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Meteorological Drought Assessment using GeoCLIM: Case Study East and West Hararghe, Oromia, Ethiopia

Abdisa Hirko[1], Gezehagn Mergia[1], Asalifewu Nigussie[1] and Tilahun Dandesa[2]

[1]*National Meteorology Agency of Ethiopia Eastern and Central Oromia Meteorological Services Centre, Adama, Ethiopia*

[2]*Oromia Bureau of Agriculture and Natural Resource, Addis Ababa, Ethiopia*

***Corresponding Authors:** **Tilahun Dandesa,** Oromia Bureau of Agriculture and Natural Resource, Addis Ababa, Ethiopia*

Abstract: *Drought is a hazardous and costly natural phenomenon with slow on-set that has dreadful impacts on economy, social life and environment of a country or region. The fact that it is slow on-set and is not quite distinguishable in when is it started or when ended makes the phenomena difficult to study (Hammouri and Naqa, 2007). Drought appears when rainfall in a region is less than statistical multi-year average for that region over an extended time period (Malaet al., 2014). It is a normal climatic event but its effect varies from region to region. There are four types of drought namely; meteorological drought, agricultural drought, hydrological drought and socio economic drought (Rathore, 2009). Meteorological drought is deficiency of rainfall which can be observed immediately (Panu andSharma, 2002). Although drought is a natural occurring recurrent extreme event (Wilhite, 1993; Shatanawi* et al., *2013), various empirical and modelling studies proved that climate change is very likely to increase the magnitude, frequency and duration of droughts over some parts of the world in the coming decades (IPCC II, 2014, Degefu and Bewket, 2013).*

In recent years, Geographical Information System (GIS) and GeoCLIM Tool have played a key role in studying different types if hazards either natural or man-made. This study stresses upon the use of GeoCLIM Tool in the field of Drought Risk assessment. In this study an effort has been made to derive spatial temporal drought risk areas facing as meteorological drought by GeoCLIM Tool and meteorological based Standardized Precipitation Index (SPI). Analysis was performed on CV, SPI, and average rainfall anomaly. SPI values were interpolated to get the spatial pattern of meteorological based drought. In the study period 25% was Very severe drought year while 75% were slight to severe drought categories. It was evident from the study that western and east tip of the study region were exposed to high frequency of severe and very severe droughts at annual time scale. Very severe droughts were more pronounced in areas where their altitude is above 1,520m-3,275m masl. Increasing tendencies of drought were observed during recent year. The results obtained can be helpful for drought management plans and will help in revealing true drought situation in the area.

Keywords: *SPI, Drought, GeoCLIM, Annual, Seasonal and Frequency*

1. INTRODUCTION

Drought is a hazardous and costly natural phenomenon withslow on-set that has dreadful impacts on economy, sociallife and environment of a country or region. The fact that it is slow on-set and is not quite distinguishable in when is itstarted or when ended makes the phenomena difficult tostudy (Hammouri and Naqa, 2007). Drought appears when rainfall in a region is less than statistical multi-yearaverage for that region over an extended time period (Mala*et al*., 2014). It is a normal climatic event but its effect varies from region to region. There are four types of drought namely; meteorological drought, agricultural drought, hydrological drought and socio economic drought (Rathore, 2009). Meteorological drought is deficiency ofrainfall which can be observed immediately (Panu andSharma, 2002). Agricultural drought is measured in termsof deficiency in soil moisture, rainfall, ground water and reduction in crop yield (Wilhite, 2000). Hyrologicaldrought is deficiency in water availability in surface and subsurface water reservoirs. While, socio-economic drought is final phase of drought that is caused by prolongshortage in agricultural production and food thus affectingoverall economy (Linsley *et al*., 1975). It is expected that drought will get worse with the overall climate changescenario and the drought affected areas are also expected toincrease spatially. But, like all other natural hazards, drought impacts can be mitigated through early detection (Sruthi and Aslam, 2015). Generally, significant deficiency of precipitation from normal over an extended period of time results in plant water stress or agricultural drought in dry land semi-arid areas where most part of East and West Harerge is situated.

To assess drought conditions in an area, different drought indices are used. Major drought indices use parameters like rainfall, vegetation and land surface temperature, soil moisture etc. (Mala *et al*., 2014). The main objective of this study is to identify occurrence of Meteorological Drought in East & West Hararge by using GeoCLIM and GIS. While sub objectives are; spatial and temporal analysis of overall drought patterns in the East & West Hararge. Analyze annual meteorological drought pattern over part of provinces and identify strength, frequency, recent and past Meteorological drought.

