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# El Niño Southern Oscillation and its impact on Rainfall distribution and productivity of major agricultural Crops: the case of Kemabata Tembaro Zone, Southern Ethiopia.

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***Abstract:***

*This study was conducted to investigate the impact of El Niño Southern Oscillation on rainfall distribution and productivity of major Agricultural crops in the Kembta Tembaro Zone of Southern Ethiopia over the past 30 years. Precipitation and temperature data were obtained from the National Meteorology Agency, crop data from the Central Statistical Agency of Ethiopia, and the Sea Surface Temperature data from the NOAA website. The rainfall trend had shown decreasing trend with high variability at all the stations ($p<0.05$). Over the same period, El Niño and La Niña event were observed. It was found that Coefficient Variation was greater than 30%, which indicates the area was prone to drought episodes. The impacts of the ENSO events on the yield of Maize, Wheat, Barely, Sorghum and Enset were assessed. Wheat and Maize were highly affected by the* ENSO *events. Enset was found to be more resistant crop to the influence of ENSO. Barely and Sorghum were affected at varying magnitude. Among the five chosen crop for this investigation two of the crops were seriously affected during the two extremes, i.e. El Niño and La Niña. From this investigation it is conclude that the overall cereal crop productivity was decreased and precipitation variability was noticed. So, having the information about ENSO phase in advance can be used to forecast ENSO and select crop types and varieties to maximize agricultural rain fed cereal crop productivity while minimizing the crop risk associated with seasonal rainfall and ENSO phases.*

**Key words: ENSO El Niño La Niña Crop yield, Climate Change**

## 1. INTRODUCTION

The El Niño-Southern Oscillations/ENSO/ is one of the most important and longest-studied climate events. It is unexpected hotness or coldness of ocean waters that would occasionally form in the East Pacific (Trenberth & Hoar, 1997). This climate event leads to large-scale changes in sea-level pressures, Sea Surface Temperature/SST/, precipitation and winds in the tropics, its consequences appears in many parts of the world. ENSO is characterized by a varying shift between a Neutral, El Niño and La Niña phases. El Niño occurs when the central and eastern equatorial Pacific sea-surface temperatures are warmer than usual one (Tolossa, Books, OER, SCARDA, & Tenders, 2015)

The lead regions of ENSO start at $5^0$ N -$5^0$ S, where SST oscillations are observed. The representative region is the Niño 3.4 and the commonly used threshold for Sea Surface Temperature departure from normal $\geq$ +0.5°c. This region provides a good measure of important changes in SST and SST gradients that result in changes in the pattern of deep tropical convection and atmospheric circulation. The criteria that are often used to classify El Niño episodes are five consecutive 3-months mean SST anomalies which exceed the threshold. Concerning the monthly and spatially SSTA and the index values of each month has been considered over the tropical Pacific region at 5°S -5°N and 150°W - 90°W. The sea surface index values -0.5 is El Niño, - 0.5 to + 0.5 Neutral between and La Niña + 0.5 for five consecutive months over the Ocean. El Niño repeatedly takes place every 2 to 7 years and can last for months for a period of up to two years.(Dilley, Chen, Deichmann, Lerner-Lam, & Arnold, 2005)

El Niño and La Niño plays vital role in causing variation to SST, which result in large scale weather disruptions both on sea and on the interior parts of the continents. Findings showed that ENSO and local rainfall are highly correlated. Conditions at sea directly affects precipitation at local and regional level, which evidenced by "Teleconnection" that affects local rainfall patterns across the globe (Glantz, Katz, & Nicholls, 1991).It is believed that ENSO is related to devastating droughts in many parts of the world, including Africa (Glantz, 1994). Ethiopia, for being reliant on rain-fed agriculture is highly affected by ENSO. Little disruption on the rainfall bearing system is highly disturbing its substantial agriculture, since Agriculture is the backbone

 doi:10.20944/preprints202001.0260.v1

of the country's economy (Degefu, 1987; Funk et al., 2016; Yemaneberhan et al., 1997) Korecha, D., and Barnston, 2014).

