characterized by diverse climatic regimes. The country has a semi-arid desert type climate in the lowlands to humid and warm temperate type in the southwest. Annual mean rainfall ranges from about 2000 mm in South West to about 100mm in North East Lowlands of Afar. Present average precipitation is 2.04 mm per day. The average annual temperature from1961-1990 was 23.08’C. Mean annual temperature ranges from less than 15 degree Celsius over the highlands to more than 25°C in the lowlands. Locally the climatology of certain location can be computed from it's long year mean of the station, basicaly more than 30 years based on WMO standards.

Practical exercises

- Compute the rainfall climatology of your area by using your local meteorological station data?
- Draw and prepare daily cumulative curve of your area and identify onset and cessation the season at point level by using your station data?

Module 3: Climate Change

The overall purpose of this Module is to introduce the concept of climate change and the major sectors which are affected by climate change and the remedies we need to take to adapt and mitigate. After completion of the module, the trainees should be able to:

1. *Define, demonstrate and understand causes, impacts and mitigation/adaptation possibilities of climate change.*
2. *The integration of different scientific perspectives on climate change through the concept of sustainable development*
3. *Make judgments on evidence of climate change from a range of different sources*
4. *Understand the major initiatives to address climate change*
5. *Understand the indigenous knowledge which are being applied by various communities in Ethiopia*

3.1 Definition of climate change

Different international organizations define Climate change in different way. Out of these, the most common ones are the by UNFCCC and IPCC**.** The United Nations Framework Convention on Climate Change (UNFCCC) define climate change as *the change that can be 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.* Whereas, the Intergovernmental 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.*

3.2 Causes of climate change

Due to change in the climate, rising levels of carbon dioxide and other greenhouse gases in the atmosphere have warmed the Earth and are causing wide-ranging impacts, including rising sea levels; melting snow and ice; more extreme heat events, fires and drought; and more extreme storms, rainfall and floods. Scientists project that these trends will continue and in some cases accelerate, posing significant risks to human health, our forests, agriculture, freshwater supplies, coastlines, and other natural resources and hence affect economy, environment, and life quality of a country. The main source of energy for the planet earth is the sun. The sun's long range radiation passes through the atmosphere to reach the earth's surface. Some of the energy is trapped, reflected and refracted in the atmosphere due to clouds and pollutants in the atmosphere.

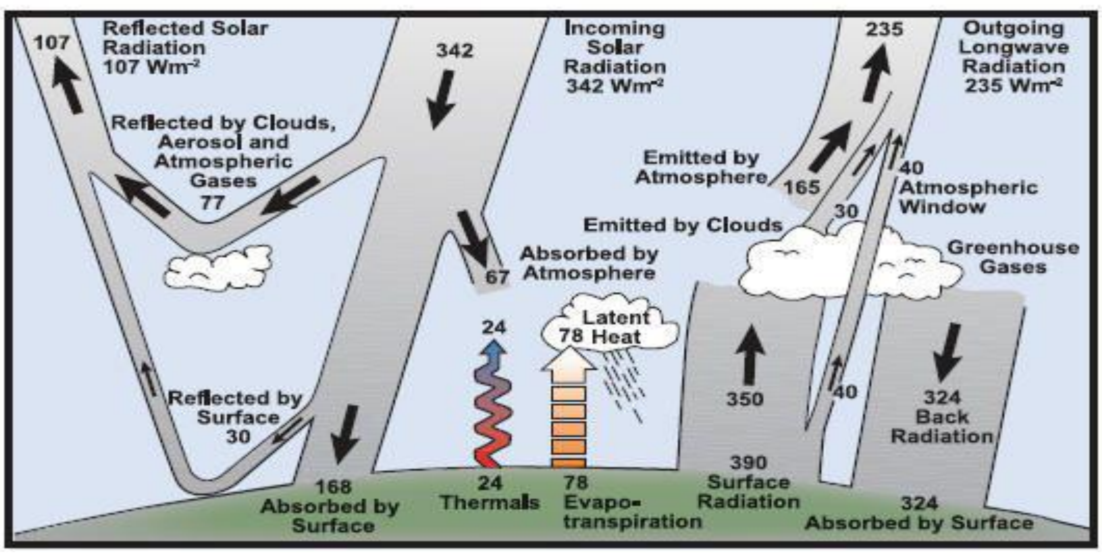


Figure 13: Global energy balance

Figure 13 Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing long wave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by long wave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates long wave energy back to Earth as well as out to space. Source: Kiehl and Trenberth, (1997).

The energy that reaches the earth's surface heats the earth and the earth in turn releases radiation in the form of long wave radiation. The presence of green house gases (GHG) in the atmosphere which have the potential to trap/absorb the long wave radiation and warm up the earth's atmosphere and provide optimal temperature that makes the earth habitable. Had it been without the presence of GHGs, the earth's temperature would have been -18o C (i.e. below the freezing point). These GHSs include CO2, CH4, CFCs, and NO2, of which CO_2 is the most abundant gas in the atmosphere.

Causes of climate change can be divided into two categories, human (anthropogenic) and natural causes as show in the figure bellow

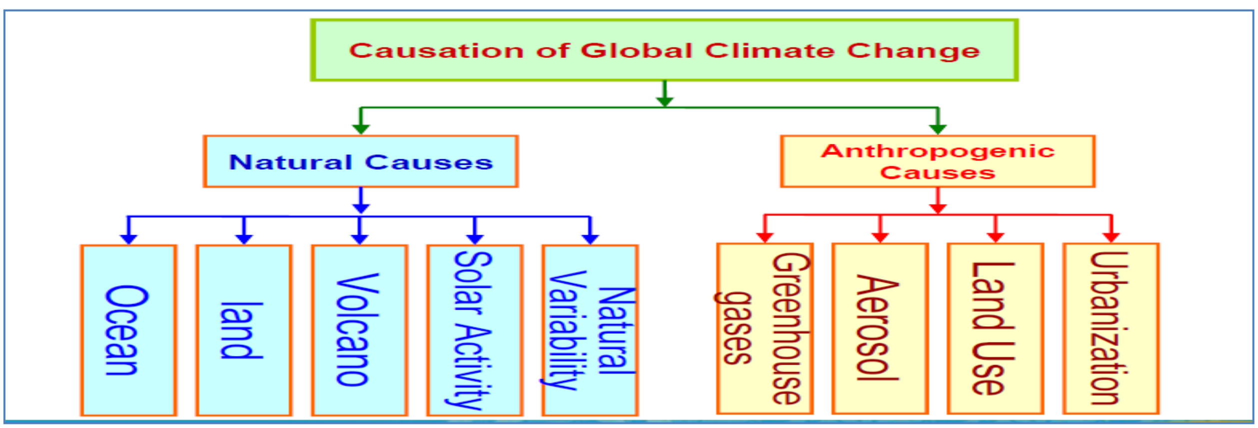


Figure 14: Causes of climate change (Anthropogenic and Ntural causes of climate change)

3.2.1 Human induced (anthropogenic) climate change

There is strong scientific consensus that climate is mainly caused by human activities. Some of human activities, such as fossil fuel burning, deforestation, industrial expansion, overgrazing, land use and agriculture are the main climate change causes. Human being influenced the environment for centuries. However, it begun since the start of the industrial revolution in which the impact of human activities have started to extend to a global scale (Baede *et al.*, 2001). The unimpeded growth of greenhouse gas emissions by the above mentioned anthropogenic causes of climate change is raising the earth's temperature. The main greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). However, there are other GHGs like, water vapour (H_2O) that can also contribute their own role to global warming.

Deforestation Cause of Climate Change

Rainforests every year help to absorb almost 20% of manmade CO_2 emissions therefore; deforestation can be classed as a major contributor to the causes of climate change. Cutting down rainforests faster than they can be replaced has a devastating effect on the carbon emission cycle producing an extra 17% of greenhouse gases. Remember trees absorb CO_2. More deforestation means more CO_2 build up in the atmosphere. By means of cutting down and burning these tropical rainforests usually pave the way for agriculture and industry which often produce even more CO_2.

Industry as Cause of Climate Change

The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles generate electricity for industries and households. The energy sector is responsible for about ¾ of the carbon dioxide emissions, 1/5 of the methane (CH_4) emissions and a large quantity of nitrous oxide.

Agricultural as Cause of Climate Change

Agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Another contributing cause of climate change is when agriculture alters the Earth's land cover, which can change its ability to absorb or reflect heat and light. Land use change such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide.

3.2.2. Natural causes of climate change

The Earth's climate can be affected by natural factors that are external to the climate system, such as changes in volcanic activity, solar output, and the Earth's orbit around the Sun. Of these, the two factors relevant on timescales of contemporary climate change are changes in volcanic activity and changes in solar radiation. In terms of the Earth's energy balance, these factors primarily influence the amount of incoming energy. Volcanic eruptions are episodic and have relatively short-term effects on climate. Changes in solar irradiance have contributed to climate trends over the past century but since the Industrial Revolution, the effect of additions of greenhouse gases to the atmosphere has been over 50 times that of changes in the Sun's output.

3.3 Observed climate change in the world, Ethiopia and in the locality

3.3.1 Global Observed Climate change

Temperatures measured on land and at sea for more than a century show that Earth's globally averaged surface temperature is rising. Since 1970, global surface temperature rose at an average rate of about 0.17°C per decade—more than twice as fast as the 0.07°C per decade increase observed for the entire period of recorded observations (1880-2015). The average global temperature for 2016 was 0.94°C above the 20th century average of 13.9°C, surpassing the previous record warmth of 2015 by 0.04°C.

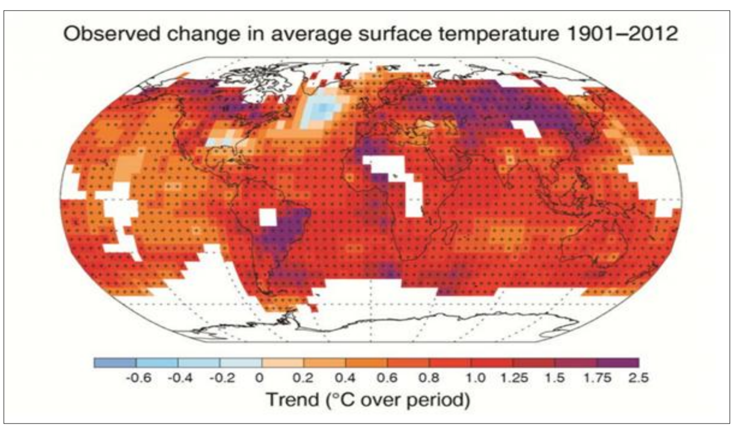


Figure 15: Observed changes in average surface temperature 1901-2012, source: IPCC-AR5.

Though warming has not been uniform across the planet, the upward trend in the globally averaged temperature shows that more areas are warming than cooling. Since 1880, surface temperature has risen at an average pace of 0.07°C every 10 years for a net warming of 0.94°C through 2016. Over this 137-year period, average temperature over land areas has warmed faster than ocean temperatures: 0.10°C per decade compared to 0.06°C per decade. The last year with a temperature cooler than the twentieth-century average was 1976.

3.3.2 Climate change over Ethiopia and in the locality

Ethiopia has three rainy seasons: June–September (kiremt), October–January (Bega), and February–May (belg). Kiremt rains account for 50–80 percent of the annual rainfall totals, and most severe droughts usually result from failure of the kiremt. The lowlands in the southeast and northeast are tropical, with average temperatures of 25°–30°C, while the central highlands are cooler, with average temperatures of 15°–20°C. Lowlands are vulnerable to rising temperatures and prolonged droughts, while highlands are prone to intense and irregular rainfall.

Observed climate change over Ethiopia: Climate trends from 1960 have shown that:

- Mean annual temperature has increased by 1°C, an average rate of 0.25°C per decade, most notably in July through September.
- The average number of "hot" nights (the hottest 10 percent of nights annually) increased by 37.5 percent between 1960 and 2003, while the average number of hot days per year increased by 20 percent.
- More intense precipitation during extreme weather events, although long-term rainfall trends are difficult to determine.
- The incidence of drought increased.
- Belg rains are increasingly unpredictable (World Bank, 2011)

Climate change projection of Ethiopia

The future projections of temperature and rainfall patterns in Ethiopia exhibit a high degree of uncertainty, but most projections agree that:

- Mean annual temperature is projected to increase by 1°– 2°C by 2050.
- The frequency of hot days and nights will substantially increase. About 15–29 percent of days will be considered hot by 2060.
- It is uncertain whether rainfall will increase or decrease; projections range from -25 percent to +30 percent by the 2050s.
- Increases in the proportion of total rainfall that falls in "heavy" events with annual increases of up to 18 percent (USAID, 2013 and Ministry of Environment and Forest, 2015).

Due to climate change, the country faces numerous development challenges that exacerbate its vulnerability including high levels of food insecurity and ongoing conflicts over natural resources. Chronic food insecurity affects 10 percent of the population, even in years with sufficient rains. Roughly two-thirds of the population earns less than $2 per day and access to basic services is limited. Rain fed agriculture contributes nearly half of national GDP and is the mainstay of livelihoods for 85 percent of the population. These rural livelihood systems – crop cultivation, pastoralist and agro-pastoralist – are highly vulnerable to climate.

3.4 Impacts of climate change over Ethiopia

Impacts of Climate change on the countries like Ethiopia is likely greater. This is because their low adaptive capacity. This leaves the different sectors highly vulnerable to changing climate. Some of sectors highly vulnerable to climate change are:

3.4.1 Climate change Impacts on Agriculture Production

The most Ethiopian farmers are small-scale subsistence farmers who remain heavily dependent on rain (only one percent of cultivated land is irrigated), employ low-intensive technologies and lack access to services. Due to this agriculture is highly vulnerable to changing rainfall and other climate patterns. The increase in minimum and maximum temperatures causes increased heat stress, evapo-transpiration and reduced soil moisture content, negatively impacting crop yields, Loss of arable land due to shifting agro-ecological zones. The change in climate will bring increased intensity of precipitation events and this will cause increased incidence of floods and landslides, damaging crops and increasing soil erosion. The other negative impact of climate change on agriculture is drought and erratic rainfall. Climate change would also have increased incidence of pests and diseases such as maize lethal necrosis, wheat rust and stem gall. (Aragie, 2013.). Even though Ethiopia's livestock sector, the largest in Africa, relies heavily on climate-sensitive resources and the customary rangeland management practiced by the country's 10–15 million pastoralists in over 60 percent of the country is dependent on limited water and forage availability that is increasingly affected by drought and degradation of land. Increased temperatures, increased unreliability of rains, especially the Belg Recurrent drought is due to climate change and this impose negative impact on live stokes such as reduction of water and feed resources for livestock, leading to lower productivity and higher susceptibility to diseases Increased incidence of heat stress; higher mortality rates, increased conflicts over limited water and feed resources Loss of grazing lands, loss of livestock-dependent livelihoods and forced migration (Gashaw, *et al*. 2014 and Giorgis, 2010).

3.4.2 Climate change Impacts on Water Resources

Ethiopia has abundant water resources in 12 river basins, but these are unevenly distributed. Projected increases in the frequency of droughts, increased evaporation and evapo-transpiration and potential changes in rainfall patterns and runoff due to climate change may further affect water resources of the country by Reducing runoff and river flows, reducing water availability, drying of wetlands, impacting key bird species, damaging and/or destruction of supply and storage infrastructure, increased conflict over usage of scarce water resources in arid regions Increased pressure on groundwater supplies; decreased reliability of groundwater sources, disruption of hydropower generation; and thus increase energy costs (USAID, 2015 and World Bank, 2011).

3.4.3. Climate change Impacts on Human Health

Ethiopia has been facing high incidence of climate-sensitive diseases. Roughly 70 percent of the population lives in malaria-endemic areas and outbreaks that occur every 5 to 8 years account for up to 20 percent of deaths for children under the age of 5. Increased temperatures will likely expand the range of malaria to highland areas and increased flooding will facilitate the spread of waterborne diseases like diarrhea. More than 70,000 deaths annually are tied to indoor and outdoor air pollutants, which a hotter, more drought prone climate will aggravate. The link between drought and health is a major concern in the country. Evidence suggests that children born during a drought are 36 percent more vulnerable to diseases and malnourishment. At present time, one of the worst El Niño droughts in 50 years has left 10 million Ethiopians in need of emergency food aid and 5.8 million without access to water, sanitation and hygiene services. The impact of climate is still hitting Ethiopia and most developing nations by expanding he range of malaria to highland areas, increased incidence of waterborne illnesses, such as diarrhea, cholera and dysentery aggravation of respiratory diseases caused by allergens and air pollution Increased malnutrition, exacerbating vulnerability to diseases (USAID, 2013, World Bank. 2011, United States Embassy. 2016 and WHO, 2015).

3.5 Climate change adaption and mitigation options and importance of climate services.

3.5.1 Climate change adaption and mitigation options

Adaptation

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood.

Even though societies have a long record of managing the impacts of weather- and climate-related events, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. This is because vulnerability to climate change can be exacerbated by other stresses.

Some planned adaptation to climate change is already occurring on a limited basis Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies.

In the case of Ethiopia, the five-year economic growth plan, the Growth and Transformation Plan (GTP II) (2015–2020), mainstreamed the country's Climate Resilient Green Economy (CRGE) strategy. The CRGE, which predates GTP II, provides a blueprint for achieving lower middle-income status by 2025 with no net increases in greenhouse gas emissions relative to 2010 levels.

Mitigation is Structural/non-structural measures undertaken to limit the adverse impact of climate and weather. Mitigating negative impacts of weather and climate is action of reducing the magnitude and intensity of disaster risks associate with extreme weather, climate variability and climate change. To mitigate the negative effects of weather and climate we have to adopt climate change mitigation strategies. This include reducing the emissions greenhouse gases, reforestation, using renewable energies,

Agriculture is one of the few sectors that can both contribute to mitigation and sequestration of carbon emissions and accounting for agriculture's carbon footprint is necessary, particularly if agriculture is included in greenhouse gas reduction commitments. However, the range and variability of estimates, and the complexity and uncertainty of accounting for indirect land use change remain to be resolved.

3.5.2 Importance of climate services

Climate services are climate information prepared and delivered to meet users' needs.

Climate services encompass a range of activities that deal with generating and providing information based on past, present and future climate and on its impacts on natural and human systems. Climate services include the use of simple information like historical climate data sets as well as more complex products such as predictions of weather elements on monthly, seasonal or decadal timescales, also making use of climate projections according to different greenhouse gas emission scenarios. Included as well are information and support that help the user choose the right product for the decision they need to make and that explain the uncertainty associated with the information offered while advising on how to best use it in the decision-making process. Examples of the uses of climate services are as follows:

- Climate predictions can be used by farmers to help them decide, for example, which crops to plant or whether to reduce livestock numbers if a drought is forecast is given. Farmers making such decisions are likely to use climate outlooks of rainfall and temperature and take into account the uncertainty estimates provided with these products;

- Statistical assessments of the future frequency of extreme weather and climate evens can be used by engineers to help them make decisions, including where to invest in disaster mitigation measures such as dams, where to locate buildings, which construction methods to use and how much heating and cooling is needed for critical infrastructure;
- Seasonal climate forecasts and monitoring of actual temperature and rainfall can be used to provide forecasts of when and where disease outbreaks are likely to occur. The impacts of predicted outbreaks can then be minimized by public awareness campaigns, stocking and shipping medical supplies and vector control programmes such as spraying;
- Climate change projections, which can indicate precipitation patterns in the 30-to-50-year timeframe, can be used to guide major investment decisions relating to long-term water management such as whether and where to build new reservoirs.

3.6 Discuss indigenous knowledge and traditional coping strategies to climate variability that can be scaled up to climate change adaptation.

Traditional early-warning systems: The pastoral communities have their own way of predicting and coping mechanisms to climate change. This activity is normally carried out by elderly people who are knowledgeable about astronomical and climate change. Some make their predictions by observing stars, wind and cloud arrangements. Others predict after considering the behaviour of different wild animals and the flowering and seeding of some indigenous trees

In the Daasanach area, men slaughter a goat to investigate the intestine alignments (locally known as numere) to predict the bad or good season. These people warn their community about the situation and discuss what to do. The pastoral community still values such knowledgeable people very highly. However, whereas some pastoralists managed to move, others who were already vulnerable had to face the reality on the spot. The Borana communities are also known in coping with the changing climate by looking the environment and search the indictors to predict future weather/climate. They relay on the traditional climate forecast knowledge particularly, reading livestock intestine and observing stars, cattle body condition and cross with Gada System for many years to forecast the climatic shock such as drought and flood (Legesse, 1973; Luseno et al., 2003).

