



Climate Change Repercussions on Meteorological Drought Frequency and Intensity in South Wollo, Ethiopia

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Received: 30 August 2021 / Revised: 5 January 2022 / Accepted: 6 January 2022 / Published online: 27 January 2022
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Abstract

Climate change and drought are the major challenges imposing irreversible damages on humans' livelihoods in the twenty-first century. Drought is one of the highest natural disasters in Ethiopia having major impacts on the environment, economic, and social capital. This study aimed to assess the frequency and intensity of meteorological drought occurrences under the current climate change in North-Eastern Ethiopia. The Standardized Precipitation Index (SPI) is used to compute the frequency and intensity of drought at 3- and 12-month scales based on 39 years (1982–2020) rainfall data. Mann–Kendall test has been used to analyse the trends of meteorological drought events to determine the magnitude of changes. The results of the study revealed that the highest frequencies of extreme meteorological droughts were recorded in between 2003 and 2012 with SPI values from -3.0 to -2.1 . On the other hand, severe meteorological drought incidences were recorded from 1982 to 2012 with annual SPI values of -1.97 to -1.53 and moderate drought were noted in between 2000 and 2012 with SPI values ranging from -1.62 to -0.99 in all-timescales. The results indicated that drought events were more severe in the summer season than in the spring season. The study concluded that the years 2003, 2005, 2009, 2010, and 2012 were the most drastic and distinct-wide drought episode that experienced extreme magnitude drought at all-timescales and the rural livelihoods were affected. Applying climate change adaptation strategies to cope with drought, improving resilience to recover from drought and developing resilient ecosystems are recommended actions.

Keywords Meteorological drought · Trends · Extremes · Seasons · Rural livelihoods · South Wollo zone

1 Introduction

Climate change is one of the world's biggest challenges in the twenty-first century which are affecting livelihoods of rural community. At present, global climate change and its socio-economic impacts are the major issues of mankind. IPCC (2007) shows that the world's surface temperature has been enhanced considerably throughout the last century and can still rise unless greenhouse gases emission are radically reduced. Amendments of climate that are attributed directly or indirectly alter the composition of the world atmosphere (Loukas et al. 2008).

Drought is a natural hazard that results from a deficiency of precipitation such that when it is extended over a season or longer period, the amount of precipitation could be inadequate to meet the needs of humans and the growth of crops (Al-timimi et al. 2012). Put differently, global climate change affects the livelihood of the people associated with drought through increasing temperature and evapotranspiration and reduces the amount of rainfall for the growing of

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crops. This means that droughts occur naturally, but global climate change has generally accelerated the hydrological processes to form their set in quicker and become more intense (Mukherjee et al. 2018). Moreover, the same authors added that drought is an extreme climatic event that is insidious because it develops slowly and sometimes sneaks abreast of one and gradually increases in intensity and duration, which can have major consequences, making it one of the most extensive natural hazards. Scientific literature has commonly classified droughts into four main categories as meteorological, agricultural, hydrological, and socio-economic droughts (Wilhite and Glantz 1985).

Ethiopia is one of the most affected countries by extreme droughts. As an outsized portion of the country is arid or semi-arid and greatly susceptible to drought and desertification, a further increase in temperature and a decrease in precipitation could increase the frequency and intensity of droughts in many parts of the country. Located in the northern Highlands of Ethiopia, the South Wollo Zone experiences increased temperature and reduced rainfalls and is susceptible to drought episodes. Droughts over the region are characterized by unpredictable and appear within 5-year intervals for the last 2 or 3 decades making endanger the growing of crops (Mohammed et al. 2017).

Many studies were conducted by different scholars on drought severity, intensity and spatial variability over Ethiopia and in particular South Wollo zone in the past decades. For example, Gebrehiwot et al. (2011) evaluate the temporal and spatial variability of drought using rainfall and remotely sensed data in arid and semi-arid areas of northern Ethiopia. Likewise, Edossa et al. (2010) employed hydrological and meteorological variables to explore drought characteristics in the Awash River, suggesting the most severe and recurrent droughts happened in the middle-to-lower Awash Basins. They indicated that a recurrent cycle of drought affects the southern Region of Tigray (north Ethiopia) over the last decade. On the other hand, a significant surge in spring drought was found in the eastern lowlands of Ethiopia compared to northern and central highlands.

Moreover, Mohammed et al. (2017) examined the patterns of drought incidence in South Wollo using standard precipitation index, find out a substantial increase in spring drought at a 3-month timescale from 1984 to 2014. Moreover, Bayissa et al. (2015), Bewket and Conway (2007), Mosaad (2015) predicted the meteorological drought occurrence over the river basin of the Blue Nile at different times. Further, Little et al. (2006), Tagel et al. (2011) and Mekonen et al. (2020) also analysed spatial and temporal drought incidents using various drought monitoring indexes in the northern highlands of Ethiopia. Those earlier studies tend to focus either on particular seasons, short-term analysis, and defined drought events, or specific regions based on the data obtained from meteorological stations.

This study focused on assessing the frequency and intensity of seasonal and long-term Meteorological drought occurrences using SPI values of 3- and 12-month time steps based on recent reanalysis data acquired from NASA under the current climate change in Southern Wollo, zone, North-Eastern parts of Ethiopia. The specific objectives were to evaluate the frequency and intensity of meteorological drought events at seasonal and annual based over 39 years and to examine the trends of Meteorological drought occurrences under the climate change conditions over the years 1982–2020.

