

Relative Evidences of Climate Change in Oromo Gadaa System and Recorded Climatological Parameters in Arsi-Oromo, Ethiopia

Misbahu Aman Abdo

College of agriculture and environmental science, Arsi University, Asella, Ethiopia

ABSTRACT

The evidence of climate change have been realized by changing patterns of climatic parameters. Yet the relative evidence of climate change in modern meteorology and indigenous knowledge of local communities have not been studied well. This study is so aimed to examine relative evidence of climate change in meteorological data and Gadaa system within five Gadaa term. Thus total of 77 respondents were purposively selected from Arsi, East Shoa and West Arsi zones. Interviews, focused group discussions, field observations and reviewing the recorded meteorological data were used in data collection. The quantitative data were analyzed by using descriptive statistics while the qualitative data were interpreted and analyzed in the form of narratives, trend analysis and descriptions. The results of temperature and rainfall have been the main climatic parameters used to realize climatic events both in modern meteorological station and Gadaa system. The Ethiopian meteorological data in five decades shows the rising of mean annual temperature by 0.014 °C and decreasing of rainfall by 0.2mm/year rate. Similarly, climate changes indicators in Gadaa system, was also shows the decreasing of rainfall induced product and increasing of hotness. Hotness have been forecasted by every individual from the temporal and spatial change in ices coverage, shifting of lowland crop, pest and disease to highland. The precipitation has been forecasted by spiritual leaders in Gadaa system from the thickness of annually developed sediment deposits and tree rings, direction of cloud and wind movements, and seasonal stars position within five Gadaa period. Hence indigenous climate change prediction system of Oromo Gadaa system should be modernized for adaptation and mitigation of extreme climate events.

Key words: Climate change Evidences, Gadaa system, prediction, Raaga

DOI: 10.7176/JEES/16-1-03

Publication date: February 28th 2026

1. INTRODUCTION

1.1. Background of the study

Ethiopia is among the largest countries of Africa which is characterized by a wide variety of landscapes, with marked contrasts in relief. The lowlands and/or highlands landscapes with different properties of altitude and physiography is experienced a variety of climates ranges from desert climate to that typical of equatorial mountains. Its range of altitudes is from 155m b.s.l. at Assale Lake, of the Danakil depression, to 4,533 m a.s.l. at Ras Dejen (EPA, 2012). The climate of Ethiopia is mainly depends upon the seasonal migration of the Intertropical Convergence Zone (ITCZ) by trade winds and related atmospheric circulations as well as the different topography of the country.

The relevance of climatic parameters, and their potential exploitation for agriculture and natural resources has been recognized since environmental impacts of economic development was understood by human. Climate change and variability may be due to external forces (natural processes) and anthropogenic (human) causes. The natural causes includes volcanic eruptions, ocean currents, the earth's orbital changes (IPCC, 2012). While anthropogenic causes cover human activities that resulted in high concentration of greenhouse gases in the atmosphere (Oxfam International, 2010 and Viste *et al.*, 2012). Climate change is somehow unpredictable extreme climate events which can be predominantly renowned from changing of long term mean temperature and precipitation (UNFCCC, 2007). Climate change is one of the most important environmental issues facing the earth today with most complex challenges.

The evidence of climate change have been felt through increasingly changing patterns of temperature, rainfall and wind. For example, an average global surface temperature increases at about 0.6°C during the twentieth century (IPCC, 2012; and Flintan, *et al.*, 2011) due to the increase in anthropogenic greenhouse gas concentrations. Moreover, meteorological records suggest a significant increase in temperature and reduction in rainfall since the early 1990s over arid and semi-arid land of Africa. In other words, not only does climate affect

development but also development affects the climate (Gashe, 2011). The accusing finger is to the human's release of greenhouse gases since the urbanization and industrial revolution.