Some of mostly Known Indigenous Climate change coping mechanism includes:

- **Moving with livestock**: Traditionally, there are no boundaries to camels moving across the territories of different clans and sub clans. However, with the prolonged drought, pastoralists are now moving with other species of livestock. In many localities, this is reciprocal while, in a few, it ends up in conflict because of the fear of spread of livestock disease.
- **Cut-and-carry feeding system**: Since the establishment of the Awash National Park several decades ago, Afar pastoralists lost their prime grazing areas and water points, but did not benefit from tourism income. Hence, conflict over use of resources in the national park has been chronic. In very recent times, there was an agreement that the pastoralists can use the border areas of the park during drought; however, demarcation of area was difficult and always led to conflicts. However, some Afar pastoralists have recently developed a cut-and-carry system (carried by people or carts), including renting carts as a community group by contributing some money and then distributing the forage within the community.
- **Settlement around water points**: In the past, many pastoralists had to sell some of their livestock to be able to pay to water, which becomes very expensive during times of drought. However, nowadays settling around water points and use of ground water by deep wall are is more common
- **Purchasing with credit**: During drought, many of the small shops in the small settlements and towns in the pastoral areas sell most of their commodities on a credit basis, charging no interest.
- **Moving with fuel**: In areas with boreholes, mainly in Somali Region, some pastoralists were observed moving with gallons full of fuel. So that, they could have easy access to the boreholes. The borehole pumps need fuel to operate, and fuel shortage is a serious problem in some areas.
- **Selection of livestock species: There** is a shift in livestock species from camel to “shoats” (sheep and goats) mostly in Somali Region, as it is easier to have small units of livestock to exchange on the market for daily consumables, and the shoats need less pasture than do camels. This does not mean the pastoralists no longer have access to

camel milk simply that the number of camels is diminishing. It was also they have also increased the use of donkeys, because of their multi-functionality in transporting water and fuel wood, while the cattle population is already wiped out on account of prolonged drought and disease.

- In Afar, there is a clear shift from cattle towards goats and camels. Moreover, the pastoralists have adopted some breeds of livestock from the border areas of Oromia Region. In Afar, it used to be only cow milk that was commonly sold, but now the pastoral women have started selling camel milk.
- **Settlement on islands**: On account of the prolonged drought in their area, the Daasanach prefer to stay on the islands in Lake Turkana in order to have easy access to water, pasture and fish, and less risk of livestock raiding by other ethnic groups.
- **Diversification**: The minorities who used to depend almost solely on fishing to be used for consumption have started marketing fish, using modern fish traps from the Turkana area in Kenya, and rearing small livestock.
- **Flexible use of trucks**: In many localities, an increasing number of pastoralists are getting richer because they own trucks that can be flexibly used to transport livestock for marketing and grazing, and to transport marketable commodities. The same truck can load a water tank when water is needed for own consumption but also to generate income by transporting water. Most communities usually use only oxen for farming. Due to death and weakness of the Oxen, the community started using Donkey instead of Oxen.

Opportunistic farming and complementary irrigation in Somali Region

Empowerment of traditional institutions: In Afar, the community underlined that the root cause of their vulnerability is closely connected to the lack of good governance. They concluded that the modern pastoral leaders are highly corrupt and are not accountable to the community. Accordingly, they have tried to strengthen their powers by penalising and/or overthrowing the corrupt leaders. They also work hard on conflict resolution, and have sometimes become successful in coming to mutual understanding to use resources in different geographic locations, at least during drought. Generally, these efforts have contributed to improving governance at the grassroots level.

Interactive discussion on indigenous knowledge

- Do you have any traditional practice to cope climate extremes in your area?
- How do you respond to climate extremes and change?

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.

1. How do you perceive climate change in your region or village?
2. what kind of climate change impacts have you observed agricultural, water, others
3. What kind of adaptations options do you propose based on the impacts of climate change in your area?
4. What kind of responsibilities do you expect from government, farmers and other stakeholders?

3.7 International, regional and national initiatives on climate change (such IPCC, UNFCCC, CRGE, etc)

3.7.1 International Initiatives to Address Climate Change

Several initiatives have been undertaken at the international level to address the issue of global warming and climate change. Over the past century, the planet has seen its temperature gradually increase. There have been numerous arguments on the exact cause of this sudden yet alarming increase in temperature. Some people base it on the degradation of the Ozone layer while others deny the temperature increase entirely. However, for most scientists the principal cause of the increase in temperature is the increase in greenhouse gases in the atmosphere. According to scientists, these greenhouse gases which consist of carbon dioxide have a blanket effect where they trap solar energy from leaving the atmosphere. Due to pressure from the public and knowledge of the severity of the ultimate result of climate change, governments and other international organizations have come together and put in place policies to negate climate change and its effects.

Some of international initiatives against climate change are:

1. **Kyoto Protocol**

The Kyoto Protocol is internationally binding treaties signed in 1997 with the aim of reducing the global emission of greenhouse gases and curbs the effects of climate change. The involved leaders met and signed the treaty in the Japanese city of Kyoto hence the treaty derives its name. In 2009, 187 countries had ratified the Kyoto Protocol. The Kyoto Protocol was to be implemented in two phases with the first phase ending in 2012. The greenhouse gases in question were carbon dioxide, nitrous oxide, methane, and sulphur hexafluoride. The treaty aimed for global emissions to have a 5% reduction by 2012 for the first phase. The second phase of the Kyoto Protocol also known as the Doha Amendment had a 2013-2020 timeline but is yet to be implemented.

2. **International Carbon Action Partnership (ICAP)**

The International Carbon Action Partnership (ICAP) is a forum bringing together different countries and public authorities which have already enforced or are planning to enforce emission trading system (ETS). It was founded in 2007 in Lebanon by leaders from more than fifteen countries. ICAP allows members to share best practices and discuss ETS with the aim of coming up with the operational global carbon market. The duty of ICAP looks into three pillars of technical dialogue, ETS know how, and capacity building. It also focuses on facilitation of future linking, trading programs, and building of strong partnership amongst countries. The partnership is currently made up of 31 members with four observers.

3. United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is a treaty signed in June, 1992 during the Earth Summit in the Brazilian city, Rio de Janeiro. The treaty was attended by all 197 member states of the United Nations and all policies indicated were to be effected by all countries within the United Nations. The United Nations Framework Convention on Climate Change spurred the Kyoto Protocol (1997) and the Paris Agreement (2011).

4. Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988. The Intergovernmental Panel on Climate Change (IPCC) terms of reference includes:

1. To assess available scientific and socio-economic information on climate change and its impacts and on the options for mitigating climate change and adapting to it and
2. To provide, on request, scientific/technical/socio-economic advice to the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). From 1990, the IPCC has produced a series of Assessment Reports, Special Reports, Technical Papers, methodologies and other products that have become standard works of reference, widely used by policymakers, scientists and other experts.

3.7.2 National climate initiative

Despite the challenges, Ethiopia hopes to capitalize on its current economic growth by becoming more resilient to the impacts of climate change while developing its economy in a carbon neutral way.

Climate change poses a huge challenge to Ethiopia's government and people. The country is faced with increasingly unpredictable rains, and sometimes the complete failure of seasonal rains – problems which are linked to climate change. Millions of Ethiopians often face severe food shortages as a result. But it is also a front runner in Africa when it comes to economic growth. The country has achieved a double digit growth rate in recent years (2005-10) and is set to achieve a real gross domestic product growth of more than 8% per annum over the next five years according to forecasts of the International Monetary Fund. This growth is in line with the governments' ambition to achieve middle income status by 2025, reflected in its Growth and Transformation Plan (GTP).

Now the Ethiopian government wants the country to achieve middle-income status by 2025 in a carbon neutral way by transforming development planning, investments and outcomes.

The country's Climate Resilient Green Economy Strategy (CRGE), which was published in 2011, sets out this vision. Initially spearheaded by the late Prime Minister, Meles Zenawi, the CRGE has widespread political support. It's viewed as an opportunity to transform the country's development model by leapfrogging to modern energy-efficient development trajectories.

Ethiopia is one of the few countries to have formally merged its aims of developing a green economy and greater resilience to climate change under a single policy framework in support of its national development objectives. While the government is still preparing its climate resilience objective, the Green Economy component of the CRGE has already been developed. It aims to develop Ethiopia's green economy by:

- Improving crop and livestock production practices to improve food security and increase farmer's incomes while reducing emissions;
- Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks;
- Expanding electricity generation from renewable energy sources for domestic and regional markets; and
- Leapfrogging to modern and energy-efficient technologies in transport, industrial sectors, and buildings.

Having articulated its policy objectives around a climate resilient green economy, the country is now getting ready to implement it. There is a flurry of activity around the design of policy and financial instruments, institutional arrangements and projects aimed at implementing the CRGE policy objectives. Among a host of initiatives there are a few interesting instruments to watch out for.

Institutional arrangements being put in place by the Government of Ethiopia represent a balance between political leadership, planning and implementation capacity. The CRGE is co-ordinate and overseen by the CRGE Ministerial Steering Committee (an initiative under the Prime Minister's Office), the Environmental Protection Agency and the Ministry of Finance and Economic Development. CRGE units have been established in key implementing line ministries and regions to translate the CRGE strategy into pectoral programmes and investment plans. Federal (line ministries) and regional entities have been identified as national implementing entities that will be responsible for implementing programmes and investment plans in partnership with non-state actors where required. We will be looking to see if the government can effectively co-ordinate these activities.

Financial instruments: The government of Ethiopia has established a funding mechanism to mobilize and disburse climate finance, known as the CRGE Facility. This facility will provide programmatic funding to disburse funds for building climate resilience and a green economy. The government aims to mobilize an estimated (US) $200 billion from national and international public and private sources to implement the CRGE over the next 20 years.

Policy instruments: Unlike many developing countries, the government is currently working to move beyond the CRGE policy document to make sure that the vision it sets out becomes a reality by developing legal instruments and mechanisms. For example, the government is tabling a Proclamation on feed-in tariffs that will provide a legal mandate to invest in green economy objectives.

The government is also designing the Sector Reduction Mechanism, which aims to set green economy, climate change resilience targets and indicators for key sectors. These will be used as a guide to priorities and prepare climate resilient green economy plans and projects, which will be submitted to the CRGE facility to access climate funds. This means that in a few years government departments will need to meet climate resilience and green economy targets to access climate finance.

Projects: Alongside investments in planning processes and instruments, the government is also designing and implementing projects as a 'fast track' approach to piloting and implementing initiatives that will support CRGE objectives. For instance, the Ministry of Water and Energy is responsible for implementing a programme to scale up the use of renewable energy.

Having developed its green economy climate resilient policy objectives, and having started to design instruments to implement and further shape these objectives, Ethiopia is getting set to address the challenges and opportunities provided by climate change.

Discussion questions

1. How do you understand climate change?
2. What kind of climate change impacts have you observed in your area?
3. How can you cope with the impacts of climate change with respect of your area?

Module 4: Weather and Climate forecast

The module aims to familiarize participants with weather and probabilistic seasonal climate forecast products.

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

1. Describe how ocean-atmosphere interactions influence rainfall in Ethiopia
2. Distinguish between El Niño and La Niña phenomena
3. List the factors considered in rainfall forecasting
4. Identify the type of forecasts and scale of forecasts

4.1. Forecast types in space and time resolution

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a given location. Meteorologist prepare weather forecasts by collecting quantitative data about the current state of the atmosphere on a given place and using scientific understanding of atmospheric processes to project how the atmosphere will evolve on that place. There are various types weather forecasting, which is issued by National Meteorological Agency of Ethiopia. Namely, now casting, short range, and medium range, monthly and seasonal forecast.

Forecasting the weather requires continuously observing the state of the atmosphere and underlying surfaces. A steadily evolving worldwide suite of observing systems is in place to monitor these conditions. Although major research challenges remain, scientists have made considerable progress in developing computerized weather prediction systems that transform these observations into coherent analyses (snapshots of the atmospheric state at a specific time). These analyses serve as the foundation for weather prediction on scales from individual clouds to the entire climate system. Analyses of past, as well as current, weather support many diverse environmental applications, including fundamental scientific investigations of the climate system. Developing useful weather forecast products requires integrating information obtained from observations, analyses, and computer models, and conveying that information along with forecast confidence to the user community. Forecast type with time can be summarized as follows.

Now casting: a short range forecast having a lead time/validity of 3 to 6 hours by analysing and extrapolation of the weather systems as observed on radar, satellites, and other observational data, and via the application of short-range numerical weather prediction. This type of forecast is mainly applied in aviation sector.

Short-range forecasts: Forecasts having a lead-time / validity period of 1 to 3 days. Short range weather forecasting is the prediction of weather beyond 12 hours up to 72 hours (three days). Example city forecast for the next three days.

Medium range forecasts: Forecasts having a lead-time /validity period of 4 to 10 days. This category of weather forecasting covers a period beyond 72 hours (three days) up to 240 hours (ten days). This type of forecast is used for planning agricultural activities.

Long range/seasonal climate outlook: Forecasts having a lead-time /validity period beyond 10 days. A season is a division of the year marked by changes in weather, ecology and hours of daylight. Seasons result from the yearly orbit of the Earth around the Sun and the tilt of the Earth's rotational axis relative to the plane of the orbit. National Meteorological agency (NMA) provides three times seasonal climate outlook per annum (Kiremt, Bega and Belg) in Ethiopia. The Kiremt season extends from June to September, Bega season from October to January while Belg season extends from February to May months.

4.1.1. Scales of Atmospheric Motion

The air in motion what we commonly call wind is invisible, yet we see evidence of it nearly everywhere we look. It sculptures rocks, moves leaves, blows smoke, and lifts water vapor upward to where it can condense into clouds. The wind is with us wherever we go. On a hot day, it can cool us off; on a cold day, it can make us shiver. A breeze can sharpen our appetite when it blows the aroma from the local bakery in our direction. The wind is a powerful element. The workhorse of weather, it moves storms and large fair-weather systems around the globe. It transports heat, moisture, dust, insects, bacteria, and pollens from one area to another.

Circulations of all sizes exist within the atmosphere. Little whirls form inside bigger whirls, which encompass even larger whirls one huge mass of turbulent, twisting eddies. Meteorologists arrange circulations according to their size. This hierarchy of motion from tiny gusts to giant storms is called the scales of motion.

Micro scale

Micro scale meteorology is the study of atmospheric phenomena on a scale of about 1 km (0.62 mi) or less. Individual thunderstorms, clouds, and local turbulence caused by buildings and other obstacles (such as individual hills) are modeled on this scale.

Mesoscale

Mesoscale meteorology is the study of atmospheric phenomena that has horizontal scales ranging from 1 km to 1000 km and a vertical scale that starts at the Earth's surface and includes the atmospheric boundary layer, troposphere, tropopause, and the lower section of the stratosphere. Mesoscale timescales last from less than a day to weeks. The events typically of interest are thunderstorms, squall lines, fronts, precipitation bands in tropical and extra-tropical cyclones, and topographically generated weather systems such as mountain waves and sea and land breezes.

Synoptic scale

Synoptic scale meteorology predicts atmospheric changes at scales up to 1000 km and 105 sec (28 days), in time and space. At the synoptic scale, the Coriolis acceleration acting on moving air masses (outside of the tropics), plays a dominant role in predictions. The phenomena typically described by synoptic meteorology include events such as extra-tropical cyclones, baroclinic troughs and ridges, frontal zones, and to some extent jet streams. All of these are typically given on weather maps for a specific time. The minimum horizontal scale of synoptic phenomena is limited to the spacing between surface observation stations.

Global scale

Global scale meteorology is the study of weather patterns related to the transport of heat from the tropics to the poles. Very large scale oscillations are of importance at this scale. These oscillations have time periods typically on the order of months, such as the Madden–Julian oscillation, or years, such as the El Niño–Southern Oscillation and the Pacific decadal oscillation. Global scale meteorology pushes into the range of climatology. The traditional definition of climate is pushed into larger timescales and with the understanding of the longer time scale global oscillations, their effect on climate and weather disturbances can be included in the synoptic and meso-scale timescales predictions.

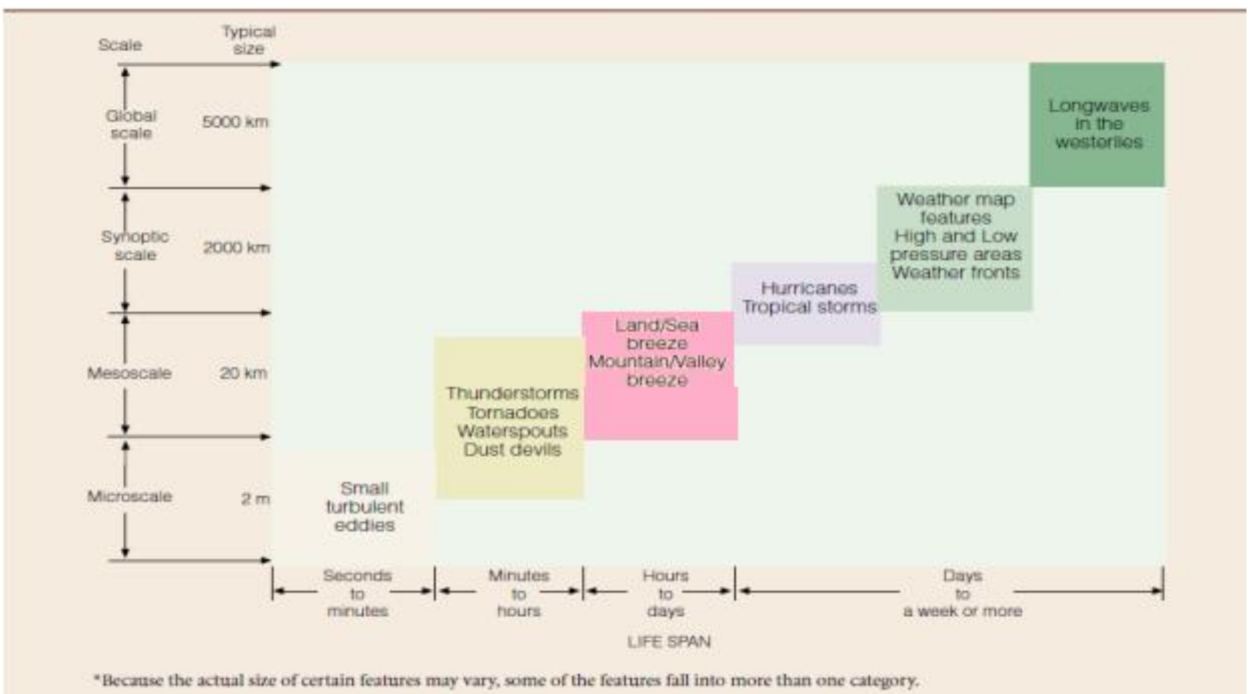


Figure 16: Different scales of meteorological phynomana and forecast

4.4. Regional and Global Tel-connection of Ethiopian Rainfall

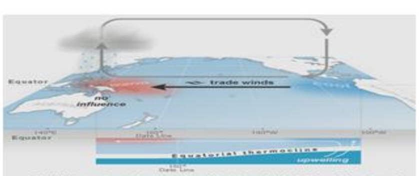
Global tele-connections describe the simultaneous occurrence of two or more atmospheric phenomena, which are very far apart in space. There are a number of examples such atmospheric phenomena Quasi-biennial Oscillation (QBO) and the tropical wide tele-connections are just two examples.The Indian Ocean Dipole (IOD) is defined by the difference in the sea surface temperature between the two equatorial areas of the Indian Ocean – a western pole near the Arabian Sea (in western Indian Ocean) and an eastern pole closer to the Bay of Bengal (in eastern Indian Ocean). The IOD affects the climate of Southeast Asia, Australia and other countries that surround the Indian Ocean Basin. The Indian Monsoon is invariably influenced by the IOD. IOD is simply the periodic oscillation of sea surface temperatures, and has two phases' namely negative and positive phases. During a negative IOD period the waters of the tropical eastern Indian Ocean is warmer than water in the tropical western Indian Ocean. This results in increased rainfall over parts of southern Australia while deficit rainfall for Ethiopia. Positive IOD when the sea surface temperature of the western end rises above normal (0.4°C) and becomes warmer than the eastern end, it leads to a positive IOD. This condition is favorable for the Indian Monsoon as it causes a kind of barrier in the eastern Indian Ocean and the entire south westerly winds blow towards the Indian sub-continent and this IOD results better rainfall for Ethiopia.

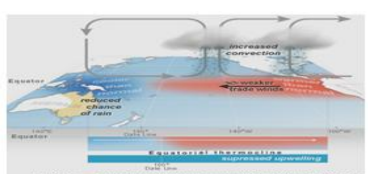
Positive event:

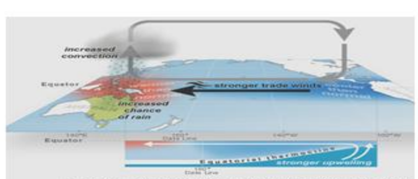
- Warmer sea surface temperatures in the western Indian Ocean relative to the east
- Easterly wind anomalies across the Indian Ocean and less cloudiness to Australia's northwest
- Less rainfall over southern Australia and the top end.