1.1 Description of the Study Area

South Wollo is one of the eleven administrative zones of the Amhara National Regional States of Ethiopia located in between 10°10' N and 11°41' N latitudes and 38°28' E and 40°5' E longitudes (Fig. 1). The total area of the zone is about 18,157.48 km², which is divided into 19 rural districts and 4 administrative towns (Dessie, Kombolcha, Haik, and Mekaneselam). Of the total area, 36.3%, 13.5%, 18.3%, and 31.9% are covered by arable land, forest, bush-lands, grazing land, and others (e.g. bare land, buildings, water bodies), respectively (Mekonen et al. 2020).

The landscape of the South Wollo zone encompasses highly varied and dissected topography (rugged terrain with very steep slopes). Elevation varieties from 927 m (over the dry plain/*Arabat*) within the east to 4261 m above sea level (Mount *Ambaferit*) in the west (Little et al. 2006). However, highland areas ranging between 1500 and 3500 m altitude are the dominating feature of South Wollo (Mekonen et al. 2020).

Taking into consideration of the vertices of topographies, the study area experiences a special climate that ranges from hot and arid lowlands in the eastern part to cold and humid highlands in the western part of the region. The region has six livelihood zones, namely, Abay-Beshilo Basin (ABB), Chefa Valley (CHV), Meher-Belg zone, Belg zone, Meher zone, and Eastern Lowland Sorghum and Cattle (SWS) (USAID 2009 cited in Mekonen et al. (2020).

As Mohammed et al. (2017), the mean annual temperature varies from 5 °C in the western highlands to 22 °C in the eastern lowlands. The annual rainfall varies between 1000 mm within the western to 1200 mm in the eastern part. A bimodal rainfall pattern with shorter spring (March–May) and longer summer (June–August) characterizes the study area which ends up in two harvest periods. The spring season is extremely influential for mid to high-latitude areas, whereas the midlands to lowland areas mainly depend upon the summer rain. Apart from a couple of pocket areas where small-scale irrigation is practiced, crop production is rain-fed.