Obtaining data from the National Meteorological Agency, FAO has been continuously reporting mean monthly agroclimatic data of Ethiopia as national level in general. Even though several studies on the climate of Ethiopia had published throughout the past two centuries, nothing shows an ongoing expansion in time series of the different climate types and their spatial variability in study area. Instead of finding indicators of climate change, they rather most focused on the implications of climatic extreme in the last decade. Therefore, the aim of this study was to investigate the indicators, statuses and trends of climate change in Sikko-Mendo Oromo community in selected zones of Oromia regional state on the base of time series. Climate, in turn, has many obvious implications on landforms and morphologically dynamic of landscapes (Assefa and Bork, 2013) as well as the wellbeing of local communities whose economy is heavily dependent on rain-fed agriculture (EPA, 2012).

1.2. Objectives

1.2.1. General Objective

This study was aimed to compare the relative evidences of climate change in Meteorological station and in Sikko-Mando Oromo's Gadaa systems in general.

1.2.2. Specific Objective

- To identify and describe existing evidences of climate change in study area
- To assess the relative evidences of climate change in meteorological station and Gadaa systems
- To investigate the techniques of climate change enquiry in Gadaa systems

2. Methods and Material

2.1. Area description

The evidences of climate change was surveyed in thematic area of Arsi University named: Arsi, East Shoa and West Arsi administrative zones of Oromia region where latitude of 5°48'5" - 9°8'20" N and longitude of 37°24'20" - 40°44'20" E (Figure 1) in Central Rift Valley of Oromia regional state is its geographically location. Its elevation and annual temperature ranges from 1600 to 3800 m a.s.l., and 11 to 27 °C respectively. The agro-ecology of area ranges from arid to humid area up to bi-modal annual rainfall of 500–2300 mm in mean having sandy to clay soil types (NMA, 2012). Its land use and land cover was cultivated, settlement, grazing, forest, swampy, lake, river, mountainous, etc. Vegetation were dominated by endogenous and eucalyptus species commonly found in riverside, hillside and mountain (MOA, 2008). According to CSA (2012) population in study area were estimated to be more than 3 million who mainly live on subsistence rain feed agriculture: crop and livestock husbandry.

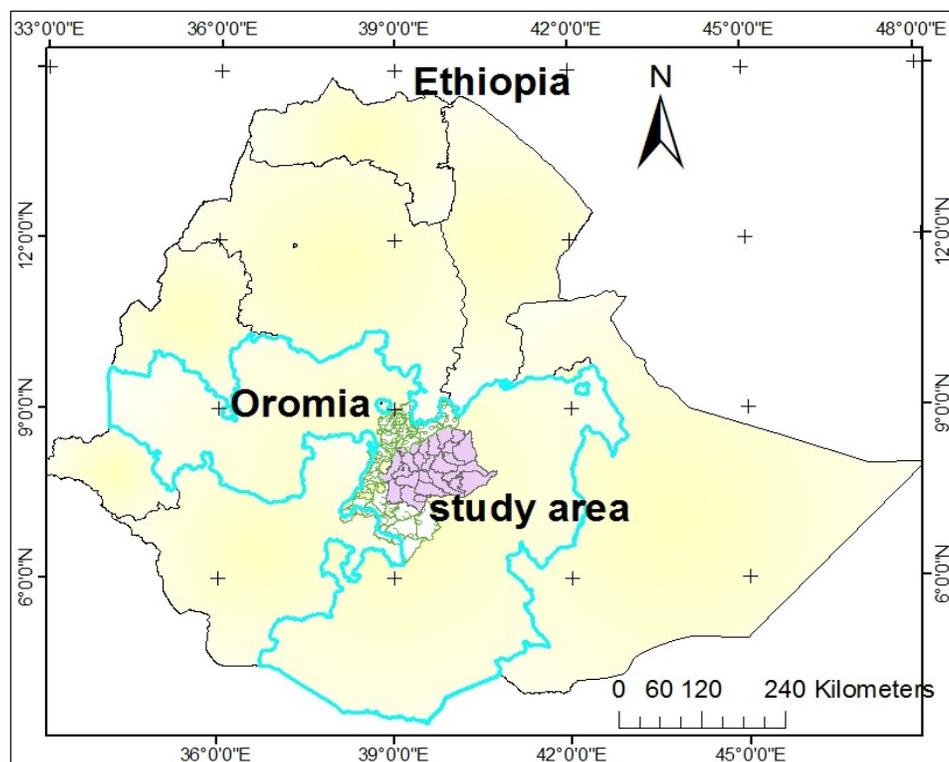


Figure 9: Map of study area drawn by using GIS (Arcmap-vesion-10.3)