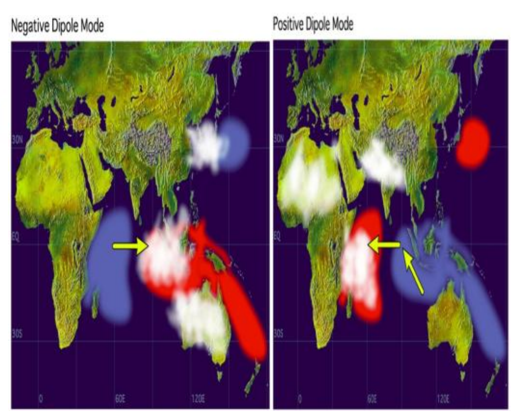
Negative event:

- Cooler sea surface temperatures in the western Indian Ocean relative to the east
- Winds become more westerly, bringing increased cloudiness to Australia's northwest
- More rainfall in the Top End and southern Australia.









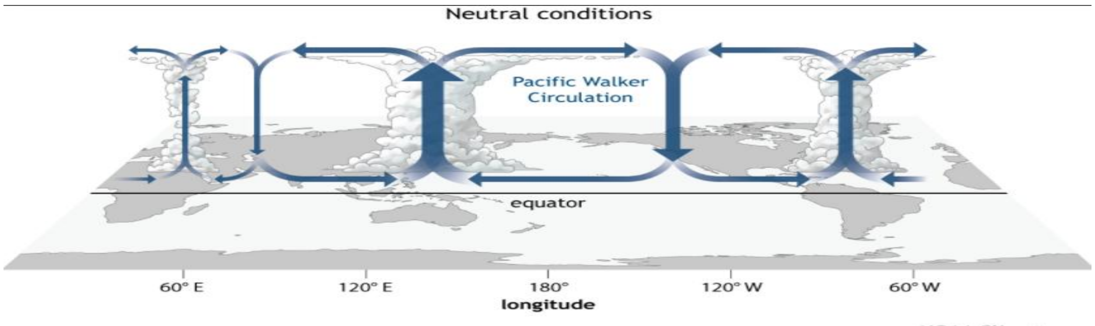


Figure 17: Tel-connection systems on IOD and ENSO and Ethiopian Rainfall

4.5. Seasonal analogue and its application

A forecasting method based on the assumption that a current synoptic situation will develop in the same way as a similar synoptic situation in the past. The analog technique is a complex way of making a forecast to remember previous weather events which is expected to be represented by an upcoming event. ENSO (El Niño-Southern Oscillation): Originally, ENSO referred to El Niño/ Southern Oscillation, or the combined atmosphere/ocean system during an El Niño warm event. The ENSO cycle includes La Niña and El Niño phases as well as neutral phases, or ENSO cycle, of the coupled atmosphere/ocean system though sometimes is still use as originally defined. The Southern Oscillation Index (SOI) quantifies the Southern Oscillation.

ENSO: Stands for El Niño-Southern Oscillation. 'El Niño' used here refers to the warming of the oceans in the equatorial eastern and central Pacific; Southern Oscillation is the changes in atmospheric pressure (and climate systems) associated with this warming (hence 'Southern Oscillation Index' to measure these changes). 'ENSO' colloquially to describe the whole suite of changes associated with an 'El Niño' event - to rainfall, oceans, atmospheric pressure etc.

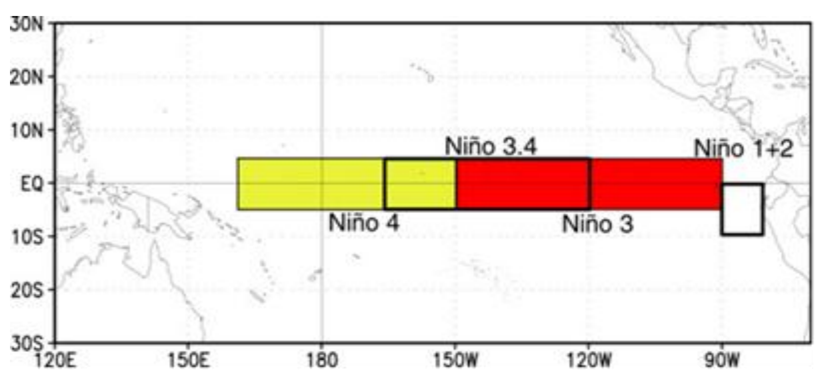


Figure 18: ENSO Regions

Using this method, the trends of the major synoptic systems are analyzed in the pre-seasonal period, and the result is compared with the ideal situation. In some other cases, depending on the type of ENSO information available, the trend of SSTs over the central equatorial Pacific and the SOI are analyzed carefully to determine the status of an ENSO event.

Statistical model: Regression models are model that use a set of independent parameters, called predictor to calculate an output, which is termed as predicted. This model could be either deterministic or stochastic. The full set of regression model could be many, the most commonly used statistical prediction model in meteorology are liner and power regression model

Dynamical model: It is basically conceptual models. The physical bases for the development of dynamics models are the governing equations that describe the earth‘s climate system.

Methods of seasonal prediction

(1) After getting the analogue years, we classify the stations into homogenous rainfall zones. NMSA has adopted the method of principal component analysis to regionalize the country into homogenous rainfall zones.
(2) Get the seasonal rainfall amount for each station.
(3) Get the deciles (<33% correspond to below normal, 33%-66%-normal and >66% -above normal).
(4) Count the number of stations with Above Normal (AN), Normal (N) and Below Normal (BN). And calculate the percentage of stations with AN, BN and N out of the total for each homogenous rainfall zone separately.
(5) Do step four for all analogue years, in particular for the best three analogue years.
(6) Calculate the average for the three selected analogue years. That will be the forecast.

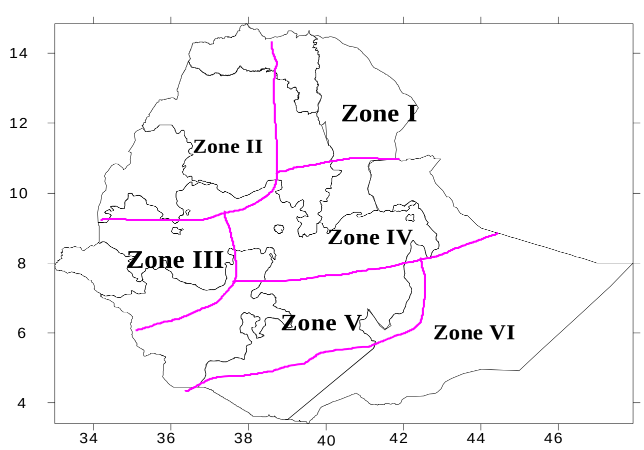


Figure 19: Homogenous rainfall zones of Ethiopia during September to December

The tercile method is used to issue seasonal prediction. But NMA uses four categories to compare the seasonal rainfall amount with the long-term mean at the end of the forecast period.

Above Normal: SRA/LYM * 100 > 125%

Normal: SRA/LYM * 100 = 125% - 75%

Below Normal: SRA/LYM * 100 = 75% - 50%

Much Below Normal: SRA/LYM * 100 < 50%

NB: SRA stands for Seasonal Rainfall Amount and LYM for Long-Range Mean

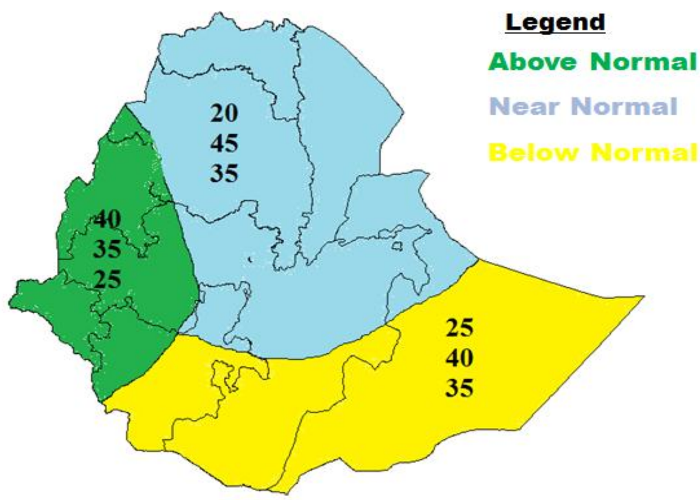


Figure 20: Sample Rainfall outlook

For example 25 40 35

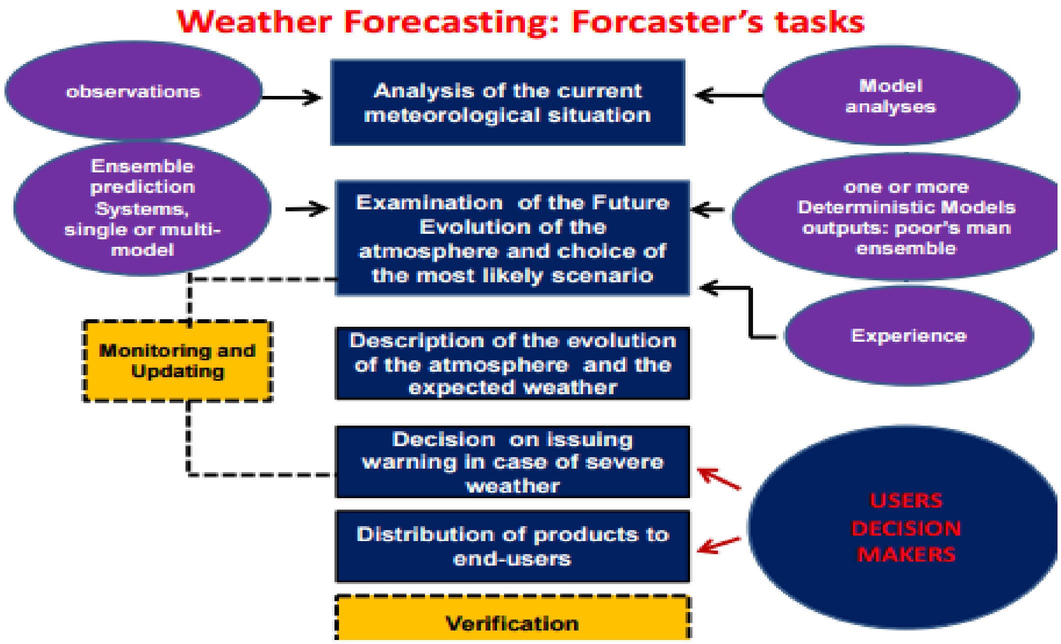
25% above Normal

40% Normal

35% below normal

40+35=75 percent indicates Normal to below normal probability from yellow color region while Generally, the yellow color region shows that most likely as there is deficient rainfall during Bega 2017/18 over southern and south-eastern portions.

The purpose of the following diagram is to summarize the above information in order to show the complexity of the task of the forecaster



4.8. Managing forecasting limitation and uncertainty

The temperate latitudes have rainfall predominantly due to frontal development of air masses, the temperate cyclones which cause rainfall in the temperate latitudes are caused due to development of dynamic induced low pressure system here, the movement of these air masses is very gradual, and hence the prediction of temperature and rainfall in these latitudes is very reliable and easy. However in the tropical latitudes the convectional rainfall takes place due to thermally induced precipitation prediction system, however apart from these trade winds and seasonal winds in these latitudes make the prediction of this weather phenomenon in the tropical areas quite difficult.

Tropical weather is difficult to forecast. Mid-latitude weather is dominated by synoptic systems moving in the westerly's, which formed the basis for the weather analysis methods developed in the 19th and 20th centuries. In the mid-latitudes, baroclinic instability results from air masses with contrasting temperature and density. There, energy is concentrated in extra-tropical cyclones that can be tracked fairly easily. By comparison, the tropics have a relatively homogeneous air mass and fairly uniform distribution of surface temperature and pressure. Therefore, local and mesoscale effects are more dominant than synoptic influences, except for tropical cyclones. For example, surface temperature and pressure can change quickly with convection and sea breezes.

An additional challenge is the sparse network of surface and upper air observations in the tropics. For vast regions of the tropics, such as the oceans and parts of Africa and the Americas, satellite sensors are the primary source of weather observations. While filling critical data gaps, satellite remote sensing has weaknesses. For example, polar-orbiting satellites view the same area at most twice per day and there are large gaps in the orbit paths across the tropics.

Opportunities to overcome forecast challenges

Numerical weather prediction (NWP) has been the key to rapid improvements in weather prediction in the mid-latitudes but its benefits are yet to be fully exploited in the tropics. NWP presents its own challenges such as the need for parameterizations, difficulties with convective processes, and systematic errors related to the assimilation of sparse and heterogeneous data.

Session Discussion

- Present and Discuss the different seasonal forecast interpretation i.e., Bega, Belg and Kiremt by using recent forecast
- Identify your specific area and explain the local seasonal tercile forecast and use it for decision making.

Module 5:Agro-meteorology

The purpose of this module is to familiarize participants with the key concepts of Agro meteorology. At the end of this module, participants should be able to:

1. *Understand and describe key agro-meteorological parameters, phonological observation and agro-climatic zone of Ethiopia.*
2. *Understand the moisture requirement of crop or pasture at its different stages, tools to monitor the moisture status and advisories on agro-meteorological bulletins make farm level decision.*
3. *Describe crop calendar, length of growing period, NDVI images and installation and uses of plastic rain gauge.*

4. *The importance of weather index insurance for risk management and its application.*
5. *Understand and describe meteorological parameters for malaria prevalence and favorability.*

5.1. *Introduction to Agro meteorology*

Agricultural Meteorology is a science that deals with the interaction between meteorological and hydrological factors, on the one hand, and agriculture in the widest sense, including horticulture, animal husbandry and forestry, on the other. Its objective is to discover and define such effects, and then to apply knowledge of weather to practical agricultural use. Its field of interest extends from the soil layer of deepest plant and tree roots, through the air layer near the ground in which crops grow and animals live, to the higher levels of the atmosphere of interest in aerobiology, the latter with particular reference to the effective transport of seeds, spores, pollen and insects. In addition to natural climate and its local variations, agricultural meteorology is also concerned with modifications in the environment.

Agro meteorological service is of great importance for countries with a primary agricultural economy. It supplies forecasts of adverse weather conditions like frost, heavy rainfall, drought, late onset and early cessation of rainfall, erratic distributing of rainfall, extreme maximum and minimum temperatures, strong wind, excess moisture and could cover, and information, which is important for sowing, application of pesticides, for harvesting, etc.

5.2. *Importance of Agro meteorological Advisory Services (AAS)*

There is hardly another branch of human activities that is as dependent on the weather as agriculture. Agricultural production is still largely dependent on weather and climate, despite the impressive advances in agricultural technology over the last half a century. More than ever, Agro Meteorological services have become essential because of the challenges to many forms of agricultural production posed by increasing climate variability, associated extreme events and climate change. These challenges have repercussions in terms of socio-economic conditions in general, especially in developing countries. Knowledge of available environmental resources and the interactions that occur in the area below the soil surface, the soil–air interface and the boundary layer of the atmosphere provides essential guidance for strategic AgroMeteorological decisions in long-range planning of agricultural systems. This applies to both favorable and unfavorable conditions and these may vary a great deal. Typical examples are the design of irrigation and drainage schemes, decisions relating to land-use and farming patterns, and within these choices, selections of crops and animals, varieties and breeds, and farm machinery.

In modern agriculture, ecology and economy are on equal terms; through environmental issues they are even interdependent. Shortages of resources, destruction of ecological systems and other environmental issues are becoming ever more serious. The large-scale and uncontrolled use of chemical fertilizers and plant protection products is not only a burden on the environment, but quite considerably, on the farmer's budget as well.

Detailed observations/monitoring and real-time dissemination of meteorological information, quantification by remote sensing (radar and satellites), and derived indices and operational services are important for tactical Agrometeorological decisions in the short-term planning of agricultural operations at different growth stages. The well- organized, and where possible, automatic production and coordinated dissemination of this information and related advisories and services are essential. Tactical decisions include "average cost"- type decisions in sustainable agriculture with low external inputs, regarding timing of cultural practices, such as ploughing, sowing/planting, mulching, weeding, thinning, pruning and harvesting. They also include, particularly for high-input agriculture, "high cost"-type decisions, such as the application of water and extensive chemicals and the implementation of costly crop protection measures.

5.3. The Influence of Different Meteorological Element on Agriculture Rainfall

- Cropping system can be planned by understanding the rainfall pattern.
- Rainfall analysis helps in taking decisions on time of sowing, scheduling of irrigation, time of harvesting etc.
- Rainfall analysis is necessary for designing farm ponds, tanks of irrigation projects.
- Amount, distribution and intensity of rainfall are the important aspects of rainfall that have considerable influence on crop production.

- Determination of Optimum sowing dates over geographical regions
- Agricultural planning on rational and scientific basis
- Identifying the regions highly vulnerable to drought and formulating anti-drought measures and strategies and

Wind

- Wind affects the plant directly by increasing transpiration and the intake of carbon dioxide.
- Hot and dry wind flow at physiological sensitive times it may result retardation in plant and root growth.
- If it is calm and the rain occurs, it would favor the disease but if it is strong it dries the leaf and no condition for germination.
- Wind may also act as a transporting agent for sand particle which may harm the vegetal surface.
- It may cause some insect pests to migrate long distance under the influence of favourable wind in lower atmosphere. For example: Locusts during the fly on swarm's southwards with the north-easterly winds during the day at temperature of 20-40^{o}c and locusts find it impossible to hold to a course if the wind speed exceeds 16-20 km/hr.

Humidity

- Humidity of the air vital of important to the life of plant.
- With temperature influences the process of infection, incubation period and sporulation and determines the number of disease cycles in one crop-growing season
- Humidity affects the intensity and quality of solar radiations, evaporation and transpiration.
- High air humidity reduces atmospheric water demand but favour many plant Pest and diseases

Evaporation

- The bulk of the water used by crop canopies is lost to the atmosphere through direct Evaporation from the soil and transpiration by the crop.
- When the water supply is limited, crop transpires less and their yield is correspondingly reduced. Normally water lost from the soil is filled up again by rainfall. But where the

amount of rainfall received not adequate to achieve this, irrigation will be necessary to optimal crop growth.

Temperature

- It control the physical and chemical reaction in plants, evaporation, soil temperature (Germination of seeds, Root function and Occurrence of plant disease)
- Influence all metabolic (Physiological or biochemical) reactions and incubation period.
- Physiological process in the organ of the plant such as photo synthesis, respiration and transpiration takes place in limited interval of temperature.
- Temperature directly dependent of altitude eg - The length of the vegetative cycle of Maize can vary from about three month at sea level to 10 months at altitude of 2500 meter.
- Each species and variety of plants has its own upper and lower temperature limit
- Temperature greatly affected the rate of crops development especially during emergency and root formation .

GDD calculation

Growing degree days (GDD), also called **growing degree units** (GDUs) or heat unit, are a heuristic tool in Phenology. GDD are a measure of heat accumulation used by horticulturists, gardeners, and farmers to predict plant and animal development rates such as the date that a flower will bloom, a crop reach maturity or a turkey will be mature enough to be butchered. GDD are calculated by taking the average of the daily maximum and minimum temperatures compared to a base temperature, T_{base}, (usually 10 °C). As an equation:

GDD = (Tmax +Tmin) / 2 - Tbase

Tb = Threshold temperature depend on the type of plant.

For example, a day with a high of 23 °C and a low of 12 °C (and a base of 10 °C) would contribute 7.5 GDDs.

$$\frac{23+12}{2}-10=7.5$$

A day with a high of 13 °C and a low of 10 °C (and a base of 10 °C) would contribute 1.5 GDDs.

$$\frac{13+10}{2}-10=1.5$$

Plant development

Common name	Latin name	Number of growing degree days baseline 10 °C
Dry beans	*Phaseolus vulgaris*	1100-1300 GDD to maturity depending on cultivar and soil conditions
Sugar Beet	*Beta vulgaris*	130 GDD to emergence and 1400-1500 GDD to maturity
Barley	*Hordeumvulgare*	125-162 GDD to emergence and 1290-1540 GDD to maturity
Wheat (Hard Red)	*Triticumaestivum*	143-178 GDD to emergence and 1550-1680 GDD to maturity
Oats	*Avenasativa*	1500-1750 GDD to maturity
European Corn	*Ostrinianubilalis*	207 - Emergence of first spring moths

Base Temperature

10 °C is the most common base for GDD calculations; however, the optimal base is often determined experimentally based on the lifecycle of the plant or insect in question.

Soil temperature:

- Soil temperature is important for biological activities, including that of microbes
- The physio-chemical as well as life processes are directly affected by the temperature of the soil.
- Under low temperature conditions nitrification is inhibited and the intake of water by roots is reduced.
- In similar way extreme soil temperatures injures plant and its growth is affected.
- Governs uptake of water, nutrients etc., needed for photosynthesis
- Controls soil microbial activities and the optimum range is 18-30oC.
- Plays a vital role in mineralization of organic forms of nitrogen (increases with temperature).

