Octa Journal of Environmental Research ***Apr. – Jun., 2026***
International Open Access Journal ISSN 2321 3655
Oct. Jour. Env. Res. Vol. 14(02): 015-023
Available online https://saracari.com/Journals/octa-journal-environmental-research.html

Research Article

Octa Journal of Environmental Research

(Oct. Jour. Env. Res.) ISSN: 2321-3655

Journal Homepage: http://www.sciencebeingjournal.com

ASSESSMENT OF CLIMATE CHANGE EFFECTS ON METEOROLOGICAL DROUGHTS AT DAWA SUB WATERSHED, GENALE DAWA RIVER BASIN, SOUTHERN ETHIOPIA

Ayana Bulti Olana
Oromia Agricultural Research Institute, Mechara Agricultural Research Center, Department of Irrigation and Drainage Engineering, Mechara, Ethiopia
*Corresponding author's E-mail:ayanabub@gmail.com
https://orcid.org/0009-0008-4690-946X

Received: 26th April 2026 **Revised:** 27th May 2026 **Accepted:** 30th May 2026

Abstract: This study investigates the influence of climate change on meteorological drought patterns in Ethiopia, Africa using CMIP5-based GCM-RCM ensembles under RCP4.5 and RCP8.5 scenarios. Bias-corrected daily temperature and precipitation data (via CMhyd) and DrinC drought indices were employed to characterize drought dynamics. The HBV Light hydrological model was calibrated (1991–2010) and validated (2011 to 2020), yielding strong performance (R^2=0.88/0.86; NSE = 0.77/0.83). Results indicate a decline in mean annual discharge (1.6–3.5% under RCP4.5; 4.6 to 4.9% under RCP8.5), while Belg season flows increased by ~39–40% in the 2020s and ~38–39% in the 2050s, reflecting altered precipitation patterns. These findings support early warning systems and inform adaptation strategies. Recommended measures include soil and water conservation, drought-tolerant crops, and water harvesting. Future research should integrate wet day frequency to improve drought prediction under evolving climate conditions.

Keywords: Climate change; CMhyd; CORDEX; DrinC; Drought; HBV

Postal Address: 19, Mechara Agricultural Research Centre, Department of Irrigation and Drainage Engineering, Mechara, Ethiopia

INTRODUCTION

Extreme rainfall events that occur when there is a lack of precipitation cause drought. According to the IPCC's Fourth Assessment Report (AR4), drought is defined as a long-term absence or significant deficiency of precipitation (Trenberth et al., 2013). Depending on how much anthropogenic greenhouse gases (GHG) are released into the atmosphere over the next few decades, the IPCC predicts that global surface temperatures could rise by 1-2°C by 2050 and by 2-5°C by the end of the twenty-first century. The IPCC has stated that human-induced changes are most likely to be the cause of the observed changes (IPCC, 2007a; 2014). Ethiopia is primarily described as a country with considerable precipitation variability that is arid and semi-arid (Negash *et al*., 2020; Kourouma *et al*. 2021; Eze *et al*. 2022). Ethiopia has seen several types of droughts over the last 57 years, varying in length and intensity. The years 1965, 1969, 1973, 1983, 1987, 1989, 1997, 1998, 1999, 2003, 2005, 2008, 2009, 2012, and 2015 were designated as drought-stricken years by (Degefu 1987; Quinn *et al*. 1987; Nicholls 1993; Webb and von Braun 1994; Ayalew 1996; Gebrehiwot *et al.* 2011; Tagel *et al*. 2011; Masih *et al.* 2014; Manpreet 2018; Bisrat and Berhanu 2019). Thirteen of the 30 historical drought occurrences that have affected the country in the last century were severe enough to affect the entire country. (McCann 1995;

