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Research Article

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The Effects of ENSO Phenomenon on Rainfall and Crop Yield in The Arsi zone, Ethiopia

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ABSTRACT
The primary coupled ocean-atmosphere phenomenon responsible for regional and global climate variability over an interannual time period is the El Niño-Southern Oscillation (ENSO). Evaluating the effects of El Niño and La Niña phenomena on rainfall and crop yield production over the The Arsi zone is the primary goal. The issues facing decision-makers simply assign grades to individuals and communities without considering the effects of ENSO occurrences on crop yield and the various ways that seasonal rainfall is used in agriculture. The knowledge is restricted on El Niño and La Niña phenomena and their impact on crop production during the Belg and Kiremt seasons in the The Arsi zone. The Central Statistical Service (CSS) provided agricultural data from 1995 to 2020, while https://data.chc.ucsb.edu/products/CHIRPS-2.0 provided satellite rainfall data from 1981 to 2021. Crop yields over the study period and the correlations between crop, ENSO phase, and rainfall data were established. When we examined the relationship between agricultural yields and rainfall during ENSO events, the crops showed that they produced more during neutral, El Niño, and La Niña events relative to rainfall amounts and the distribution showed a decline during El Niño compared to neutral and La Niña events. Meher and Belg crop yields were more affected by strong ENSO episodes. Over the The Arsi zone, the ENSO phases affect the distribution of seasonal rainfall and agriculture productivity. In the end, this research can provide important insights for developing effective mitigation and adaptation strategies to lessen the effects of climate change.
Keywords: Belg; Kiremt; Effect; Rainfall; ENSO; Crop Yield

INTRODUCTION

The El-Niño-Southern Oscillation (ENSO) is the most important coupled ocean atmosphere phenomenon to cause global climate variability on inter-annual time scale. Basically, the phenomenon is related to the quasi periodic redistribution of heat across tropical Pacific region. ENSO is characterized by a varying shift between a neutral phase and two extreme phases such as El Niño and La Niña (Cirino et al., 2015). The El Niño phase is marked by a deep layer of warm ocean water across the eastern and central equatorial Pacific region (Trenberth, 1997). La Niña related condition is opposed to those of El Niño a deep layer of cooler than average ocean temperatures across the east-central equatorial Pacific region. Monthly and spatially Sea Surface Temperature anomaly (SSTa) and the index values of each month has been considered over the tropical Pacific region of 5°S - 5°N and 150°W - 90°W (Rasmusson & Carpenter, 1983; Goddard et al., 2001). ENSO is the inter-annual fluctuation of the atmosphere-ocean system in the equatorial Pacific and it has three phases: warm (El Niño), cold (La Niña), and neutral (Chen et al., 2014; Yu et al., 2015; FAO, 2019; Goddard et al., 2001). Neutral conditions occur when neither El Niño nor La Niña is present. El Niño is a recurrent global atmospheric oceanic phenomenon associated with an increase in SST in the central tropical Pacific Ocean. The natural mode of climate variability associated with El Niño-Southern Oscillation (ENSO) as well as increase in anthropogenic activities has greatly contributed to the observed changes in rainfall and temperature within the country (Diro et al., 2012; Rowell et al., 2015). ENSO describes naturally occurring climatic events which result from the tropical Pacific Ocean (WMO, 2014), and atmospheric temperature fluctuations that can have major implications on global weather patterns (Sutton et al., 2019). The extreme events of ENSO termed as El Niño and La Niña, encompass a wide range of natural climatic conditions (Girishkumar et al., 2012; Zhang et al., 2012). In Ethiopia, El Niño phases of ENSO are generally associated with lower stream flow and La Niña phases were associated with higher stream flow; although this is not always the case (Zaroug et al., 2014; Abtew et al., 2009). Extremely dry years in Ethiopia were most likely associated with El Niño events while extremely wet years were associated with La Niña events (Abtew et al., 2009).

The geographical location and topographic complexity of Ethiopia produce high rainfall variability in the region across space and time (Gamachu, 1988). Spatial variations include the rainfall seasonal cycle, amount, onset, and cessation times, and length of growing season (Segele & Lamb, 2005), but sometimes, rainfall can be temporally varied from days to decades in terms of the direction and magnitude of rainfall trends over regions and seasons (Jury & Funk, 2016; Seleshi & Zanke, 2004). Moreover, these spatiotemporal variations in rainfall were attributed to, in Ethiopia at The Arsi zone, the variable altitudes (Gamachu, 1988; Korecha & Barnston, 2007). It boosts the risk of heavy rainfall and flooding in some parts of the world and the risk of drought in some parts (FAO, 2019). The SST of the tropical Pacific shows a discrepancy both spatially and temporally (Philip, 2018) and a very high correlation exists between precipitation and SST (Wu et al., 2008; Chen et al., 2014). Several studies have been conducted on the spatiotemporal variability and trends of rainfall in Ethiopia (Mohammed et al., 2018; Moloro, 2018; Weldegerima et al., 2018; Abegaz & Mekoya, 2020; Geremew et al., 2020). However, there is seasonal rainfall variability and it has an impact on The Arsi zone. The impact of rainfall (ENSO events) on crop production has been assessed differently by various authors in the sub humid areas. The risk associated with climate variability poses a direct impact from the start of land preparation to final harvest (Akinseye et al., 2013; Mesike & Esekhade, 2014). The characteristics (e.g., amount, temporal distribution and geographical coverage) of rainfall during the main rainy season were the most important determinants of agricultural activity. The erratic rainfall patterns, including onset and cessation dates and distribution of rainfall govern crop yields and determines the choice of the crops to grow (Getachew & Tesfaye, 2015), thus requiring appropriate management Belay (2010) reported that rainfall variability directly or indirectly affects agricultural production by influencing the growth and development of vegetation, emergence and distribution of crop pests, livestock diseases, aggravating the frequency and distribution of adverse weather conditions, reducing water aggravating the frequency and distribution of adverse weather conditions, reducing water supplies and enhancing the severity of soil erosion. While rainfall variability has always been a major challenge for Ethiopian at the The Arsi zone, Kiremt rainfall is less variable in most parts of the country compared to the Belg season (Bewket & Conway, 2007; Ayalew et al., 2012; Mengistu et al., 2014). Belg rainfall is highly variable, and its impact on agriculture is higher due to variable onset (Abebe, 2006).