The principal cause of drought in Ethiopia is affirmed with the occurrence of ENSO resulted from fluctuation of global atmospheric circulation, which is triggered by SSTA occurring in the ocean. For instance 1982, 1997, 1998, 2015/16 were ENSO induced drought years in Ethiopia with very strong *El-Nino* event and the year 1988, 1989, 1999, 2000, 2007, 2008, 2011 were strong La Niña event observed in the country. ENSO episodes have an impact on seasonal rainfall performance and rainfall variability over Ethiopia due to remote teleconnections (Gissila, 2001),(Korecha & Barnston, 2007). Most of the drought years were recorded during *kiremt seasons,* which the main cropping season due to El Niño episode. Since agriculture is heavily dependent on rainfall, productivity and production are strongly influenced by climatic and hydrological variability due to ENSO phases, in Ethiopia study showed that ENSO-based seasonal climate reduces crop yield, the degree of crop yield variability over time is determined by the amount, pattern, and frequency of rainfall.(Tolossa et al., 2015)

All areas of the country have been hit by ENSO with a varying magnitude from region to region. Particularly the farming community was highly stressed by ENSO episodes at every decade; they are not able to find pasture for animals and facing the other extremes accompanied by flooding and flooding over. It's reported that 50% - 90% of crops have failed during ENSO in the aforementioned years.(Workicho et al., 2016, Negeri, 2017). The area chosen for this study was Kembata Tembaro Zone, where the majority of the people are dependent on annual and seasonal rainfall for their survival. The livelihood of people was based on a mixed way of agriculture, which is totally reliant on rainfall i.e., cultivating crops and rearing animals. The variability of rainfall is affecting both crops and rearing of animals due to insufficient rain for their crops and pasture for their animals. The productivity of crop and their herd are declining from time to time. El Niño to the study area means complete failure of moisture. Hence, the aim of this work is assessing the effect of El Niño in the past three decades (i.e. 1987-2017). This study tries to measure the effect of El Niño shock on major agricultural crops, determining the influences of ENSO on the local rainfall distribution and to give an insight on how to live with this unavoidable event in Kembata Tembaro Zone South central Ethiopia where the local farmers and subsistent agriculture were subjected ENSO Phases induced calamities.

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## 2. Methods

### 2.1 Study area

The study site is located in SNNPR in Ethiopia, 350 km far away from Addis Ababa. The site encompasses seven words: Kedida-Gamela, Damboya, Angacha, Doyogena, Kachabira, Hadero-Tunto and Tembaro Woredas (Fig.2). Ambaricho Mountain which is commonly shared by all the districts, Kataa and Dato mountains are also important landmarks found in the study site. The longest river in the area is the Lagabora. The highest and the lowest points in the study site are 1400 and 3028 meter above sea level at the top of mount Ambaricho and near Ajora waterfall. The study site has a total population of about 1,080,837and a total area of 1,355.89 Km (Comenetz & Caviedes, 2002). The site gets dominant rainfall during the summer season (June - August) of Ethiopia and mainly covered with separate and fragmented home garden forest. The mean monthly temperature is about 27°C. Its area is subdivided into different Agro Ecological zones such as (*Dega/temperate*), woinadega (sub-tropical/ and, Kola (Tropical), with variability to climate elements. All forms of landscape are commonly seen at different altitudes from steep mountains to flat land plane land (Fig.1).

### 2.2. Data collection

Data were obtained from different primary and secondary sources, Daily rainfall data of 30 years (1987 to 2017) were obtained from National Meteorological Agencies of Ethiopia. Missing data were filled using NIPALS algorithms (Nonlinear Iterative Partial Least Squares) (Andrecut, 2009); (Wright, 2017). Crop data were obtained from Statistical Authority and the Sea Surface Temperature data over Nino regions, (http://www.esrl.noaa.gov/psd/data/climateindices/list/).

### 2.4. Data Analysis

#### 2.4.1. Rainfall distribution

The seasonal and annual rainfall distributions were analyzed based on historical rainfall data using XLStat software version 15 for spring (Belg), summer (Kiremt*)* and winter (Bega) seasonal rainfall data of 30 years. Six stations data were used for the study due to their fitness and Representative Metrological data of six stations for three decades were used for the analysis, and the coefficient of variation of seasonal and inter-seasonal rainfall variability and anomaly were analyzed by:

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$$cv = \left(\frac{SD}{\bar{X}}\right) * 100 \qquad \text{(Eq 1)}$$

$$Where\ \bar{x} = \frac{\sum Xi}{N}$$ And

$$SD = \sqrt{(Xi - \overline{x)2}} \qquad \text{(Eq2)}$$

$$RAi = \frac{Xi - \bar{x}}{SD}. \qquad \text{(Eq3)}$$

Where: **SD**: Standard Deviation, $\bar{X}$: Long year mean, **N**: is the total number of year taken, **Xi**: rainfall for each month /rainfall anomaly of each year. If the Rainfall Anomaly of each year is more than 0.5, between -0.5 and 0.5 and less than -0.5, meteorologically the season is **wet, normal, and dry**, respectively. Local rainfall variability will be analyzed and characterized using (Eq4.). This computation were made for homogenous rainfall regime during summer (kiremt) and spring /Belg/ seasons across the study site that enabled to show the degree of long-term temporal Zonal rainfall variability on both seasons.

Regional rainfall index **Rk** is calculated using the following formula:

- $R_{k,i} = \sum_i^m Wix\left(\frac{Ri,k - \bar{m}}{SD}\right)$ (Eq4.)

Where

**Rk**: regional level areal rainfall index,

$\mathbf{w_i}$ weight applied to the $i^{th}$ of n stations,

$\mathbf{Rk}_{,i}$ : rainfall at $i^{th}$ station during year k, and

**SD:** average standard deviation of the station's rainfall. If $\mathbf{R_k}$ is more than 0.5, between -0.5 and 0.5 and less than -0.5, meteorologically the zonal seasonal rainfall is categorized under Wet, Normal and Dry season, respectively. (Abdsa et.al. 2017).

**2.4.2. Rainfall Trend Test Analysis**

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The Mann-Kendall trend test is a non-parametric test to detect a trend in a series of values, which is available in Excel using the XLSTAT statistical software. Is a nonparametric test used to identify a trend in a series, even if there is a seasonal component in the series (Mann, 1945). (Kendall, 1975) (Hirsch & Slack, 1984) .

### 2.4.3. Analysis of relationships between crop yield and ENSO

Average Zonal crop yields for their specific fields with *Kiremt* Zonal rainfall data for the period from the 1987s to 2017were classified into three ENSO episodes, namely, El Niño, La Niña and Neutral, based on Oceanic Nino region index value. **A** percentage crop yield deviating due to ENSO variability were calculated by the following methods

$$R=\left(\frac{\Delta P}{\overline{Yn}}\right)*100 \quad \text{(Eq.5.)}$$

$$\overline{Yn}=\frac{1}{i}\sum_1^i Yn \quad \text{(Eq.6.)}$$

$$\overline{Yla}=\sum_1^j Yla,$$

$$\overline{Yel}=\frac{1}{k}Yel, \qquad \frac{1}{N}\sum_1^N R \quad \text{Where}$$

**R:** reduction of each crop yield and overall crop yield reduction in percentages, respectively,

**N:** is number of cereal crops grown in the same year, in this case, five major cereal crops grown

**ΔP**: change in productivity of crop yield in quintal per hectare (Qt/ha) due to ENSO.

**Yn, Yla** and **Yel:** average of crop yield in Qt/ha for ENSO phase

**i, j** and **k**: the number of ENSO years, respectively, whereas

**Yn, Yla** and **Yel**: the amount of crop yield harvested in (Qt/ha) during ENSO years and (i+ j+ k=16 years of cropping season were taken for this study was from 1987- 2017); and

ONI is the Oceanic Niño Index value for the reproductive growth period of the cropping season in the respective year (Abdsa et.al. 2017). Finally analysis was done after all the necessary process like cleaning, filtering and rearranging the raw data of rainfall, and crop was completed. The results were present in table's graphs and charts.

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## 3. Result and Discussion.

### 3.1. Result

#### 3.1.1. Characteristics of Rainfall

The rainfall distribution across the study duration demonstrates that there was substantial variability in rainfall distribution. Both spring and summer rainfall have shown a decline and contributed to the existing climate change and variability. The characteristics of average rainfall and its relation with anomaly index were strongly correlated and precipitation has shown a sharp decline during El Niño (Fig: 2).

