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# REVIEW ON PATTERNS AND CONSEQUENCES OF DROUGHT IN ETHIOPIA

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## ABSTRACT

Due to its complexity and unforeseeable effect in a short period, drought creates troublesome effects on society, the environment, and the economy of the country. Despite this view, systematic reviews on the patterns and consequences of drought in Ethiopia are few; even the reviews did not comprehensively evaluate both the pattern and consequence aspects of drought in Ethiopia. So, this fills the gap. By considering publication date, language, and subject scope, 26 journal articles including reports and previously reviewed articles were used. The result indicated high spatiotemporal variation of drought in Ethiopia. Moreover, most parts of northeastern and rift valley basins of Ethiopia experienced severe drought mainly in 1984, 2009, and 2015. Concerning the socioeconomic consequences, livestock death and crop failure were the main reported problems in Ethiopia. However, environmental consequences of drought in Ethiopia were not investigated in detail. Therefore, socioeconomic and environmental consequences of drought should be investigated.

## KEY WORDS

consequences, drought, Ethiopia, spatial pattern, temporal pattern

## CLASSIFICATION

JEL: O13, O44, Q15, Q51

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## BACKGROUND AND JUSTIFICATION

Drought is a worldwide natural hazard, which harms society, the environment, and therefore the economy. Drought, as a complex natural event, is characterized by a lack of precipitation over a prolonged time; and its effect can only be seen slowly over some time [1]. In contrast to other extreme events (such as floods, tornadoes, and hurricanes), drought develops slowly and steadily, creating it difficult to see the onset and last [2].

In Ethiopia, drought exhibited strong spatial variation and different rainfall regimes because of its complex topographical and geographical features [3]. As a result, Ethiopia has experienced one of the most severe La Niña-induced drought in the last forty years following four consecutive failed rainy seasons since late 2020 [4]. Studies have shown that drought-prone areas in Ethiopia were the upper Blue Nile basin [5], southern and eastern zones of Tigray region [6], northeast Ethiopia like south Wollo, north Wollo, and Afar region [7], and most parts of Somalia region and eastern parts of Oromia Region [8].

Since drought is a frequent climatic event, its consequences are shown through harm to agricultural production, reduction of water supply and energy production, mass migration, and loss of life [9]. In Ethiopia, extreme weather events owing to insufficient total rainfall amount and long dry periods affected the agriculture, socioeconomic, and environment of the northern, southern, and eastern parts of the country which result in great human suffering and losses of life [7]. Similarly, according to [10] report, the incidence of drought during the main rain season has resulted in complex consequences on crop and livestock production, surface hydrology, and biodiversity in the northeastern parts of Ethiopia. Moreover, more than one million people were targeted for nutrition interventions including more than 185 000 children severely malnourished, and more than 206 000 pregnant and lactating women with acute malnutrition [4]. For these reasons drought characterization at local and nearby scales has tremendous implications for drought management consisting of early warning, practice and contingency making, and weather change model programs [10]; and to ensure socio-economic growth and development [11].

Although several studies have been conducted on drought-related issues in Ethiopia, we confirm that their main focus was on meteorological drought patterns (spatial and temporal) and somewhat agricultural droughts. Reviews were done in Ethiopia; for instance, by [12] on drought vulnerability and the impacts of climate change on livestock production and productivity in different agroecological zones of Ethiopia. This review was mainly on the impacts of climate change on live stocks and adaptation strategies on agro-pastoralists of southern parts of Oromia (Borana), Somalia, Afar, and some parts of Tigray region in recent drought episodes. Additionally, [13] reviewed the cause and effects of recurrent drought on Ethiopian agriculture productivity. However, the spatiotemporal patterns and possible consequences were not well reviewed in detail and country-wide. Therefore, this review work is crucial to condense the current state of knowledge, understand the extent, patterns, potential consequences, and determine future research needs.