Gebrehiwot *et al*. 2011). Ethiopia has experienced drought at least once every ten years since 1970. Due to the El Nino phenomenon, drought has become more severe and frequent nationwide in recent decades, occurring about every three to five years (Margaret 2003; Qu et al. 2019). Some research studies have mentioned the impact of global warming on changes in drought (Trenberth *et al.,* 2013; Dai, 2012). Drought is frequently divided into different categories: agricultural, hydrological, and meteorological. A period of months to years with precipitation below normal or a prolonged period of no precipitation in a region is known as a meteorological drought. It is usually accompanied by high temperatures, strong winds, and low humidity, all of which can raise potential evapotranspiration and is known as a meteorological drought (Raghavan and Liong, 2015, Muse *et al.,* 2023). To evaluate the meteorological drought, we utilize the Standardized Precipitation Index (SPI), one of the primary drought indices. The benefit of employing SPI (Vu, Raghavan, and Liong, 2015) is that it just requires precipitation data as input, which makes it perfect for places like the research region of this paper where data collection of other meteorological parameters may not be possible. Due to its ease of adaptation to local climate, low data needs, and flexibility to be calculated at nearly any period, the SPI is regarded as the most suitable indicator for tracking drought variations (Ntale and Gan, 2003). SPI is suggested to be used as a universal meteorological drought index for more effective drought monitoring and climate risk management (WMO, 2009). Global Climate Models (GCMs) at very small or large scales have been used in earlier research evaluating the effects of climate change on Ethiopia. Particularly for areas lacking a meteorological station, these GCMs offer decision-makers very little useful information regarding the specific impacts and spatial extent of meteorological drought, climatic variability, and change. (Prudhomme *et al.* 2014; Georeactors *et al*. 2019; 2020; Haile *et al.* 2020; Hirko *et al*. 2021). One of the issues impeding efforts to accurately and confidently forecast or predict catastrophic climatic phenomena in many parts of Africa, including Ethiopia, is the paucity of data resulting from the uneven deployment of meteorological stations around the nation.

EXPERIMENTAL

Description of the Study Area: The Dawa River watershed lies between 38^0 2' 48' and 41^0 2' 34''E and between 4^0 5'8'' and 6^0 27' 18''N (Fig.1). It is situated 567 kilometers southwest of Addis Ababa and comprises part of Ethiopia's southeast highlands.

Climate and Topographic Data: The National Meteorological Institute states that the climate of the Dawa River Basin is primarily sub-tropical and tropical agro-climatic, with temperatures between 150 and 28.80 degrees Celsius and rainfall between 600 and 1250 millimeters. The DEM was utilized to offer a range of data that aided in creating a map of the landforms, soil types, and hydrologic information to study the catchment-drainage networks. The research areas' terrain is usually shown by a 12.5 m by 12.5 m digital elevation model.

Methodology for Gathering and Preparing Data: The simulation of the HBV model is validated and calibrated using the streamflow data. Melka Guba station supplied daily streamflow data for the Dawa sub-basin from the Ministry of Water and Energy (MoWE). The FAO 2016 provided the land use and land cover photos used in this study, while the Harmonized World Soil Database (HWSD) provided the soil data. According to LULC data, ArcGIS Version 10 covers and classifies areas with trees, bushes, grassland, crops, aquatic vegetation or flooded areas, lichen mosses or sparse vegetation, bare areas, built-up areas, and water bodies.

Standardized Precipitation Index Methods: McKee (1993) initially presented the SPI through an analysis of past monthly precipitation. A time scale of period 'i' months (i = 3, 6, 12, 24, 48) is determined by selecting a set of average periods based on a moving window. The normal-SPI, log-SPI, and gamma-SPI Standardized Precipitation Index methods are widely used to assess the severity of meteorological drought. Long-term precipitation patterns Mishra and Singh, 2010 can be utilized to compute the Mckee *et al,* 1993. Each index has the same classification, as shown in Table 2, where dry times are indicated by negative SPI values and wet periods are indicated by positive SPI values Cacciamani *et al.,* 2007.