This study is essential for the topic since it will raise awareness of the problems and establish a priority list for their solution. Analysis of the spatio-temporal impact of ENSO Phenomenon and evaluation of the effects of ENSO over the study area. A single country or a group of countries were the focus of the earlier research objects. According to empirical evidence, ENSO and climate change will have distinct effects on different regions of the same country (Cashin et al., 2017; Laosuthi & Selover, 2007). Therefore, the goal of this study is to advance scientific understanding of impacts of El Niño and La Niña phenomenon on rainfall and crop yields production over The Arsi zone. The problems on decision makers just give marks to people and societies without assessing ENSO events for different seasonal rainfall usage on agricultural activities and impacts on crops productivity. The limitation awareness on El Niño and La Niña events and effects on Belg and Kiremt seasons' crop production over The Arsi zone. The results of prior national and regional studies in the subject area help to fill the gaps and give information. To improve community resilience to climate change, this knowledge is necessary in order to develop efficient mitigation and adaptation strategies. In order to create a pattern of innovation that must be implemented in the process of producing food crops in order to deal with climate change issues in the future, knowledge about the influence of ENSO on crop production per product became important.

MATERIALS AND METHODS

Study Area

The Arsi zone is in Oromia Region, central Ethiopia, with a latitude, longitude and elevation of 7°35'N, 39°10'E or 7.583°, 39.167° or (latitude between 7.176° up to 8.716°, longitude between 38.773° up to 40.734°) and 2,313 meters (7,589 feet) with respectively (Fig1). It is bordered on the south by Bale, on the southwest by the West The Arsi zone, on the northwest by East Shewa, on the north by the Afar Region and on the east by West Hareghe. The Arsi zone, located in south eastern Ethiopia, has an area of 20,737.24 square kilometers and is divided in to 24 woredas.

The average temperature ranges 10-25 ^{0}C. Its altitude ranges from 1500 to 4245masl. The zone receives rainfall twice per year (Belg-FMAM and Meher-JJAS) and on average receives from 500 to 1200mm. Extreme high and low seasonal rainfall variability impacts on crop productivity. This study is important for selected study area to notification the problems and give priority for the problems to be solved in societies on agricultural activities. Rainfall patterns across Ethiopia were seasonal. The Kiremt (JJAS) rains (June-September) tend to be reliable and provide the most rainfall to the central and northern regions of Ethiopia. The Belg (February-May), also known as the short rains, were often associated with less reliable rainfall and greater regional variability (erratic rainfall distribution) than the Kiremt rains. In some years, there was very little rainfall during the Belg rains, especially in El Nino events.

Data sources

For the characterization of spatial and temporal analysis of Neutral, El Nino and La Nina conditions (weak, moderate and strong) for Belg (FMAM) and Kiremt (JJAS) seasons as a function of frequency, magnitude, intensity, and severity status, long-term data were acquired from the Early Warning System Network (FEWS NET) Climate Hazards Center (CHC) has developed a series of products and software tools for agro-climatological analysis. In such cases, Climate Hazards Group Infra-Red Precipitation with Stations (CHIRPS) satellite rainfall data (https://data.chc.ucsb.edu/products/CHIRPS-2.0/) is a vital source of rainfall data (Asfaw et al., 2018; Dinku et al., 2018; Belay et al., 2019). Among the products is the Climate Hazards Group Infra-Red Precipitation with Stations (CHIRPS), a gridded rainfall estimate produced in near-real time with a spatial resolution of 0.05 degrees (0.05◦ × 0.05◦) or (~5km), a time series from 1981 to the present. Source of data: (Funk et al., 2015; Toté et al., 2015; Lemma et al., 2019; Dinku et al., 2014). The crops of teff, barley, wheat and maize data as input sources from the Central Statistical Service (CSS) of Ethiopia for input of this research study area.

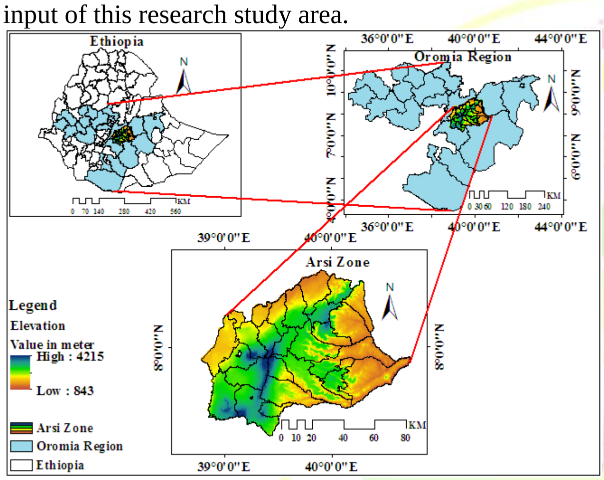


Figure 1. Study Area of The Arsi zone, Oromia and Elevation in meter.

Methodology

In this study selected and analyzed seasonal Belg (FMAM) and Kiremt (JJAS) CHIRPS rainfall data from years 1981-2021 were acquired from GeoCLIM Tool by importing CHIRPS-Prelim in the format of ire_ppt_dekad.climdata. Spatially, the interpolation method is basic when we use GeoCLIM; the type of interpolation algorithm could be used in the process, Simple (idw_s) or Ordinary (idw_s) inverse distance weighting (IDW). For this study used tools like QGIS Software used for clip of The Arsi zone shape file from central map of Oromia, Ethiopia shape, GIS Software used for indication of study area and elevation, Python used for temporal analysis, Artificial Neuron Network (ANN) for crop prediction and GeoCLIM Software used for spatial rainfall analysis of the result (Belg-FMAM and Kiremt-JJAS seasons) over study area.