## METHODS

The reviewers followed three stages for the screening of articles published in 2015 onward on drought patterns and consequences in Ethiopia, Figure 1. In the first stage, the Google scholar engine was used as the primary platform for the search of articles. The first phase of screening was to obtain articles that found the selected phrases. On Google scholar, the full search code relevant to 'spatiotemporal patterns and consequences of drought was identified as follows: ('spatiotemporal patterns of drought in Ethiopia' OR 'consequences of drought in Ethiopia' OR 'impacts of drought in Ethiopia'). Secondly, visual evaluation of the paper's abstract,

keywords, and year of publication following the first screening process. Only the abstracts related to the scope of the study were used for the third screening. Finally, only the research documents (articles, reviews, and reports) covering patterns and consequences of drought in Ethiopia were extracted from the second screening as targeted documents. 26 articles, reviews, and, reports were selected for this review, Table 1.

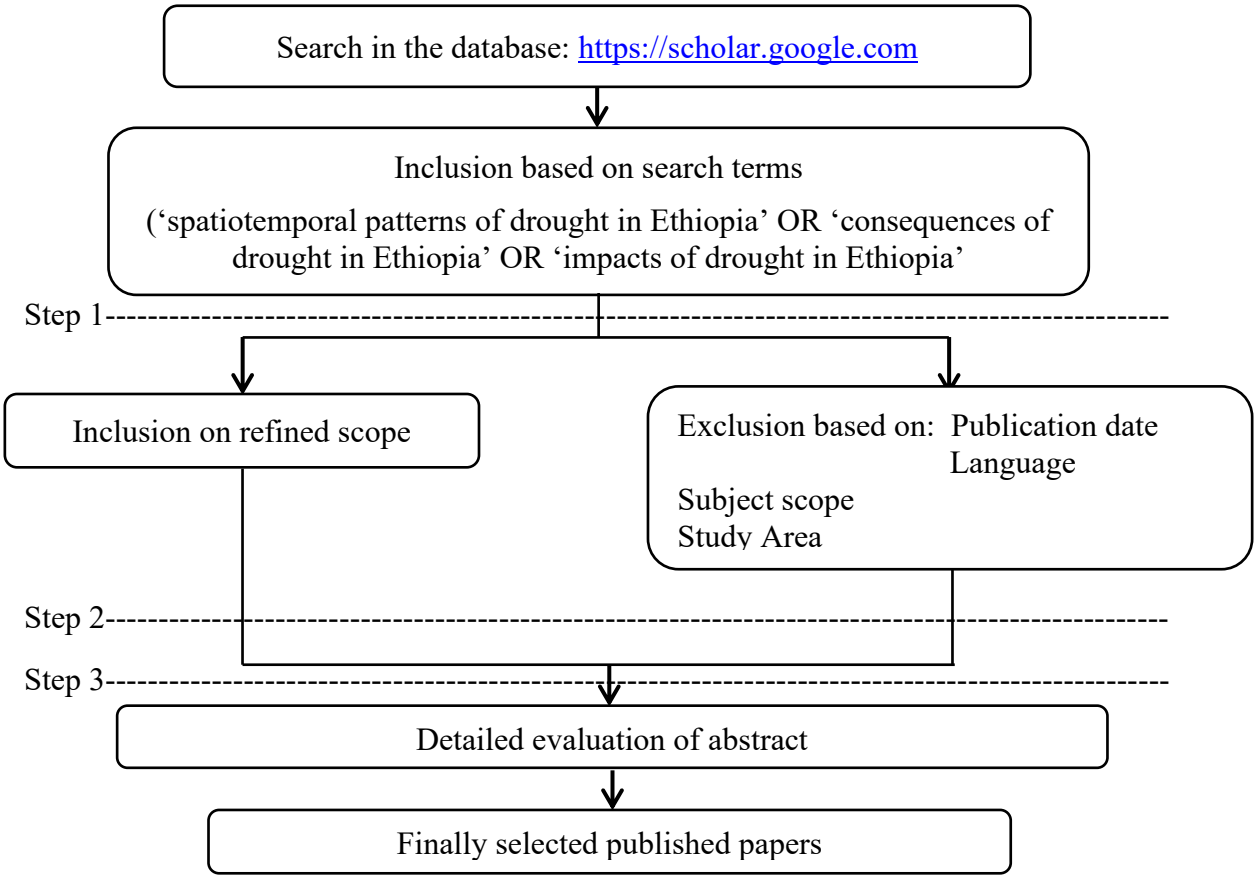


**Figure 1.** Methodological framework for this review.

**Table 1.** List of documents (articles, review papers, and reports) used for this review (continued on p.510).

| No. | Author/s and year of publication | Title | Category |
|---|---|---|---|
| 1 | Senamaw et al., 2021 | Mapping the spatial and temporal variation of agricultural and meteorological drought using geospatial techniques, Ethiopia | Pattern related |
| 2 | Mera, 2018 | Drought and its impacts in Ethiopia | Consequences |
| 3 | Bayissa et al., 2017 | Evaluation of Satellite-Based Rainfall Estimates and Application to Monitor Meteorological Drought for the Upper Blue Nile Basin, Ethiopia | Pattern related |
| 4 | Nasir et al., 2021 | Meteorological Drought in North western Escarpment of Ethiopian Rift Valley: detection seasonal and spatial trends | Pattern related |
| 5 | Hermans and Garbe, 2019 | Droughts, livelihoods, and human migration in northern Ethiopia | Consequences |
| 6 | Wolteji et al., 2022 | Multiple Indices Based Agricultural Drought Assessment in the Rift Valley Region of Ethiopia | Pattern related |
| 7 | Zeleke et al., 2017 | Trend and periodicity of drought over Ethiopia | Pattern related |

**Table 2.** List of documents (articles, review papers, and reports) used for this review (continuation from p.509).

| | | | |
|---|---|---|---|
| 8 | Bayissa et al., 2019 | Developing a satellite-based combined drought indicator to monitor agricultural drought: a case study for Ethiopia | Pattern related |