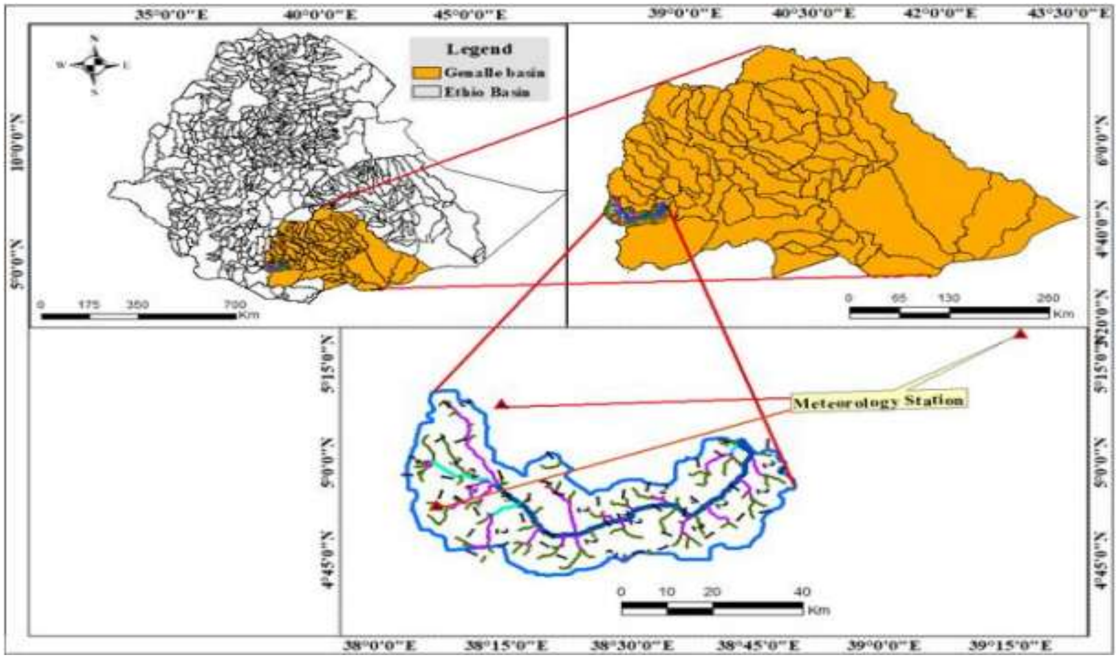

Figure 1: Location Map of the Study area (Source: Ethiopian Geospatial Map, 2016)