#### 3.1.2. Rainfall Anomaly

It was found that, irregularity of average rainfall was frequently recorded. Particularly the years onwards 1998 the rainfall distribution have shown rapid decline. The rainy pattern always shows a deviation from its normal distributions in the recent years. Particularly JJAS/summer or kiremit/ failed for consecutive years and continuously varying due to instability of weather conditions over the mainly rainy bearing sea surface (Fig: 3).

#### 3.1.3. Trend test

Trends and variability of rainfall across the study site, both on seasonal and annual base, there are significant variations among the station in a rainfall distribution. All the station's observation, analysis has shown that there was a clear declining trend in its precipitation. According to the Mann- Kendall trend test, there were decreasing trend for all the stations. It was found the P-value for all stations were strongly significant (Angecha, 0.11, Doyogena, 0.00, Durame, 0.0001, Kedida, 0.01, Hadero, 0.002 and Mudulla, 0.001.Because the value of all station rainfall was much less than $\alpha = 0.05$ (Table. 1).

#### 3.1.4. The characteristics of Local Rainfall in the three Phases of ENSO

Concerning the relationship between the local rainfall distribution and the Sea surface temperature (El Niño) the result has shown that, there was a strong correlation between the sea surface temperature and the distributions of Local rainfall. The variability/decline was not uniform across the three decades. It varies from decade to decade. As it was clearly demonstrated

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in (fig4), the distributions of annual rainfall during El Niño years were highly affected and have shown variability. The rainfall condition in the initial decades was better than the last decades. In the last two decades the rainfall distribution was highly affected and have shown rapid decline. In some of the stations, the result of rainfall distribution showed fluctuations and complete absences. From the findings one can say that El Niño years and Local rainfall distributions were positively correlated, i.e., little distortion on weather condition on the sea causes a serious impact on the distributions of local Rainfall (Fig:6.).

The result of this investigation has depicted that La Niña is another weather-related event that create the excess amount of precipitation conditions which is linked to the decline in SST. Across the study period the finding has shown an increase in local rainfall distribution due to La Nina phase. All the stations which were chosen for this study had a surplus of precipitations during La Niña. It was found that during Lan Niño season on the sea the local precipitation distribution was better and even causes some causality in lower areas of the study. As reported from the National Meteorology Agency, Zonal Agricultural bureaus and the local communities La Niña events affected lives seriously by producing extra precipitation beyond the Normal and not commonly observed during Neutral periods (Fig:7). During the Neutral phase the rainfall distribution have shown the normal fluctuation across the study site neither surplus nor deficiency were observed (Fig: 5).

#### 3.1.5. Coefficient of Variation: Inter-Seasonal to Seasonal Rainfall Variability

In order to describe the precipitation pattern of the study site whether it is variable or not, Coefficient of variation of the rainfall for the entire study site was done. According to the findings of the study coefficient of variation (CV) of rainfall ranges between 42 minimum and 45maximum in Belg/spring/ and 33 and 49 minimum and maximum is recorded at a summer / Kermit. It was found that there is a high variability in rainfall distribution among the stations was noticed in the pas thirty year's record. (Table: 2).

### 3.2. Crop Yield and ENSO phase

The correlation between crop productivity and ENSO revealed that there was strong correlation between ENSO phases and Agricultural productivity. Except Neutral, both Extremes have shown a decline and complete failure of crops. The impact of ENSO phases on average crop productivity (maize, wheat, Barely, Sorghum and Enset), has shown that the patterns of crop on both phases were subjected to stress. During El Niño, crops were severely affected by droughts and moisture deficiency and surplus of precipitation during La Niña. The result of the study has shown that across the stations/distiricts/ there were significant effects on all types of crop. It was found that Wheat and Maize were highly affected cereal crops in all cases. One can say that wheat and maize are more vulnerable to both La Niña and El Niño Episodes, the yield of maize and wheat have shown deviation. The yield of wheat deviated by (-6 to -65%).The yield of wheat and maize is highly deviating from its normal average. For instance like that of the wheat, maize is also showing a negative yield/production declining which ranges from –4 % of Hadero to -26% of Angecha station during El Niño Episodes respectively. (Table: 3).