The GeoClim is a program designed for climatological analysis of historical rainfall and temperature data. The GeoClim provides non-scientists with an array of accessible analysis tools for climate-smart agricultural development. These user-friendly tools can be used to obtain and analyse climate data, blend station data with satellite data to create more accurate datasets, analyse seasonal trends and/or historical climate data, create visual representations of climate data, create scripts (batch files) to quickly and efficiently analyse similar “batches” of climate data, view and/or edit shapefiles and raster files, and extract statistics from raster datasets to create time series.

1.1. Scope of the Study

All areas are a complex and vast for all provinces in Ethiopia that could not do on one simple paper and the same is true to assess all drought types. For this reason; the scope of the study delimited on annual Meteorological drought assessmentusing GeoCLIM to analysis and interpret its strength, frequency, and distribution over East &West Hararge province.The study only used GeoCLIM dataset due to uneven long year station data over the parts of study area *(Figure1)*.

- Blend station information with satellite data to create improved datasets
- Analyze seasonal trends and/or historical climate data
- Analyze drought for a selected region by calculating the standardized precipitation index
- Create visual representations of climate data, create scripts (batch files) to quickly and efficiently analyze large quantities of climate data
- View and/or edit shape files and raster files, and extract statistics from raster datasets to create time series.

The CHIRPS dataset and the GeoCLIM tool were used to estimate SPI for the months, seasonal and annual. Spatial rainfall average was obtained for every year for each of the Hot spots identified.

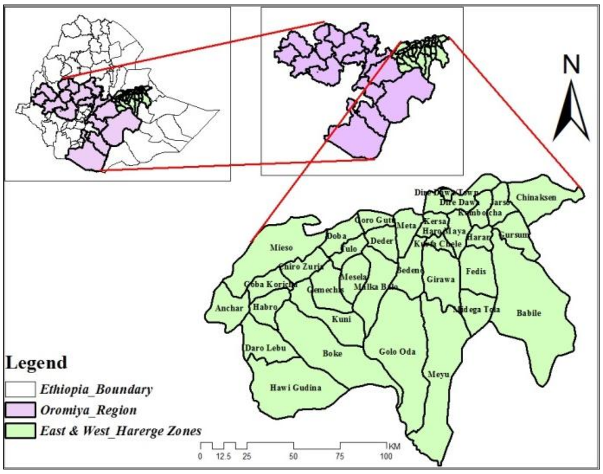
1.2. Objective of the Study

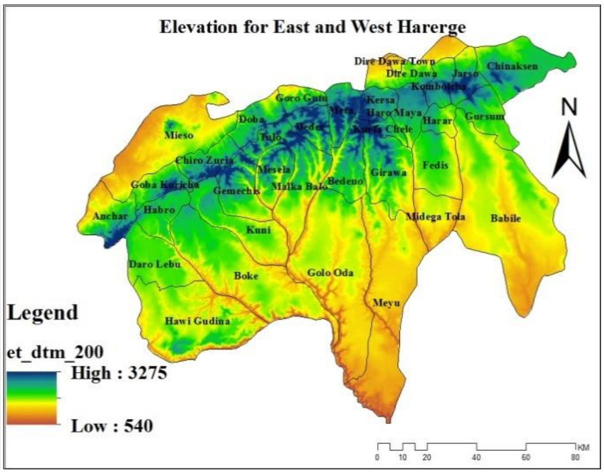
- The main objective of the study is to identify occurrence of Meteorological Drought
- To analyze annual meteorological drought pattern over parts of provinces
- To identify strength, frequency, recent and past Meteorological drought

1.3. Study Area

East& West Hararge is among the eighteen provinces in Oromia regional state, Ethiopia which are situated in the Eastern part of the region. It lies between 40^0 03’N to $7^0$52’N latitude and 42^0 98’E to 9^0 79’E longitude, including different woreda (*Figure1*). Its altitudes range from 540m-3275m.The capital city of Harer which is located at a distance of 519Km from Finfine(Addis Ababa) and covers an area of 23,525 km^2 area coverage which consists of 67% lowland, 25% midland, and 8% highlands*(East and West Harerge Socio-economic Office)*. The capital of West Hararge zone is Chiro Town which is located at a distance of 326 Km from Finfine (Addis Ababa) and the total area of the West Hararge Zone is 17535 km^2. The average annual rainfall of East and West Harerge ranges between 530 and 1100 mm and CV over most parts of area ranges from 21-30%, with considerable spatial and temporal variability in quantities and distribution *(Figure3 & 4)*.The average annual temperature ranges between