2.2. Source of Data

The climatic data of the study area were obtained from respondents, records of meteorological agencies and different literatures. The climatic condition were also obtained from spiritual leader (Raaga) in Gadaa sytem which is a unique endogenous Oromo's self-governance system since very ancient. It practically governs all the socio-political and economic life of Oromo ethnic group in Ethiopia. The preliminary sparse climatic information on temperature and rainfall for selected study sites were also obtained from recorded metrological data at National Meteorological Agency and householders' experience. Some longest rainfall and temperature records were started in 1950s whereas many other records were started in the 1980s, following the response to the 1980th drought. However the modern National Meteorological Agency (NMA) was established on December 31, 1980 (NMA, 2012). The secondary data used in this study were obtained from many unpublished and some published documents.

2.3. Sample Size and Sampling Techniques

The sample size for this study is used to determine number of respondents from whom primary data can be generated through the survey of Sikko Mando Oromo in Arsi, East Shoa and west Arsi administrative zones. Hence the number of selected respondents were 95% of total listed population for spiritual leaders (Raagas, who knows and responsible for climate prediction more than others) and 5% of target householders for householders' survey.

A total of 77 respondents were purposively selected from study area. The site identification and selection was based on the site having high potential of the gadaa system followers. Respondent households were purposively selected from where this gadaa system followers dominantly found in. The survey was conducted from mid-January to mid-February in 2018.

2.4. Methods of data collection

In addition to data available at the Ethiopian Meteorological Agency, the climatic data were generated through a community survey conducted in Arsi (Sikko Mando communities) found in Arsi, East Shoa and West Arsi zones of Oromia. The primary data for this study were collected through interviews with Raagas, those are the spiritual leader in Gadaa system, community level focused group discussions, and field observations in January, 2018. This study was also used the recorded climatic data at Meteorological stations as well as on climate wizard tools website. The climate wizard tools is one of the global historical climate network that put together a huge climatic database at global scale. In our case it includes daily data of several meteo-stations in Ethiopia, whose source is

always the National Meteorological Agency (MOA, 2008). Whereas the climatic data in Gadaa system were those have been seen by spiritual leaders of Gadaa system.

2.5. Methods Data Analysis

Using statistical software known as SPSS v. 22 the quantitative data obtained from survey and meteorological data were analyzed by descriptive statistics such as frequencies, means and percentages. The temporal variation in mean of temperature and precipitation above 40 years were analyzed by using trends analysis. The trends of temperature and precipitation data were compared with recorded data. The qualitative data obtained from focus group discussions and key informants interviews were analyzed and interpreted in the form of narratives, trend analysis and descriptions.

3. RESULT AND DISCUSSION

3.1. Meteorological Evidences of climate change

The recorded temporal distributions of rainfall and temperature of Ethiopia in five decades from 1950 to 2005 were used meteorological data in climate wizard tools. The investigation of climatic parameters and climate classification is a base for climate change control. Climate change is accelerating by human activity and thus causing socio-economic and ecological trouble. A long-term rising in averages temperature and decreasing of precipitation were successfully recorded meteorological data in Ethiopia. From 1950 to 2005 the annual averages temperature of Ethiopia was increased by the rate of 0.014°C whereas the annual mean rainfall was decreased by 0.2 unit. Thus in Ethiopia the estimated annual averages temperature of 2018 is greater than that of 2005 by 0.182°C whereas averages rainfall is less by 2.6 unit (figure 2). In fact, the precipitation and temperature determine the characteristic of other climatic parameters such as hail, cloud, frost, air pressure and wind movements. Similar to climatic condition in this finding NMA (2012) reported the global climate change since the recent decade of the 20th and the starting of the 21st century was the warmest global record. The increased world mean temperature by 1.08°F since the start of the 20th century was caused the changes in precipitation, atmospheric moisture and atmospheric circulation. The recorded trends of climatic events; mainly precipitation and temperature, in Ethiopian was also reported by MOA (2008); NMA (2012) and Massimiliano et al (2015) as well. According to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), the Earth's average surface temperature increased $0.6 \pm 0.2^{\circ}\text{C}$ in the 20th century. McSweeney et al. (2007) and World Bank (2010) were also reported that Ethiopian mean annual temperature from 1960 to 2006 was increased by 1.3°C with an average rate of 0.28°C per decade and also projected to increase by 1.1 to 3.1°C by the 2060s and 1.5 to 5.1°C by the 2090. This climate projections has also suggested a rising frequency of rainfall variability both severe flooding in rainy season and droughts in dry season of a year.