| 9 | Philip et al., 2018 | Attribution Analysis of the Ethiopian Drought of 2015 | Pattern related |
| 10 | Liou and Mulualem, 2019 | Spatio–temporal Assessment of Drought in Ethiopia and the Impact of Recent Intense Droughts | Both |
| 11 | Mekonnen et al., 2020 | Spatial and temporal drought incidence analysis in the northeaster highlands of Ethiopia | Pattern related |
| 12 | Mohammed et al., 2017 | Meteorological drought assessment in north east highlands of Ethiopia | Pattern related |
| 13 | OCHA, 2022 | Ethiopia Drought report update #4 | Both |
| 14 | Teshome and Zhang, 2019 | Increase of Extreme Drought over Ethiopia under Climate Warming | Pattern related |
| 15 | Tefera et al., 2019 | Drought Occurrence Pattern in Tigray Region, Northern Ethiopia | Pattern related |
| 16 | Wassieet al., 2022 | Trends and spatiotemporal patterns of meteorological drought incidence in North Wollo, north eastern highlands of Ethiopia | Pattern related |
| 17 | Mohammed and Yimam, 2021 | Analysis of meteorological droughts in the Lake's Region of Ethiopian Rift Valley using reconnaissance drought index (RDI) | Pattern related |
| 18 | Amsalu, 2019 | Review on the Cause and Effects of Recurrent Drought on Ethiopian Agriculture Productivity | Consequences |
| 19 | Tesfamariam et al., 2019 | Characterizing the spatiotemporal distribution of meteorological drought as a response to climate variability: The case of rift valley lakes basin | Pattern related |
| 20 | Kourouma et al., 2022 | Spatiotemporal climate variability and meteorological drought characterization in Ethiopia | Pattern related |
| 21 | Bogale & Erena 2022 | Review on Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-Ecological zones of Ethiopia | Consequences |
| 22 | Mengistu, 2016 | Impacts of Drought and Conventional Coping Strategies of Borana Community, Southern Ethiopia | Consequences |
| 23 | Araro et al., 2020 | Climate Change and Variability Impacts on Rural Livelihoods and Adaptation Strategies in Southern Ethiopia | Both |
| 24 | Menghistu et al., 2018 | Farmers' perception of drought and its socioeconomic impact: the case of Tigray and Afar regions of Ethiopia | Consequences |
| 25 | Gebre et al., 2017 | Application of Remote Sensing and GIS to Characterize Agricultural Drought Conditions in North Wollo Zone, Amhara Regional State, Ethiopia | Both |
| 26 | Teshome, 2016 | Rural households' agricultural land vulnerability to climate change in Dembiaworeda, Northwest Ethiopia | Consequences |