13^{0}C to 28^{0}C and is characterized by erratic rainfall and recurrent failure of crops. Besides, in recent years the frequency of rain failures has increased in most of the woredas, especially in lowland areas.The zone is bounded by east Shewa, Arsi zone & Afar in the West, Bale zone in the south, East Somali regional state and Dire Dawa Administration in the north.*(Figure1&2) &(East and West Harerge Socio-economic Office).*





Fiaure1. *Studv area Location* ***Figure2.*** *East and West Hararge Province Elevation.*

2. DATA AND METHODOLOGY

Drought events result from a prolonged lack of precipitation. Depending on the timescale of these dry periods, they have impact on different water resources: meteorological conditions and agriculture are affected by relatively short timescales, while streamflows and reservoirs start to be affected by precipitation anomalies longer than 6–12 months. The SPI was created to account for this large temporal variation of the dry periods, and to better analyze different impacts produced. Its calculation depends only on the monthly precipitation record from a specific location. This record is fitted to a probability distribution and normalized, so positive (negative) values of SPI indicate values greater (less) than the median precipitation across the location. The greatest strength of this index is the ability to quantify precipitation anomalies inmultiple timescales, assessing different hazards such as meteorological droughts (1–2 months).

Drought events are divided into four categories according to SPI values: Very severe drought (extreme) (SPI ≤ -2.00), Severe drought (-1.50 > SPI >-1.99),Moderate drought (-1.00 > SPI >-1.49) and Slight drought(0 > SPI >-0.99).

Table1.1. *Drought Severity Class.*

SPI Value	Drought Severity Class
Above 0	No drought
0.0 to -0.99	Slight drought
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 and less	Very severe drought

2.1. Data Analysis and Result

The analysis with inputs of GeoCLIM Tool using Chirps Rainfall data mentioned below on (figure3, 4 & 5)was done to identify annual Meteorological drought and CV over the province.

a. Overview of GeoCLIM

The GeoClim is a program designed for climatological analysis of historical rainfall and temperature data. The GeoClim provides non-scientists with an array of accessible analysis tools for climate-smart agricultural development. These user-friendly tools can be used to obtain and analyse climate data, blend station data with satellite data to create more accurate datasets, analyse seasonal trends and/or historical climate data, create visual representations of climate data, create scripts (batch files) to quickly and efficiently analyse similar "batches" of climate data, view and/or edit shapefiles and raster files, and extract statistics from raster datasets to create time series.

b. Scale of Application

GeoClim can be used to evaluate any climate time series from a single observation location to multiple stations distributed across large regions.

c. Data Requirements

GeoClim accepts a variety of data types, including shapefiles, raster files, and formatted text files. Each of these files types must be formatted as time series of climate variables – precipitation and temperature.

d. User Community, Support, and Licensing

GeoClim is freely available from FEWS NET and includes a user manual as well as several online tutorials.

e. Application within the Participatory Process

GeoClim can be used to evaluate and visualize trends in climate over recent historical periods and to assess the magnitude of projected changes (drought)in climate. Thus, within the participatory process it may be used in:

- **Assessing the Situation**

f. GeoClim Highlights

- Blend station information with satellite data to create improved datasets
- Analyze seasonal trends and/or historical climate data
- Analyze drought for a selected region by calculating the standardized precipitation index
- Create visual representations of climate data, create scripts (batch files) to quickly and efficiently analyze large quantities of climate data
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The CHIRPS dataset and the GeoCLIM tool were used to estimate SPI for the months, seasonal and annual. Spatial rainfall average was obtained for every year for each of the Hot spots identified.

i. Pixels and Image Resolution

▪ Pixels are different sizes e.g.