5.4. Basic agro-meteorological terms (e.g., dry spell, wet spell, water logging)

Dry spells: periods of consecutive number of days with no rainfall. It is a period of abnormally dry weather, shorter and less severe with little or no effect on soil moisture or water level. Prolonged dry spells: Periods of 10-15-20 consecutive days without precipitation, which might result into crop damage / failure, and lowering of water reservoir levels.

Water logging: - Refers to the saturation of soil with water. Soil may be regarded as waterlogged when it is nearly saturated with water much of the time such that its air phase is restricted and anaerobic conditions prevail.

Wet spell :- Wet spell is defined as a rainy day x mm of rainfall or seven days spell where the total amount of rainfall equals to x mm or more and the condition that 3 out of these seven days must be rainy with rainfall of more than 2.5 mm of each day.

5.5. Agro climatic Zones

Agro climatic Zones classification utilizes the concept of water balance, length of growing period and its associated onset date, dependable length of growing period, and expected minimum growing period at a given probability level. Based on this classification the country is divided into 53 distinct growing period zones. These growing period zones could be grouped into three major agro-climatic zones; Areas without significant growing period (N), Areas with single growing period (S), and Areas with double growing period (D). Based on crop evaporative demand versus availability the number of distinct zones in each major agro climatic zone N, S and D are 5, 21 and 27 respectively. By combining growing period, zones with temperature and moisture regimes these 53 distinct growing period zones are regrouped into 14 agro climatic zones. This indicates that Ethiopia has a vast climatic and agro climatic resources base.

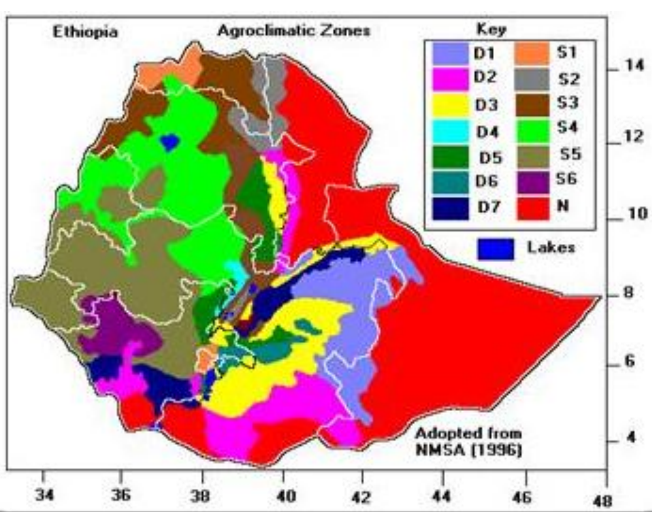


Figure 21: Agro climatic zone of Ethiopia Source: Agro climatic Zones of Ethiopia (NMSA 1996)

5.6. Agro-Meteorological Observation

Agro-Meteorological Observation (Meteorological and agricultural observations)

Meteorological and climatologically data are now a day used in planning various human activities, one of the most important being agriculture. For many years, the only data used for agricultural purposes were of rainfall and temperature but in some domains, Additional meteorological data were soon required, with the advance made in the physical sciences, new meteorological observation were gradually introduced Humidity, wind, Soil temperature, Sunshine duration, Cloudiness, evaporation and atmospheric pressure etc. The data for all this meteorological elements were and will continue to be, very important for agriculture. However, that data from the meteorological element alone had limited application and were not sufficient to satisfy the growing demand of agriculture. The effect of weather on agriculture cannot be determined by observing only the weather.

In addition to meteorological observation Agro meteorologists began observing plant, soils, domestic animals, the occurrences of pests and disease etc. modern agro meteorology needs and uses data from both observations of the weather and of agriculture.

Agro meteorological Observation

The agro meteorological observation is far more than meteorological but it must be Born in mind that nearly all elements of agricultural production depend on, or are some How related to, the weather and climate. Some of the agro meteorological observations are

- Plant development (Phenology)
- State of the plant
- Damage from adverse weather phenomenon
- Extent of weeds
- Soil moisture in the field of crops
- State of soil surface (water logging, wilting)
- Pest and Disease condition of the plant etc.

Depending up on their applicability and use, the agro meteorological observation can be divided in two main groups:-

- Observation made for specific research purposes
- Observation used as permanent (routine) in a network of agro meteorological observation.

Phonological observation and its application

In the development process from the germination of seeds, plants show several visible external changes, which are the result of the environmental conditions. These external change are called phonological phases (stages) of plant development and the observations are called phonological observations.

Objective:

1- The beginning and end of the phases serve as a means to judge the rates of development of the crop.
2- It is possible to define the regulations in the development of a crop in relation with its surrounding as well as with regard to meteorological factors.
3- To use it in research works and also in the operational agro meteorological forecasts including expected yield and
4- The mean dates of appearance of phonological phases in an area form the crop calendar.

Observation of damage to plants by unfavorable weather phenomena

The main weather factors that adversely affect crop

a. excessive rains or floods
b. scanty rains or drought
c. untimely rains
d. thunderstorms and hail storms
e. excessive or defective insolation
f. high wind

g. abnormal extreme temperature or humidity

General condition of the field

Scale for the evaluation of the condition of the field and evaluation should be considered for every crop at every development stage. It should be carried out visually according to the following scale.

Very Good:- The condition of the crop is excellent and corresponds to that of the best years for a given crop. The plant all the plots are dense and healthy. A high yield is expected.

Good: - the condition of the crop is good but with some defect. Example the stand is uneven, many weeds, damage due to pest or diseases.

Medium: - the condition is satisfactory and medium yield is expected.

Bad: - the condition is poor. The development of the plant seems to have been inhibited.

Total loss: - The crop has entirely or almost entirely perished.

Definition and Methodology of Observation of Individual phenological Phases

Sprouting:- is defined as when seeds have developed shoots and the first leaves have unfolded in different spots on the plots. the sprouting stage has begun. Uniformly of emergency is described qualitatively by the following criteria**.**

Third leaf: - when the third leaf unfolded the 3^{rd} leaf stage begin.

Tillering: - When the ends of the first leave on the lateral shoots project from the sheath of the leaves of the main stem, tillering phase begins. Cereals begin to branch out several days after the appearance of the third leaf. The lateral shoot forming in the axils in underground stem nods lay directly one on the other and constitute the so-called “tailoring node”

Shooting (stem extension) :- This phase is defined as the beginning of the growth of the Stem

Earring :-(stem extension) This phase is defined as the forming of ears of cereals. This phase begins for rice when half of the ear project from the sheath of the upper leaf and for maize (corn) when the upper part of the tassel appears.

Flowering:-When 10% of the plants in the plot show open flowers it is noted as the "First flowering" stage. When > 50% of the plants in the plots have one or more open flowers, it is "Full flowering".

Milky Ripeness phase: - The grain must be almost as long as completely formed grain. It must be green and burst emits its content when it is pressed between the fingers.

Waxy Ripeness phase: - The principle indications that the waxy ripeness stage has begun is that the grain turns yellow and becomes waxy to the touch the grains Losses their elasticity. A fingernail pressed against the grain leaves a permanent mark.

Full Ripeness:-This phase is recognized by the fact that the grain becomes hard and split when we hit with a knife.

Features of the Phonological growth and developments

1. Cereals: Wheat, Barley, sorghum, Millet Rice and Oats

- **Emergence: -** The appearance of the 1st leaf above soil surface.
- **Third leaf:** - The period when appears with 1cm. Length.
- **Tillering:** Branching out of the stem. The appearance of the tiller in the axel of one of the lowest leaves and when it reaches a length of about 1cm.
- **Shooting:** The period when the 1st stem node appears on the main stem of plant at a height of about one or two centimeters above the soil surface. Sometimes it is difficult to see the node, but could be felt by touching with the finger.
- **Earring Heading): -** (Wheat and Barley)- The moment when half of the ear has come out of the sheath of the upper leaf.
- **Teaselling:** - For sorghum, millet, rice and oats.
- **Flowering:** - When the flowering opens.
- **Wax (dough) ripeness**:- (With the exception of millet) – such ripeness comes when the grain from the middle of the ear reaches the colour typical for the ripened grain, but their stiffness is like wax (or dough). The grains can be cut out with a fingernail. Plants are already yellow and many of the lower are dry, but the stems are still flexible. Harvesting by hand is normally done at this stage.

2. **Pluses, Beans and peas**

- **Emergence: -** The appearance of the cotyledons above soil surface.
- **Budding:** - The appearance of the 1st flower buds on the stem.
- **Flowering**: -The plant is considered to be flowering even when there is only one blossom.
- **Ripeness:** - The plant starts to wilt, the pods become yellow and dry. The grains reach the size and colour typical of their variety

3. **Teff**

- **Emergence:** - The appearance of the 1st leaf above soil surface.
- **Third leaf**: - The period when appears with 1cm. Length.
- **Teaselling:** - For sorghum, millet, rice and oats.
- **Flowering:** - When the flowering opens.
- **Ripeness:-** The plant start to wilt, become yellow and dry. The grains reach the size and colour typical of their variety.

4. Maize (Corn)

- **Emergence:** - The 1st leaf appears above soil surface.
- **9th leaf:** - The period when appears the ninth leaf with 1cm. Length.
- **Tasseling**: The top of the tassel appears out of the upper leaf. The moment when it firs observed, it is about 1cm long.
- **Flowering**: the moment when the first flower opens and the pollen is shed.
- **Wax ripeness**: when the grains from the middle of the cob acquire the colour typical of the ripened grain. If squeezed, their hardness is like wax. Some parts of the plants (lower leaves, the tassel) are already yellow and dry.
- **Full ripeness**: The grains are hard and most of the leaves become yellow and dry.

5. Oil seeds: Nug and others

Emergence, Elongation, Budding, Flowering, Green ripeness and Yellow dark ripeness

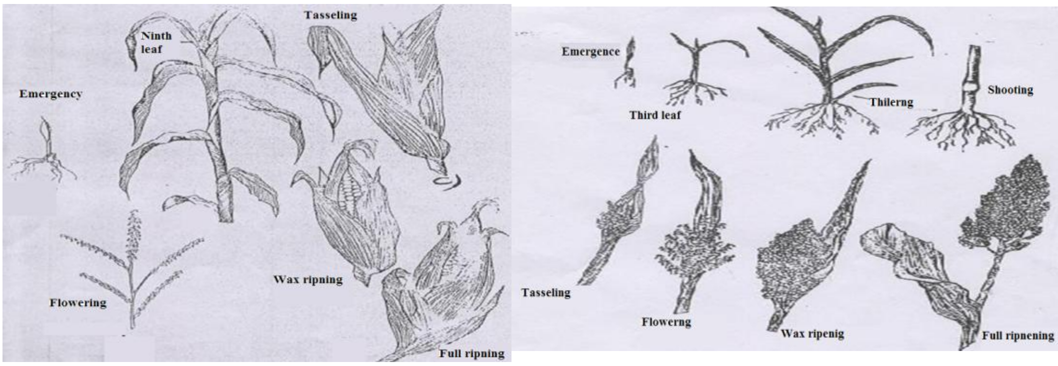


Figure 22: Phenological Phase of Maize (left) and Sorghum (right)

Selection of fields for phenological observation

- The site of the station must be representative of the crop-soil-climate conditions of the area.
- To determine the influence of weather on agriculture
- The station must be uniform with or representative of the general area for which data required in terms of crop-soil-climate relationship.
- For this reason the location of the station at transitional zones between areas with distinctly different climatic, soil or surface cover conditions should be avoided.
- Phenological observations should not be made for operational purposes on crop involved in agricultural experiments such as testing of fertilizers, irrigation experiments and so on.
- The Phonological observation however could be carried out in the control plots of such experiments, where all conditions are the same as the surrounding.
- The field work carried out should also be typical of the area. It should be stated that if irrigation is the general practice of the area, phonological observation should also be carried out in the irrigated field.

- Due to crop rotation over the years, a given crop is sown in different fields. Hence phonological observation on that particular crop should also move from one field to another. But, it is advisable to perform observations on the following crop in rotation as the same field.
- The field selected for observation should be about one hectare (10,000m2), whenever possible.
- If fields of a sufficient size are not to be found in the area of a given Agrometeorological stations the observation could be carried out in small fields. However, it is not advisable to make phonological observations in fields smaller than 0.2ha.

Time of Phenological observations

- The phonological observations should be performed three times a week. If one of the selected days is an official holiday, the observation should be performed a day earlier or later.
- As a national practice phonological observation should be carried out at the end of a ten day period following the Gregorian calendar and should be sent the next day.

Crop Selection

- As a national practice three major food or cash crops should be selected. The crop should be representative of the area including cultural and agronomic practice.

5.7. Crop water balance

Crop water balance (water soil balance) is moisture accounting system to determine whether the water requirement of a crop satisfied or not. Soil water balance can also be used to develop an index called water requirement satisfaction index (WRSI).

Major parameters develop soil water balance

1. Potential evapotranspiration (reference evapotranspiration)
2. Actual evapotranspirtaion
3. soil water holding capacity
4. crop type, crop cycle, and crop coefficient
5. planting time

Computation of crop evapo-transpiration and crop coefficient

Evapotranspirtaion (ET) is the combination of two separate processes whereby water is lost to the atmosphere from Soil surface by evaporation and Crop by transpiration.

Evapotranspirtaion rate is normally expressed in millimeters (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, dekade, month or even an entire growing period or year.

Effect of crop factors on ET

- Crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields.
- Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics result in different ET levels in different types of crops under identical environmental conditions.
- Crop evapotranspiration under standard conditions (ETc) refers to the evaporating demand from crops that are grown in large fields under optimum soil water, excellent management and environmental conditions, and achieve full production under the given climatic conditions.

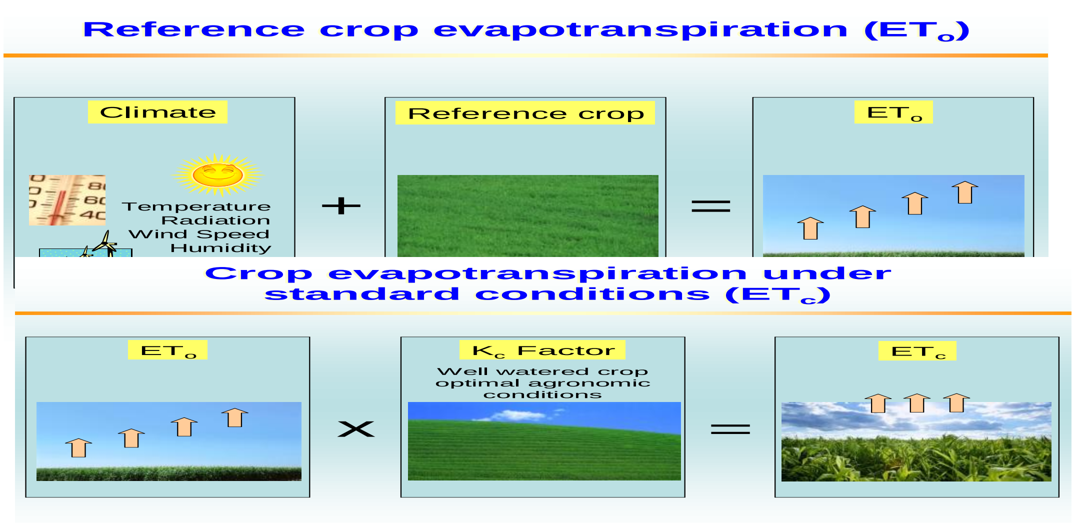


Figure 23: Crop Evapotranspirtaion

Measurement of evapotranspiration Soil moisture deficit method

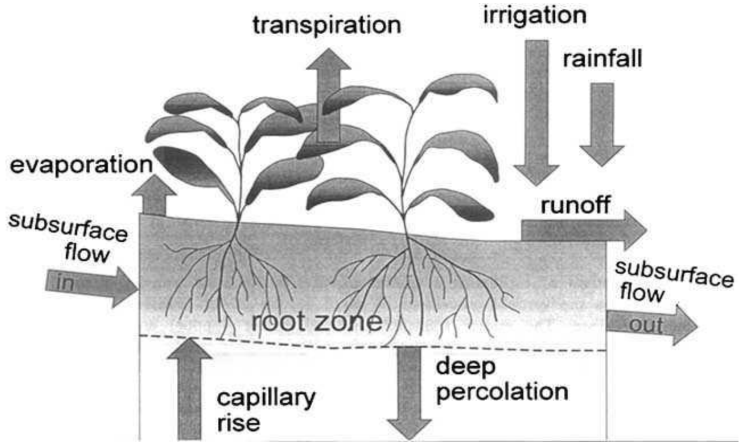


Figure 24: Measurement of evapotranspirtaion Soil moisture deficit method

Reference Evapotranspiration (ETo) or sometimes referred to as potential evapotranspiration is defined as the evapotranspiration from a 10cm tall grass that completely covers the ground, and is supplied with adequate water.

Crop coefficients

The crop coefficient, Kc, is basically the ratio of the crop ETc to the reference ETo,

<u>Kc= ETc/ETo</u>

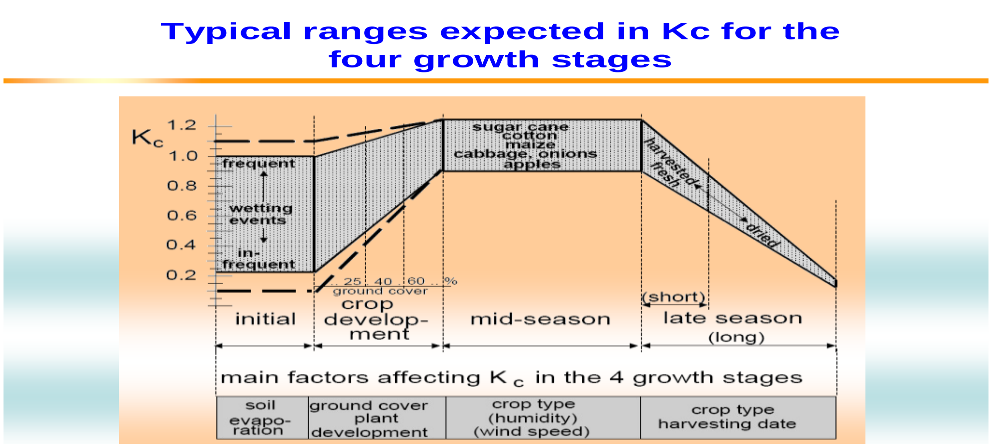


Figure 25: Kc for four growth stage

Soil water balance

$\Delta S = P + I - D - R - ET$

Where: ΔS = change in water content in the crop root zone

P = Precipitation

I = Irrigation

D = downward drainage

R = Run off

ET= Evapotranspiration

Water Requirement Satisfaction Index (WRSI)

Water is among the most important elements affecting agriculture, as it is one of the limiting resources for crop growth. This limiting factor is mostly caused by unreliable seasonal rainfall. Total seasonal rainfall amounts can be sufficient, but the distribution of rainfall throughout the season is mostly the cause of crop failure .This uneven distribution of rainfall exposes the crops to mild to severe intra-seasonal dry spells which decrease crop yields, Crop water requirements depend mainly on the nature and stage of growth of the crop together with the environmental conditions. These factors include soil characteristics, crop phenological stage and climate characteristics.

$$\mathbf{WRSI} = \frac{\sum \mathbf{ETa}}{\sum \mathbf{ETc}} * \mathbf{100}$$

Crop water requirement (CWR) / crop evapo-transpiration (ETc)

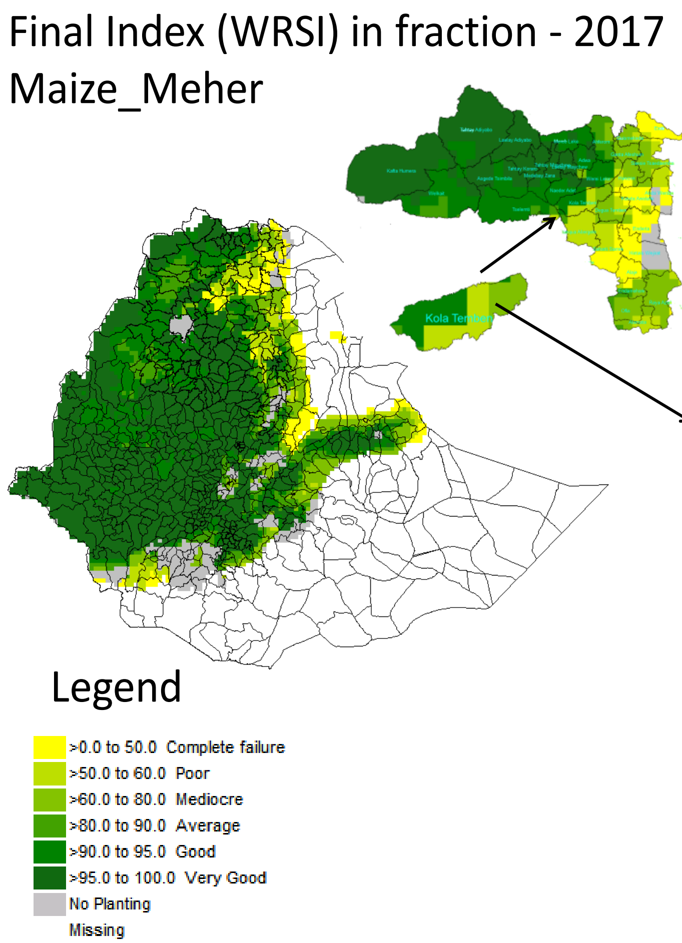
Crop water requirement ETc represents the maximum amount of water required to replenish for the water lost through evapotranspirtaion. The water requirement of the crop (ETc) at a given time in the growing season is calculated by multiplying standard reference crop evaporation (ETo) by Kc. Kc values define the water use pattern of a crop.

