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# Temporal Drought Assessment of Lake Hawassa Sub-basin, Central Main Rift Valley basin of Ethiopian

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**Abstract**

Drought is a period of abnormally dry weather sufficiently prolonged because of a lack of precipitation that causes a serious hydrological imbalance and has connotations of a moisture deficiency with respect to water use requirements. The main objective of this research is to find out if Lake Hawassa sub basin is facing drought conditions. Accordingly, a number of objectives were accomplished like analysis of drought occurrence, trends of drought and delineating regions with high vulnerability to drought hazards.

In this study, three temporal drought indices (Standardised Precipitation Index, Reconnaissance Drought Index and Stream flow Drought Index) were used to assess drought using metrological data and stream flow data. DrinC software is used for the analysis of Standardised Precipitation Index, Reconnaissance Drought Index and Stream flow Drought Index. Mann-Kendall test have been used together with the Sen's Slope Estimator for the determination of drought trend and slope magnitude.

Based on this research, Standardised Precipitation Index shows the drought during 1993 is the highest drought (6.87) with duration of four months, Reconnaissance Drought Index shows drought during 2015 is the highest drought (9.32) with duration of seven months and Stream flow Drought Index shows drought during 1982 is the highest drought (20.45) with duration of eleven months. The three indices show a high drought occurrence even if the time of occurrence is different. They also indicate an increasing drought trend within the data years.

The results obtained from this study show that Lake Hawassa sub basin is facing drought conditions. Furthermore, it was concluded that the combination of various indices offer better understanding of drought conditions.

**Keywords:** DrinC; Drought; Lake Hawassa Sub-basin

## Introduction

Climate change is one of the characteristics of natural atmospheric circulation. The effect of fluctuations in the atmospheric elements such as rainfall and temperature are achieved, and environmental phenomena of drought and climate change are integral parts. Numerous studies indicate that the frequency of extreme events such as droughts has increased, particularly in the twentieth century. Major drought events have been reported in the USA, the Horn of Africa, Australia, and southern Europe over the past few [1].

Rain fed farming is the main form of crop production in Ethiopia; like for many of neighboring regions in Africa. However, it is highly variable in most parts of the country both in terms of length of the rainy season and amount of rainfall. Due to this variation, frequent drought has been occurring in various parts of Ethiopia affecting crop production, food market prices and ultimately, the cost of living. Drought is a period of abnormally dry weather sufficiently prolonged because of a lack of precipitation that causes a serious hydrological imbalance and has connotations of a moisture deficiency with respect to water use requirements. The deficiencies have impacts on both surface and groundwater resources and lead to reductions in water supply and quality, reduced agricultural productivity, diminished hydro-electric power generation, disturbed riparian and wetland habitats, and reduced opportunities for some recreation activities [2]. In addition to precipitation, a number of factors play a significant role in the evolution of a drought. These factors include evaporation, which is affected by temperature and wind, soil type and its ability to store water, the depth and presence of groundwater supplies, and vegetation.

Many drought events have been observed and recorded in human history. Drought is the single most important climate related natural hazard impacting Ethiopia from time to time. Knowing where a drought might take place and how severe it is to become is very important for a society in terms of having substantial development. Lake Hawassa sub-basin is located in the central main rift valley basin of Ethiopian. It falls in two administrative regions, Oromia and Southern Nations Nationalities Peoples Region (SNNPR) and has a total area of 1455.22 km² of which 93.6 Km² is the Lake surface areas. In all areas of Lake Hawassa sub-basin widespread drought conditions and crop failures have been common and rain-fed agriculture is yet to provide minimum food requirement for rapidly growing population. We also know that Drought brings a hardship to people in that area and effects to the whole town or region, and even the whole world. Impacts from drought can cause many problems to natural and climate system and human activities by reducing social well-being. Therefore, an intensive scientific research on characterization of drought condition in Ethiopian in general and in Lake Hawassa sub-basin in particular is essential to minimize the risk that comes from drought. In this study, three temporal drought indices calculator (Standardized Precipitation Index, Reconnaissance Drought Index and Stream flow Drought Index) were used to assess drought using metrological data and stream flow data. DrinC software is used for the analysis of SPI, RDI and SDI. Mann-Kendall test have been also used together with the Sen's Slope Estimator for the determination of drought trend and slope magnitude [3].