○ CHIRPS pixel = 0.05 degrees ~ 5 km

○ ETa pixel = 1 km

○ eMODIS NDVI pixel = 250m

▪ The smaller the pixel, the finer the image, the more spatial information is in the image, and the closer you can zoom into the image

Images with smaller pixels are said to have higher resolution

2.2. Standard Precipitation Index (SPI) Computation with GeoCLIM Tool

SPI was designed to quantify the rainfall deficit for multiple timescales in the studied area using GeoCLIM Tool used chirps data and we used CHIRPS pixel = 0.05 degrees ~ 5 km. The SPI is a z-score and represents the drought event departure from the mean, expressed in standard deviation units. SPI is a normalized index in time and space. This feature allows comparisons of SPI values among different locations. Although SPI can be calculated from 1 month up to 72 months, 1-24 months is the best practical range of application (Guttman, 1999; WMO, 2012). We, therefore, computed the SPI values at 12 months or annual (SPI-12). The SPI-12 was used to assess droughts which used to assess the annual drought. Positive SPI values indicated greater than mean rainfall and negative values indicated less than mean rainfall.

2.3. Annual Average Rainfall and CV for East & West Hararge from 1990-2018 years

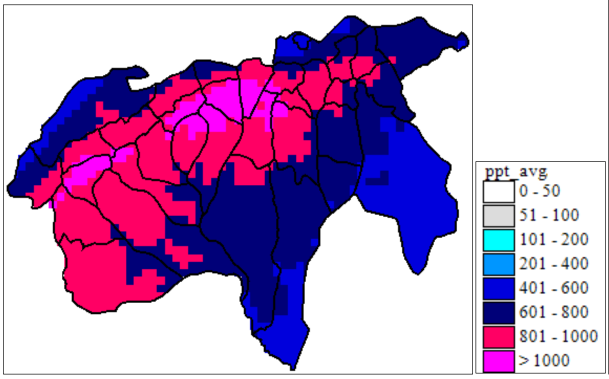


Figure3. *Annual average rainfall (mm)*

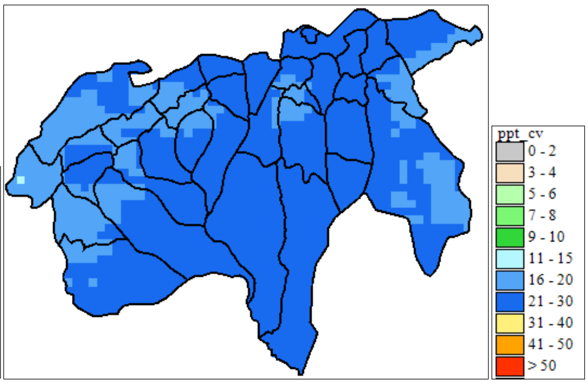
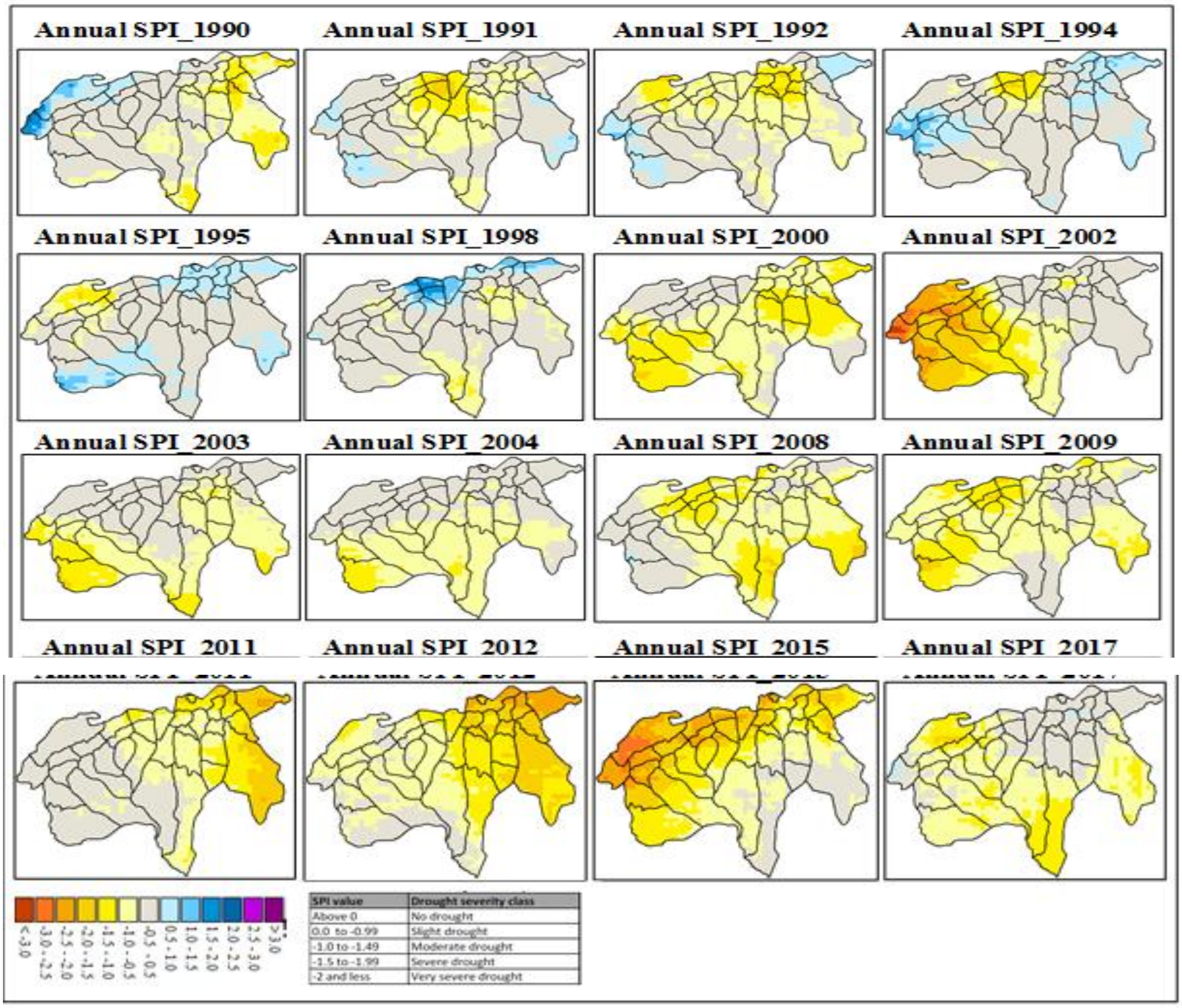