Generally, climatic seasons in Ethiopia, similarly in the The Arsi zone, are categorically divided into three main seasons. These were; i) main rainy season from June to September, ii) dry season from October to December/January, and iii) smaller rainy season from February/March to May, known locally as Kiremt, Bega and Belg respectively (Yilma et al., 2004, NAMSA, 1996, NMA, 2015 season classification). Based on this classification, we used Belg and Kiremt with ENSO phases and crops like teff, barley, wheat and maize for analysis of yield Qn/Ha showing an increment or decrement during 1981-2021 over the The Arsi zone.

RESULTS AND DISCUSSION

According to the findings, the Belg and Kiremt seasons of the The Arsi zone strongly correlate with seasonal rainfall and ENSO in the Pacific. Positive and negative rainfall anomalies were brought on by opposing SST anomalies in Ethiopia (Dubache et al., 2019; Fetene et al., 2019). According to Seleshi and Camberlin (2006) and Weldegerima et al. (2018), warm ENSO periods (El Niño years) were often associated with lower precipitation and drought years in many regions of Ethiopia, whereas cold ENSO times (La Niña years) were associated with higher precipitation amounts. Exceptionally dry years in the The Arsi zone was probably related to El Niño occurrences, while exceptionally rainy years were probably associated with La Niña events, according to the spatial and temporal records of this research area. The result of this study analysis showed as follow with positive and negative significant impact of ENSO across seasonal Belg and Kiremt seasons' crops production.

Spatial rainfall analysis of FMAM and JJAS seasons with the ENSO Phenomenon

Most of Ethiopia, except the southern and southeastern lowlands, experiences the small rainy season known as Belg (February until May). High maximum temperatures were frequent, and rainfall during the season is highly varied in both time and place (NMSA, 1996b). The small rains, often referred to as the Belg (FMAM) rains (February to May), were more frequently linked to regional variability (erratic rainfall distribution) than the Kiremt rains in the The Arsi zone. Occasionally, especially in El Niño years, the Belg rains don't produce much precipitation. From the result study area analysis of the Figure shown as below FMAM mean rainfall is 300 mm up to 400 mm in most of the zone. But mean rainfall distribution is less than 250 mm (Fig2 (a)). In case of JJAS mean rainfall is between 400 mm up to 750 mm in most of The Arsi zone (Fig2 (b)). Belg and Kiremt seasons rainfall climatology during 19981-2021 and as below maps analysis shown neutral FMAM and neutral JJAS years (for the neutral years of 1981, 1985, 1989, 1990, 1992, 1993, 1996, 2001, 2003, 2012, 2013 and 2019). On the map analysis of Belg and Kiremt seasons rainfall climatology with comparison of neutral condition on both Belg and Kiremt seasons were almost similar rainfall distribution except pocket areas of The Arsi zone.

Belg (FMAM) season climatologically rainfall distribution showed that in the Fig2 (a) and (c) from 200 mm up to 500 mm in case of neutral FMAM condition with the magnitude of 250 mm up to 500 mm with respect to Belg season over the The Arsi zone. These rainfall situations were favorable for major crops production across maize, wheat, barley and teff as well as better for Belg agricultural activities, land preparation, sowing, and crop growing and flowing stages over the The Arsi zone.

Similarly, Kiremt (JJAS) season climatologically rainfall distribution showed that in the Fig2 (b) and (d)) from 500 mm up to 750 mm in case of neutral JJAS condition with the magnitude of 500 mm up to 750 mm (high spatial rainfall coverage) concerning Kiremt season over the The Arsi zone. These rainfall situations were favorable for major crops production across maize, wheat, barley, and teff indicated as better for meher agricultural activities, land preparation, sowing, and crop growing and flowing stages over The Arsi zone. JJAS rainfall amount and distribution had a high contribution for meher crops of cereals.

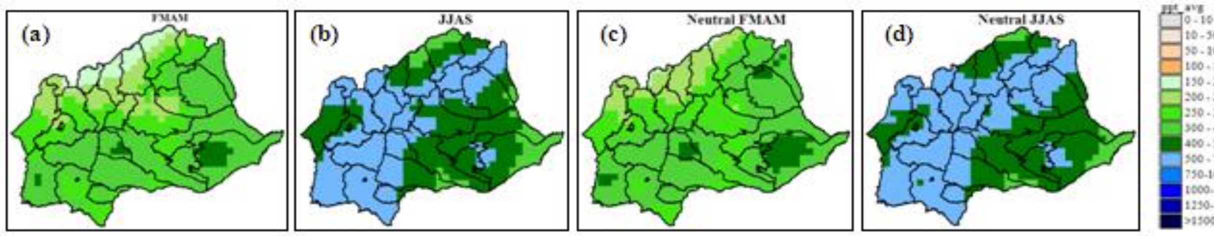


Figure 2. Spatial rainfall climatology and neutral analysis of Belg and Kiremt seasons.

Spatial rainfall distribution of JJAS season for climatologically, Neutral, El Niño and La Niña years

Spatial rainfall analysis of El Niño-JJAS, Strong, Moderate and Weak El Niño showed that in the Figure below. Mean rainfall El Niño-JJAS is between 300 mm up to 750 mm (Fig3 (a)). The rainfall distribution has shown us in the Figure below a decrement at central and eastern parts of The Arsi zone compare to mean rainfall of JJAS with the magnitude (Fig3 (b)). At strong El Niño-JJAS means rainfall has less rainfall amount and distribution than moderate and weak El Niño-JJAS. Weak El Niño-JJAS has better mean rainfall distribution with the magnitudes of 400 mm up to 600 mm (Fig3 (d)). From the result of study area, spatial analysis of La Niña-JJAS, Strong, Moderate and Weak La Niña showed that in the Figure below. From the result study area analysis of the Figure shown as below, strong La Niña-JJAS mean rainfall distribution is between 500 mm up to 750 mm and at pocket areas has got from 750 mm up to 1000 mm rainfall amount (Fig3 (f)). At moderate La Niña-JJAS mean rainfall is almost similar to strong La Niña-JJAS with the magnitudes at Fig3 (g) and Fig3 (f) respectively over The Arsi zone.