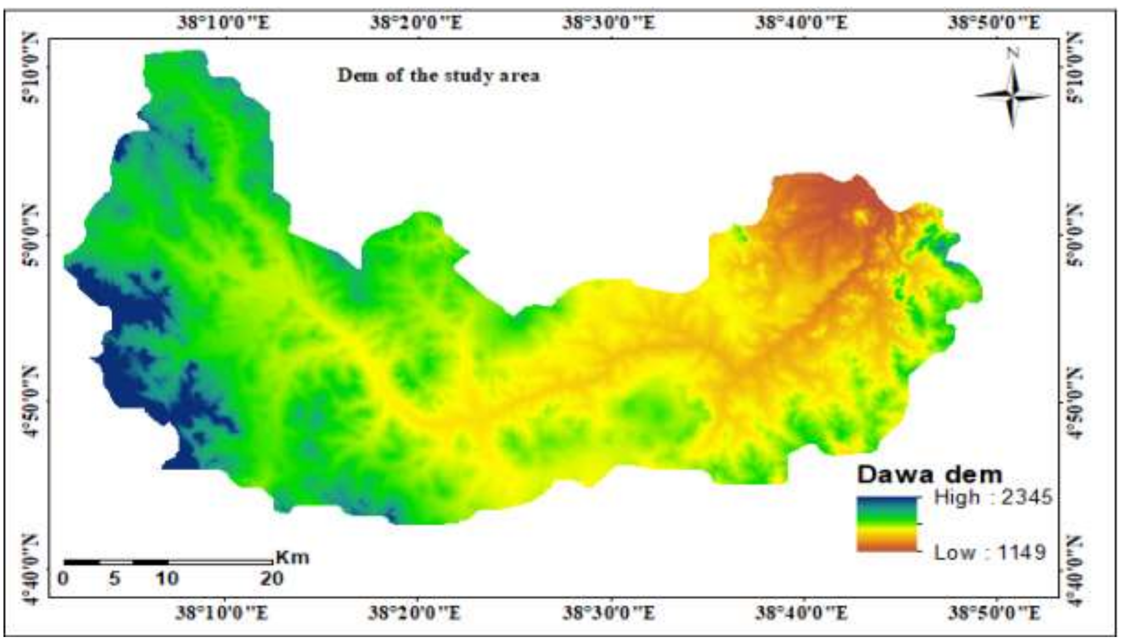

Figure 2: Digital elevation model of Dawa Sub-watershed

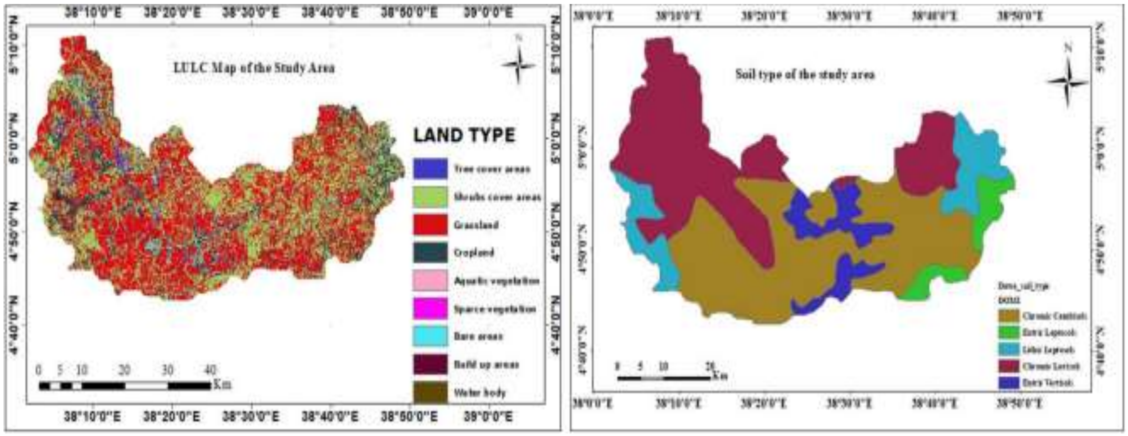

Figure 3. A. Land Use Land Cover (2016) B. Soil Type

Table 1. Distribution of LULC and Soil Types in terms of Area

LULC			Soil		
LULC type	Area (ha)	Area (%)	Soil type	Area (ha)	Area (%)
Tree cover areas	10112	4.3	Chromic Cambisols	98032	41.5
Shrubs cover areas	86543	36.7	Chromic Luvisols	85854	36.3
Grassland	110428	46.9	Lithic Leptosols	24630	10.4
Cropland	24863	10.6	Eutric Vertisols	17408	7.4
Aquatic vegetation/ flooded	4.6	0.00	Eutric Leptosols	10506	4.4
Lichen mosses/sparse vegetation	63	0.03	-		
Bare areas	3518	1.5	-		
Build up areas	204	0.1	-		
Waterbody	30	0.01	-		

Table 2. Category of Drought according to SPI Values (McKee *et al.,* 1993, Raghavan *et al.,* 2015)

SPI Values	Drought Category
0 to -0.99	Mild drought
-1 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
≤ -2	Extreme drought

Meteorological Drought Indicators Selection

Meteorological drought indicators are typically based on precipitation**,** temperature**,** and evapotranspiration data. Their selection depends on:

- Data availability and quality
- Climatic characteristics of the region
- Temporal scale (monthly, seasonal, annual)
- Sensitivity to drought onset and recovery
- Ease of interpretation for stakeholders and decision-makers

The Palmer Drought Severity Index (PDSI), Palmer Z-Index, Standardized Precipitation Index (SPI), Standardized Precipitation and Evapotranspiration Index (SPEI), Effective Drought Index, and deciles are a few examples of meteorological drought indexes. In our study, we employed the Standardized Precipitation Index (SPI) due to its reliance on readily available precipitation data and its straightforward computational approach, making it one of the most practical and widely used methods for drought assessment.