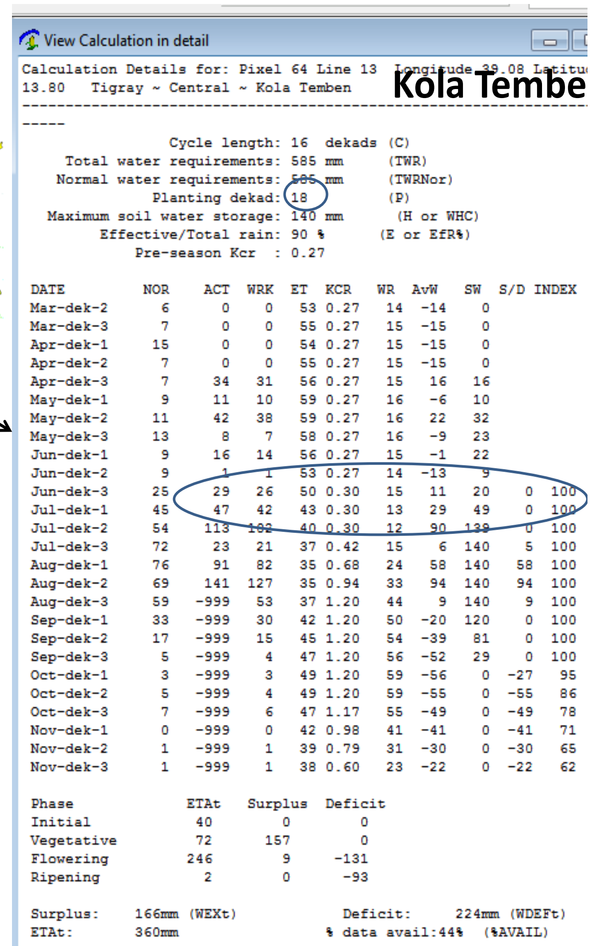
ETc = ETo * Kc

ETc = Maximum crop evapotranspiration

Kc = Crop coefficient

ETo = standard reference crop evaporation





Calculation Details for: Pixel 64 Line 13 Longitude 39.08 Latitu
13.80 Tigray ~ Central ~ Kola Temben

Cycle length: 16 dekads (C)
Total water requirements: 585 mm (TWR)
Normal water requirements: 585 mm (TWRNor)
Planting dekad: 18 (P)
Maximum soil water storage: 140 mm (H or WHC)
Effective/Total rain: 90 % (E or EfR%)
Pre-season Kcr : 0.27

DATE	NOR	ACT	WRK	ET	KCR	WR	AvW	SW	S/D	INDEX
Mar-dek-2	6	0	0	53	0.27	14	-14	0		
Mar-dek-3	7	0	0	55	0.27	15	-15	0		
Apr-dek-1	15	0	0	54	0.27	15	-15	0		
Apr-dek-2	7	0	0	55	0.27	15	-15	0		
Apr-dek-3	7	34	31	56	0.27	15	16	16		
May-dek-1	9	11	10	59	0.27	16	-6	10		
May-dek-2	11	42	38	59	0.27	16	22	32		
May-dek-3	13	8	7	58	0.27	16	-9	23		
Jun-dek-1	9	16	14	56	0.27	15	-1	22		
Jun-dek-2	9	1	1	53	0.27	14	-13	9		
Jun-dek-3	25	29	26	50	0.30	15	11	20	0	100
Jul-dek-1	45	47	42	43	0.30	13	29	49	0	100
Jul-dek-2	54	113	102	40	0.30	12	90	139	0	100
Jul-dek-3	72	23	21	37	0.42	15	6	140	5	100
Aug-dek-1	76	91	82	35	0.68	24	58	140	58	100
Aug-dek-2	69	141	127	35	0.94	33	94	140	94	100
Aug-dek-3	59	-999	53	37	1.20	44	9	140	9	100
Sep-dek-1	33	-999	30	42	1.20	50	-20	120	0	100
Sep-dek-2	17	-999	15	45	1.20	54	-39	81	0	100
Sep-dek-3	5	-999	4	47	1.20	56	-52	29	0	100
Oct-dek-1	3	-999	3	49	1.20	59	-56	0	-27	95
Oct-dek-2	5	-999	4	49	1.20	59	-55	0	-55	86
Oct-dek-3	7	-999	6	47	1.17	55	-49	0	-49	78
Nov-dek-1	0	-999	0	42	0.98	41	-41	0	-41	71
Nov-dek-2	1	-999	1	39	0.79	31	-30	0	-30	65
Nov-dek-3	1	-999	1	38	0.60	23	-22	0	-22	62

Phase	ETAt	Surplus	Deficit
Initial	40	0	0
Vegetative	72	157	0
Flowering	246	9	-131
Ripening	2	0	-93

Surplus: 166mm (WEXt) Deficit: 224mm (WDEFt)
ETAt: 360mm % data avail:44% (%AVAIL)

Figure 26: Analysis of WRSI for each pixel (10*10 km)

Relation between crop water use and yield

Doorambos and Kassam outlined in their FAO publication "Yield response to water" that there is a clear relation between crop yield and water use. This relation is the basis of the use of a water balance calculation in crop forecasting. It is possible to establish a maximum yield (Y_m) based on a season without water stress and water deficit. The total evapotranspiration is then at his maximum (ET_m). In semi-arid circumstances yield is usually reduced due to water stress leading to a lower actual yield (Y_a) and lower actual evapotranspiration (ET_a)

Yield response to water

The authors introduced the so-called yield response factor (k_y) to explain the yield reduction due to water stress. They established the yield response factor for a large number of crops in a limited number of climates. Doorenbos and Kassam found this relation to be near linear for most crops.

The general formula is:

1 – (Ya / Ym) = Ky (1 – [ETa / ETm])

Where,

Ya = actual yield

Ym = maximum yield

ETa = actual evapotranspiration

ETm = maximum evapotranspiration

Ky = yield reduction response factor.

Rangeland Water Requirement Satisfaction Index

The rangeland WRSI is computed as a continuous calculations based on 5 dekade cycle length by using a cop coefficient of one. Poor supply of water, will not entirely satisfy the rangeland vegetation water demand

The rangeland WRSI is the classic FAO water satisfaction index computed for periods of 5 dekads, with normal evapotranspiration kept at potential level (KCR=1) and an assumed water holding capacity (WHC) of 50 mm. Similar to moving averages, the value assigned to a dekad corresponds to the five-dekad period centered about that dekad. Thus 3 for dekads 1 to 5, 4 for dekads 2 to 6... (Mukhala and Hoefsloot 2004).

$$\mathbf{RWRSI} = \frac{\mathbf{AET}}{\mathbf{WR}} \times \mathbf{100}$$

$$\boldsymbol{WR} = \boldsymbol{PET} \times \boldsymbol{Kc}\ (\mathbf{1})$$

Where WR is rangeland water requirement, from Penman-Monteith Equation (Shuttleworth, 1992), PET is potential evapotranspiration, and AET is actual evapotranspiration, representing the actual amount of water withdrawn from the soil water reservoir, Kc is crop coefficient.

Rangeland WRSI: For two bad years (EL-Nino) years 2002 & 2009 and two good year (LaNina) 1998 & 2010

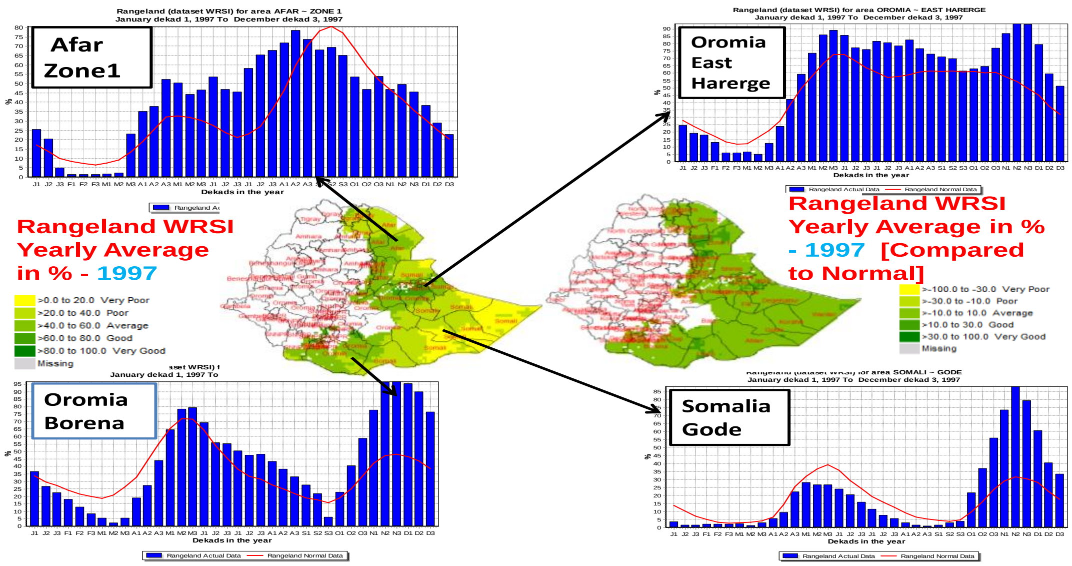
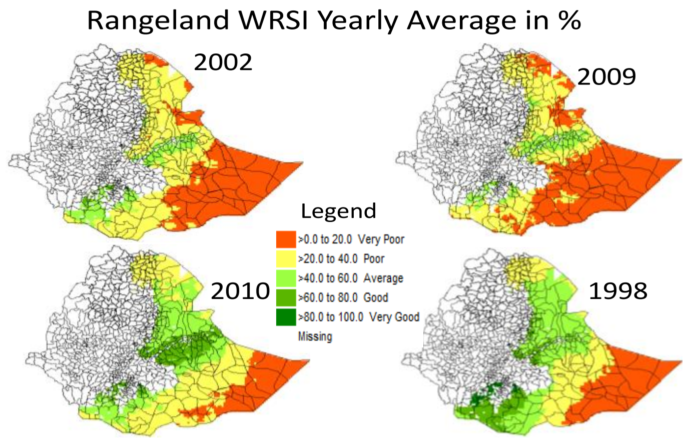


Figure 27: Yearly trained of Rangeland WRSI

5.8 Installation, data collection and application for plastic rain gauge (20 mm, 20 mm, 40 mm, etc)

Plastic Rain Gauges be installed at framers field and linked with the NMA system via Goe/GPS-coordinate mechanism and thus daily reading is easily accessed by NMA. Farmers will be trained on recording of daily rainfall performance and records are used to develop advisories. Wether, climate and agro meteorology information will be disseminated every season and following the seasonal forecast the installation of plastic rain gauges will takes place and dissemination of guidelines on the application of agro meteorological information at local level will be done.



Key steps for utilization of plastic rain gauges:

- The collection of rainfall starts after the heralding news from the National Meteorological Agency for the onset or rainfall in that particular area.
- The reading of rainfall using the plastic rain gauge may be once, twice or more depending the rainfall seasonal pattern. The collected rain after reading will be everyday, then summation of daily rainfall will be made dekadaly.
- Based on the cumulative rain observed using the plastic rain gauge, for two consecutive dekads with threshold values of twenty-twenty millimeters of rainfall, the planting date will be decided by the farmers themselves. This amount obtained is believed to be sufficient for the emergence of seedlings by recharging the upper top sub soil.
- 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 also can be monitored by comparing the actual crop water balance with the normal based on the rainfall amount from the gauge.


Figure 28: Utilization of plastic rain gauge at the field for farming practice decision

Crop selection, planting of crops, application of agricultural inputs, harvest and post harvest operations will take place depending on the onset and cessation of the seasonal rainfall. The selection of crops depends on the seasonal length of rainy period and the expected amount of rainfall in the season; this is mainly from the climatology of the station.

Crop Water Balance

Maize

Sowing= 20+20=40 mm

Initial = 0.17*LGP, WR=0.3*PET

Vegetative = (0.4-0.17)*LGP*1.2, WR=0.8*PET

Flowering =(0.79-0.4)*LGP*1.2, WR= 1.2*PET

Ripening = (1-0.79* LGP*0.6, WR= 0.9*PET

Teff

Sowing= 20+20=40 mm

Initial = 0.16*LGP*.3, WR=0.3*PET

Vegetative = (0.42-0.16)*LGP*1.2, WR=0.8*PET

Flowering =(0.82-0.42)*LGP*1.2, WR= 1.2*PET

Ripening = (1-0.82)* LGP*0.25, WR= 0.9*PET

5.8. Interpretation and use of agro meteorological advisory

Why weather for agriculture

- **t**o help develop sustainable and economically viable agricultural systems, improve production and quality, reduce losses and risks,
- decrease costs (increase efficiency in the use of water, fertilisers, chemicals, labour and energy), conserve natural resources and decrease pollution by agricultural chemicals or other agents that contribute to degradation of the environment.

Sustainable Agriculture

All agricultural production systems and practices which are economically viable, environmentally sound, and socially acceptable and which contribute to a better quality of life for agricultural producers and their families and the general public.

Sustainable Agriculture Management includes

- Soil management
- Crop management
- Livestock management
- Water management
- Integrated Pest Management (IPM)

All these components of Sustainable Agriculture require meteorological information, thus, the pathway available to achieve sustainable increase in agricultural production is through the improvement in productivity per units of land, water, fertilizer, agro-chemical and time, without any further deterioration of the natural resources and the Public Weather Services can play an important role in it.

Opportunities

- Wide gap between potential and actual yields –large untapped production reservoir, particularly in the rain fed / limited irrigation areas
- Many agricultural bright spots :Technologies on the horizon, post-harvest technology ,biotechnology, information and space technology and use of weather & climate information

Components of Public Weather Services required for Agricultural

Management Processes

- Average Weather Information (Mean, Variability) & extremes (Past)
- Prevailing Weather Information (Present)
- Forecast Weather Information (Future)
- (in Short, Medium & Long Range)

Use of Long Range Forecast (LRF) in Agriculture

- For seasonal planning on
- Type of crop/variety to be sown
- Proportion of area under different crops
- How much of land, if any, to keep fallow
- Redistribution of inputs (seed, fertilizer, pesticides etc.)
- Arranging for Power & Water Resources
- Preparation of Contingency Plans
- Preliminary enquiries on exports/imports
- Help make the best use of a good season and minimize the harmful impacts of the adverse one

Prevailing Weather and Short & Medium Range Forecasts

Sustainable Agriculture Production System requires full use of the prevailing and forecast weather in short, medium and long range for achieving full production potential of a given environment, mainly because the inputs such as irrigation, fertilizers, pesticides etc. which have resulted in increased production are all weather information sensitive.

The prevailing weather and forecasts in short and medium range, particularly of precipitation and temperature are vital for:-

- deciding sowing - yes/no, at what depth
- enhanced irrigation use efficiency
- assessing likely incidence of pests and diseases
- enhanced fertilizer & chemical use efficiency and reduced environment & health hazards

- harvest and post-harvest operations
- Necessary interventions, wherever needed, by the Government in view of significant aberrations in the weather over different parts of the country.
- It is of little use to look at the forecasts in isolation. To be effective, it must be able to trigger a timely response to protect livelihoods before lives are threatened. In other words, the forecast/response system must be geared to protect future capacity to subsist as well as able to ensure current consumption. Thus, the forecast must be sensitive to changes in food security status.

Agro meteorology Application

- Agro meteorology involves the application of meteorological information and data to weather sensitive problems of Agriculture.
- Most farm operations are weather sensitive, for example the application of fertilizers and pesticides, planting and harvesting.
- These operations yield best results when executed under the right weather conditions.
- Through medium and long range forecasts, it is Agro meteorology's intention that farmers take advantage of any optimum weather conditions prevailing or avoid catastrophe(disaster/total failure)
- To provide weather related information to farmers, in order to reduce weather-related hazards that agriculturalists may face, with the ultimate intention of improving the nation's food security situation.
- To carry out research in collaboration with Agriculturalists and other scientific disciplines in order to establish ways in which various aspects of weather affect agriculture, such that the best advice on weather related issues may be rendered to the agricultural community.

Total Rainfall Analysis (TRF):- total rainfall is the summation of all day to day rainfall recorded. Summation from day one up to day ten (means first dekad summation of recorded rainfall.

Percent of Normal Analysis (PON):- percent of normal precipitation is one of the simplest measurements of rainfall for a location. Analyses using percent of normal are very effective when used for a single region or a single season. It is calculated by dividing actual precipitation by normal precipitation typically considered to be a 30-year mean and multiplying by 100%.

Moisture Index/Status Analysis (MI or MS):- soil moisture determinations measure either the soil water content or the soil water potential. Moisture index or moisture status is the division of actual total rainfall to ETO (Evapo transpiration) calculated from cropwat4 software (ETO/ mm/day *10 days).

Temperature Analysis: - maximum temperature is the hotness of temperature in a day at peak. Minimum temperature is the coldness of temperature in a day at minimum peak. Average temperature is the medium of both (summation of maximum and minimum then divide by two) average temperatures.

5.9. Agro meteorology advisory

What is Agro met advisory?

A set of recommendations provided to the farmer on farm management and planning options based on observed weather and climate information and forecast.

What is the major reason for Agro Met Advisory?

Due to the impact of weather and climate processes on crop cultivation starting from farm land preparation and planting to the stage of harvesting of crops.

The following are the basic required Knowledge and skill for the application of Agro met advisory in Agricultural activities. Thus, it is expected from agro meteorological experts to understand the concepts and analyzed the parameters.

Understanding and Using Agro meteorological Indices

- The Simple Atmospheric Moisture Index
- Soil Moisture Index
- Water Requirement satisfaction Index (WRSI)

Understanding and Using Agro meteorological Concepts

- Soil water Balance Concept
- Crop Water Requirement
- LGP(Length of Crop Growing period

Advisories based on the simple moisture Index (MI)

The simple moisture Index is computed as the ratio of total rainfall at a given period to the potential evapotranspiration of same period for particular areas. MI is calculated as follow:

MI = Rainfall/PET

The moisture threshold for agricultural purpose is generally categorized as follow:

MI≥1 ………Humid

MI<1 and Mi>0.5…Moist

MI<0.5 and Mi>0.25… Sub Moist/Moderately dry

MI>0.1 and Mi<0.25… Dry

MI< 0.1………… Very dry

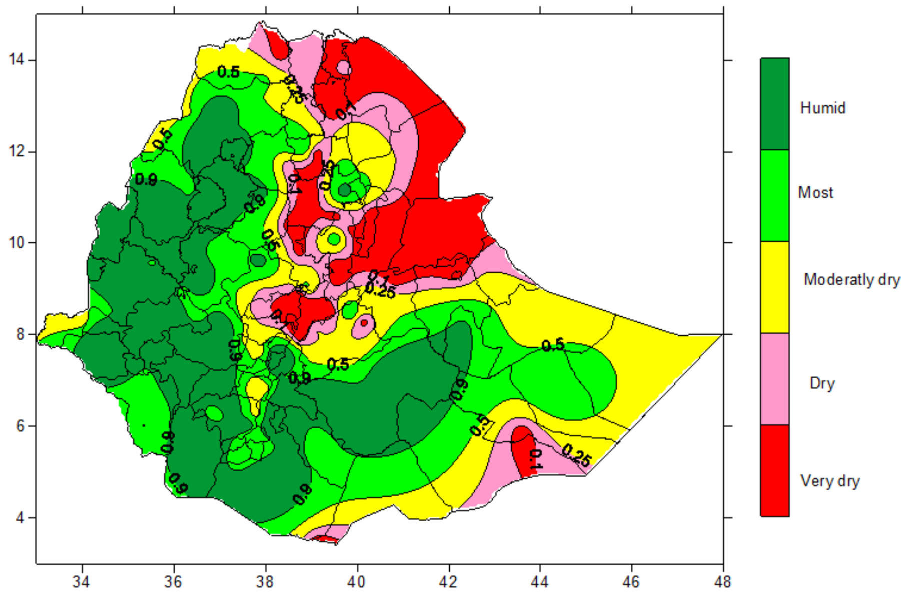


Figure 29: Shows the spatial interpolated of moisture status

The above indices are depicted in many of the agro met advisories disseminated by the Meteorological Services. In general the following can be considered as an approximate description:

- If the MI < 0.25 (lays on dry or very dry category), the moisture condition may not be promising to rain-fed agricultural activities. However, it could be very conductive for harvesting or post harvesting activities when it appears at the end of the growing season.
- If MI<0.5 and Mi>0.25 (lays on Sub-Moist or Moderately dry category), the situation supposed to be good for land preparation and improvement of pasture.