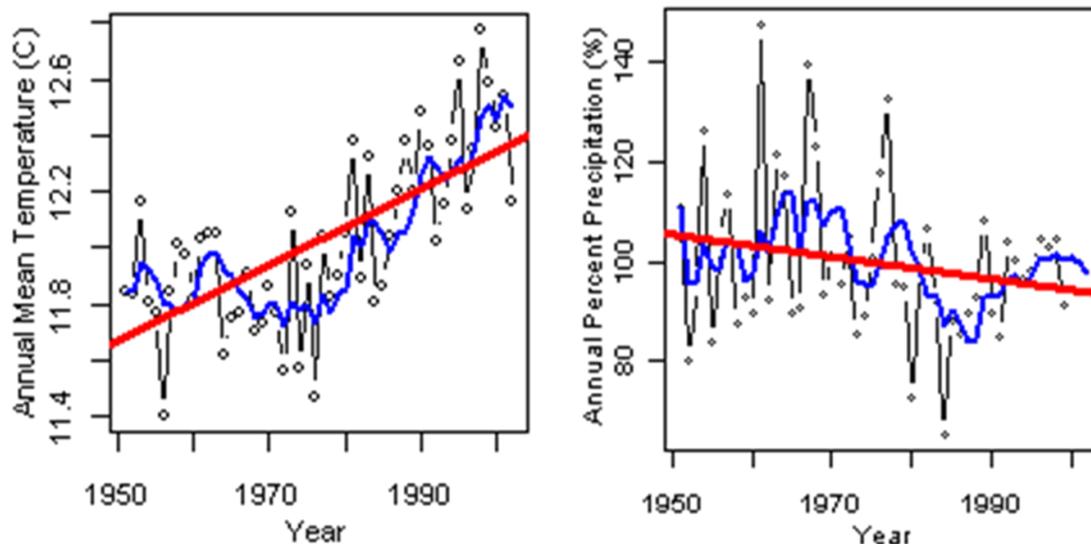


Figure 10: Ethiopian precipitation and temperatures condition in five decades

3.2. Evidences of Climate change in Oromo Gadaa system

Gadaa system is socio-economic, environmental and political vigilant indigenous democratic leadership system uniquely used by Oromo ethnic group in Ethiopia. Environmental management of Gadaa system is widely recognized in their traditional governance. The spiritual leader in Gadaa system named “Raaga” can easily