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## Materials and Methods

### Description of study area

**Location and coverage:** Lake Hawassa watershed is located in the Central Main Rift valley basin of Ethiopian and lies between latitude 6˚48'45"-7˚14'49" N, and longitude 38˚16'34"-38˚43'26"E. The lake watershed falls in two administrative regions, Oromia and Southern Nations Nationalities Peoples Region (SNNPR) and has a total area of 1455.22 km² of which 93.6 Km² is the Lake surface areas obtained from digitized in October 2004. The elevation of the area generally ranges from 1680 m.a.s.l. to 2940 m.a.s.l. comprising escarpments, ridges, plateau, undulating to rolling and dissected plains, depressions, and swamps. The Lake Hawassa watershed contains five sub watersheds: Dorebafena-Shamena, Wedesa-Kerama, Tikur wuha, Lalima-Wendo Kosha and Shashemene-Toga sub watersheds. Lake Hawassa watershed is a Closed-catchment Lake with no surface water out flow. The lake is fed both by few ephemeral streams on the north-west and western side of the catchment and by the Tikur Wuha River, which is the only perennial river, enters Lake Hawassa draining the Cheleleka swamp on the north eastside. From the total area of the watershed 66% of the area is under intensive cultivation out of which 95% small holder cultivation and 5% is mechanized cultivation.

**Climate:** Based on the Moisture Index Classification of climate, the climate of the watershed in general is dry sub-humid in the northern part of the high lands and moist sub-humid in the eastern and southern part of the catchment area. The watershed is characterized by three main seasons [4]. The long rainy season in the summer from June-September is known locally as Kiremt and is primarily controlled by the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ), which lies to the North of Ethiopia at this period. The wet period (locally named as Kiremt) represents 50%-70% of the mean annual total rainfall. The dry period (locally named as baga) extends between October and February when the ITCZ lies to the south of Ethiopia. During March and May, the "small rain" season (locally named as belg) occurs when about 20%-30% of the annual rainfall falls. The average annual rainfall is estimated to be about 975 mm. The mean monthly Temperature varies from 170ºC to 220ºC. The mean maximum temperature is 300ºC. The mean monthly minimum temperature is as low as 90ºC between the months of December to February. The long term mean monthly relative humidity values varies from 53% to 76%. The area receives an adequate sunshine hours of 100 to 200 hours per month from March to October and 200 to 300 hours every month in the dry season [5]. The wind speed data records show that the area experiences moderate and frequent winds. The dry season winds, which are able to cause wind erosion occur some times in the catchment and reaches to the speed about 150 km/day.

**Data availability and analysis:** Monthly precipitation, monthly maximum and minimum temperature and monthly flow data of five stations, namely Hasawita, Yirba Dub, Shashemene, Wondogenet and Hawassa have been collected from the National Meteorological services Agency of Ethiopia. Even if the stations are five, only Hawassa station has long year of data and the data in these stations is continuous. In this study, monthly data from 1973-2016 is used as input for the analysis of SPI, RDI and SDI.

**Drought Indices Calculator (DrinC) setup:** DrinC (Drought Indices Calculator) aims at providing a user-friendly tool for the calculation of several drought indices. Key objective in its design was the widest possible applicability for several types of drought (meteorological, hydrological, agricultural) and different locations. DrinC was programmed in Visual Basic [6]. During the development of DrinC, emphasis has been given on maintaining a simple, comprehensive and user-friendly structure. Two recently developed and two more widely known indices were included in DrinC: the Reconnaissance Drought Index (RDI), the Stream flow Drought Index (SDI), the Standardized Precipitation Index (SPI) and the Precipitation Deciles (PD). In this research only SPI, RDI and SDI are used for analysis.

**Mann-Kendall (MK) and sen's slope setup:** Mann-Kendall (MK) Test has been used together with the Sen's Slope Estimator for the determination of trend and slope magnitude. The Mann Kendall Trend Test (sometimes called the M-K test) is used to analyze data collected over time for consistently increasing or decreasing trends ("monotonic trends") in Y values. It is a non-parametric test, which means it works for all distributions (your data doesn't have to meet the assumption of normality), but your data should have no serial correlation. If your data does follow a normal distribution, you can run simple linear regression instead.

**Drought Indices Calculator (DrinC) input data:** For the SPI calculation, the 44 years precipitation record for hawassa station is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Since SPI is normalized, wetter and drier climates can be represented in the same way [7]. 44 years monthly precipitation data is organized and used as an input for SPI analysis. Precipitation missing data have been filled using station average and normal ratio methods. Double mass curve technique is used to test the consistency and accuracy of rainfall records at all stations. For calculation of RDI, 44 years of precipitation, maximum and minimum monthly temperature data is organized and used as an input for RDI. Drought severity can be assessed through the computation of the Reconnaissance Drought Index (RDI) and more precisely through its standardized form (RDIst). Positive values of RDIst indicate wet periods, while negative values indicate dry periods compared with the normal conditions of the area. Stream flow index (SDI) uses monthly stream flow values. The monthly data available is from 1980-2013(34 years) for Hawassa station. Drought severity can be categorized in mild, moderate, severe and extreme classes [7]. The filling of the missing data among different methods available to estimate missing flow observation data, regression analysis method was used to fill the missing flow data since the good correlation was obtained by this method.