RESULTS AND DISCUSSION

Meteorological Drought Characterizations Using Standard Precipitation Index

A meteorological drought analysis was conducted in the Dawa River watershed at Malka Guba, which was found in the Genale Dawa River basin using SPI from Yabello meteorological stations fr om 1991 to 2020. Most often, a short time range i s taken into consideration for meteorological drought study via SPI-6, SPI-9 and SPI-12 (Tareke, 2022a). However, for areas lacking hydrological data (streamflow), SPI-12 and above are used for hydrological drought analysis. However, in this study, SPI-6, SPI-9 and SPI-12 for monitoring meteorological droughts, and the results showed that the severity of the drought rose as the time scale increased from SPI-6, SPI-9 to SPI-12, and the frequency of occurrence increased over a long-time scale analysis. The estimated SPI values were grouped according to the types of drought, as shown in Appendix Table 16. The number of total drought occurrences computed at 6, 9, and 12-month timescales (Feb to May) in the main rainfall season (*Belg*) with weak, moderate, severe, and extreme drought accounted for more than 50% in Figure 31. However, as can be seen from the SPI data, they were of different magnitude classes. Extreme droughts ranged from -2.06 to -3.07 for 6 months, -2.02 to -2.54 for 9 months, and -2.4 to -2.78 for 12 months for various months, respectively, in 1991, 1993, 1994, and 1999 at Yabello station. In the years 1991, 1994, 1999, 2000, 2001, 2008, 2011, 2016, 2017 and 2019, severe drought was noted for 6-month periods with SPI values between -1.5 and -1.83, 9-month periods with SPI values between -1.5 and -1.93, and 12-month periods with SPI values between -1.49 and -1.97 for each of those years. This is consistent with a recent discovery made by Habtamu (2019). Because it is a reliable indication for such climatic zones, ongoing and persistent drought monitoring is therefore necessary to establish when droughts start and end (WMO, 2012).

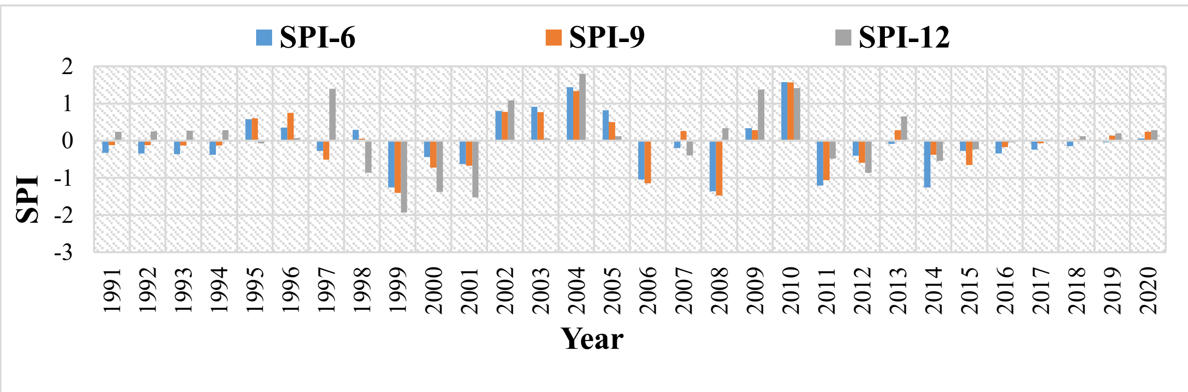

Figure 1: Meteorological drought time series in the Dawa watershed using SPI

Meteorological Drought Characterizations

Table 3. Characterization of drought type and its monthly SPI -6 Months

Drought	Year	Month	SDI
Extreme	1991	4-7	-2.43, -2.06, -2.16, -2.2,
	1993	11-12	-2.09, -2.19
	1994	1-2	-2.21, -2.13
	1999	9	-3.07
Severe	1991	8	-1.85
	1992	3, 9	-1.56, -1.7
	1994	3	-1.73
	1999	10	-1.76
	2000	4,7, 8	-1.53, -1.57, -1.59
	2001	9, 10	-1.59, -1.73
	2008	9	-1.54
	2011	4	-1.5
	2016	10	-1.58
	2017	5-8	-1.59, -1.83, -1.7, -1.63
	2019	4	-1.58
	1991	4	-1
	1992	3, 4	-1.44, -1

Moderate	1993	3, 9, 12	-1.42, -1.14, -1.34
	1994	1, 2	-1.34, -1.26
	1995	8, 10-12	-1.2, -1.01, -1.23, -1.22
	1996	1, 10	-1.07, -1.21
	1998	11-12	-1.21, -1.22
	1999	1, 2, 5-8, 11	-1.34, -1.46, -1.06, -1.28, -1.27, 1.26, -1.08
	2000	1-3, 5, 6, 9, 10	-1.01, -1.01, -1.29, -1.31, -1.48, -1, -1.05
	2001	7,8, 11	-1.18, -1.11, -1.01, -1.01
	2003	11	-1.17
	2006	6-9	-1.09, -1.11, -1.37, -1.39,
	2008	5-8	-1.4, -1.36, -1.3, -1.2
	2010	11, 12	-1.28, -1.14
	2011	1-3, 5-8	-1.24, -.1.2, -1.46, -1.18, -1.22, -1.06, -1.13
	2014	5-7	-1.11, -1.27, -1.3
	2016	12	-1.24
	2017	1, 2, 4	-1.24, -1.03, -1.35
	2018	10-12	-1.14, -1.4, -1.27
	2019	1-3, 5	-1.24, -1.2, -1.3, -1.44
Normal	All the rest months		-