forecast future climatic condition based on past climatic events. Past climatic events can be obtained by observing the thickness of layer of trees ring and sediments, star, and wind direction within five Gadaa periods and in their life experience. Indicators of climate changes can be more than list however the respondents were listed eighteen of them that they have been well understood and used in Oromo Gadaa system. The decreasing of none timber forest products (NTFP), forest coverage, crop production and double cropping, and increasing of temperature were evaluated by communities as very high whereas the trends of rising of trees disease incidence were evaluated by communities as low (table-1). According to spiritual leaders the thinner layer of sediments or tree rings coming after three layer in average means the drought were occurred after three years. The community's estimation of climate change were in consistence with the trends of temperature and rainfall simulated in figure-2. As respondents point out the accusing finger are to anthropogenic cause of climate change like population growth, biomass energy, expansion of agricultural land, low productivity and small land holding, poor policy and degradation land resources in general. In consistence to climate change induced effects in this finding were also reported by Viste, et al., (2012). In addition to climate change and variability in this finding Mekonnen, et al. (2018) reported the increased mean 40 years' temperature by 0.047 °C/year while mean annual rainfall has declined by 10.16 mm since 1983. As reported by Berhanu and Beyene, (2015) the average temperature in Borana rangelands has upward trend with 0.3% of an average annual rate of increase in the recent four decades. While the annual rainfall has experienced a long-term declining trend in mean within the last several decades. Madeleine et al., (2017) was reported the expansion of malaria by climate change and associated human health problems. Berhanu and Beyene, (2014) also reported the severity of drought, commodity price fluctuation, crop pests, and death and illness of family members in Ethiopia. Goll et al (2014) and FAO (2010) report also shows world forest degradation has been serious global problems even if the mean plantation was increased since 2000. This is because of Getahun et al (2016) report: Large animal population induced overgrazing and Ethiopian population is more than 90 million, with 2.6% annual growth rate, of which 85% is dependent on agriculture in expense of forest land. Assefa and Bork (2013) lack of ownership stimulates illegal logging and the so called tragedy of commons. Weak policy implementation on land use, low capacity of forest institutions, land use conflict and policy discrepancy were aggravating forest loss. Implementation of investment and settlement policies without assessing environmental impact was also a major problem (Moges et al, 2010).

Table 4: Indicators of climate change as evaluated by community in five Gadaa periods

| No | Selected Indicators of extreme climatic event | N | Mean | SD | SE | Min. Value | Max. Value |
|----|---|----|-------|-------|---------|------------|------------|
| 1 | Decreasing of NTFP like Beehives | 77 | 4.95 | 0.223 | 0.02546 | 4.00 | 5.00 |
| 2 | Decreasing of Forest coverage | 77 | 4.948 | 0.223 | 0.02546 | 4.00 | 5.00 |
| 3 | Decreasing of Crop production | 77 | 4.792 | 0.522 | 0.05944 | 3.00 | 5.00 |
| 4 | Rising of Temperature | 77 | 4.688 | 0.654 | 0.07455 | 3.00 | 5.00 |
| 5 | Decreasing of Double cropping | 77 | 4.688 | 0.730 | 0.08321 | 2.00 | 5.00 |
| 6 | Decreasing of Water availability | 77 | 4.156 | 0.365 | 0.04161 | 4.00 | 5.00 |
| 7 | Decreasing of Livestock production | 77 | 4.104 | 0.307 | 0.03500 | 4.00 | 5.00 |
| 8 | Rising of Crop disease incidence | 77 | 4.104 | 0.307 | 0.03500 | 4.00 | 5.00 |
| 9 | Decreasing of Pasture availability | 77 | 4.104 | 0.307 | 0.03500 | 4.00 | 5.00 |
| 10 | Rising of Drought frequency | 77 | 4.052 | 0.223 | 0.02546 | 4.00 | 5.00 |
| 11 | Temporal and spatial variability of rainfall | 77 | 4.009 | 0.319 | 0.0297 | 3.00 | 5.00 |
| 12 | Drying of hydrological area | 77 | 4.000 | 0.324 | 0.02697 | 3.00 | 5.00 |
| 13 | Rising of Flooding rate | 77 | 3.948 | 0.223 | 0.02546 | 3.00 | 4.00 |
| 14 | Decreasing of Forest products & services | 77 | 3.896 | 0.307 | 0.03500 | 3.00 | 4.00 |
| 15 | Overall land productivity | 77 | 3.675 | 1.473 | 0.16786 | 0.00 | 5.00 |
| 16 | Shifting of lowland crop to highland | 77 | 3.411 | 1.413 | 0.15915 | 0.00 | 5.00 |
| 17 | Rising of Livestock disease incidence | 77 | 3.351 | 1.345 | 0.15330 | 0.00 | 5.00 |
| 18 | Rising of Trees disease incidence | 77 | 2.234 | 0.999 | 0.11380 | 0.00 | 4.00 |