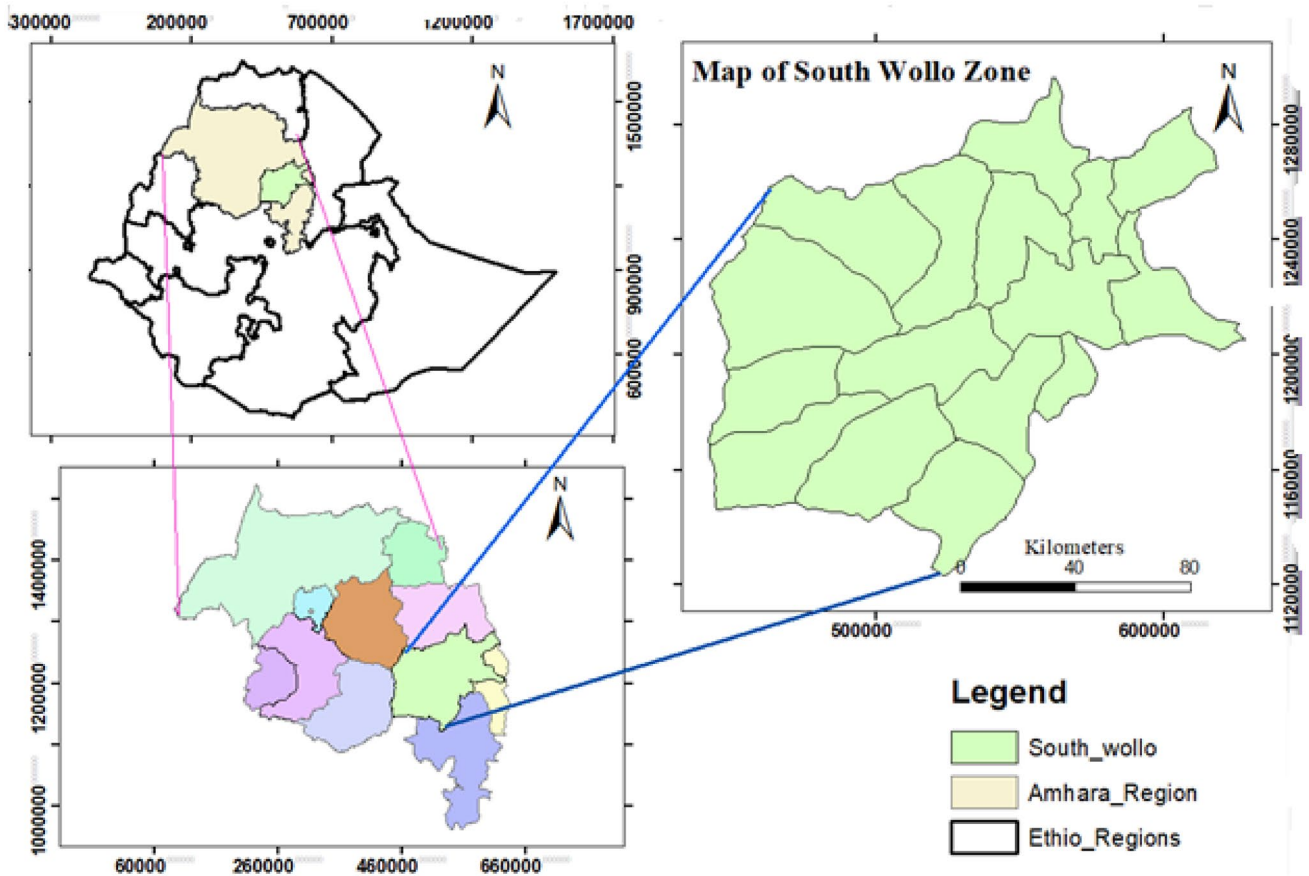


Fig. 1 Map of the study area

As the topography is extremely rugged, erosion is a critical problem in the study area. It is highly degraded and devastated in terms of native trees, but does have significant eucalyptus plantations. Alpine species unique to extreme highland areas are found in western highland parts of the study area. Local people are involved in subsistence agriculture for their livelihood. Unlike other areas of East Africa, where highlands generally are the foremost food secure parts of a country, the reverse often is that the case in Ethiopia. The crowded, steep-sloped highlands above 2000 m, including large parts of South Wollo, are among the country's most famine-prone areas (Little et al. 2006).

2 Methodology

Monthly rainfall data for the period (1982–2020) were obtained from the National Aeronautics and Space Administration (NASA) and ground based station used as an input variable to calculate meteorological drought. The data obtained from NASA validation were made by the ground based station data from the period 1984–2013. Different indices are developed through time to quantify the

magnitude of Meteorological drought. Most of those indices are supported by direct observed measurement of climatic variables like rainfall, evapotranspiration, and temperature (Steinemann et al. 2005).

The frequently used indices include the Palmer Drought Severity Index (PDSI), the Percent of Normal, and the Deciles approach, the Standardized Precipitation Index (SPI), Standard Precipitation Evapotranspiration Index (SPEI), Crop Moisture Index (CMI), and Standardized Water Supply Index (SWSI). However, for this study, the Standard Precipitation Index (SPI) was employed for analysing the frequency and intensity of drought in the study area.

As McKee et al. (1993) and Iwata et al. (2015) indicated, the SPI is a powerful, flexible index, and easy to calculate making it the only required input parameter in the calculation of rainfall and temperature anomalies. The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the supply of numerous water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale (WMO 2012).

McKee et al. (1993) used the threshold limits shown within the SPI value (Table 1) to describe drought

Table 1 The SPI values threshold limits and meteorological drought levels. Source: WMO (2012)

2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
– 0.99 to 0.99	Near normal
– 1.0 to – 1.49	Moderately dry
– 1.5 to – 1.99	Severely dry
– 2 and less	Extremely dry

strengths resulting from the SPI. The same authors also defined the criteria for a drought occurrence in any of the timescales. When a drought event occurs anytime the SPI is constantly negative and reaches an intensity of – 1.0 or less. The event ends when the SPI becomes positive. Each drought occurrence, therefore, has a duration defined by its beginning and end, and intensity for every month that the event continues. The positive summation of the SPI for all the months within a drought event is frequently designated the drought's "magnitude" (WMO 2012).

Although SPI can be calculated from 1 month up to 72 months, 1–24 months is the best practical range of application (WMO 2012). The researcher, therefore, computed the SPI values at two timescales, i.e. 3 months (SPI-3) and 12 months or annually (SPI-12). The SPI-3 is used to assess droughts during the spring (Belg) and summer (Kirmet) seasons, which represent the shorter and longer rainy seasons, respectively, and SPI-12 is used to assess the annual drought. Positive SPI values indicated greater than mean rainfall and negative values indicated less than mean rainfall.

Then, the SPI value provides a comparison of the rainfall over a specific period with the rainfall totals from the same period for all the years included in the historical record (Cooper 2010). The rainfall data acquired from NASA were analysed using the standardized Precipitation Index (SPI) using R-studio and Microsoft Excel. Moreover, the rank-based nonparametric Mann–Kendall (MK test) was used to assess the significance of monotonic trends in hydro-meteorological time series analysis. The occurrence of drought within the study area is identified from the SPI statistic multiple-time steps. Therefore, in this study, SPI for 3- and 12-month timescales are computed to study the characteristics of drought in short and long periods. The 3-month SPI is used to describe the spring (March–May) with a short rainy season and summer (June–August) with a long rainy season drought, while the 12-month SPI is used to characterize annual droughts that occur due to rainfall deficit from the normal historical record.

Conceptually, the SPI is equivalent to Z score, the number of standard deviations that the observed value would deviate from the long-term mean. The statistical procedure is:

$$SPI = \frac{X_i - \bar{X}}{\sigma},$$

where X_i = observed precipitation value of the selected period during the i th year; \bar{X} and σ = the mean and the standard deviation, respectively, over the selected period.

On the other hand, the formula for Mann–Kendall trend test is a rank correlation test between the ranks of observations and their time arrangement. For a time series $\{x_t: t = 1, 2, \dots, n\}$, the test statistic S is given by Kendall and Gibbons (1990).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n a_{ij},$$

where

$$a_{ij} = \text{sign}(x_j - x_i) = \text{sign}(R_j - R_i) = \begin{cases} 1 & x_i < x_j \\ 0 & x_i = x_j \\ -1 & x_i > x_j \end{cases}$$

and R_i and R_j are the ranks of observations x_i and x_j of the time series, respectively.

3 Results

Validation results indicated that the data obtained from NASA are highly related with the observed one which were collected from the meteorological service agency (Fig. 2). The trend line of both the observed and the NASA data are in line with and increasing trends.

3.1 Frequency and Magnitude of Drought Events

In the years from 1982 to 2020, about 61% of annual rainfall was recorded in the summer season and 17% in the spring season (Fig. 3). Drought months with different magnitude categories at short- and long-timescales (SPI-3 and SPI-12) are also recorded. Drought months for 3 months (belg and kiremt rainfall) and 12 months (annual rainfall) are calculated using SPI analysis. Drought frequency was measured by the number of years, which experienced negative SPI values in the total time series of 39 years.