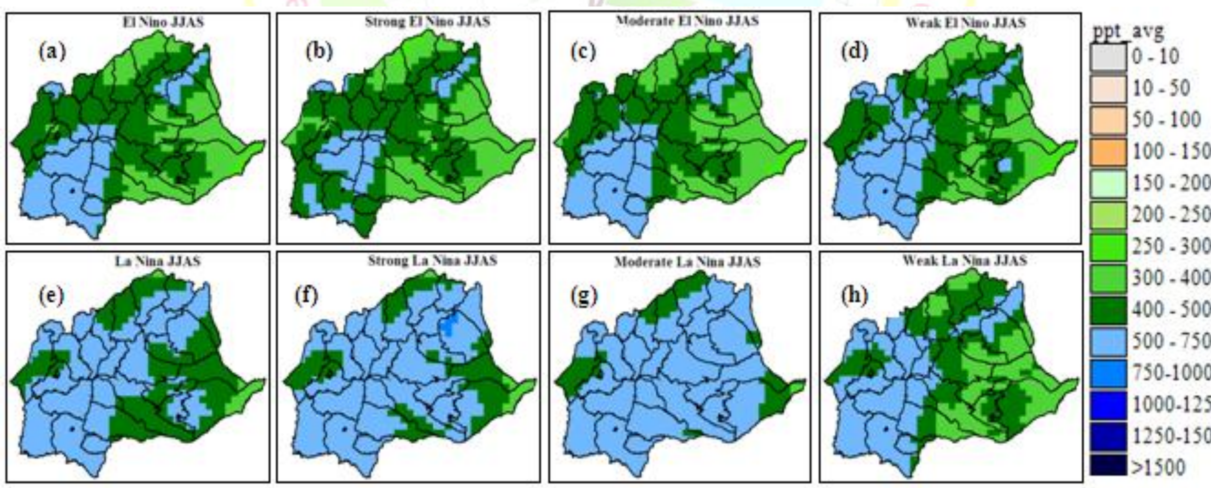


Figure 3. Spatial rainfall analysis of El Niño and La Niña events (Strong, Moderate and Weak) for Kiremt season.

Spatial rainfall distribution of FMAM season for climatologically Neutral, El Niño and La Niña years

Spatial rainfall analysis of El Niño-FMAM, Strong, Moderate and Weak El Niño showed that in the Figure below. Weak El Niño-FMAM map analysis showed us better mean rainfall amount and distribution than mean rainfall of strong and moderate El Niño-FMAM at the south west and eastern parts of the Arsi zone, with the magnitudes of 400 mm up to 500 mm (Fig4 (l)). Similarly, from the result of the study area, spatial analysis of La Niña-FMAM, Strong, Moderate and Weak La Niña showed that in the Figure below. We looked at the Fig4 analysis; strong La Niña-FMAM mean rainfall showed higher rainfall amount and distribution than moderate and weak La Niña-FMAM at the south southeastern parts of the Arsi zone, with the magnitudes of 400 mm up to 750 mm (Fig4 (o)).

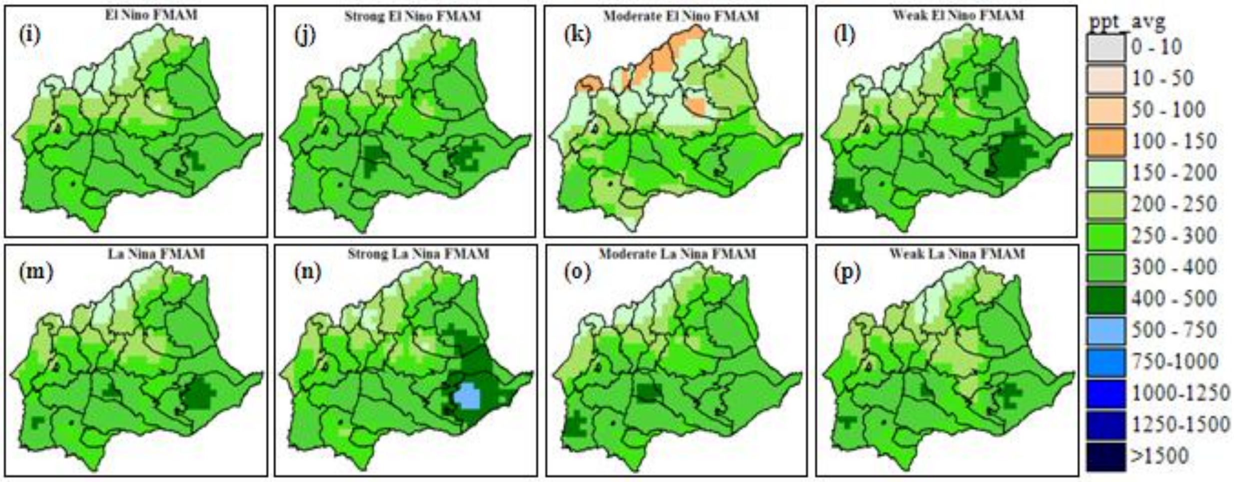


Figure 4. Spatial rainfall analysis of El Niño and La Niña events (Strong, Moderate and Weak) for Belg season.

ENSO phases based on Sea Surface Temperature (SST) with Seasonal ITCZ movement

The phase of ENSO is classified based on Sea Surface Temperature (SST) between +0.5 and -0.5^{0}C, above 0.5^{0}C and below 0.5^{0}C of Neutral (normal), El Niño (hotness) and La Niña (coldness) conditions with a magnitude respectively. The seasonal cycle of Ethiopian rainfall is dominated by the meridional migration of the Intertropical Convergence Zone (ITCZ) across Ethiopia (Griffiths, 1972; Segele et al., 2009a). Similarly Inter Tropical Convergence Zone (ITCZ) movement in north and south has great characteristics on seasonal rainfall enhancement at the Arsi zone. We visualized from Fig3, the seasonal rainfall distribution over The Arsi zone on the phase of El Niño-JJAS compared to La Niña-JJAS most parts have got 300 up to 500mm and at few parts of south west the Arsihave got 600mm and in La Niña phase in the magnitude of 750mm Kiremt rainfall distribution. La Niña episodes were also associated with heavier-than-normal rains during the June to September long rains in the central and highland areas of the Arsi zone. After continued and heavy Kiremt (JJAS) rains in many areas, flash and river flooding occurred in La Niña events. El Niño-FMAM and La Niña- FMAM rainfall distribution in Fig4 indicated below normal and above normal rains with respectively.