On other hand La Niña crop failure and production decline was also observed, in Angecha and Doyogena districts barely was less affected, and while in Kachebira, Mudulla and Hadero was highly affected. Sorghum in Angecha and Doyogena was less affected by both Eli Niño and La Niña. However, the productivity of Sorghum was seriously affected in the case of Kachebira (89%) and Hadero (-73%) both El Niño and La Niña (Table.3). The relationship between the two extreme phases of ENSO and the fate of selected crops, it was found that crops were subjected for stress in both phases of ENSO. It is only ENSET that had shown resistance to the effect of ENSO phases, while all other crops have seemed to be less resistant to ENSO (Fig., 8 &9).

## 4. Discussion

### 4.1. Trends and variability of rainfall

The findings of the have shown that there was a decreasing trend and increasing variability of rainfall in Kembta Tembaro Zones of southern Ethiopia in the past thirty years, which was getting worse during ENSO episodes both on seasonal and annual base. Analysis at all the stations observation has shown that there was a clear declining trend in precipitation distribution. The MK test Statistic indicates that there were significant variation in all the stations both on long and short rainy seasons ($p<0.05$) (Table1.).

Seasonal variations analysis have shown that in summer the rain look likes stable, fluctuates and sharply decreasing. Sharp decrease was observed in recent decades as compared with those the previous years. Among the stations (HaderoTunto & Mudulla) shows relatively stable distribution while others show high fluctuation and decrease frequently. In some of the months of spring, high and in summer very low/complete absence of precipitation were observed, this seems unusual but this is due to the situation of weather over the Pacific Ocean (Stephanie Gleixner.,et.al.2016). The weather system which evolves on equatorial Pacific is the major driving forces for the CV. The temperature over the equatorial Pacific affects rain bearing winds to the area, which is even termed as ENSO phase. Study confirmed that seasonal anomalies of Ocean basins are strongly linked with Ethiopians Spring and summer rainfall via large-scale circulation. A -/+/positive SSTA over equatorial east Pacific alter the rain producing large scale circulation over Ethiopia, is significantly correlated with dry/wet events in spring and wet/dry events in summer(Zeleke, Giorgi, Tsidu, & Diro, 2013).

Ethiopia in General and the study site in particular are highly dependent on spring and summer season rainfall for their lives. Ethiopia by its nature is experiencing Mono modal, Bimodal and Tri modal rainfall regimes. The study site selected for this study has a bimodal rainfall distribution i.e. the area receives rainfall during spring & summer. Variability of rainfall from the extreme points has negative implications for the wellbeing of people. According to the result of this study, the rainfall was found to be highly variable. Coefficient of Variation (CV) indicated that (CV) of rainfall ranges between 42 - 45min and max for Belg/spring/ and 32 and 49 min and max for summer/Kermit season. From this result one can say that the study site highly vulnerable to drought calamities as observed from CV. All most all the station CV greater than 30% varies and coincides with findings of this investigation (Zarch, Sivakumar, & Sharma, 2015). Season to Season rainfall patterns have passed though high variability. It was found that there was a high variability in rainfall distribution among the stations in the past thirty year's record (Table 2). If a precipitation value less than 20% is considered as fewer variables, between 20-30% moderately variable and greater than 30 % variability can be taken as highly variable. An area with record of >30% precipitation value are said to be more vulnerable to catastrophes of drought (Sharman& Kumar 2016).

### 4.2. Relationship between ENSO phase and Local Rainfall

Little disruptions over the sea highly affect the distributions of rainfall and causes disorder to entire aspects of life. In the study site 12 El Niño events were recorded and affected the

 doi:10.20944/preprints202001.0260.v1

distributions of rainfall. Four of the El Niño was very strong and while the rest are moderate and weak, one can say that the frequency of the occurrence of El Niño is becoming shorter and requires adjustment of people on how to cope it up with ENSO. El Niño results in crop failure due to moisture stress and La Niña results in crop yield failure due to excessive wetness. As we have noticed from discussion with expertise of Zonal Agricultural office both of the events were interchangeably occurring in the area and attracting the attentions of researchers on how to live with the situations. For instance, in the El Niño years when summer rain is failing in 2016 and 2017 crop production was completely failing and farmers become dependent on both Local and International aid providing agencies. El Niño years are not always followed by La Niña but sometimes it is possibly replaced by La Nina which is bad news for farmers. Out of the four strong El Niño two of them were replaced each other occurred in 2015 & 2016(Fig.5 and Fig.6).