Table 4. Characterization of drought type and its monthly SPI -9 Months

Drought	Year	Month	SPI
Extreme	1991	8, 10	-2.05, -2.02,
	1994	2, 3	-2.25, -2.16
	1999	12	-2.54
Severe	1991	4-7, 9, 11	-1.58, -1.69, -1.87, -1.93, -1.93, -1.77
	1992	3	-1.55
	1994	11, 12	-1.64, -1.91
	1999	9	-1.5
	2000	1, 7-10	-1.93, -1.81, -1.66, -1.73, -1.58
	2001	12	-1.7
	2002	1	-1.68
	2008	9	-1.55
	2011	4-6	-1.53, -1.55, -1.55
	2017	4-6, 8	-1.87, -1.57, -1.68, -1.67
	2019	2-5	-1.51, -1.63, -1.7, -1.51
Moderate	1991	3, 12	-1.06, -1.32
	1992	2, 5, 6	-1.08, -1.08, -1.15
	1993	10	-1.26
	1994	1, 4, 10	-1.14, -1.36, -1.06
	1998	10-12	-1.11, -1.46, -1.07
	1999	1, 2, 5-7	-1.21, -1.44, -1.36, -1.39, -1.48
	2000	2-6, 11	-1.24, -1.37, -1.42, -1.31, -1.39, -1.38
	2001	10, 11	-1.32, -1.42
	2006	7-9	-1.07, -1.08, -1.27
	2008	5-8	-1.03, -1.15, -1.17, -1.34
	2011	2, 3, 7-10	-1.15, -1.24, -1.36, -1.08, -1.2, --1.14, -1.4,
	2017	1, 3, 7, 9	-1.27
	2018	10-12	-1.24, -1.2, -1.3, -1.44
	2019	1-3, 5	
Normal	All the rest months		

Table 5. Characterization of Drought type and its Monthly SPI -12 Months

	Year	Month	SDI

Drought Extreme	1991 1993 1994 1999	4-7 11-12 1-2 9	-2.43, -2.06, -2.16, -2.2, -2.09, -2.19 -2.21, -2.13 -3.07
Severe	1991	8	-1.85
	1992	3, 9	-1.56, -1.7
	1994	3	-1.73
	1999	10	-1.76
	2000	4,7, 8	-1.53, -1.57, -1.59
	2001	9, 10	-1.59, -1.73
	2008	9	-1.54
	2011	4	-1.5
	2016	10	-1.58
	2017	5-8	-1.59, -1.83, -1.7, -1.63
	2019	4	-1.58
Moderate	1991	4	-1
	1992	3, 4	-1.44, -1
	1993	3, 9, 12	-1.42, -1.14, -1.34
	1994	1, 2	-1.34, -1.26
	1995	8, 10-12	-1.2, -1.01, -1.23, -1.22
	1996	1, 10	-1.07, -1.21
	1998	11-12	-1.21, -1.22
	1999	1, 2, 5-8, 11	-1.34, -1.46, -1.06, -1.28, -1.27, 1.26, -1.08
	2000	1-3, 5, 6, 9, 10	-1.01, -1.01, -1.29, -1.31, -1.48, -1, -1.05
	2001	7,8, 11	-1.18, -1.11, -1.01, -1.01
	2003	11	-1.17
	2006	6-9	-1.09, -1.11, -1.37, -1.39,
	2008	5-8	-1.4, -1.36, -1.3, -1.2
	2010	11, 12	-1.28, -1.14
	2011	1-3, 5-8	-1.24, -.1.2, -1.46, -1.18, -1.22, -1.06, -1.13
	2014	5-7	-1.11, -1.27, -1.3
	2016	12	-1.24
	2017	1, 2, 4	-1.24, -1.03, -1.35
	2018	10-12	-1.14, -1.4, -1.27
	2019	1-3, 5	-1.24, -1.2, -1.3, -1.44
Normal	All the rest months		-

To mitigate the adverse effects of climate-induced drought in the Dawa Sub-watershed, the following actions are recommended:

- Implement climate-resilient water management strategies, such as rainwater harvesting, small-scale irrigation, and groundwater recharge systems, to buffer against rainfall variability.
- Strengthen early warning systems by integrating meteorological drought indices with local knowledge to provide timely alerts and guide preparedness.
- Promote drought-tolerant crop varieties and adaptive farming practices, including conservation agriculture and agroforestry, to enhance agricultural resilience.
- Enhance climate monitoring and research capacity in the Genale Dawa Basin to support localized climate modeling, scenario analysis, and policy development.
- Foster community-based adaptation planning, ensuring that local stakeholders are engaged in designing and implementing drought mitigation strategies.
- Integrate climate change adaptation into regional development plans, aligning water, agriculture, and disaster risk management policies with long-term climate projections.

CONCLUSION

Climate change has significantly altered meteorological drought patterns in the Dawa Sub-watershed, intensifying both the frequency and severity of drought events. These changes are closely linked to rising temperatures and erratic rainfall patterns, as confirmed by recent studies using indices like SPI and SPEI. The region has experienced prolonged dry spells and shifting seasonal rainfall, which threaten water availability, agricultural productivity and local livelihoods.

Acknowledgements: The authors would like to express their gratitude to the Oromia Agricultural Research Institute for providing financial support and the scholarship, and to the Mechara Agricultural Research Center for facilitating the funding. Furthermore, the authors extend their sincere thanks to the Ethiopian National Meteorological Agency and the Ethiopian Ministry of Water and Irrigation for supplying the meteorological and daily discharge data, respectively.

REFERENCES

Ayalew M. (1996). Former head of the early warning and planning department, of the relief and rehabilitation commission. Addis Ababa, Ethiopia: Letter.

Bisrat, Berhanu B. (2019). Drought in Ethiopia: Temporal and spatial characteristics in Ethiopia. Addis Ababa, Ethiopia: Addis Ababa University, Institute of Technology (AAIT).

Cacciamani, C.; Morgillo, A.; Marchesi, S.; Pavan, V. (2007). Monitoring and Forecasting Drought on a Regional Scale: Emilia-Romagna Region Methods and Tools for Drought Analysis and Management; Springer: Berlin/Heidelberg, Germany, pp. 29–48

Dai, A. (2013). Increasing drought under global warming in observations and models. Nature Climate Change, Vol. 3, pp. 52-58, DOI: 10.1038/nclimate1633

Degefu W. (1987). Some aspects of meteorological drought in Ethiopia. In: Drought and hunger in Africa. Cambridge: Cambridge University Press

Eze E, Girma A, Zenebe A, Okolo CC, Kourouma JM, Negash E. (2022). Predictors of drought-induced crop yield/losses in two agro-ecologies of Southern Tigray, Northern Ethiopia. Sci Rep. 12(1):62–84

Gebrechorkos SH, Hulsmann S, Bernhofer C. (2019). Regional climate projections for impact assessment studies in East Africa. Environ Res Lett. 14(4):044031.

Gebrechorkos SH, Hulsmann S, Bernhofer C. (2020). Analysis of climate variability and droughts in East Africa using high-resolution climate data. Global Planet Change. 186: 103130–103130

Gebrehiwot T, van der Veen A, Maathuis B. (2011). Spatial and temporal assessment of drought in the Northern highlands of Ethiopia. Int J Appl Earth Obs Geoinf. 13(3):309–321.

Haile GG, Tang Q, Hosseini-Moghari S-M, Liu X, Gebremicael TG, Leng G, Kebede A, Xu X, Yun X. (2020). Projected impacts of climate change on drought patterns over East Africa. Earth's Future AGU-Adv Earth and Space Sci. 8(7):1–23.

Hirko A, Mergia G, Nigussie A, Dandesa T. (2021). Meteorological drought assessment using GeoCLIM: Case study East and West Hararghe, Oromia, Ethiopia. Int J Res Environ Sci. 7(1):31–37

IPCC (2007). Climate change (2007) The physical science basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, Eds., Cambridge University Press, Cambridge

Kourouma JM, (2021). Assessing the Spatio-temporal variability of NDVI and VCI as indices of crops productivity in Ethiopia: a remote sensing approach. Geo Nat Hazards Risk. 12(1):2880–2903

M. T. Vu, V. S. Raghavan, and S.-Y. Liong. (2015). Ensemble Climate Projection for Hydro-Meteorological Drought Over a River Basin in Central Highland, Vietnam

Manpreet SM. (2018). Ethiopia drought analysis using remote sensing. Ontario, Canada: University of Waterloo

Masih I, Maskey S, Mussa FE, Trambauer P. (2014). A review of drought on the African continent: a geospatial and long-term perspective. Hydrol Earth Syst Sci. 18(9):3635–3649.