Generally, from the study result, the ENSO conditions have a variation on seasonal Belg (FAMM) and Kiremt (JJAS) rainfall amount and distribution. Neutral, El Niño and La Niña phenomena effects on the Arsi zone with the magnitude of normal, deficit and excess seasonal rainfall distribution in respectively. On map analysis, strong, moderate and weak El Niño JJAS indicated low or deficit rainfall distribution, whereas strong, moderate and weak La Niña JJAS indicated an excess. The system of SST and ENSO phenomena has characteristics through seasonal and annual variations. Inter Tropical Convergence Zone (ITCZ) movements have a factor on the seasonal rainfall enhancement on the Arsione rainfall amount and distribution.

Belg (FMAM) season naturally has erratic and unpredictable rainfall distribution, as we observed from the result study, there was a deficit in rainfall distribution under El Niño conditions, especially at strong and moderate El Niño seasons. The occurrences Neutral, El Niño and La Niña during 1981-2021 twelve (12), thirteen (13) from these four years weak, four years moderate and five years strong El Niño condition and sixteen (16), from these seven years weak, four years moderate and five years strong La Niña condition with respectively in The Arsi zone. Table 1 shows that La Niña conditions (weak La Niña, almost similar to normal conditions) in Belg (FMAM) and Kiremt (JJAS) seasons have a higher chance of occurrence than El Niño in the Arsi zone. We observed that the seasonal rainfall distribution, which is weak La Niña (similar to normal conditions) a dominant event as compared to El Niño conditions. The frequency of occurrence El Niño and La Niña conditions in moderate four (4) and strong five (5) years is almost similar during the period of 1981-2021 (Table 1).

Temporal rainfall analysis of FMAM and JJAS seasons for Neutral, El Niño and La Niña (weak, moderate and strong) years

The graph below shows that the rainfall pattern over The Arsi zone by ENSO (Neutral, El Niño and La Niña) events including the strength of event at different magnitudes for the zone. The graphs that explain the influence of the ENSO phases (Normal, El Niño, and La Niña) over rainfall of the Arsi zone was provided below with seasonal Belg-FMAM and Kiremt-JJAS time series analysis.

The relationships of normal years, El Niño years and La Niña years with Belg (FMAM) season rainfall at different strengths were presented in Fig5 (a). In this figure, the amounts and distribution of Neutral FMAM rainfall were slightly higher than El Niño events during weak (wk-EL), moderate (mod-EL) El Niño phase, and weak (wk-La), moderate (mod-La), strong (strg-La) La Niña phase. But FMAM rainfall of strong El Niño events was more than FMAM rainfall of Neutral events. The seasonal rainfall varies with respect to normal, and below normal precipitation occurred during weak and moderate El Niño and La Niña states on the graph shown in Fig5 (a).

In general, Belg February-March-April-May (FMAM) season rainfall amount and distribution in The Arsi zone was above normal during the strong El Niño (strg-EL) season, which was supported by the results shown in (Fig5 (a)) of The Arsi zone. The result shows, the amount of rainfall was increased when the strength of events was increased (strg-EL). Slightly the amount of FMAM reduction depends on the magnitude of El Niño and La Niña events (weak, moderate, or strong) during 1981-2021.

Table 1. List of El Niño, La Niña years (Strong, Moderate and Weak) and Neutral years

El Niño Years (13)			La Niña Years (16)			Neutral Years (12)
Weak(4)	Moderate(4)	Strong(5)	Weak(7)	Moderate(4)	Strong(5)	Neutral(12)
2004-05	1986-87	1987-88	1983-84	1995-96	1988-89	1981
2006-07	1994-95	1991-92	1984-85	2011-12	1998-99	1985
2014-15	2002-03	1982-83	2000-01	2020-21	1999-00	1989
2018-19	2009-10	1997-98	2005-06	2021-22	2007-08	1990
		2015-16	2008-09		2010-11	1992
			2016-17			1993
			2017-18			1996
						2001
						2003
						2012
						2013
						2019

Sources: https://ggweather.com/enso/oni.htm

At the season of Kiremt (JJAS) rainfall amount and distribution examined the association between strong La Niña (strg-La) and Neutral years with rainfall in The Arsi zone, and the results were presented in Fig5 (b). The reason that we only considered strong La Niña (strg-La) events was because there were fewer instances of weak La Niña (wk-La) but higher in moderate La Niña (mod-La) than normal event during 1981-2021. The results show that above average (mod-La and strg-La events) and below average rainfall (wk-EL, mod-EL and strg-EL) events seem to be rainfall variation observed over Kiremt (JJAS) season in The Arsi zone during 1981-2021.

However, we calculated the deviation from normal by averaging all above and below normal rainfall and comparing them to determine the influence of the strong La Niña events (strg-La), based on strength. Our results were similar to the notion of strong El Niño (strg-EL) being associated with below-average rainfall, while strong La Niña (strg-La) associated with above-average rainfall which was seen in Fig5 (b) of Kiremt (JJAS) season. The influence of starting dates of the La Niña seasons were noted with respect to flood or extreme flood conditions, and when La Niña started in Kiremt June-July-August-September (JJAS) season, so there was a maximum chance for flood or extreme flood to occur. Whereas the influence of El Niño noted with respect to dry spell occurrence and drought conditions.