## KEY TERMS AND CONCEPTS

**Climate:** This is typically described by the summary statistics of temperature, precipitation, soil moisture and sea surface temperature of a particular region, averaged over a set time-scale, usually 30 years.

**Climate variability:** This is the variation around the average climate, ranging from daily/weekly variability to seasonal and intra-decadal variations.

**Climate change**: is the change over an extended period in the mean and/or the variability of atmospheric properties such as temperature and precipitation.

**Drought** is relative term but can be defined as period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought has multiple aspects and can be classified into four main types, namely, meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought [14].

**Agricultural drought**: Shortage of precipitation during the growing season that affect crop production due to soil moisture deficit.

**Meteorological drought**: A period with an abnormal precipitation deficit; or is water shortage induced by a difference in precipitation and evaporation. Meteorological droughts have the potential to affect agricultural productivity by reducing the availability of soil moisture.

**Hydrological drought:** Occur when surface and subsurface water resources are insufficient for established water uses in a specific water resource management system.

**Socioeconomic drought:** It occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

**Temporal pattern:** is defined as a segment of signals that reappears frequently in the whole temporal signal sequence.

**Spatial pattern:** An analysis tool used to study people or objects in terms of their physical location.

**Consequence:** A result of a particular action or situation, often one that is bad or not convenient in this case drought.

**Crop yield:** The measurement of the amount of cereal, grain, or legume produced per unit area, normally measured in metric tons per hectare.

# RESULTS AND DISCUSSION

## SPATIAL PATTERNS OF DROUGHT IN ETHIOPIA

Research in different parts of the country has been conducted about the spatial patterns of drought. Most of the reports showed the occurrence of drought in notheastern and rift valley basins of Ethiopia.