3.1.1 Drought Frequency

The total number of drought months at a 12-month timescale (January–December) is found to be 91 months, which constitutes 19% of the total number of monthly records in the study periods. On this timescale, the highest frequency of extreme drought was recorded in the year 2003 with an SPI value of – 3.0. As shown in (Fig. 4), the years 2003,

Fig. 2 Validation of the temperature data from NASA with the observation data

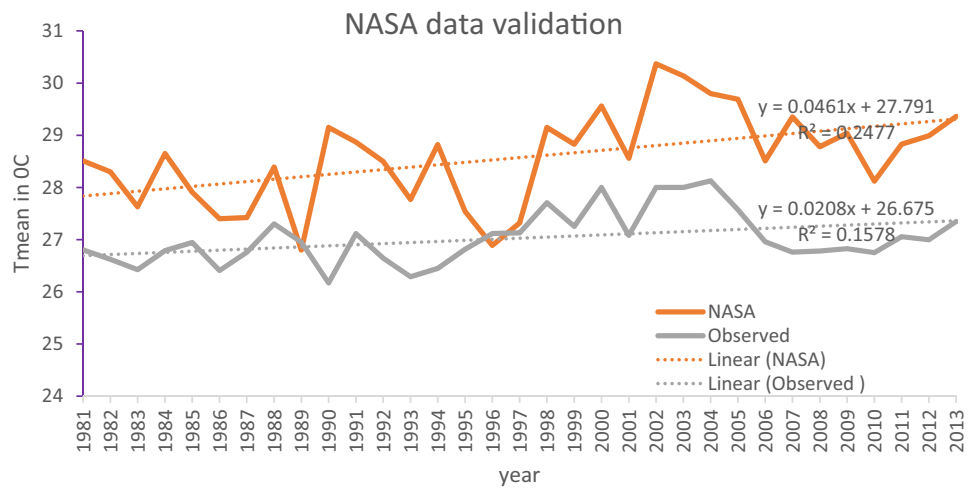


Fig. 3 Total monthly rainfall records in the study area (1982–2020)

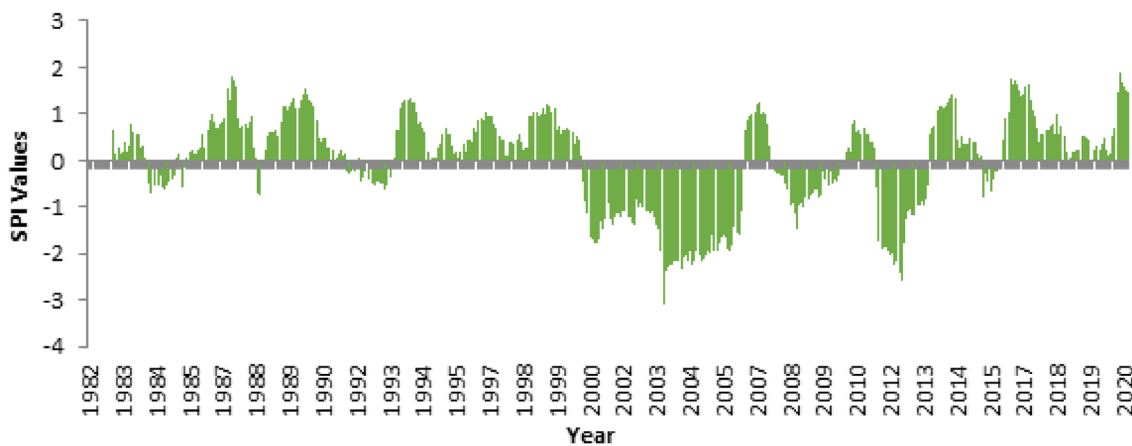
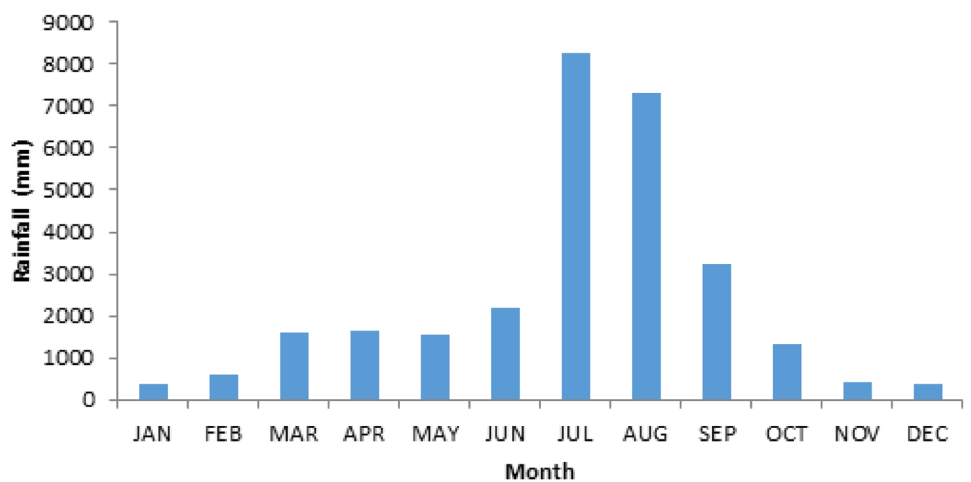