McCann J. (1995). People of the plow: an agricultural history of Ethiopia, 1800-1990. Wisconsin: The University of Wisconsin Press

McKee, T. B., Doesken, N. J., and Kleist, J. (1993). The relationship of drought frequency and duration to time scales. Proceedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, CA. American Meteorological Society, Boston, MA, pp. 179-184.

McKee, T.B.; Doesken, N.J.; Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference on Applied Climatology, Anaheim, CA, USA, 17–22

Mishra, A.K.; Singh, V.P.(2010). A review of drought c oncepts. J. Hydrol, 391, 202-216.

Muse, N.M.; Tayfur, G.; Safari, M.J.S. (2023). Meteorological Drought Assessment and Trend Analysis in Puntland Region of Somalia. Sustainability, 15, 10652. https://doi.org/10.3390/su151310652

Negash E, Gebresamuel G, Embaye TA, Nguvulu A, Meaza H, Gebrehiwot M, Demissie B, Gebreyohannes T, Nyssen J, Zenebe A. (2020). Impact of headwater hydrological deficit on the downstream flood-based farming system in northern Ethiopia. Irrigation and Drainage Engineering 69(3): 342–351.

Nicholls N. (1993). What are the potential contributions of El Nino-Southern Oscillation Research to Early Warning of Potential Acute Food-deficit Situations? Workshop on Usable Science: Food Security, Early Warning, and El Nino, Budapest, Hungary, Boulder: National Center for Atmospheric Research, 25–28 October, 169–177

Ntale, H. K. and Gan, T. Y. (2003). Drought indices and their application to East Africa. International Journal of Climatology, 23:1335-1357

Prudhomme C, Giuntoli I, Robinson EL, Clark DB, Arnell NW, Dankers R, Fekete BM, Franssen W, Gerten D, Gosling SN, (2014). Hydrological droughts in the 21st century, hotspots and uncertainties from global multimodel ensemble experiment. Proc Natl Acad Sci USA. 111(9):3262–3267

Qu C, Hao X, Qu JJ. (2019). Monitoring extreme agricultural drought over the Horn of Africa (HOA) using remote sensing measurement. Remote Sens. 11(8):902.

Quinn WH, Neal VT, Antunez de Mayolo SE. (1987). El Nino occurrence over the past four and half centuries. J Geophys Res. 92(C13):14449–14461.

Tagel G, Veen V. d, Maathuis B. (2011). Spatial and temporal assessment of drought in the Northern highlands of Ethiopia. Int J Appl Earth Obs Reinform. 13(3):309–321

Trenberth, K. E., Dai, A., van der Schrier, G., Jones, P. D., Barichivich, J., Briffa, K. R., and Sheffield, J. (2013). Global warming and changes in drought. Nature Climate Change. 4:17-22

Vu, M. T., Raghavan, V. S. and Liong, S. (2015) Ensemble Climate Projection for Hydro-Meteorological Drought Over a River Basin in Central Highland, Vietnam, 19, pp. 427–433.

Webb P, von Braun J. (1994). Famine and food security in Ethiopia: Lessons for Africa. Chichester: John Wiley & Sons

World Meteorological Organization (WMO) (2009). Experts agree on a universal drought index to cope with climate risks, WMO Press Release No. 872

Source of Financial Support: The study was supported through funding from Oromia Agricultural Research Institute.
Conflict of Interest: No conflict, declared.

Abbreviations

CORDEX- Coordinated Regional Climate Downscaling Experiment
RCP - Representative Concentration Pathways
R2- Coefficient of Determination
DrinC- Drought Indices Calculator
NSE - Nash-Sutcliffe Efficiency
HBV- Hydrologiska Byråns Vattenbalansavdelning
CMhyd- Climate Model for Hydrology
HWSD - Harmonized World Soil Database
MoWE- Ministry of Water and Energy