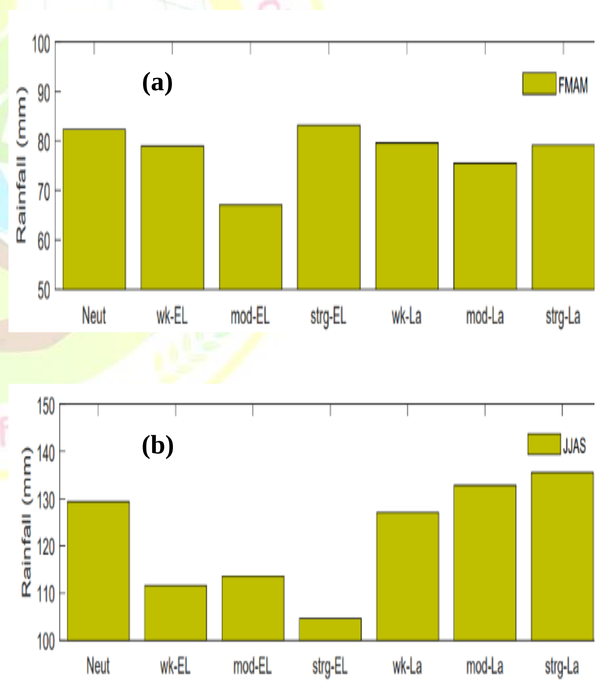


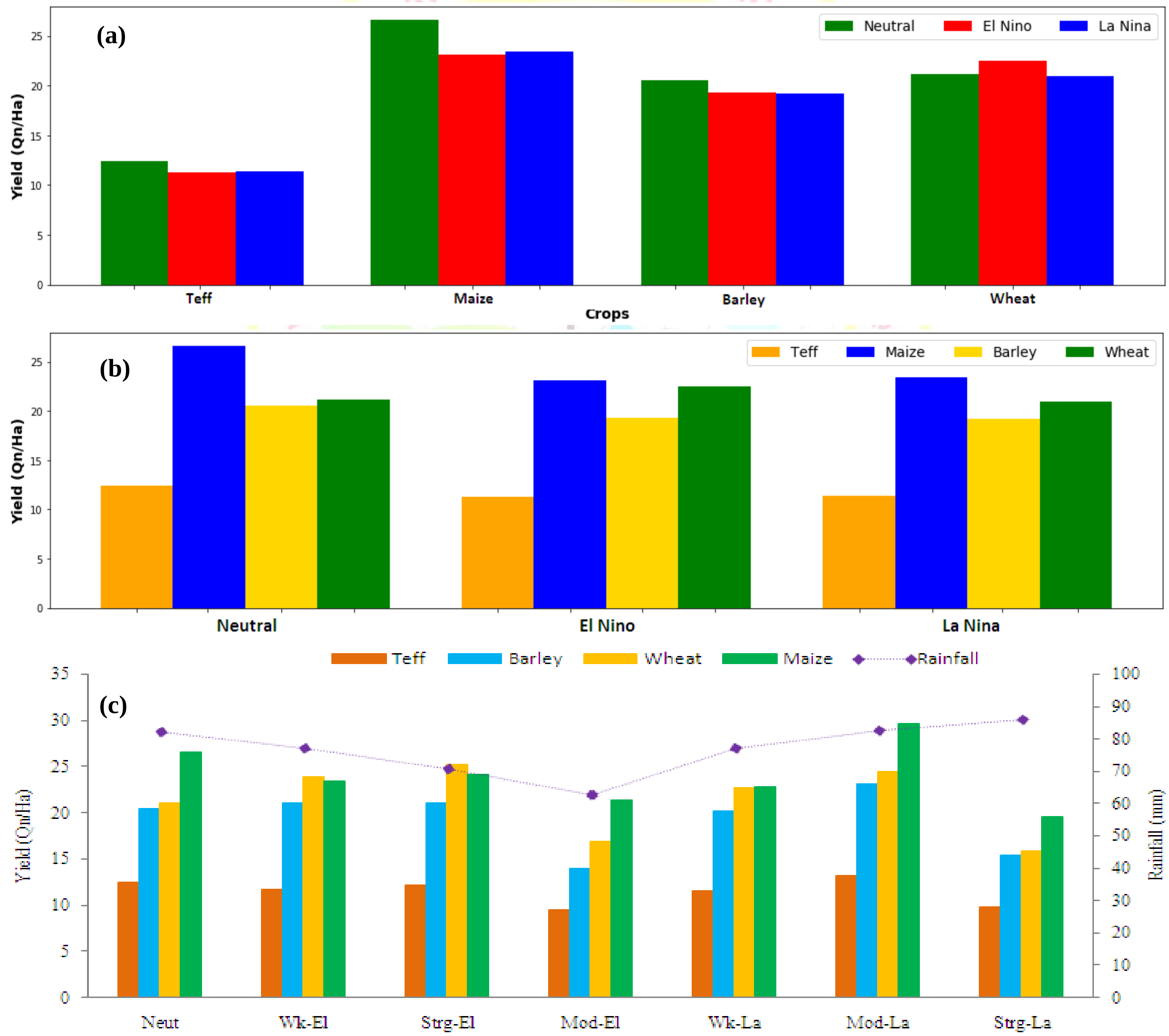
Figure 5. Mean Rainfall of Belg (FMAM)-(a) and Kiremt (JJAS)-(b) seasons time series of Neutral, El Niño and La Niña (Weak, Moderate and Strong) Years during 1981-2021.

Crop Productivity and ENSO Phases

The figure below shows the yields Qn/Ha deviation in The Arsi zone during Neutral, El Niño and La Niña years. The crop yields an increment and decrement in The Arsi zone was evaluated with respect to ENSO (Neutral, El Niño and La Niña) events. The results were presented in Fig6 (a), maize crop production shows an increment during Neutral than El Niño and La Niña events for all event strengths, maize crop show that in the Figure less yield productivity Qn/Ha at El Niño and La Niña events in The Arsi zone. Similarly, Barley and Teff indicated in the Figure better crops productivity during Neutral event with the magnitude of Barley higher yield Qn/Ha than Teff yield Qn/Ha respectively.