Fig. 4 Annual distribution of drought occurrences/12 months of SPI/(1982–2020)

2004, 2005, and 2012 were the worst drought years across the zone having 24 records (5% of total records) with an SPI value ranging from -3.0 to -2.1 . The total number of

severe droughts at a 12-month timescale was 28 with SPI values from -1.97 to -1.56 which is recorded between 2000 and 2012; the total number of the moderate drought

Table 2 Yearly mean (SPI) drought severity (January–December) in Southern Wollo zone between 1982 and 2020. Source: Authors' compilation

Year	Yearly mean SPI value	Drought severity
2001	− 1.304132525	Moderate drought
2002	− 1.108511342	Moderate drought
2003	− 1.886046172	Severe drought
2004	− 2.113958706	Extreme drought
2005	− 1.844448987	Severe drought
2012	− 1.733105912	Severe drought

was 39 which is 8.3% of the total record with SPI values ranging from − 1.48 to − 0.99 recorded between 2000 and 2012. The rest records are found to be normal and nearly normal.

Considering the yearly average records of the 12-month timescales (Table 2), the year 2004 was an extreme drought year, 2003, 2005, and 2012 were severe drought years and 2001 and 2002 were moderate drought years.

3.1.2 Summer Season Droughts

Taking into consideration of the 3-month timescale, the total number of drought events of the summer season (June–August) in the entire period of analysis was found to be 20 months which was 17% of the total summer months. As shown in Fig. 5, among the records, two are extreme droughts occurred in 2005 with SPI values ranging from − 2.7 to − 2.1. Eight records were severe droughts recorded between 1982 and 2012 with SPI values ranging from − 1.96 to − 1.53, and 10 were moderate droughts occurred between 2002 and 2019 with SPI values ranging from − 1.45 to − 1.

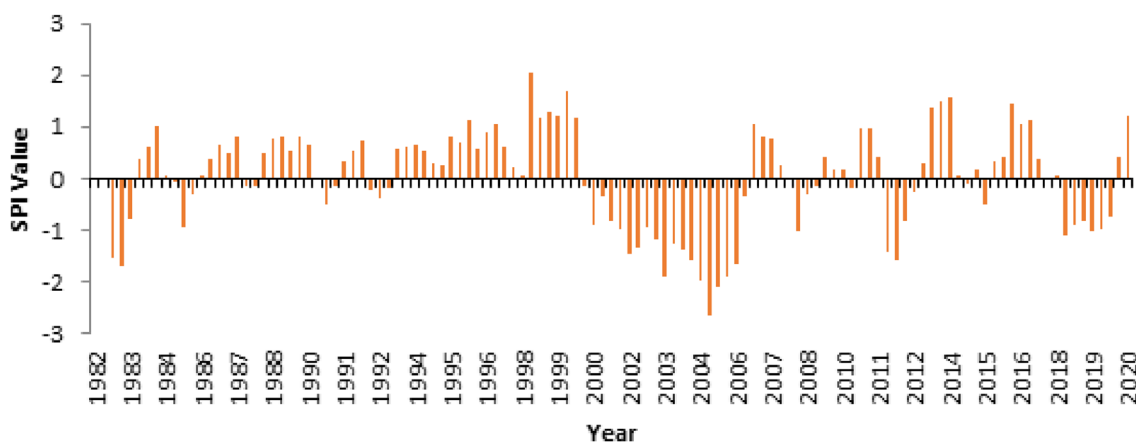


Fig. 5 Seasonal distribution of drought occurrences in summer/3 months SPI/(1982–2020)

3.1.3 Spring Season Drought

The total drought events with extreme, severe, and moderate intensities computed at a 3-month timescale (March–May) with varied magnitude were accounted for 12 observations. Extreme droughts occurred in 1 month in 2009 with SPI values of − 2.46, a severe drought occurred in 2003 and 2010 with SPI values − 1.62 and − 1.49, respectively, and moderate drought recorded in 9 months between 1998 and 2013 with SPI values ranging from − 1.44 to − 1.01 (Fig. 6).

Table 3 showed that the drought severity records for summer (June–August) and spring (March–May) in the study area. Drought occurrence trends for 3-month (spring and summer) and 12-month (annual) timescales were shown in (Fig. 7). SPI values of May, August, and December were considered to represent the drought conditions from March–May (spring season), June–August (summer season), and January–December (annual rainfall), respectively.

Table 3 showed that the total number of drought occurrences is much larger in the summer season than in the spring season over the study periods (1882–2020). There were 20 drought records in the summer season compared to 12 records in the spring season. Considering the drought severity, 10 extreme and severe records were observed in summer whereas only three records of extreme and severe droughts were recorded in spring.