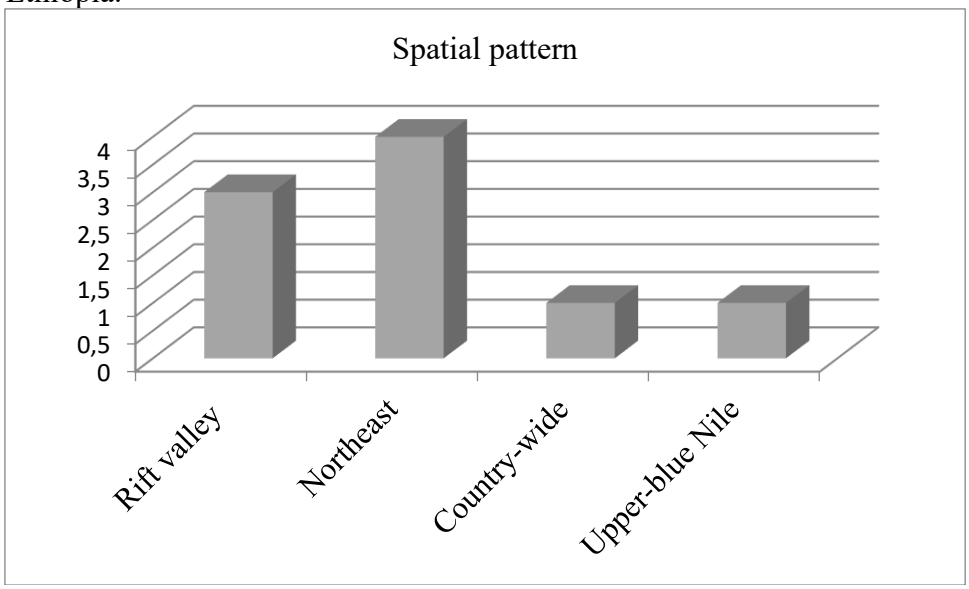


**Figure 2.** Spatial pattern of drought in Ethiopia.

For instance, by using a combined (meteorological and agricultural) drought risk map [15], reported north part of the Waghimra zone as frequently affected by very severe agricultural drought, while the southern and central parts of the study area affected by slight to sever agricultural drought condition in 2000 to 2016 time period . They also confirmed the occurrence of prolonged and recurrent drought features from informal interviews with Waghimra Zone agricultural experts and agreed with the fact that the area experienced successive drought events during the last 17 years. Similarly, [16] showed the presence of very severe and severe drought in the west, northwest, southwest, east, southeast, and northeast parts of north Wollo zone, while other parts of the study area experienced different types of drought by using combined drought risk mapping method within 2000 to 2015 time period. By gathering information from published and unpublished sources, and confirmed the presence of severe agricultural drought in the study area for 2 to 3 years of cropping seasons. Studies in north Wollo by [16] also indicated that the highest drought frequency was registered in the Bugna, Wadla, Habru, Kobo, Woldiya, and Dlanta districts from 2000 to 2019 time period. Moreover, by using Standardized Precipitation Evapotranspiration Index (SPEI) method, [6] reported the western, eastern, and southern zones of Tigray region as high drought risk areas, while central and northwestern zones as low drought risk areas.

By using the standardized rainfall anomaly and empirical orthogonal function analysis method, [17] reported the general drying trend over eastern, central, northern, and northeastern parts of Ethiopia from 1980 to 2015 time period. They also showed the rainfall variability by using the contour-based seasonal rainfall analysis of *bega* and *kiremt* seasons over north eastern, central, southern, and southeastern parts of the country. In addition to this, [18] reported severe drought in the east and northeastern parts in *kiremt* season and central and eastern parts in *belg* season within the 2000 to 2016 time period; by using PCA-based combined drought indicator (CDI-E) method.

Contrarily, [19] reported frequent and intense drought during the years 1979 to 2014 particularly in 1997 in southern and southwestern regions of Ethiopia; by using the standardized precipitation index (SPI) and the Palmer drought severity index. This contrast may be due to the methods used to calculate drought indices, the length of record periods, and the number of stations used for trend analysis. Nevertheless, using the reconnaissance drought index method, [20] elaborated the frequencies of drought for different intensity classes and time scales as complex and localized patterns. They explained that the southern part of the Ethiopian rift valley was prone to mild drought intensity with an average 20% probability of drought occurrence during spring. Additionally, in the same season, large parts of the Ethiopian rift valley also experienced severe drought episodes. Typically, Arbaminch, Wolaita Sodo, Arsi Negelle (being the highest), Ziway and Kulumsa stations had severe drought events. [20] also indicated the absence of considerable spatial pattern of drought except for the mild and moderate drought events during summer. At the annual time scale, the central and northern parts of the Ethiopian rift valley experienced moderate drought. They also generalized the presence of frequent drought in Arsi Negelle, Wolaita, Wondo Genet, and Ziway in the spring season; whereas Arsi Negelle and Hawassa in summer. They also confirmed the occurrence of frequent drought in Ziway at the annual time scale. Similarly, [21] reported the incidence of agricultural drought in the rift valley region of Ethiopia, including the highlands region except for the northwest parts and the central parts of the rift valley region in 2016 for the three consecutive months (June, July, and August), using multiple indices-based agricultural drought assessment methods. Moreover, [22] reported the occurrence of a moderate-intensity drought in the rift valley lakes basin of Ethiopia with an average year of 1.68 and 1.76 in the *Belg* and *Kiremt* seasons respectively by using standardized rainfall anomaly (SRA) within 1981 to 2017 time period.