- If Mi<1 and Mi>0.5 (lays on moist category), the condition supposed to be good for crops particularly at vegetative stage.
- If Mi>1 (lays on humid category), this situation supposed to be good during Flowering and Reproductive stage of the crop.

Advisory using Soil Water Index (SWI)

This index is an indicator of the soil moisture status at the end of a particular dekad. Therefore, it may be used as a tool to assess the crop water status in the next dekad based on the available moisture in the soil**.** The SWI is computed based on the soil characteristics and the actual soil moisture conditions and the moisture at Field Capacity (FC).

Actual stored soil moisture/field capacity, t he soil water index threshold is generally categorized interpreted as follow:

SWI > 100%.......... tend to water logging

SWI = 100%.......................... Sufficient

SWI = 60 - 99%....................Satisfactory

SWI = 10 – 60%...................Stress range

SWI = 0 – 10 %.................Wilting range

Physical meaning associated with the values of Soil Water Index will be summarized as follow:

- If SWI is equal to 100% the condition referred as there is enough soil water in the crop root zone to support the crop through the next dekad without experiencing any water stress. If greater than 100%, the soil releases the water and act as water logging.
- If SWI is equal to 60 to 90%, the conditions ranging from some degree of stress (on the lower end) to areas with enough moisture to avoid crop stress in the next dekad.
- If SWI is equal to 10 to 60%, the crop is likely to experience water stress (from severe to moderate), if there is no rainfall in the next dekad.
- If SWI is equal to 0 to 60%, the soil is already at very low moisture level such that continued drought may cause wilting of the crop.

Sources: - principle and application of climate and weather information in agriculture 2004.

For example under poor soil moisture conditions, which hinder proper seed germination and emergence and which consequently would require the replanting of expensive seeds. Thus, a farmer must know what the existing soil moisture is and what the changes in the soil moisture can be. This will help him to avoid planting in the wrong time.

5.10. *Weather Index Insurance for Climate Change Adaptation and Agriculture Development*

Rural farmers in Ethiopia are vulnerable to a range of risks and constraints that impede their socio-economic development. Weather risk, in particular, is one of the major risks in agriculture production. Weather shocks can trap farmers and households in poverty. In addition, the risk of shocks also limits the willingness of farmers to invest in measures that might increase their productivity and improve their economic situation. the variability of climate and the dynamism of weather, The impacts of a given weather event differ according to the specific agricultural system, available moisture in the soil, type of soil and crop, and availability of other risk management tools (such as irrigation). Additionally, the negative impacts of weather events can be aggravated by poor infrastructure and mismanagement. The biggest source of risk to household welfare in rural areas of Ethiopia is drought and flood which might consider as a potential for weather related risk modeling.

A new type of insurance, weather index insurance (WII), offers new opportunities for managing weather risk. If it designed and introduced carefully, it has the potential to contribute significantly to sustainable development, by addressing a gap in the existing climate risk management portfolio[1]. WII is also a key tool in building adaptive capacity: as a risk transfer mechanism within a comprehensive strategy for managing climate risk in the face of climate change; as a mechanism to help people access the resources needed to escape climate-related poverty; and as a mechanism to incentivize risk reduction.

Weather based insurance

- Weather based index insurance - recognition as one of the methodologies that can be used sustains livelihoods and reduces poverty.
- Due to high levels of poverty, the farmers were not credit worth and hence they could not access loans to purchase inputs.
- The insurance helps farmers obtain financing necessary to obtain certified seeds, which produce increased yields and revenues as well as greater resistance to disease.
- However, development of these index strategies is hindered by gaps in available climate data gaps could likely be eliminated through appropriate efforts in data collection and availability**.**

Weather risks in agriculture

The risk that we are discussing is weather. Obviously, given the vast variety and complexities of global climates, it is difficult to generalize when discussing weather-related risks. The impacts of a given weather event differ according to the specific agricultural system, variable water balances, type of soil and crop, and availability of other risk management tools (such as irrigation). Additionally, the negative impacts of weather events can be aggravated by poor infrastructure (such as poor drainage) and mismanagement.

From a weather risk management standpoint, there are two main types of risk to consider. These relate to (1) sudden, unforeseen events (for example, windstorms or heavy rain) and (2) cumulative events that occur over an extended period (for example, drought). The impacts that either of these types of risk have vary widely according to crop type and variety and timing of occurrences. Key weather risks are shown in table 1.

Types of risk

The five primary sources of risk in agriculture are as follow:

- *Production risk:* includes weather, insects, disease, technology and any other events that directly affect production quantity and quality.
- *Price risk:* uncertainty in the market for your commodity, such as changes in the prices of inputs and/or outputs.
- *Financial risk:* the method in which capital is acquired and financed and the firm's ability to pay financial obligations.

- *Institutional risk:* changes in governmental and/or legal policies and standards that affect agriculture.
- *Personal risk:* risk common to all businesses such as death, divorce, or injury to the proprietor.

Table 5.1: Main Weather-Related Risks Affecting Agriculture

HAZARD	COMMENT
Drought (rainfall deficit)	• Crop varieties adapt to mean rainfall and water balance • Rain-fed agriculture predominates globally • Annual or multiannual • Key risk to livestock
Excess rainfall and flood	• Excess rainfall cause direct damage and indirect impacts • Riverine, flash, costal flood • Watershed management, drainage, irrigation have impact on flood
High temperature	• Impact on evapotranspiration and related to drought • Seasonality and vulnerability to crop stages
Low temperature	• Frost (short-term low temperature, early and late season damages) • Freeze (winterkill) • Growing degree day (lack of warmth during season)
Wind	• Frontal windstorm • Local windstorm
Hail	• Localized, but may be severe

Source: A*griculture and rural development discussion paper 5 0, World Bank, November 2011*

Experience of weather index insurance in Ethiopia

The country's first national index-based disaster insurance program was implemented in 2006. Developed by a partnership of the World Food Programme (WFP) and the Government of Ethiopia, the pilot project attempted to demonstrate the transfer of national drought risk to the global insurance market. For the second phase of the Ethiopia drought insurance project, WFP and the World Bank have developed a piece of software called LEAP, which stands for Livelihoods, Early Assessment and Protection. Based on the FAO Water Requirement Satisfaction Index (WRSI), the software allows users to quantify and index the drought and excessive rainfall risk in a particular administrative unit in Ethiopia.

The second index insurance pilot is being developed in Ethiopia by Oxfam America (OA) and Swiss Re, in collaboration with IRI, the Relief Society of Tigray (REST) and other partners. Still at a relatively early stage, this project is taking a farmer-centric approach, and is working to integrate index insurance with other risk reduction activities such as improved agronomic practices, conservation measures, and seasonal and daily weather forecasting.

Nyala Insurance S.C. is one of the leading private insurance companies in Ethiopia and provides a range of products, including both life insurance and general insurance. To help farmers protect themselves against droughts that significantly reduce crop yields, Nyala recently introduced crop insurance products. Different products for different farmers In recent years Nyala has provided two types of crop insurance: multiple-peril crop insurance (MPCI) and index-based weather insurance, each designed to meet the needs of different farmers.

5.11. Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is the most frequently used within agro meteorological analysis. NDVI makes use of the vegetation's typical low reflection in the red (red energy is mostly absorbed by growing plants for Photosynthesis) and strong reflection in the Near Infrared (Infrared energy is mostly reflected by plants due to their cellular structure).Due to its robustness and simplicity, NDVI has become one of the most popular remote sensing based products.

It is defined as:

NDVI = (NIR – VIS) / (NIR + VIS) or ***NDVI = (NIR – Red) / (NIR + Red)***

NIR (Near-Infrared) energy sensed from vegetation is controlled by the plants internal leaf structure.

LOW NIR = stressed or non-green vegetation (wilting)

HIGH NIR = healthy green vegetation

Red energy detected from vegetation is controlled by the vegetation’s chlorophyll content.

LOW Red = healthy green vegetation absorbs visible red energy

HIGH Red = stressed or non-green vegetation reflects red energy

NDVI values are ranging from -1 to +1.
HIGH NDVI values = healthy, green vegetation (typical range of vegetation values from 0.2 - .08, with values > 0.5 indicative of denser vegetation)
LOW NDVI values = stressed or non-green vegetation

NIR and VIS are, respectively, the reflectance (%) in the near infrared and in the red channels. It is easy to understand the index when the characteristics of absorption and reflection of the radiation by green leaves is studied.

The chlorophyll of the plant absorbs the majority of the radiation in the visible part of the spectrum, principally the red portion (0.6–07 μm), and is highly reflective in the near-infrared. Thanks to this property of green vegetation, NDVI is a direct indicator of the plant's photosynthetic activity and variations due, for example, to moisture stress are among the typical phenomena that can successfully be monitored by NDVI. The NDVI has been extensively used in vegetation monitoring for crop yield assessment and forecast.
For example, both GIEWS and MARS try to improve their yield forecasts by using the low-resolution imagery registered by synoptic earth observation systems, such as the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), active since about 1980, and SPOT (Satellite Earth Observation System) – VEGETATION (Multi-spectral scanning radiometer (on board SPOT 4 and 5 satellites) acquiring images in 4 channels with 1 km spatial resolution) since 1998. (See, for example, the MARS Bulletin for Morocco http://mars.jrc.it/mars/Bulletins-Publications

On line access of NDVI

http: // early warning.usgs.gov/FEWS/map viewer/search/Africa/East%20Africa

NMA Source: - GEONECAST

LEAP Software downloaded dekadal from METEOSAT and USGS

- NDVI (Normalized Difference Vegetation Index) is a satellite derived indicator of the amount and vigor of vegetation.
- Images of NDVI are sometimes referred to as "greenness maps" since they represent the vegetative vigor of plants.
- By NDVI measure, vegetation is pictured as a scale, or index, of greenness NDVI Illustration

Example: Oromia Livestock insurance uses NDVI as an Index

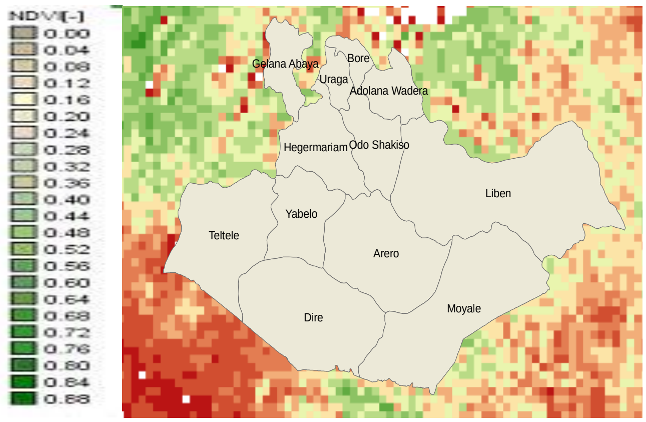


Figure 30: NDVI in 8 Woredas of Borana Zone in March, 2010

ZNDVI

- For contract design, NDVI need to be converted into ZNDVI (deviation from normal)
- ZNDVI is standardized NDVI (compares each NDVI value against long-term average)

$$ZNDVI = \frac{MeanNDVI}{Standarddeviation}$$

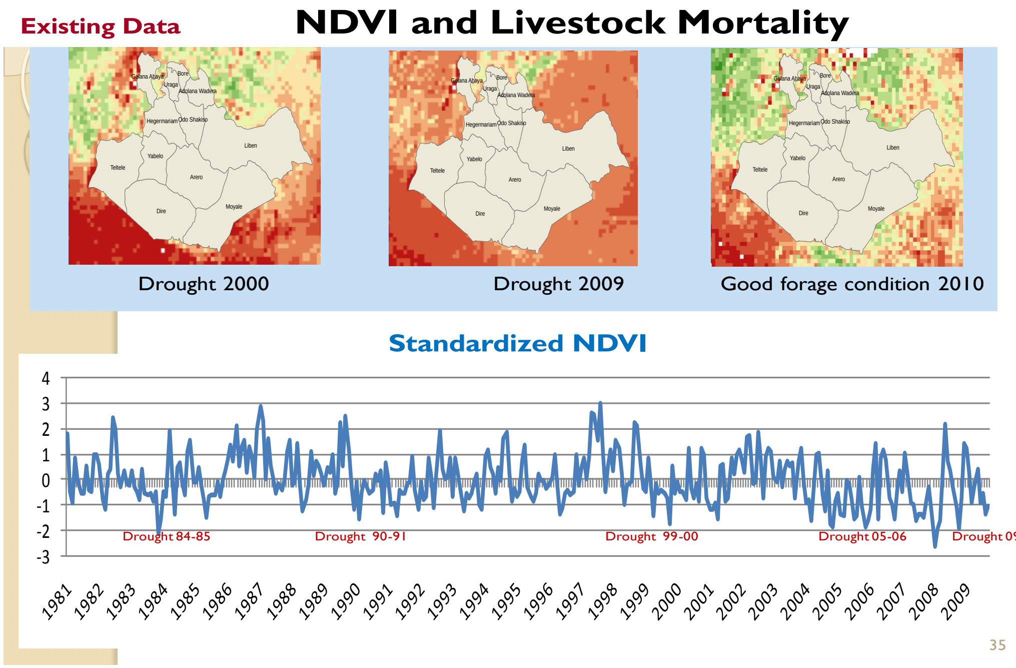


Figure 31: Trained of NDVI and livestock mortality

Table Amount of premiums for different types of livestock unit for all the 8 woredas

Woredas (Geographical coverage of the contracts)	*Annual premium*	*Amount of Premium in Birr for a*		
		Cattle	*Camel*	*Goat or Sheep*
Dillo	9.75%	487.5	1463	68.25
Teltele	8.71%	435.5	1307	60.97
Yabello	7.54%	377	1131	52.78
Dire	9.49%	474.5	1424	66.43
Arero	8.58%	429	1287	60.06
Dehas	9.36%	468	1404	65.52
Miyo/Moyale	11.05%	552.5	1658	77.35

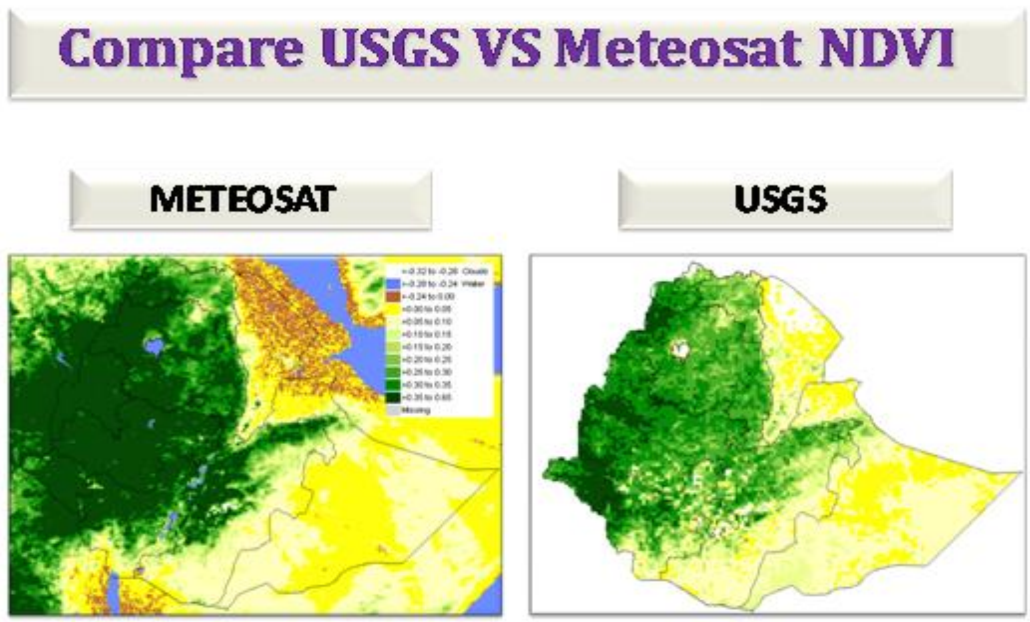


Figure 32: LEAP Software downloaded dekadal from METEOSAT and USGS

Problems Associated with the Use of Satellite Data

- In order to estimate the LST and NDVI precisely it is necessary to have cloud-free AVHRR pixels in the images.
- It is necessary to obtain clear sky radiances in order to obtain accurate temperature profiles over the ground surfaces.
- Therefore, it is necessary to identify cloud-free fields of view for making estimates of surface variables from upwelling radiances measured by an instrument such as AVHRR.

5.12. Crop Calendar and LGP

The Crop Calendar is a tool that provides timely information about seeds to promote local crop production. It contains information on planting, sowing and harvesting periods of locally adapted crops in specific agro-ecological zones. It also provides information on the sowing rates of seed and planting material and the main agricultural practices.

Detailed information about crop stages - also known as the "crop calendar" - plays an essential role in crop monitoring and forecasting. This is because the effect of environmental conditions on crops depends very much on crop growth stages. For instance, water requirements are normally low at the initial growth stages, while they reach a maximum just after flowering.

Information about crop stages can be obtained from different sources, in isolation or in combination. An effective system involves field observers, usually agricultural extension staff, using a system of regular reporting, either by radio or by mail. National crop monitoring systems also rely more and more on satellite technology. Using a series of Normalized Difference Vegetation Images (NDVI), it is possible to monitor vegetation development. Assuming that crops follow a pattern similar to natural vegetation

The length of the growing season or growing period"(LGS or LGP)

The Length of Growing Period (LGP) is the length of time (in days) that enough moisture is available in the soil for (rain fed) plant growth and the mean daily temperature is above 5°C.

The estimation of growing period is based on a water balance model, whereby precipitation (P) is compared with potential evapotranspiration (PET). Precipitation includes rainfall, dew, hail and snow. Provided the temperature is high enough for plant growth, the P/PET ratio determines the beginning and the end of the growing period. The potential evapotranspiration (PET) is defined as the amount of evaporation and transpiration that would occur if a sufficient water source were available[2]. PET is the combination of two separate processes whereby water is lost from the soil surface by evaporation and from the crop by transpiration. PET is calculated by means of the FAO Penman-Monteith equation (1998), based on parameters such surface and air temperatures, wind speed, relative humidity, and solar radiation.

Generally it is assumed that there is enough moisture for crop growth when precipitation is greater than half potential evapotranspiration ($P > 0.5$ PET). A dry land is a place where annual potential evaporation exceeds annual precipitation.

A differentiation can be made between a normal growing period, when P exceeds full PET (P > PET) and an intermediate growing period, when P exceeds half PET, but is less than PET (0.5PET<P<PET).

Climatic data for LGP calculation

For the calculation of LGP, data are needed on rainfall (P) and potential evapotranspiration (PET). Additional data on soil moisture storage capacity is also needed in case P exceeds PET for considerable length of time.

The LGP is an expression of the climatic potential for crop growth and long-term data are needed for a reliable estimate. Series of at least 10 consecutive years are needed, but preferably 20 years or more. Monthly data can be used for a generalized LGP calculation, whereby results are expressed in broad classes (e.g. “LGP = 90-120 days”). To calculate a more precise LGP, rainfall data over short periods are needed (e.g. 10-day periods).

Annual number and type of Growing Periods

The LGP is calculated over a whole year. Within a year there may be more than one growing period. The annual rainfall distribution can be distinctly unimodal (one rainy season) or bimodal (two rainy seasons). In case of two growing periods, there can be various combinations of normal and intermediate growing periods. Most of Ethiopia has bimodal rainfall, with two distinct peaks around the months of April and August respectively. However this does not necessarily mean there are two growing periods. There are only two growing periods if they are separated in time by a period when precipitation is less than half evapotranspiration (P < 0.5PET).

The variation in number and type of GP is illustrated in case of two or more growing periods, it is important to know the length of the dry period in between the growing periods. This is particular important for the production of annual crops. If the dry period is relatively short (e.g. 30 days), the crop cycle may extend over two successive GPs. However, if the dry period is more than 30 days, most annual crops will not be able to make use of two successive GPs during their growth cycle. In this case the length of each individual GP is more important than the total length of GP in a year.

LGP 150 days, one GP 60 days normal + 90 days intermediate

Variability of rainfall and Growing Period

Annual variability in total length of GP

The annual variation in rainfall, and therefore LGP, can be quite high, particularly in arid and semi-arid environments.

In the majority of years there are two periods when Precipitation is more than half Potential Evapotranspiration (P > 0.5 PET).