Wheat product show that slightly an increment during El Niño case than Neutral and La Niña cases in The Arsi zone. All crops in rank from first to fourth (maize, wheat, barley and teff) show that high yield productivity during Neutral event except wheat product in El Niño event. At strong El Niño year 2015, there was the deficient of rainfall amount and distribution but the yield Qn/Ha production was better relative to the other events Neutral and La Niña conditions. The reason behind might be better crops capacity of less moisture resistance, might be high crops variety and soil types of moisture capacity during strong El Niño event over The Arsi zone, it needs more investigation relate to soil types and crops.

Generally, when we compared yield productivity across maize, wheat, barley and teff with rainfall in the ENSO events, crops indicated that better yield productivity during Neutral, El Niño and La Niña events, in terms of rainfall amount and distribution, showed a decrement during El Niño than Neutral and La Niña events. The reason during El Niño case the rainfall amount and distribution were low in seasons, especially in Kiremt. Strong events had more influence on the seasonal yield productivity as illustrated in Fig. (b) and Fig 6 (d). However, the amount of crop yield reduction was different amongst the seasons during the El Niño and La Niña cases, the reason was low and high rainfall distribution, respectively.



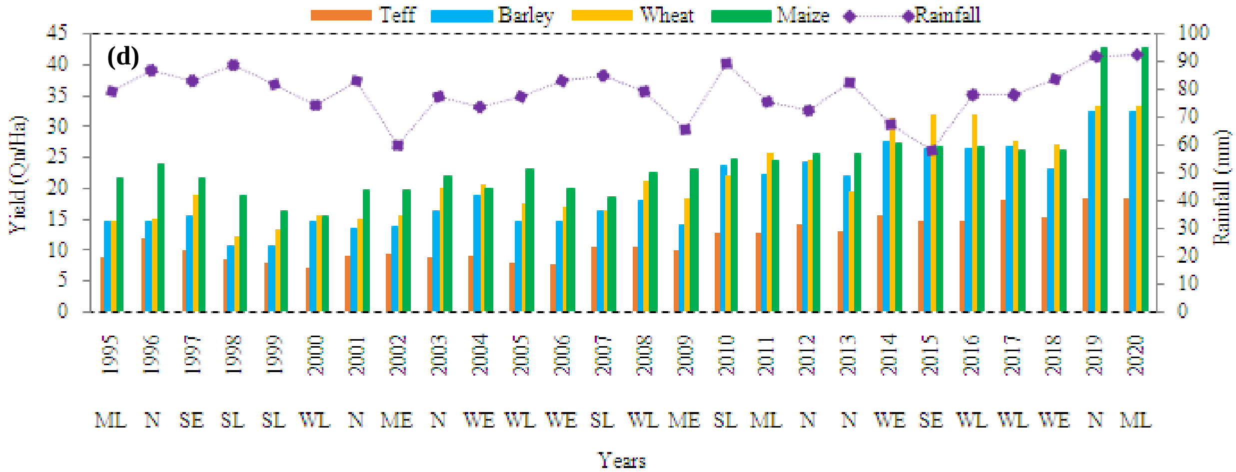
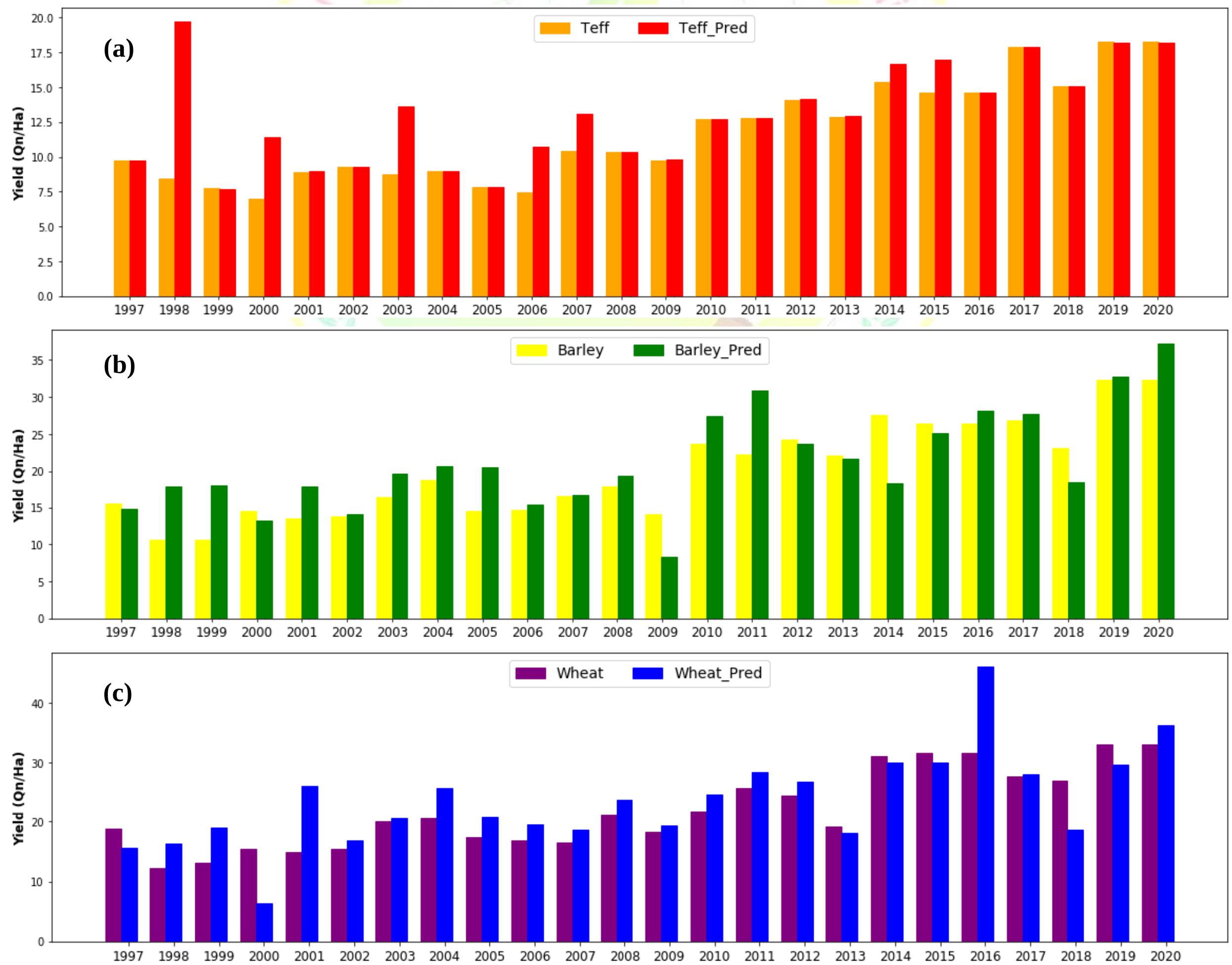


Figure 6. Yield Qn/Ha with rainfall in ENSO (Neutral, Weak El Niño, Strong El Niño and Weak La Niña, Moderate La Niña, Strong La Niña) events during 1995-2020.