## TEMPORAL PATTERN OF DROUGHT IN ETHIOPIA

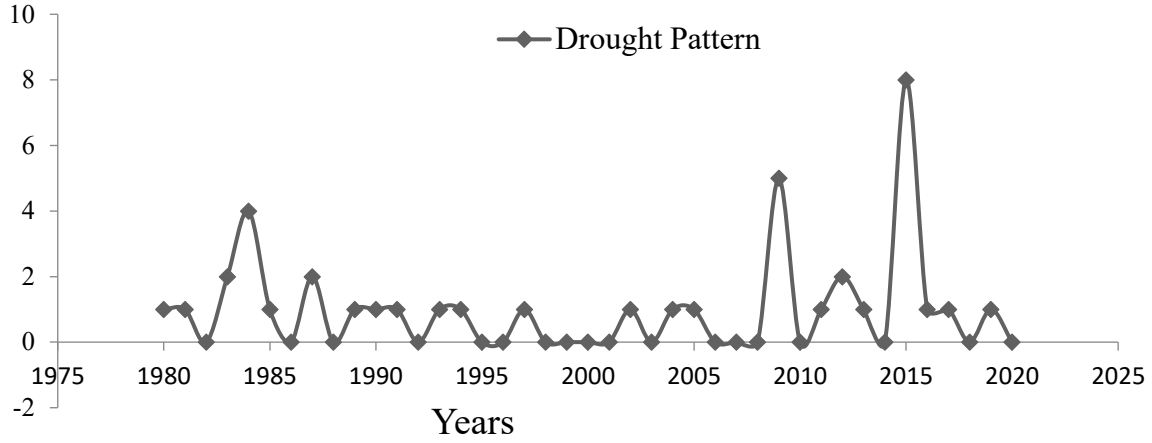


**Figure 3.** Temporal pattern of drought in Ethiopia from 1980-2020

By using a ZSI-based drought frequency mapping method, [16] identified the years 2002, 2004, 2009, 2011, 2014, 2015, and 2019as meteorological drought. On the other hand,[23] indicated the occurrence of extremely severe drought during the *kiremt* rainy months of July 1987 and 2015, August 1984, and September 2009. In the same manner, by using the PCA-based CDI-E method, [18] reported the occurrence of severe drought during 2009 and 2015 years, within 2000 to 2016 time period. Likewise, [15] indicated the occurrence of severe drought on a large spatial extent mainly during the summer season of the years 2009 and 2015 in the Waghemra zone, within the period 2000 to 2016.

In contrary to the aforementioned report, [16] also indicated two years, 2005 and 2015 as drought years and 2009 and 2013 as slight-drought years from 2000 to 2015 year period. From these reports, within the neighbouring zones and nearly the same study period, the year 2009 was a severe drought in Waghemra zone, while slight drought in north Wollo. This difference might be due to the data and methods used to calculate drought development. Because, to generate a meteorological drought map, [16] used SPEI, while [15] used SPI.

In the same way, by using SPEI with 3, 6, 12, and 24-month time scales, [6] reported the year 1902 as the strongest drought severity at 3-month, 6-month and 12-month time scales; whereas the year 2012 was the highest drought severity at the 24-month time scale, within the 1901 to 2016 time period in Tigray Region. By using community professionals' and experts information, [24] also indicated the years 1995, 1999, 2000, 2004, 2009, 2013, 2014, and 2017 as drought years. However, it is not reliable to conclude from local experts' information. Hence, integrating meteorological/satellite data with expert information would help to conclude the occurrence of drought in the specific area and period.