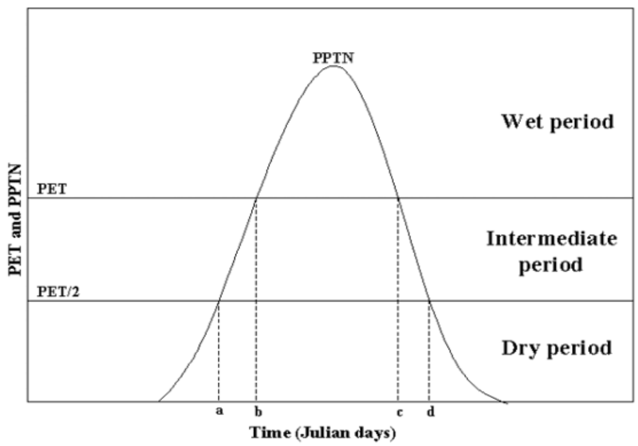


Figure 33: normal season is shown in has the following characteristics:

A Beginning Period

The beginning of the growing period occurs when precipitation (PPTN) equals half PET and marks the start to the normal rainy season, shown as *a* in fig. 5.15. A value of one half PET has been chosen as germinating crops do not evapotranspire at the full rate of PET and false starts to the rainy season are eliminated. The beginning marks the transition from the dry period to the "intermediate" period when PET/2 < R < PET.

A wet (humid) Period

this is the period during which precipitation exceeds PET. The beginning and ending dates (shown as *b* and *c* in fig. 5.15, respectively) are the two points where the precipitation and PET curves cross.

An End to the Growing Period

The end of the growing period occurs at the point where the precipitation curve crosses the one half PET curve (labeled as *d* in fig.5.15).

Climatic classification Based on LGP

Table 5.3 of LGP classes (FAO/LUPRD, 1984)

Length of Growing Period	Universal
< 45	Arid
46-60	Semi-arid
61-120	Sub-moist
121-180	Moist
181-240	Sub-humid
241-300	Humid
>300	Per-humid

5.13. Malaria prevalence and climatic favorability

Global climate change remains one of the biggest environmental threats and its impacts on human health remain an important focus. Climate variations are thought to have a direct impact on the epidemiology of many vectors borne disease. Malaria is a major public health burden in the tropics, with the potential to significantly increase in response to climate change. Over the past century the world has warmed by 0.6˚C, with a range of ecological consequences. According to the WHO, malaria kills over one million people each year, while 300 to 500 million people are suffering from chronic malaria around the world. This is one of the most common and serious diseases of our time. Global change inflicted by man in ways of increased emissions of greenhouse gases or disrupted nutrient cycles has been known to cause great ecological responses.

- Human health is affected by climate in number of ways directly or indirectly as with infectious disease such as malaria, meningitis, etc.
- Malaria is one of mostly known virulent infectious disease, which is sensitive to climate conditions.
- Malaria is mosquito born disease that is globally studied at most (WHO, 2005).
- It is a persistent threat to health in developing nations including Ethiopia.
- It is major constraint to economic development and reduces the likelihood of living a healthy life, especially among women, children and the rural poor.
- About 3.2 million people are at risk of globally, annually, it kills about 1-3 million people out of 500 million cases.

- environment by itself encourages the interactions among the Anopheles mosquito, malaria parasites and human hosts, providing:
- Surface water in which mosquitoes can lay their eggs;
- Humidity for adult mosquito survival; and
- Temperatures that allow both the mosquito and the malaria parasite to develop and survive.

The Ethiopian Experience:- Epidemic malaria risk is high in Ethiopia. It is estimated that two-thirds of Ethiopia's population of 77 million are at risk of epidemic malaria (Connor et al. 2008). A first step towards dealing with an epidemic is to ensure that the local health institutions have the capacity to respond adequately and are not overwhelmed by the number of cases. This can be achieved only if there is sufficient lead time for advanced preparation and mitigation, which requires early warning of where and when epidemics are likely to occur (Ghebreyesus et al. 2008). A health information system that includes the capability for early warning and response depends on many things including seasonal and shorter time-scale forecasts, real-time weather information and early detection of cases (Connor et al. 2008), as well as information about community preparedness, health services and health statistics to shift efforts between risk management to effective case management as an epidemic develops (WHO 2004).

Study Subjects

Daily climate variables such as daily mean temperature (T), minimum temperature (Tm), and maximum temperature (TM) (°C), relative humidity (RH) (%), wind speed (W) (km/h) and precipitation (P) (mm) were collected from Station.

Methods and Materials

- Grover-Kopek et al. 2006
- The suitable climatic conditions for transmission of malaria in Africa are; when the; Malaria index:
    1. Monthly precipitation accumulation is at least 80 mm,
    2. Monthly mean temperature is between 18°C and 32°C and
    3. Monthly mean relative humidity is at least 60%.

Quality control for all the data has been made by using Statistical Downscaling model (SDSM)

- Tool: surfer version 8
- Overlapping of gridded maps of routinely collected temperature, humidity and Rainfall data

As per Grover-Kopek et al. 2006, the climatic conditions is favorable for transmission of malaria in Africa are; when the monthly precipitation accumulation is at least 80 mm, the monthly mean temperature is between 18°C and 32°C and the monthly mean relative humidity is at least 60%.; Accordingly the same method was applied on Temperature, Rainfall and Humidity using meteorological data collected from some representative meteorological stations of Ethiopia in order to demarcate all the possible malaria expected areas of the country.

Malaria indicators

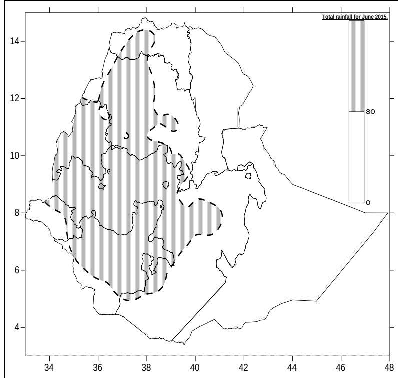
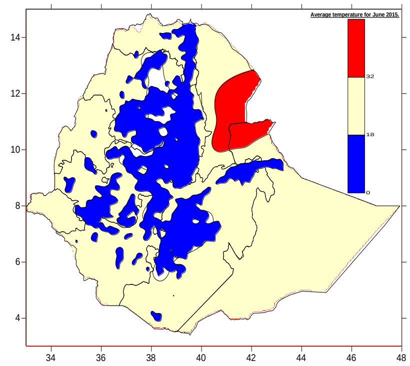
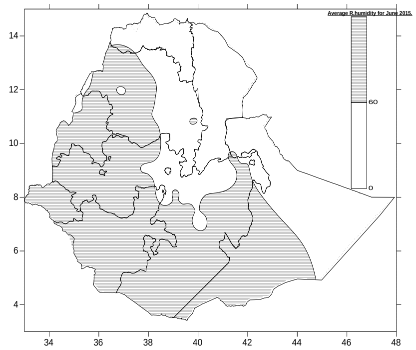
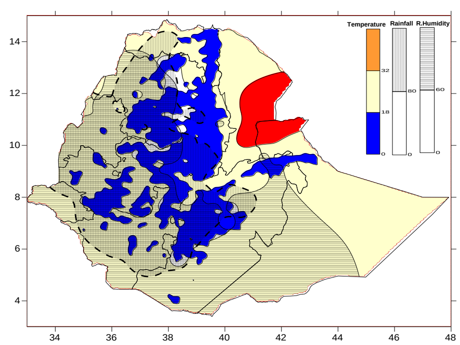
Rainfall	Temperature	Relative Humidity
		
	Malaria vulnerable areas	
		

Figure 34: Malaria indicator

Temperature Humidity Index (THI) Conditions

With respect to Temperature-Humidity Index (THI), the climatic condition for human being was developed by the US weather Bureau in 1959; it is applied to the temperature and humidity datum over representative stations of the country in order to review the weather condition which was comfort, moderate and discomfort over all areas covered by indicated climate data sources.

$THI=(0.55*T+0.2*T_dT_d)+5.3$

Where T is Temperature, T_dT_d dew point temperature

THI < 21 :- Comfortable

THI = 21-26:- Moderate
THI >26:- Uncomfortable

Table 1: Moisture index

Discussion:-

1. *The following shows values of dekadal (ten daily) Moisture Index (MI) during the kiremt season, what type of advisory can be provided?*

Compute MI given the following for dekadal RF and Dekadal ETo?

Station	*Dekadal RR*	*Dekadal ET0*	*Mi*	*Remarks on the physical implication*
A	*21*	*30*		
B	*16*	*15*		
C	*19*	*12*		
D	*10*	*27*		
E	*3*	*30*		

2. Discuss the Average Crop calendar of your locality and also the importance of the use of Phenological Observations for agricultural extension?
3. Discuss weather index insurance for small scale farmer?
4. Discuss the effects of climatic variables, particularly, rainfall, temperature and relative humidity on malaria incidence using time series analysis?
5. Discuss the use of phenological observation for Agrometeorological advisory?

MODULE 6: AGRONOMIC APPLICATION OF WEATHER AND CLIMATE INFORMATION

Purpose of the module:

- *To enhance the awareness of farmers how to apply weather and climate information for agricultural practices at farm level*
- *To increase the understanding of farming community how to adapt the adverse impact of weather and climate variability.*
- *To introduce various copying strategies and mitigation mechanisms in agricultural practices*

Introduction

In a sensible mode, the proper combination between Weather/Climate information with agronomic activities is commonly referred as Agro meteorology, abbreviated from agricultural meteorology. It is an interdisciplinary holistic science which acts as a bridge between physical and biological sciences and puts the science of meteorology to the service of agriculture, in its various forms and facets, to help with the sensible use of land, to accelerate the production of food, and to avoid the irreversible abuse of land resources (Smith, 1970).

Agro meteorology is also defined as the science investigating the meteorological, climatologically, and hydrological conditions that are significant to agriculture owing to their interaction with the objects and processes of agriculture production (Molga, 1962).

In agro meteorology the main scientific disciplines involved are atmospheric sciences and soil sciences, which are concerned with the physical environment, and plant sciences and animal sciences (including their pathology, entomology, and parasitological, etc.), which deal with the contents of the biosphere.

6.1. ***Cropping system in Ethiopia and their dependency on rainfall***

Rain fed agriculture is the main agricultural production system in most part of arid and semiarid regions, including Ethiopia, of the world.

In many cases, farmers probably have many different combinations of crops on their farm, and they manage each combination in a different way. Growers have many reasons for making these choices. In essence, what they plant depends on how much moisture is in the soil and whether the rains are early, on time, or late. And of course it depends on what they want to grow for their own use and to sell.

In many cases, farmers cultivate multiple crops of more than one life-cycle because the diversity provides multiple benefits, such as soil conservation, interruption of pest lifecycles, diverse nutritional household requirements, and reduced market risk. In this module, some type of cropping system will be examined at a certain detail as follow:

Major type of cropping systems in Ethiopia

Môn cropping:

As indicated in figure 6.1, it refers to planting the same crop year after year in sequence.

Disadvantages:

- Reduce soil fertility
- Encourages pests, diseases and weeds
- damage the soil structure

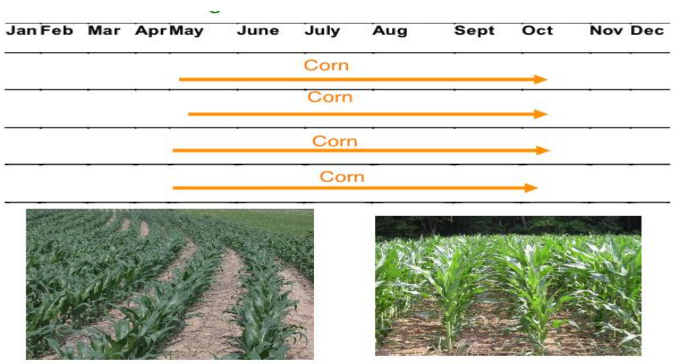


Figure 35: Year after year monoculture cropping systems

Crop rotation

This means changing the type of crops grown in the field each season or each year (or changing from crops to fallow). Example Planting maize one year, and beans the next.

Advantage:

- It improves the soil structure and fertility.
- *Pest control benefits*
- Interrupts weed life cycles by alternating annual crops with perennial forage crops

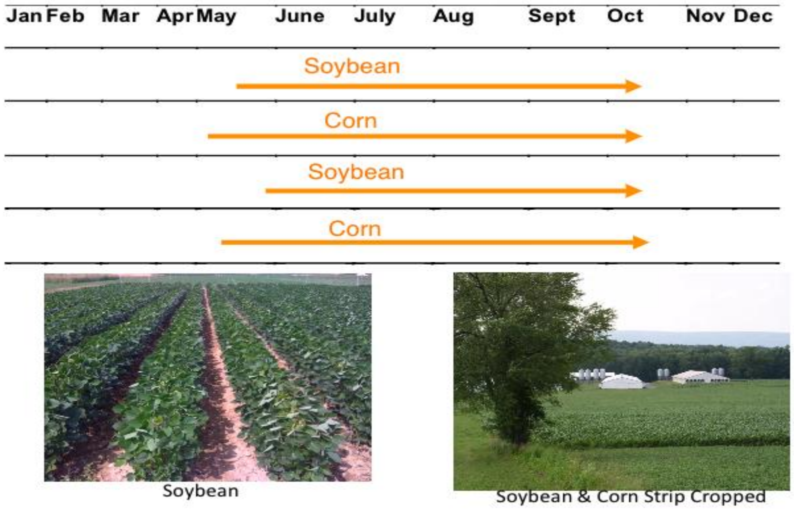


Figure 36: Simple annual crop rotation between Corn and Soybean

Double cropping,

As illustrated in Figure 6.3, Where growing seasons are long and/or crop life cycles are short (ex. leafy greens), three crops may be planted in sequence within a season, as a triple-crop.

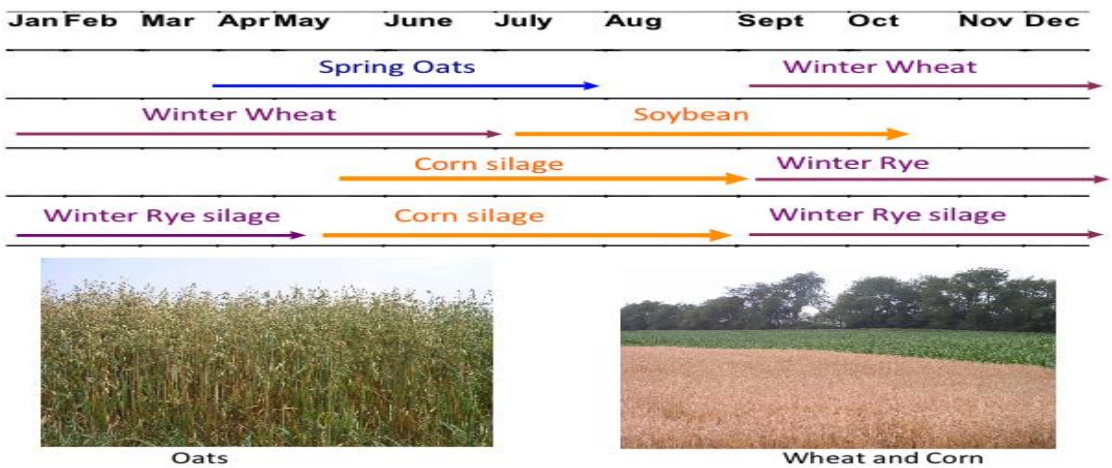


Figure 37: double cropping annual crop

Sequential cropping

This involves growing two crops in the same field, one after the other in the same year. In some places, the rainy season is long enough to grow two crops: either two main crops or one main crop followed by a cover crop. (Example: Planting maize in the long rains, then beans during the short rains.)

Intercropping:

This means growing two or more crops in the same field at the same time. (Examples: Planting alternating rows of maize and beans, or growing a cover crop in between the cereal rows.)
It is possible to do this in different ways: Broadcasting the seeds of both crops, and dibbling the seeds without any row arrangement. This is called mixed intercropping. It is easy to do but makes weeding, fertilization and harvesting difficult. Individual plants may compete with each other because they are too close together. Planting both the main crop and the intercrop in rows is called row intercropping. The rows make weeding and harvesting easier than with mixed intercropping. A possible problem is that the intercrop may compete with the main crop for light, water and nutrients. This may reduce the yields of both crops.

Strip cropping

This involves growing alternate strips of various types of crops in the same field. In most cases it consists of growing erosion resisting /dense crops/close growing/ or cover crops and erosion permitting crops (row crops) are grown in alternate strips

Figure 38: : Maize and Sod planted as strip cropping

Advantages:

- it produces a variety of crops, the
- legume improves the soil fertility,
- Reduce pest and weed problems.
- Residues from one strip can be used as soil cover for neighboring strips.
- managing the single crop within the strip is easy,
- Competition between the crops is reduced.
- reducing runoff flowing through the close growing sod strips
- Increasing the infiltration rate of soil under cover condition

- Reducing KE of the flow
- Filtering sediments

1. Relay cropping

Example: planting maize, and then sowing beans between the maize rows four weeks later. This is growing one crop, and then planting another crop (usually a cover crop) in the same field before harvesting the first. This helps avoid competition between the main crop and the intercrop. It also uses the field for a longer time, since the cover crop usually continues to grow after the main crop is harvested.

Question 6.1:

Among the above which cropping system often used in your locality? Why does it prefer?

6.2. ***Application of weather and climate forecast for different agricultural practices: (Land preparation, Sowing/Seed bed, weeding, planting, harvesting, transplanting, fertilizer application (split), etc)***

Weather forecasting is defined as prediction of the state of the atmosphere for a given location applying the principles of physics, supplemented by a variety of statistical and empirical techniques and by technology. Weather forecasts are important because they are issued to protect life and property, to save crops and to tell us what to expect in our atmospheric environment.

Farming community may use the weather forecast in the range of determining the very onset of the season up to the market chain which may extend to change the stocks on their shelves in different weather condition.

Weather and climate information for Land preparation/Sowing

The primary purpose of land preparation prior to planting is to create a soil structure favorable for crop growth, to incorporate residues, and to control weeds and diseases.

To determine the right time of when to begin land preparation and the proper type of tillage, growers should access timely and reliable agro meteorological information. This may include that farmers need to ensure whether enough moisture is available in the soil or not. Tilling the crop land when soil was not at the correct moisture content may cause clods. Thus, farmers are always advised to start land preparation when moderately dry moisture condition prevails over the area of interest.

Deciding when to plant is one of the most important decisions a farmer has to make. To determine the correct planting time, experts always considers both the amount of rainfall received and the potential evapotranspiration of the areas for the last ten days (dekad) and it termed as Simple Moisture Index (MI). If the ratio of these two parameters (MI) is equal to 0.5, that dekad is supposed to be the correct planting time. The main aim of considering the moisture condition of the areas is to make sure the seeds germinate quickly and evenly.

Some guidelines for sowing/planting:

- Should select the right crop type and variety based on the seasonal weather forecast at the time of cultivation.
- Avoid planting at a time of false onset signal of the season
- Plant at least if moist moisture condition prevails over the growing areas so as to ensure seeds to germinate evenly.
- Determine the amount of seeds sowing per hectare (large amount for moisture stress areas and vice versa for moisture excess area)
- When planting the crop, ensure putting the seed at the right depth and seedbed.

> Question 6.2:
>
> Discuss the importance of weather and climate forecast to make farm level decision?

6.3. Use of weather and climate information for fertilizer and chemical applications

Fertilizer may play a critical role in meeting future growth in crop production and yield advancements. In fact, research indicates that fertilizer is responsible for approximately half of all crop production on a global basis. To enhance yields, fertilizer use needs to both increase and be properly balanced to sufficiently replenish the vital nutrients that crops consume every year.
The skilful use of fertilizer application is greatly dependent on our knowledge of the moisture condition that is existing at the time of fertilizer application. The following are some of the basic recommendation concerning fertilizer application:

- 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 actual application of fertilizer should be based on the above lists of recommendation. Thus,

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. For the planning of fertilizers, we can use the dekadal rainfall probability at 80% probability level. However, the application of fertilizer should be implemented by taking into account local agro-ecological features. (Met User Guide, 2017).

Question 6.3:

Explain the basic recommendation concerning fertilizer application?

6.4. ***Weather and climate impact monitoring (flood, drought, water logging, landslide, and pest and disease outbreak)***

Flood

In simple terms, flood can be defined as an overflow of large quantities of water onto a normally dry land. Flooding happens in many ways due to overflow of streams, rivers, lakes or oceans or as a result of excessive rain. Some floods occur abruptly and recede quickly whereas others take several days or even months to form and to recede because of variation in size, duration, and the area affected.

Main Causes of Flooding

Many conditions result in flooding. Hurricanes, clogged drainages, and rainfall are some of the conditions that have led to flooding in various regions across the globe. Here are the leading causes of flooding.

Rain

Rain is the leading contributor to most of the flooding cases witnessed across Ethiopia. Too much rain causes water to flow overland contributing to flooding. In particular, it is due to high rainfall intensity over a prolonged period.

Depending on the rainfall distribution, the amount of rain, and soil moisture content, short rainfall period can also result in flooding. Light rains for longer periods – several days or weeks, can also result in floods.