3.2 Trends of Drought Occurrences

The SPI value for 12 months (annual) timescale showed decreasing trends which indicate increasing droughts with negative rainfall anomalies at 1998, 1991–1992, 2000–2005, 2008–2010, 2011–2012 and while positive rainfall anomalies were observed at 1985–1988, 1988–1991, 1994–1999, 2014, and 2016–2017 in the studied period. The trend line of SPI value for 3-month timescale during summer similarly

Fig. 6 Seasonal distribution of drought occurrences in spring/3 months SPI/(1982–2020)

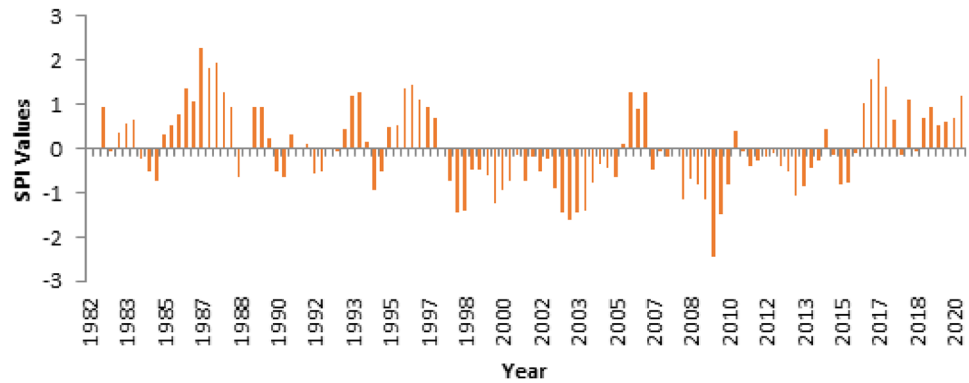


Table 3 Drought severity for the summer (June–August) and spring (March–May) in southern Wollo between 1982 and 2020

Summer (June–August)				Spring (March–May)			
Year	Month	SPI values	Drought severity	Year	Month	SPI values	Drought severity
1982	August	– 1.53089	Severe drought	1998	April	– 1.44213	Moderate drought
1983	June	– 1.69006	Severe drought	1998	May	– 1.3961	Moderate drought
2002	June	– 1.4514	Moderate drought	2000	March	– 1.24826	Moderate drought
2002	July	– 1.35587	Moderate drought	2003	March	– 1.42344	Moderate drought
2003	June	– 1.17632	Moderate drought	2003	April	– 1.62171	Severe drought
2003	July	– 1.9164	Severe drought	2003	May	– 1.43045	Moderate drought
2003	August	– 1.25593	Moderate drought	2004	March	– 1.38034	Moderate drought
2004	June	– 1.38469	Moderate drought	2008	April	– 1.1336	Moderate drought
2004	July	– 1.5839	Severe drought	2009	April	– 1.14408	Moderate drought
2004	August	– 1.95837	Severe drought	2009	May	– 2.45679	Extreme drought
2005	June	– 2.66663	Extreme drought	2010	March	– 1.49203	Severe drought
2005	July	– 2.10943	Extreme drought	2013	April	– 1.0665	Moderate drought
2005	August	– 1.91122	Severe drought				
2006	June	– 1.66415	Severe drought				
2008	July	– 1.01489	Moderate drought				
2011	August	– 1.41208	Moderate drought				
2012	June	– 1.56866	Severe drought				
2018	July	– 1.08062	Moderate drought				
2019	July	– 1.01573	Moderate drought				
2019	August	– 1.00082	Moderate drought				

showed decreasing trends, which indicates increasing occurrences of drought events from time to time across the study area. As shown in Fig. 5, the trend line showed that there is a significant decline, especially from 1984–1985, 2000–2006 and in 2012 extreme and severe drought records.

The computed SPI values for 3-month timescale during spring revealed that the occurrence of positive rainfall anomalies was observed from 1985 to 1988, 1993, 1997, 2006, 2016, and negative rainfall anomalies were recorded 1984, 1990–1992, 2003–2009, 2010, and 2013.

Moreover, the indexes for the consecutive dry days in each year over the 39 years were computed. As shown in (Fig. 8), the trend line showed increasing for the number of consecutive dry days from 1982 to 2020 and extreme outliers were observed in the years 2000 (100 days), 2004

(111 days) and 2012 (117 days). This indicates that in the years with a large number of consecutive dry days (CDD) there were extended dry months with negative rainfall anomalies.

The Mann–Kendall (MK) trend test showed decreasing changes in SPI values, suggesting an increasing tendency of drought incidence at the 3-month timescales during (spring and summer) and at 12-month annual timescale (Fig. 6). The trend showed that there was no statistically significant difference in drought trends, ($p > 0.05$) was observed at all-timescales. Z values for all timescales were negative that showed a decreasing the SPI value trends as a result of increasing drought severity.

Even though trends at all timescales were not statistically significant, increasing tendencies of the drought were