Figure4. *East and West Harerge ProvinceCV.*

The maximum average rainfall is over Highland whereas minimum average is over lowland of the study area. CV is in the range of moderate threshold over the study area (Figure3 & 4).



SPI value	Drought severity class
Above 0	No drought
0.0 to -0.99	Slight drought
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 and less	Very severe drought

Figure5. *Spatial distribution of drought incidences*

According to spatial analysis SPI 1-12 obtained (annual) from the GeoCLIM Tool, 16 Slight –Very severe drought events occurred in the period 1990–2018 in the province of East &West Hararge. The most important events were in the 2002, 2011, 2012 & 2015's, (all reached the very severe threshold); in the 1990', 1991's, 1992's, 1994's, 1995's, 1998's, 2000, 2003, 2004, 2008, 2009 and 2017 areas of province were slight to severe threshold.In recent year frequent number of events, with greater SPI values, as can be seen in (Figure5.).

3. CONCLUSION

In this study, a brief drought analysis was presented using GeoCLIM Tool. It is a very important tool for quantifying drought and comparing its characteristics over time and space. We used SPI, in this study, to examine the magnitude and frequency. Here, droughts occurrences were analyzed at 12-month time scales (Figure5). Though almost parts of province in the study region suffer from drought, it is important to consider that all parts of province did not experience well-defined drought episode during the same periods. In other words, temporal distribution and frequency of droughts varied markedly among each parts of province.Very severe droughts were more pronounced in areas where their altitude is above 1300-3,275masl. Similarly, areas in western and east tip of the study region were exposed to high frequency of severe and very severe droughts at annual time scale (Figure5). Some of the drought years in the study province identified by this GeoCLIM Tool analysis were among the worst drought years in the history of Ethiopia. The year 2002, 2012 & 2015, for example, was the most drastic and distinct-wide drought episode. Almost both province experienced extreme magnitude drought at annual timescales in the specified year. Generally, the entire study area can be considered as drought prone area. Increasing tendencies of drought were observed during recent year (Figure5). The patterns of drought events in the study area are highly localized.

The findings of this study have implications for drought management, early warning system, preparedness and contingency planning and climate change adaptation. In real sense, drought is a climatic event that cannot be prevented very easily, but interventions and preparedness to drought can help to cope with drought by developing more resilient ecosystems, improving resilience to recover from drought and taking various adaptation strategies like using weather information,water harvesting, making irrigation system moreefficient and a geographical shift of agricultural system.

Special attention (local-scale planning) should be given, while decision makers plan to effectively manage drought

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