River Overflows

Rivers or streams can overflow their banks. This happens when the river or stream holds more water upstream than usual, and it flows downstream to the neighboring low-lying areas, typically referred to as the floodplains. As a consequence, this creates a sudden discharge of water into the adjacent lands leading to flooding.

Dams in rivers may also at times overwhelm rivers when the carriage capacity is exceeded, causing the water to burst and get into the floodplains. Flood caused by river overflow has the potential of sweeping everything in its path downstream.

Impact of flood on Agriculture

- Destroy soil structure (causes of soil erosion)
- Destroy crop land and remove growing crops
- Form gully in the crop fields
- Remove the fertile soil from the uplands
- Burial of fertile bottom land with infertile upland
- Uprooted perennial crops from the field etc…

Question 6.4:

- Do you have any other impact of flood in your experience at your local area? If so, what copping strategy has been taken?

Drought

- Drought is a climatic hazard that occurs in almost every region of the world including Ethiopia. It causes physical suffering, economic losses, and degradation of the environment.

Type of drought

- Meteorological drought is an expression of rainfall departure from normal over some period of time. Meteorological drought definitions are usually region specific and are based on a thorough understanding of the climatology of the region.
- Agricultural drought occurs when there is not enough soil moisture to meet the needs of crops at a particular time.

- Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir, and groundwater levels.

Effect of Drought on Agriculture

- It results in less water in the soil, in the streams, and reservoirs,
- less water for livestock and wildlife,
- Reduce crops yield and poor performance of pastures.
- Depressed farm income, closure of farm-supporting industries,
- Cause livestock's mortality

Question 6.5:

What are locally used techniques for drought protection?

The most widely used indices for drought monitoring

Percent of Normal $= {x_i}/{\bar{x}} * 100$

Drought year < 75 percent

Drought-prone area > 20 percent

Chronic Drought-prone area > 40 percent

Table 6.1: drought threshold

Class	Rang
Moderate Drought	Seasonal Rainfall -26% to -50% of the normal
Severe Drought	Seasonal Rainfall -< - -50 % of the normal

Deciles

To avoid some of the weaknesses within the "percent of normal" approach developed the technique of ranking rainfall values in deciles as an indicator of drought. The rainfall occurrences over a long-term precipitation record are divided into sections for each ten percent of the distribution.

Table 6.2: Deciles range and moisture threshold

Decile range	Percent value	Classification
Decile 1-2	Lowest 20% values	Much Below normal
Decile 3-4	Next 20% values	Below normal
Decile 5-6	Middle 20% values	Near normal
Decile 7-8	Next highest 20% values	Above normal
Decile 9-10	Highest 20% values	Much above normal

Dependable Rains (DR*)*

Dependable rainfall is defined as the rainfall depth X is the amount of rain that can be expected or might be exceeded in a given period for a specific probability, it refers to the minimum amount of rain one can rely on during the reference period, and therefore is often denoted as 'dependable rainfall' in agriculture / irrigation sciences.

Standardize Precipitation Index (SPI)

SPI is calculated by taking the difference of the precipitation from the mean for a particular time scale and then dividing by the standard deviation.

Table 6.3: Standardize Precipitation Index

SPI Value	Moisture Category
2.0 and Above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0 to -0.99	Near Normal
-1.00 to - 1.99	Moderately dry
-1.50 to – 1.99	Severely dry
-2.0 or less	Extremely dry

Water logging

When the conditions are so created that the crop root-zone gets deprived of proper aeration due to the presence of excessive moisture or water content, the tract is said to be waterlogged. To create such conditions it is not always necessary that underground table should enter the crop root-zone. Sometimes even if water table is below the root-zone depth the capillary water zone may extend in the root-zone depth and makes the air circulation impossible by filling the pores in the soil.

Causes of Water logging:

- Inadequate drainage of over-land run-off increases the rate of percolation and in turn helps in raising the water table.
- The water from rivers may infiltrate into the soil.
- Seepage of water from earthen canals also adds significant quantity of water to the underground reservoir continuously.
- Sometimes subsoil does not permit free flow of subsoil water which may accentuate the process of raising the water table.

Effects of Water logging:

- Creation of Anaerobic Condition in the Crop Root-Zone: Excessive moisture content creates anaerobic condition in the soil. The plant roots do not get the required nourishing food or nutrients. As a result crop growth is badly affected.
- Growth of Water Loving Wild Plants: When the soil is waterlogged water loving wild plant life grows abundantly.
- Impossibility of Tillage Operations: Waterlogged fields cannot be tilled properly.
- Accumulation of Harmful Salts: The upward water movement brings the toxic salts in the crop root-zone.
- Lowering of Soil Temperature: The presence of excessive moisture content lowers the temperature of the soil. In low temperature the bacteriological activities are retarded which affects the crop growth badly.
- Reduction in Time of Maturity: Untimely maturity of the crops is the characteristic of waterlogged lands. Due to this shortening of crop period the crop yield is reduced considerably.

Solution to the Problem of Water logging:

- Controlling the loss of water due to seepage from the canal
- Preventing the loss of water due to percolation from field channels
- Augmentation of outflow and prevention of inflow
- Quick disposal of rainwater

Pest and Disease

The extent of crop injury inflicted by pest and diseases varies from year to year. When pest rapidly increases in number, effective control measures should be taken. In order to set good and effective controlling scheme, we should to develop and put methods which enable us to predict the likely occurrence of pest and disease at areas of interest.

The major methods to predict the formation of pest and disease

- Weather condition occurring during the periods between two adjacent growing seasons: *Weather condition for the period between two consecutive growing seasons determines whether pathogens or their vectors survive.*
- Weather condition for the growing season: The growing season weather conditions are very essential factors in predicting a number of plant diseases, providing a major impact on the spread and development of the disease. Predictions are usually based on meteorological data, namely, temperature and Humidity. When these two factors occur in definite combination at a certain moment, the disease outbreak may occur.
- Crop damage at the growth resumption: In this regard, forecasters should take into account the extent of infestation depends on the weather condition for the given period. The level of infestation at initial determines the subsequent disease development.

Effect of Pest and Disease on crop development

- Reduce the performance of crop growth
- Cause complete crop yield failure

Controlling mechanism

In general pest and disease can be monitor in two ways:

Cultural:

- Select pure seed
- Tillage the crop field two times or more
- Avoid weeds as soon as possible
- Picked pest out by hand and destroy them
- Plant pest and disease attractive crops with other host crops

Question 6.6:

What are others controlling mechanisms in your local areas?

Chemicals:

- Use them according to the prescription/implementation manuals

6.5. Mitigation practices on negative impacts of weather and climate in Agriculture

Mitigation is Structural/non-structural measures undertaken to limit the adverse impact of climate and weather.

- The main mitigation practices of weather and climate variability
- Using tailored climate and weather information
- Using mulch reduce los of moisture due to rate of evaporation
- Wind break Against strong wind
- Rain water harvest
- Collect and store forage

Climate risk copping strategies
(e.g. water harvesting, pest and disease management, etc)

Copping strategies with climate risk is the ability the resist the risks associated with climate change.

- These strategies include using of water conservation methods like:
- plastic mulching
- using pond water
- harvesting rainwater during rainy season for usage during dry season
- using pesticide
- improving farming mechanism
- using selected drought resistance seed varieties

There is several adaptation measures that the agricultural sector can undertake to cope with future climate variability and weather.
These include:

- Heater or smoke
- Changing planting dates;
- Planting different varieties or crop species;

- Development and promotion of alternative crops;
- Developing drought varieties
- More use of inter cropping
- Using sustainable fertilizer and tillage practices (improving soil drainage, furrow, etc).
- Improve weed management.
- Utilized water harvesting techniques.
- Improve pest and disease controlling mechanisms.
- Implement new irrigation system or improved the existing ones
- Improved livestock management (Providing housing and shade, change to heat-tolerant breeds, change in stocking rate, altered grazing and rotation of pasture).
- More use of agro forestry practices.
- Improved forest fire management (altered stand layout; landscape planning; dead timber salvaging; clearing undergrowth; insect control through prescribed burning).
- Develop early-warning systems and protection measures for natural disasters.

6.6. Preparation of climate related Disaster Risk and Risk Management Plan

- Disaster risk is usually described as a function of the hazard and the vulnerability context including the resilience of the societal system under threat.
- The purpose of Disaster Risk Management is to reduce the climate related risk and to prepare and initiate an immediate response for disaster hit.

Integrating the use of technology with weather and climate information

To reduce the impact of weather and climate variability, it is advisable to use integrated information and technology. Information include weather, climate and soil data. Technology is use of modern farming equipment and better farming mechanism also includes use of modern weather data collecting systems.

Weather and climate information can used integrating with modern farming technologies like:

- Use of new mechanization tools;
- Using organic fertilizers like compost; and
- Tracing (Horizontal farming).

Impact of extreme climate (high temperature, cold stress, drought, flood, etc) in livestock

Extreme events: - A meteorological event can be described as "extreme" because of its intensity or its frequency.

The main meteorological extreme events that affect livestock in Ethiopia includes hot stress, cold stress, drought, flooding and heavy fall, cause enormous losses of standing forage, livestock. In that respect livestock production is very specific because of its greater vulnerability to climate variability, which can have devastating effects on, grasslands, forests and livestock.

- Extreme High Temperature, influence pest and diseases incidence on forage crops, livestock and poultry.
- Effect of drought on livestock and poultry
- Exposed them for disease
- Reduce livestock and poultry production
- Caused them to migrate searching pasture and water
- Can be a cause of conflict due to scarcity of pasture and water
- Mortality of livestock and poultry

Module 7: Accessing weather and climate information

This module aims to guide participants in assessing weather and climate information products for decision making.

At the end of this module, participants should be able to:

1. Identify the key ways of weather and climate communication systems

2. Understanding weather and climate information accessing from NMA website

7.1. Sources and formats of weather and climate information and selecting the best source of climate information for different application

National Meteorological Agency of Ethiopia established 11 Regional Meteorological Service Centers in each regional state. For example in Oromia region there are three Regional Meteorological Service Centre's namely for western part Jimma, eastern and central part Adamaa and for the southern part Balerobe. In Amhara region there are two Meteorological service centers for western Amhara in Bahirdar and for eastern Amhara in Kombolcha. Where as in the remaining regions there are one Meteorological service centers namely Tigray, Afar, Somali, SNNPR, Benishangulgumuz and Gambella regions.

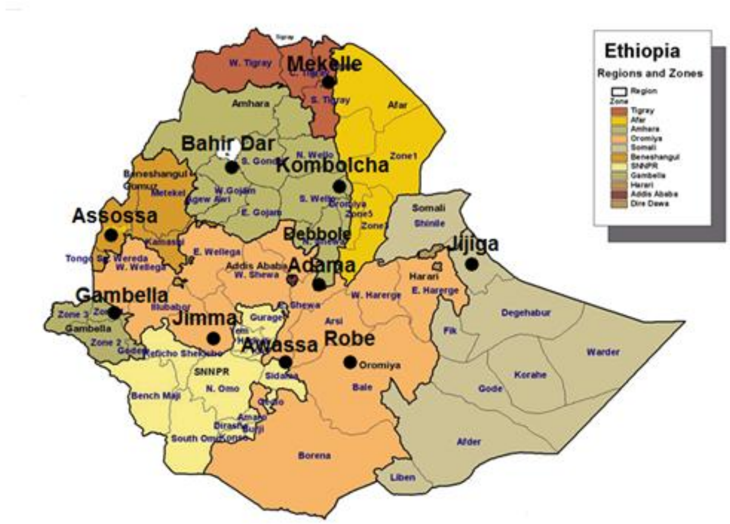


Figure 39: 11 Regional meteorological service centers

The National Meteorological Agency (NMA) has established meteorological service centers in all regional states in addition to the main center in Addis Ababa to disseminate meteorological information to decision makers, users and the public at large. NMA in collaboration with different partners has been implementing different programs that are designed to strengthen weather, climate information and early warning system provisions in Ethiopia for climate resilient development. Different activities have been carried out, especially to create awareness among key stakeholders on the use of weather and climate information and its interpretations using government and private medias.

NMA is consistently disseminating short, medium and long-term forecasts of weather conditions as well as early warnings of extreme events such as flood and drought. for use by different economic sectors and other stakeholders as well as the public at large through different medias. The Government of Ethiopia takes appropriate measures in order to mitigate the negative impacts of such disasters based on the information provided by the NMA. Currently different technologies are used to deliver meteorological information to end users and stakeholders. NMA uses its own audio-visual studio to record and disseminate weather forecasts. It strives to use the latest technologies available to disseminate weather, and climate information such as Radio, Television, Website, E-mail, social media, print media, Bulletins and Newsletters, forum and Press conferences. Press release is also used in the event of severe weather warning. The following are some details on the use of the media.

The print media: Providing Weather and climate information to the needs of the print media is an important task of NMA, because it provides to the public weather forecasts and early warnings physically. Furthermore, it is useful to educate the public on issues related to meteorology, such as weather service provision, steps to be taken to manage risks and mitigate adverse impacts associated with severe weather.

Bulletins and Newsletters: These are Agro-Meteorological, Hydro-Meteorological, Climatological and Health and Climate Bulletins These bulletins provide non-real time information such as weather summaries, rainfall amounts and distribution, temperature values, hydrological and agro-meteorological data, etc. The design and printing are done at NMA for daily, weekly, ten-daily and Monthly issues.

Radio: Radio continues to be one of the most common and important means in disseminating weather and climate information. Many radio stations include weather forecasts in their news programs and some even schedule comprehensive and complete weather segments.
Most radio stations, both public and private, have weather format in their productions. Occasionally climate related information is included in their news bulletins. Few radio stations have weekly-dedicated programs for climate and environment issues.

Television: Television is very popular in Ethiopia as a dissemination medium for public weather products because of its extensive graphics capabilities, powerful visual impact and the fact that it enables viewers to directly assess the severity of an impending event. Many television stations carry weather forecasts and related information as part of their news programs. In Ethiopia there are eight regional, two cities administration and one national television stations. The language coverage includes more than ten local languages and three international languages (English, French, and Arabic).

Users feedback assessment which have been conducted in 2015, indicates that the vast majority of people in Ethiopia get weather and climate information through television and radio. Hence, to make weather and climate information widely and effectively available for the society, there should be an improvement in the content.

Forum: In addition to awareness creation workshops with various socio-economic sectors, NMA has established venue of performance evaluation forum with stakeholders including media both in the Federal and Regional levels on a permanent basis.

- The NMA believes that the comments, critical opinions, and questions raised from users and stack holder during discussion in the forum has great value to improve the quality of NMA's services as well as its delivery mechanism. NMA also obtained better experience and success from the customers & stakeholder's forum, which have been held formally every four months following issuance of seasonal forecasts.

Press conferences: Holding press conferences for mass-medias on Weather forecasting and early warnings on an unusual and extreme weather related events which needs especial attention is the most useful tool used by NMA. On the other hand, NMA organizes and coordinates Press conferences to address requests from media which may have been observed during severe weather incident. In such situations, NMA sends an invitation letter to all public and private media to attend a press conference.

Press release: This is one of the tools which NMA uses:

- To disseminate advise and educational information to the public on weather.
- To provide weather forecast and early warnings on the adverse effects of weather and climate and also to issue official statements to convey information to the Media house on a particular weather related matter.

Internet: The advent of the Internet provided a good opportunity to the international meteorological community in determining how best to tie together its potential for Exchanging, disseminating and relaying of weather and climate information products. It is a very effective way for the National meteorological Agency to make all information and services available to interested parties.

E-mail: This is a quick and efficient method for weather and climate information dissemination for a fixed user or group of users. The drawback is that the recipient has to access the mailbox in a non-real time basis and as a result, this is not a good method for urgent warnings.

Website: A location connected to the Internet that maintains one or more web pages. It is a very important tool used to disseminate information to the public, NMA have launched 24 hours services via website to enable the users to access all meteorological information except raw data.

NMA Website: It avails Meteorological information/services both in Amharic and English language to make the information easily accessible and understandable by national and international users.

- Weather forecasts for major cities are prepared and disseminated for the users using different local languages.
- Active everywhere if internet is available
- Google based maps
- Digital climate analysis tools

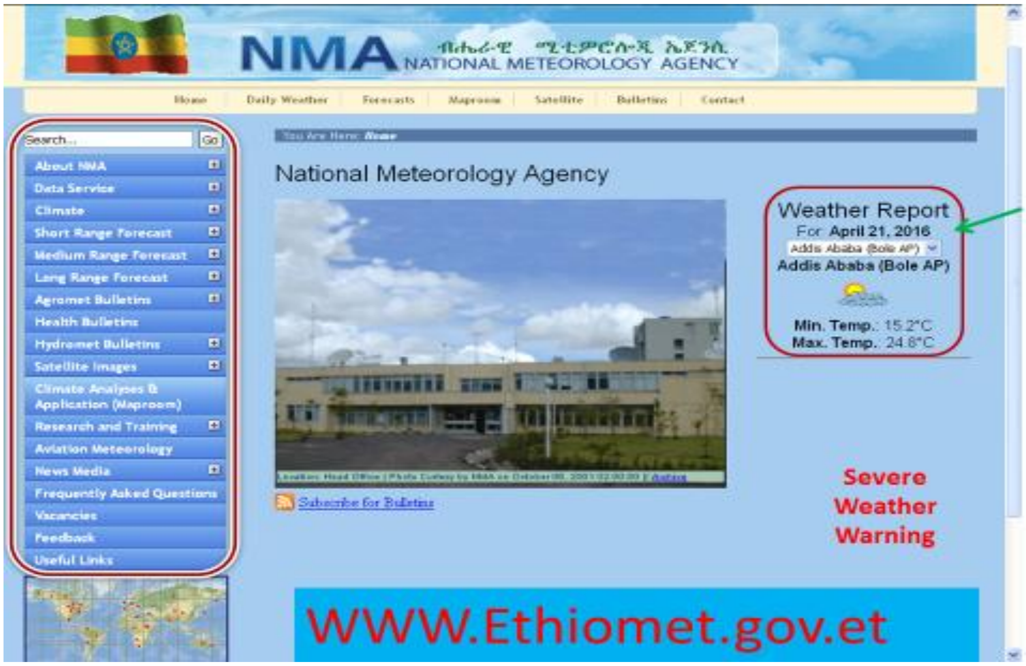


Figure 40: Screen shot of NMA website with contents

Distribution and Density of Media houses in Ethiopia

- According to the information gathered from the Ethiopian Broadcast Authority, there are five print media outlets that are owned by government and a total of 20 (12 magazine+8 bulletin) privately owned print Medias since November 2016 in Ethiopia.
- In the case of broadcast media there are twenty-seven government owned and twenty-three privately owned radio stations, Most of them are FM radio stations.
- There are 44 community radio stations run by different communities in different parts of Ethiopia.
- In Ethiopia so far television stations are owned by government. There are 8 regional TV stations and two cites administration besides the National TV.
- When we see their language coverage more than ten local languages and three international languages (English, French, Arabic) are covered by Medias in Ethiopia.
- Most of radio stations both public, private have weather format in their productions and occasionally cover weather, and climate related issues as news.
- As per the interview with eight magazine editors, none of them have dedicated a page for weather and climate information. The good thing is they have interest to cover if they received readymade articles.

Discussion

- How did you access weather and climate information in your area?
- Which dissemination mechanism is reachable and easily accessible?

References

Aragie, E. 2013. Climate Change, Growth, and Poverty in Ethiopia. Robert S. Strauss Center.

Baede, A.P., Ahlonsou, M. E., Ding, Y., and Schimel, D., (2001). The Climate System: an Over view in Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881.

Common wealth Scientific and Industrial Research Organisation (CSIRO). 1996, Modelling Climate: CSIRO Atmospheric Research Greenhouse Information Paper. Australia 1996. http://www.dar.csiro.au/publications/info98_4.htm.

Gashaw, T., et al. 2014. Climate change and livestock production in Ethiopia, Journal for Advances in Life Science and Technology, Volume 22.

Giorgis, K. 2010. Agricultural based Livelihood Systems in Drylands in the Context of Climate Change, FAO ENRM Working Paper.

Kiehl, J. T., and K. E. Trenberth, 1997: Earth's annual global mean energy budget. Bull. Amer. Met. Soc., 78, 197-208.

Luseno**,** W. K., J. G. McPeak**,** C. B. Barrett**,** P. D. Little**,** and G. Gebru.2003. Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Development* 31(9): 1477-1494.

Ministry of Environment and Forest. 2015. Second National Communication to UNFCCC.

United States Embassy. 2016. The Humanitarian Response of the USG to the Current Ethiopian Drought.

USAID. 2013. Ethiopia Climate Vulnerability Profile.

USAID. 2015. What Power Africa Means for Ethiopia.

World Bank. 2011. Ethiopia Climate Risk and Adaptation Profile.

World Health Organization. 2015. Ethiopia Statistical Profile.