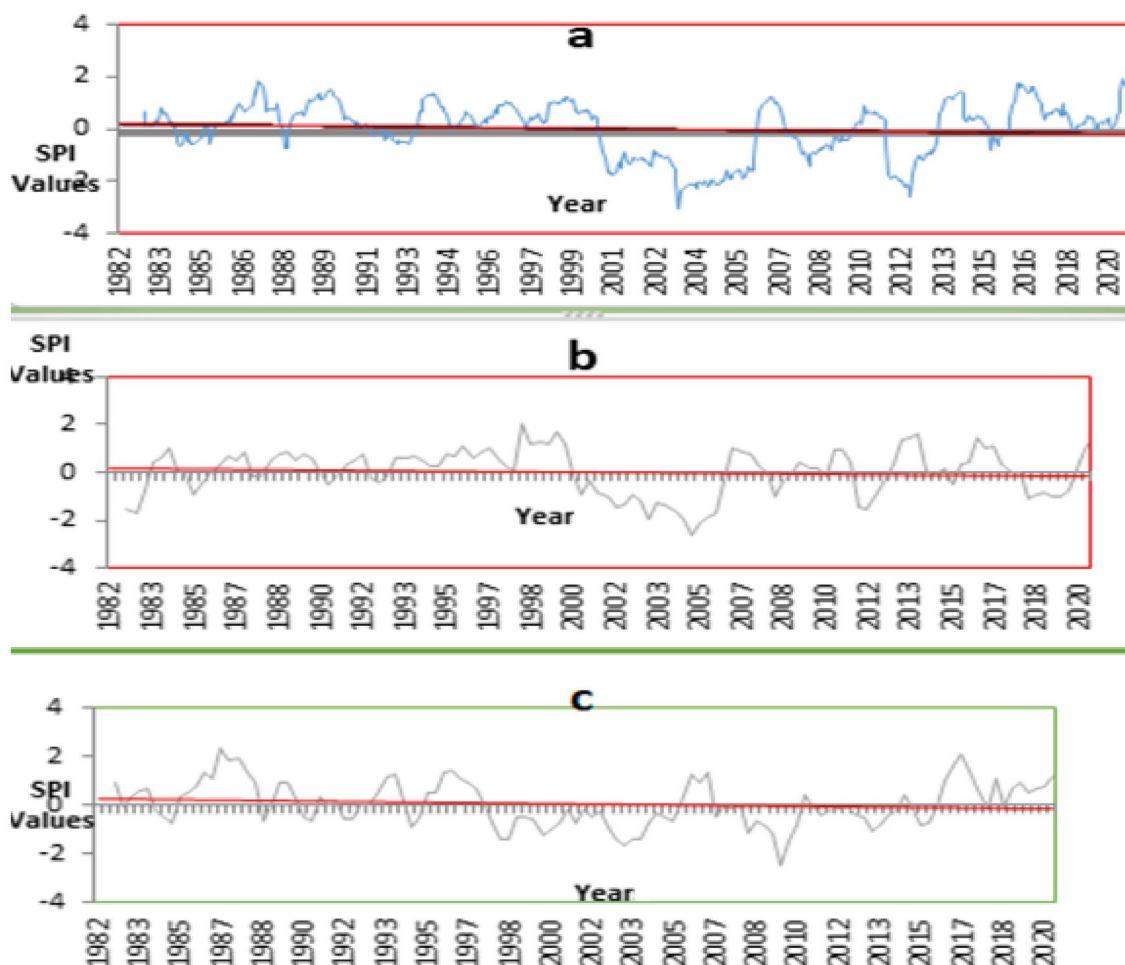
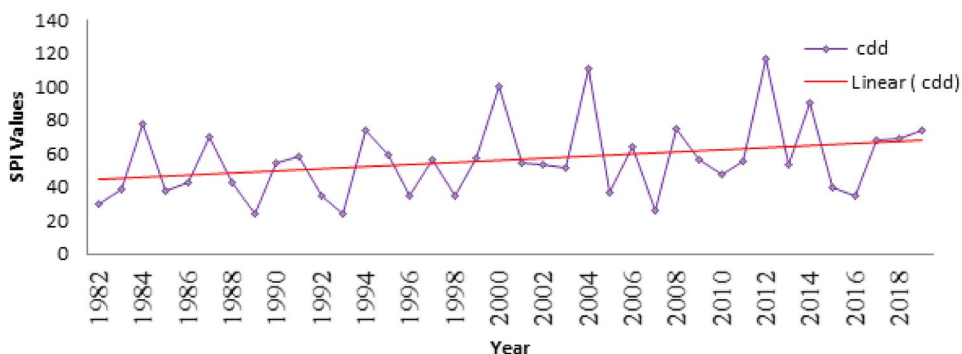


Fig. 7 Drought trends at annual (a), summer (b), and spring (c)

Fig. 8 Trends of continuous dry days in the years 1982–2020 in Southern Wollo



observed during spring, summer, and annual timescales in the study area.

Moreover, the Rainfall and SPI values across the study years are positively correlated to each other. As pertained in (Fig. 9) below, both rainfall and SPI values showed similar either decreasing trends that indicated as rainfall increase the SPI values also increase and approaching positive one and

above that predicts normal or non-drought scenario. But as rainfall decrease, the SPI graph also decreases approaching a negative one and below that indicated drought occurrences.

In this study, a brief drought analysis of annual and seasonal timescales using SPI using R-Studio was presented. Magnitude, frequency, and trends of drought events in South Wollo zone from 1982 to 2020 in 3- and 12-month timescales

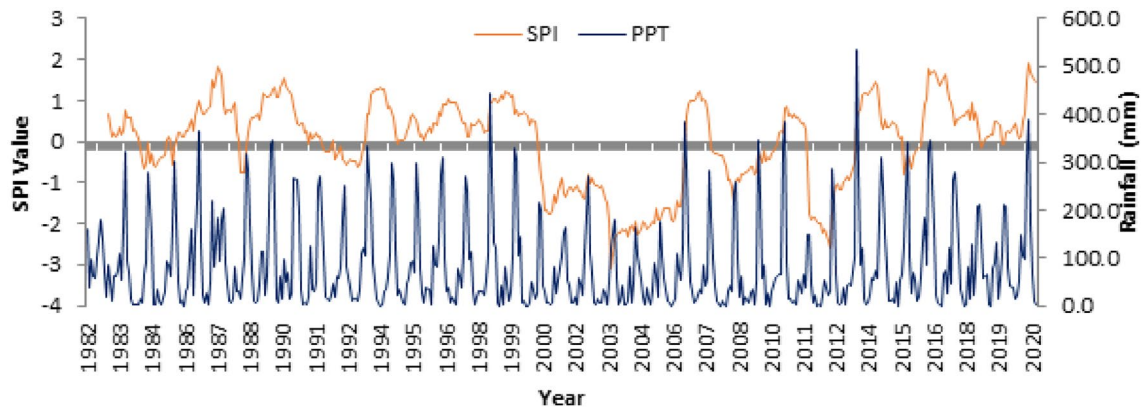


Fig. 9 Trends of SPI and rainfall

were assessed. The study area experiences bimodal rainfall (spring and summer) occurring between March to May and June to August, respectively. Therefore, the SPI at a 3-month timescale for both seasons were computed.