0=Unknown/ no change, 1= Very low, 2=Low, 3= medium, 4=High & 5=Very high

3.3. Climate change prediction skills in Oromo Gadaa system

Trends of temperature and rainfall is the major climatic parameters used in forecasting of future climatic events in Gadaa system. Increasing of temperature condition was forecasted by every farmers in study area based on the trends of: decreasing temporal and spatial coverage of ice in humid area of highland, shifting of lowland crop like maize to highland area, and expansion of lowland pest and disease such as malaria to highland area. Inline to this finding CSA, (2012) reported as the changing and variability of climatic events can be assured from temperature and rainfall variation in amount, distribution and intensity. Mekonnen, et al. (2018) also realized climate changes mainly the changing in extent of temperature in Arsi Negele district from the changing of communities wearing style: because community could not wear cold resisting clothes which they used to wear before.

The rainfall is mainly forecasted by spiritual leaders and highly experienced elders in Gadaa system. The spiritual leaders in Gadaa system forecast future climatic condition based on the differences in thickness of sediment deposited, structure of tree rings developed, direction of seasonal cloud movements versus stars position and the structure of livestock intestine seen within different year of consecutive five Gadaa period (five decades). According to spiritual leaders a sediment deposit and tree ring developed in one year has different structure and color from that deposited in another year. One layer of sediments down in to the land shows that the sediment deposited in a year and one rings of tree's stem shows that it is deposited in one year. Their thinner layers of sediments or tree rings shows lower rainfall in that years. The thinnest layer coming after three layer of sediments or tree rings in average means the lowest and drought producing rainfall were occurred after three years. The changes in direction of winds and cloud movements in different season have been assumed to determine the rain in main rainy season whereas the stars position have been used to know the season of a years. Similar to rainfall variability in this finding EPA, 2012 and Massimiliano et al (2015) report's also shows that the rainfall producing wind in Ethiopia is influenced by variations associated with the position of the inter tropical convergence zone.

Table 5: Major factors used to forecast future climatic condition

| Extreme Climatic event | Major factors used to forecast future climatic condition | Responsible person |
|------------------------|---|--|
| Rising of temperature | Decreasing temporal and spatial coverage of ice area Shifting of lowland crop to highland Expansion of lowland pest and disease to highland | Community Community Community |
| Decreasing of rainfall | Thickness of each layers of sediment deposit Structure of tree rings Direction of cloud movements vs stars position Structure of livestock intestine | Spiritual leaders Spiritual leaders Spiritual leaders Spiritual leaders |

4. CONCLUSION AND RECOMMENDATIONS

The climatic events are mainly affected by variability and or change in mean annual and seasonal temperature and rainfall. In recent five decades a rising of mean annual temperature by 0.014 °C and decreasing of mean annual rainfall by 0.2 unit were well recorded meteorological data of Ethiopia within recent five decades. The estimated mean annual temperature in 2018 was greater than that of 2005 by 0.182 °C whereas that of mean annual rainfall is less by 2.6 unit. The trends of temperature and rainfall recorded were consistence with the climate change simulated by communities following Oromo Gadaa system. From listed indicators of climate changes the respondents were rated that the decreasing of forest coverage, double cropping and crop production and the increasing of temperature were very high. In Oromo Gadaa system the trends of rainfall and temperature have been the major climatic parameters used in forecasting upcoming climatic events. The rainfall has been mainly forecasted by spiritual leaders and highly experienced elders in Gadaa system whereas the temperature has been forecasted by ever communities governed under Oromo Gadaa system. As indicators of climatic events, the temperature was forecasted from the temporal and spatial variability in ice coverage at highland, shifting of lowland crop, pest and disease to highland. The spiritual leaders in Gadaa system forecast coming precipitation mostly from the thickness in layers of sediment deposited and tree rings developed in in different year, direction of cloud and wind movements in different season within five Gadaa period. According to spiritual leaders a sediment deposit and tree ring developed in different year have different structure and color. The thinnest layer of sediments or tree rings coming after three layer in average means the drought were occurred after three years. The changes in direction of cloud movements in different season from that of usual also affects the rain in main rainy season. The stars position have been used to know the season of a years. Therefore, such indigenous climate change prediction system of Oromo Gadaa system have to studied in detail and modernized for

sustainable community based participatory climate change adaptation and mitigation. The climate change prediction from differences in color of livestock intestine developed in different years need further investigation.