Nevertheless, [25, 26] identified the year 2015 as one of the driest years in large parts of Ethiopia; owing to the delay of the main rain season (*kiremt*) and reduced precipitation below normal conditions. [21] also reported both severe and extreme drought in the central rift valley of Ethiopia in June and August 2015, but not in July 2015. They also indicated that all months experienced both extreme and severe droughts with the highest record in August 2016. Using the SPEI method, within 1983 to 2016 years, [27] reported the occurrence of severe, persistent, and frequent *Kiremt* drought in the years 1983, 1984, 1985, 1987, 1989, 1990, 1991, and 1993 in all livelihood zones. 1999 was also the most severe temporal *Belg* drought in SPEI3 in all livelihood zones. The highest extreme severity drought was recorded in SPEI3 in 1984. Moreover, by using the SPI and the standardized SPEI, from 1983 to 2020, [28] reported the years 1984/85, 1997/98, and 2015/16 as the most severe and countrywide drought episodes.

## SOCIO ECONOMIC CONSEQUENCES OF DROUGHT

Climate variability (drought) aggravated food insecurity, water scarcity, disease rises, and widespread poverty, failure in crop production, including staple crops such as wheat and maize and cash crops such as coffee. It is likely to affected crop yields negatively and therefore food security [17]. The socioeconomic consequences of drought in Ethiopia affect people's health, safety, crop, and livestock production.

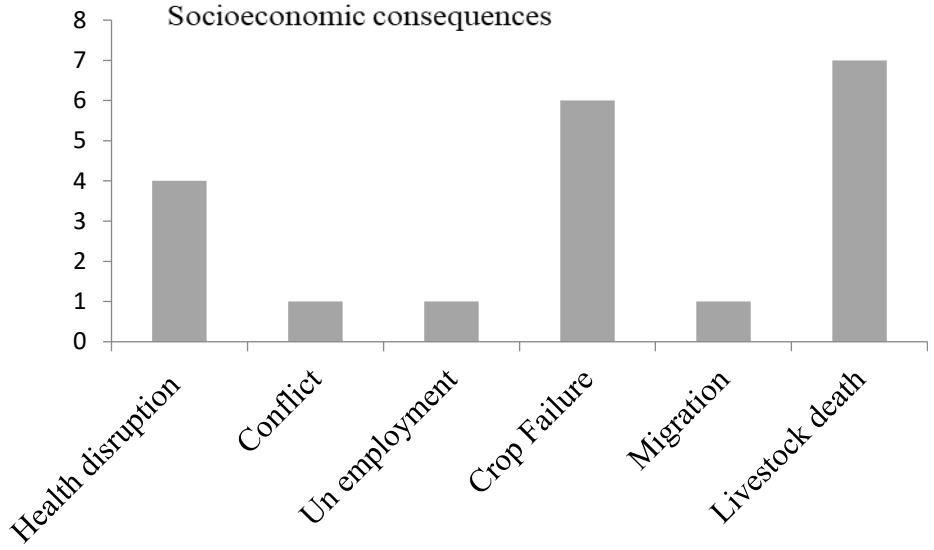


**Figure 4.** Socioeconomic consequences of drought in Ethiopia.

These consequences include public safety and health, conflicts between people due to scarce (the absence) of resource degraded by drought, and lifestyle changes [13]. In addition to this, [29] listed the socioeconomic consequences of drought on the household as food insecurity, lack of choices in food preference, malnutrition, human, unemployment, and reduction in household income. Moreover, socioeconomic consequences of drought includes widespread failure of seasonal crops, pasture, forage, significant livestock deaths in pastoralist areas, starvation of the affected population [12]. Furthermore, drought increases mobility, primarily by triggering short-term migration to closer destinations to cover immediate needs [30].