Results indicated that occurrences of drought in South Wollo zone showed temporal variation. The total number of drought events was higher in the summer season than in spring at 3-month timescales (Table 3). Twenty drought records were observed in summer, but in spring only 12 records were observed over the 39 years. This finding agrees with the findings of Mohammed et al. (2017), who found out that the total number of drought events was higher in the summer season than in spring in southern Wollo zone. Summer is the main rainy season in the study area, contributing to more than 61 percent of the annual rainfall (Fig. 2). Failing to rain at this season means a failure of a significant per cent of crop production in the zone.

In the study area, the extreme magnitude of droughts was experienced at all scales over the study years. At the annual scale, the highest frequency of extreme drought was recorded in the years 2003–2012 with an SPI value ranging from -3.0 to -2.1 . The results showed that the years 2003, 2004, and 2012 were the worst drought years across the zone having 24 records (5 percent of total records). In summer seasons (3-month timescales), extreme magnitude drought events were recorded in 2005, with SPI values ranging from -2.7 to -2.1 ; and in the spring season, extreme drought was recorded in 2009 with SPI value of -2.46 .

The study conducted by Viste et al. (2013) supported this result and indicated that the year 2009 was an exceptionally widespread drought year in all zones and at the national level, 2009 was the second driest year in the period, surpassed only by the historic drought year 1984.

Moreover, extreme and severe drought records were larger in summer than spring with 10 and 3 drought records, respectively. The result is in agreement with the reports of NMA (2007) that showed the 2003 El Niño, has resulted

in 2003–4 drought and famine in Tigray and Wollo affected 7.6 million people.

Considering severe drought occurrence, it was recorded between 2000 and 2012 with SPI values ranging from -1.97 to -1.56 at 12-month timescales, from 1982 to 2012 with SPI values ranging from -1.96 to -1.53 in summer and 2003–2010 with SPI value -1.62 and -1.49 in spring. Moreover, moderate droughts were recorded between 2000 and 2012 with SPI values ranging from -1.49 to -0.99 , between 2002 and 2019 with SPI values ranging from -1.45 to -1.00 , and between 1998 and 2013 with SPI values -1.44 to -1.01 annually, in summer and spring, respectively.

The occurrences of extreme magnitude droughts have important implications on rain-fed agriculture (Ellis et al. 2010; Morid et al. 2006). The impacts of the 1984 drought greatly expanded food insecurity, malnutrition, devastated livelihoods, and caused the loss of millions of lives in the region particularly during the summer season.

Moreover, the Rainfall and temperature trend anomalies across the study years are negatively correlated with each other and hence as temperature showed an increasing trend, rainfall showed a decreasing trend in the study area. This finding agrees with the findings (Legesse et al. 2013) who found that the South Wollo Zone, northern highlands of the country could experience increased temperature and reduced rainfalls, and hence become vulnerable to more severe drought conditions.

The most remarkable characteristic of a drought in the study area is the change in its frequency as the timescale changes on shorter timescales, droughts became more frequent but their duration was short. The opposite is true for longer timescales. Their frequency becomes less but remains for a longer time. At the 3-month scale, drought frequency increased, but its duration decreased. This means that drought became more frequent at shorter timescales, but stayed for shorter periods.

As a whole, the temporal SPI analysis shows that in the long and short timescales extreme, Severe and moderate drought incidents in the years 1982, 1983, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, and 2015 were recorded which agrees with the study conducted by Teshome and Zhang (2019) that revealed, the years 2002, 2009, 2015, and 2016 were extreme drought event years in Ethiopia.

4 Conclusion

A brief Meteorological drought analysis was presented using SPI. It is an important tool for quantifying drought incidences and comparing their characteristics over time. The study employed SPI to show the magnitude, frequency, and trend of drought occurrences. Drought occurrences were analysed both at 3- and 12-month timescales. The study revealed that extreme droughts were more pronounced in all-timescales (in 12 months and 3 months). The years 2003, 2005, 2009, 2010, and 2012 were the most drastic and distinct-wide drought episodes that experienced extreme magnitude drought at 3-month (summer, spring) and 12-month timescales in the specified years. From the study, it can be concluded that the study area is categorized as drought-prone affecting the growing of crops. Meteorological drought tendencies were observed during spring, summer, and annual timescales. The results of this study have repercussions for the early warning system, drought management, preparedness, and climate change adaptation. In a real sense, a drought is a climatic event that cannot be prevented very easily, but preparedness and interventions to drought can help to cope with drought by developing more resilient ecosystems, improving resilience to recover from drought, and taking various adaptation strategies. Finally, climate change adaptation strategies to cope with drought, improving resilience to recover from drought and developing resilient ecosystems are recommended actions for government and stakeholders.

Funding Funded by Bahir Dar University and Bureau of forest, environment and climate change.

Availability of data and materials The dataset supporting the conclusions of this article is included within the article.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Consent for publication All authors read the manuscript and agree to publication.

Ethics approval and consent to participate The authors hereby declare that, this manuscript is not published or considered for publication elsewhere.

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