## Result and Discussion

**Month SPI:** Agricultural drought in Hungary was related to SPIs with time scales of 2 to 3 months. Therefore the meaning of the above results is that the watershed experienced extreme drought for three (3) months in the aforementioned years. The consequence is its negative impact on agricultural production in the watershed since SPI-3 drought is associated with soil moisture. The findings suggest crop losses could have occurred during the period which is normally the minor production season. Furthermore, drought intensities are highly variable and become less than -1.0 and greater than 1.0 on several occasions.

**6-Month SPI:** An extreme drought occurred in the year 1973 with a magnitude of -2.45 and a severe drought in the year 1990 and 1999 with a magnitude of -1.86 and -1.52 respectively. For the year of 1973 the seasonal period in which the extreme drought occurred is, October-March. For the year 1990 and 1999 the seasonal period in which severe drought occurred is April-September.

The implication for the SPI-6 drought is low basin flows that can be associated with it. The SPI-6 drought is typically a hydrological drought since it represents surface water availability conditions. This implies that years with negative SPI-6 values had low river flows [8]. The drought years could be connected with low rainfall years and may be attributed to climate change and variability.

**9-Month SPI:** The 9-month and 12-month SPI reflects long-term conditions of drought. WMO state that this time scale can be related to stream flows and reservoir levels. This low stream flows and reservoir levels including ground storage availability indicate there is a low flow regime in the watershed in the indicated drought years [9].

**12-Month SPI:** An extreme drought occurred in the year 2015 with a magnitude of -2.28. The seasonal period in which the extreme drought occurred is, October-September.

Similar to 9-month SPI, 12-month SPI is longer time scales, which relate to stream flows, reservoir levels and long term storage including ground water storage availability, thus resulting in low flow regimes in the watershed. The total monthly drought characteristics in terms of magnitude, duration and severity. The drought during the month of February is the longest drought (9 months) with a magnitude of 11.21 and intensity/severity of 0.80. The highest intensity/severity having a value of 0.92 occurs during the month of december. During december the drought magnitude is 7 months which is less than the longest drought duration which occurs during the month of February. This shows that the longest the drought duration is not necessarily the sever one [10].

Drought frequency distribution (probability of occurrence) 3-month spi drought probability of occurrence

It is clearly observed that the near normal condition occurred most frequently with value of 68% and the extreme drought events occurred least frequently with a value of 2%.

**6-Month SPI drought probability of occurrence:** It is clearly observed that the near normal condition occurred most frequently with value of 67% and the extreme drought events occurred least frequently with a value of 2%.

**9-Month SPI drought probability of occurrence:** It is clearly observed that the near normal condition occurred most frequently with value of 70% and the extreme drought events does not occurred. Among the drought condition that occurred, the moderate drought condition occurred least frequently with a percentage of 7%.

**12-Month SPI drought probability of occurrence:** It is clearly observed that the near normal condition occurred most frequently with value of 64% and the extreme drought events occurred least frequently with a value of 2%. For all the different time scales, the near normal droughts condition occurred most frequently and the extreme drought events occurred least frequently.

## Conclusion

In this research different drought index techniques are used to assess drought in Lake Hawassa sub basin. From the results obtained as an output of Standardize Precipitation Index (SPI), Reconnaissance Drought Index (RDI), literature review and data processing and analysis made in the previous sections, the following conclusions have been made. Based on 44 years of precipitation data, SPI evaluation shows that it is possible to assess the drought magnitude, duration and intensity. The SPI output shows the drought during 1993 is the highest drought (6.87) with duration of four months. There is an increasing annual drought trend within forty four years. Since RDI uses both precipitation and temperature, it is more precise than SPI. The drought during 2015 is the highest drought (9.32) with duration of seven months. During spring, there is an increasing drought trend.

According to SDI, The drought during 1982 is the highest drought (20.45) with duration of eleven months. Increasing trends with a magnitude of 0.077 within thirty four years. From the above three temporal drought index. We can conclude that there is a high drought occurrence even if the time of occurrence is different. The indices also show an increasing drought trend within the data years. From the whole analysis, implementing Integrated Water Resources Management (IWRM), such as mitigating upstream-downstream user conflicts and coordinating between water users, communities and sectors is required to protect or reduce the impact of drought to the community that are found in the sub basin.

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