In the same way, [17] reported the consequences of drought in Ethiopia as frequent crop failure and reduction in livestock productivity; which in turn makes Ethiopia dependent on large humanitarian aid. [24] also stated loss of crop and livestock and their products; which was used as income source in the Konso district. They also reported cattle and goats death due to the reduction of available water and animal feed, and the interruption of their overall metabolic activity. Besides, the socio-economic status of the farmers like their health condition was disrupted. Additionally, to purchase crops, they spent 22 728$ and 30 772$ for *Woina-Dega* and *Kolla* agro-ecology zone. According to [11, 27], the recurrence of meteorological drought episodes due to the timely deficit of precipitation in the crop growing season has affected rain-fed agriculture towards a decline in crop yield (crop failure), forage problems that potentially lead the farmers to food insecurity problems.

As mentioned by [12], the main consequences of drought were reduced livestock productivity, feed shortage, water shortage, and decreased mature weight and/or longer time to achieve mature weight, lowering livestock immunity, and exposing animals to new diseases and vectors. [29] also indicated a decrease in income of farmers; for instance, the income from livestock in a normal year ranges from 3 000 ETB to 20 000 ETB. But, in a drought year, this income ranges from 1000 to 10 000 ETB. The mean incomes from livestock were reported to be 12 833 ETB and 5 659 ETB during normal and drought years, respectively. The prices of

cattle in normal and drought years range from 5 000 ETB to 12 000 ETB and from 2 500 ETB to 5 000 ETB where the average cattle price was 8 228 ETB and 4 096 ETB in the respective years. As a result, farmers whose livelihoods depend on agriculture (livestock rearing and crop production) suffered from escalating living costs; as their income decreased from livestock.

According to [29], around 68% of the livestock killed throughout the study were cattle. On the other hand, within a decade, the maximum size of animals in the research area was reduced by 315%.The price of all staple grains shows an upward trend throughout the peak drought periods. As a result, the terms of trade of livestock-grains is decreasing which induces food insecurity in pastoral areas, especially in the home of poor households. Based on the [4] report, between October 2021 and mid-April 2022, more than 344 000 people have been displaced in search of water, pasture, and assistance, including 175 000 people in Somali Region and 139 000 people in the southern Oromia Region; and 2,1 million livestock died to date, while at least 22 million are at risk, More than 2 000 schools are closed including 1800 schools in Somali, 334 schools in East and West Hararge zones in Oromia regions alone, affecting more than 682 000 students.

**Figure 5.** Severe drought consequences in Ethiopia [29].

## ENVIRONMENTAL CONSEQUENCES OF DROUGHT IN ETHIOPIA

Drought affects the environment in different ways. Destruction of fish and wildlife's habitat, lack of food and drinking water for wild animals, increase in disease in wild animals, migration of wildlife, increased stress on endangered species or even extinction, lower water levels in reservoirs, loss of wetlands, and wildfires [13]. Besides, the environmental consequences of drought are characterized by decreased biomass or vegetative cover, land degradation, loss of rangelands, and soil loss by wind erosion [11]. Moreover, climate variability (drought) caused environmental degradation, shrinking and drying up of water bodies, and the wetlands that

result in scarcity of water, loss of biodiversity and associated livelihoods of people, and disruption of ecological systems, poor regeneration tree species, the spread and abundance of invasive alien species [17].

## CONCLUSION AND RECOMMENDATIONS

This review focused on patterns and consequences of Drought in Ethiopia. The spatiotemporal patterns of drought in Ethiopia are highly variable that leads to varied consequences in different parts of the country. Assessing the patterns and possible consequences of drought will be very important to provide evidences for concerned bodies to prepare early warning systems, preparedness plan, and reduce the negative consequences of drought in Ethiopia. Drought affected parts of Ethiopia are mainly northeast Ethiopia such as south Wollo, north Wollo, Waghimira, Tigray and Afar region; and eastern parts of rift valley basins of Ethiopia. 2015, 2009, and 1984 were the severe drought years in the country. Most of the recent studies related to drought are spatiotemporal patterns and trends analysis. Some studies used satellite data and meteorological data only, and some studies used local experts report. To generalize the trends of drought using only either of these methods are difficult. Moreover, the socio economic and environmental consequences were not well investigated. So, after analysing the patterns and trends of drought, further investigation on the consequences should be undertaken.

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