Artificial neuron network analysis result shows that for crop prediction on teff, barley, wheat and maize; however, the performance of crop prediction was better in time scales except drought years. From the Figure 7 (a), (b), (c), (d) of the result demonstrated through comparison between crop yield and crop prediction of teff, barley, wheat and maize, respectively, have better crop prediction performance. The extent El Niño events reliably predict crop yields as crop varieties influence on artificial neuron network prediction. The rainfall parameter stand as the factor including temperature, soil moisture and relative humidity affected crop yields during ENSO (El Niño) events.



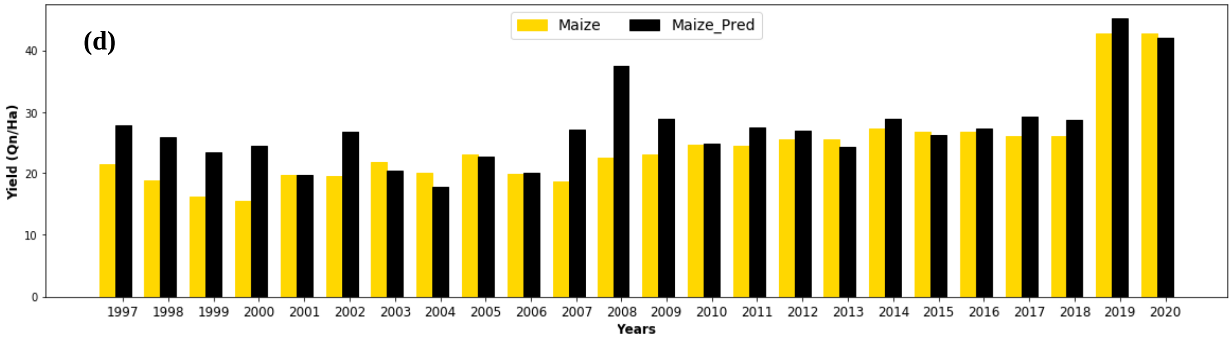


Figure 7. Time series analysis of crop prediction for (a) teff, (b) barley, (c) wheat and (d) maize.

Our findings indicate that most of the Belg (FMAM) and Kiremt (JJAS) seasons deficit rainfall amount during El Niño period and excess rainfall amount during La Niña period in the Arsi zone. This was similar with the findings for the Arsi zone seasonal rainfall distribution in the Neutral, El Niño and La Niña events between 1981 and 2021. The location and amount of the seasonal rainfall in the area were influenced by the migration of the ITCZ (Segele et al., 2009). Furthermore, the peculiarities of rainfall in various regions of the nation were impacted by large-scale phenomena like ENSO. A few studies addressed the local-level effects of atmospheric circulation (e.g., geopotential height, wind velocity, and rapid warming) (Segele et al., 2009; Taye et al., 2020), but the majority of prior studies concentrated on the large-scale effects of atmospheric circulation on the country's rainfall for the summer season (Seleshi & Zanke, 2004; Korecha & Barnston, 2007; Gleixner et al., 2017). This suggests that additional research was necessary to establish the extent of ENSO influence on local precipitation that has a significant impact on zones. To more fully assess how atmospheric circulation can affect the relationship between ENSO and national, regional, zonal, etc., climates, a further study was required. Each indication has inherent advantages and disadvantages, and its usefulness was frequently adapted for a particular application or decision-making process. Based on its performance for drought and wet monitoring over the Arsi zone, the three phases of ENSO were employed for this study to identify the distribution of normal, deficiency, and excess seasonal rainfall.

CONCLUSION

We concluded that the ENSO Phases (El Niño and La Niña events) have an influence on crop productivity in the Arsi zone. Crop yields increase or decrease depending on seasonal Belg and Kiremt rainfall variability with respect to ENSO Phases in the Arsi zone. For this reason, this study was directed toward the analysis of rainfall in spatial and temporal on both seasons Belg (FMAM) and Kiremt (JJAS) scales, investigated their potential trends, and detected their significance over the Arsi zone, along with investigate the ENSO (Neutral, El Niño and La Niña) that significantly influenced Arsi zone seasonal rainfall as well as yield production. ENSO Neutral conditions dominated in Belg-FMAM and Kiremt-JJAS seasons, with the relation of crop productivity over the Arsi zone. The time series analysis of crop yields indicated no significant impact on El Niño events. The extent El Niño events reliably predict crop yields as crop varieties influence on artificial neuron network prediction. The ENSO Phases (El Niño and La Niña events) have an impact on seasonal rainfall distribution and crop productivity over the Arsi zone. One of the most well-known climate modes, the ENSO (El Niño and La Niña), can cause widespread climate variability and crop loss, providing a serious threat to regional and zonal food security.

To improve crop production, water availability, and other aspects, it is advised that farmers pay attention to weather and climatic information provided by meteorological forecasts, early warning, and agro-meteorology advisory services (from the Ethiopia Meteorology Institute, EMI). It is also necessary to conduct additional research on how El Nino and La Nina events spread, including the use of several climate models to determine the variability of rainfall and intensity of rainfall distribution over time at the woreda, regional, and national levels. Ultimately, this study can offer significant insights for formulating efficient adaptation and mitigation methods for reducing the effects of climate change.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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