ACKNOWLEDGEMENTS

The Author would like to thank Culture and Tourism of in Arsi, East Shoa and West Arsi zones for cooperation during data collection. Abbaa Gadaas and all others respondents are highly appreciated for the valuable information they provided during data collection. Special thanks goes to Arsi University for financial support to this research project as well.

5. REFERENCES

- Assefa and Bork, 2013. Deforestation and forest management in the Chencha and Arbaminch areas of southern Ethiopia: Environmental management. 53:284-299pp.
- CSA, 2012. Welfare monitoring Survey, Summary Report. Federal Democratic Republic of Ethiopia (FDRE), Central Statistical Agency (CSA), Addis Ababa, Ethiopia.
- Dulla Gashe, 2011. Culture in sustainable development thinking: An indigenous water management system in Borana (Oromo) people: Wegeningen University of Social science.
- EPA, 2012. National report of Ethiopia, the United Nations conference on sustainable development. Addis Ababa: Ethiopia.
- Flintan, F., Boku Tache and Abdurehman Eid, 2011. Rangeland fragmentation in traditional grazing areas and its impact on drought resilience of pastoral communities: Lessons from Borana, Oromia and Harshin, Somali regional states, Ethiopia.
- Food and Agricultural Organization (FAO), 2010. Global Forest Resources Assessment.
- Goll I., Nick B., Jianhua L., McKay J. and John S., 2014. Causes of deforestation and forest degradation in Liberia. *Journal of Agriculture and Forestry Sciences*. 2:20-30pp.
- IPCC, 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the IPCC. Cambridge University Press, Cambridge, UK, and New York, USA. 582pp.
- Madeleine C., Thomson I., Christine L. Hershey, Adam B., Pietro C., Bradfield L., and Tufa Dinku, 2017. Using rainfall and temperature data in the evaluation of national malaria control programs in Africa. *The American Society of Tropical Medicine and Hygiene*. 13pp.
- Massimiliano F., Carlo B., and Paolo B., 2015. *The Climate of Ethiopia*.
- Melaku Getahun, 2016. Oromo indigenous knowledge and practices in natural resources management: land, forest, and water in focus. 181pp
- MOA, 2008. Relief interventions in pastoralist areas of Ethiopia. Minster of Agriculture and Rural Development. Addis Ababa, Ethiopia. 48pp.
- Moges, Y., Eshetu, Z., and Nune, S., 2010. Ethiopian forest resources: Current status and future management options in view of access to carbon finances. Ethiopian Climate Research and Networking and the United Nations Development Programme, Addis Ababa, Ethiopia.
- NMA, 2012. Twenty seven years meteorological data (temperature and rainfall) for Yabello station. National Meteorological Agency. Addis Ababa, Ethiopia.
- Oxfam International, 2010. Rain doesn't come on time any more: poverty, vulnerability, and climate variability in Ethiopia, Addis Ababa Ethiopia.
- UNFCCC, 2007. Climate Change: impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change (UNFCCC), Ethiopia.
- Viste, E., Sorteberg, A., and Diriba Korecha, 2012. Recent drought and precipitation tendencies in Ethiopia. *Springer-verlag, TheorApplClimatol* (2013) 112:535–551pp.
- Wassie Berhanu and Fekadu Beyene, 2014. The impact of climate change on pastoral production systems: A study of climate variability and household adaptation strategies in southern Ethiopian rangelands. World Institute for Development Economics Research.
- Wassie Berhanu and Fekadu Beyene, 2015. Climate variability and household adaptation strategies in southern Ethiopia. *Journal of Sustainability*. 2071-1050pp.
- Zenebe Mekonnen, Habtemariam Kassa, Teshale Woldeamanuel and Zebene Asfaw, 2018. Analysis of observed and perceived climate change and variability in Arsi Negele District, Ethiopia.