Because of complete reliance on a rainy fed agriculture and low adaptive capacity ENSO induced irregularity of rainfall was frequently recorded. The rainy pattern always shows a deviation from its normal distributions. Particularly JJAS/summer/ failed for consecutive years and continuously varying due to instability of weather conditions over the mainly rainy bearing sea surface. Similar study confirmed that the precipitation pattern of Ethiopia in summer season rainy is mainly governed by ENSO i.e. weather conditions over the sea. For the sake of this study from the thirty years rainfall data, twelve of them are identified as a year which is highly affected by Eli Niño. During all the Phases of Eli Niño as compared to La- Nina and Neutral years, the pattern of rainfall is highly deviated. The study confirmed that ENSO phases are highly affecting the distributions of rainfall and its anomaly. The rainfall anomaly is predicted to vary during the summer season, based on emerging ENSO developments. ENSO occurrence is a major challenge to Ethiopia's economy and rainfall pattern in general (Li, Xu, & Liu, 2011).

### 4.3. Crop Yield and ENSO phase

Five major crop types grown in the study area were selected for the analysis, (Maize, wheat, Barely, Sorghum and Enset). Crops were selected for their staple nature and presence of relevant data. In the course of ENSO phase changes from normal situations were observed, crop productivity has decreased for overall crop yield. Mainly both El Nino and LaNina events were responsible for the decline. Throughout El Niño the moisture is highly declined and Vice versa. The site was smash by twelve El Niño events and affected by moisture stress and extreme of

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climate variability. The occurrence of strong El Niño is the one that leads to drought condition if frequently (Nepstad et al., 2004). It was found that there is a strong correlation between ENSO phases and Agricultural productivity. Except Neutral, both Extreme phases have shown a decline and complete failure of Wheat and maize. Research also confirmed that ENSO-related SSTs were strongly related to rainfall and corn yields, where SST resulted in 57% of the variability in yields (Cane, Eshel, & Buckland, 1994).During El Niño event the study site, was severely affected by droughts due to failure in crop production. The region is less frequently subjected to La Niña related calamities as compared to El Niño. El Niño is frequently occurring in the area every 2-7 years. However, both the catastrophes are causing a disaster to crops in the area.

The study demonstrated that there were significant effects on all types of crop. Wheat and Maize are highly affected cereal crops. Both crops were more vulnerable to both La Niña and El Niño effects. The yield of maize and wheat are repeatedly shown deviation (-6 to -65% deviation of yield of wheat and maize deviating from its normal average (–4 to-26%) during El Niño Episodes respectively, However, Baerly-2% to -83% and Sorghum (-68%-(-34%)). Studies on the effects of El Niño events were associated with low grain yields in different parts of the world (Garnett & Khandekar,1992). The changes from normal situation, the major cereal crop productivity has decreased for overall cereal crop yield due to El Niño and La Niña occurrence, by 16% due to a El Niño incidence and by 5.3% due to La Niña event. Cereal crop production was more vulnerable to El Niño episode while the reduction during the La Niña episode is less area. El Niño shocks are likely to cause on average a reduction in cereal crop production (Abdisa A. et.al. 2017). The abnormalities of weather conditions on Sea associated with the El-Nino resulted in decrease of crop production, loss of life & property (Babu, 2009).

If the yield is greater than 75% and less than 25%, is a demarcation line to call it as high or low productivity. As a common fact, rainfall distribution and crop productivity are correlated. The case of this studies both positive and negative correlation is observed. For maize productivity across the study site at all the station, the result found was positive, which ranges from 21 - 39% positively correlated. Concerning the relationship between wheat productivity and precipitation distribution at one of the words the yield of wheat and precipitation distribution during ENSO phases were negative correlation, this probably due to altitudinal variations and other climatic factors because the negative value was recorded where the altitude is higher than 3000 meter

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above sea level. The long-term changes in crop yields are partially related to climate variations. A weak positive correlation was found between precipitation and yield. Generally it is explained that 33-50% of the yield variability of precipitation and temperature variations observed. The changes in rainfall and temperature are reflected in estimated crop yields. The lowest yields were observed in wet as well as in warm years, whereas the highest yields were more frequent in dry years and the highest yield in warm years.(Chmielewski & Potts, 1995).

 doi:10.20944/preprints202001.0260.v1

### 5.1. Conclusion

From the investigation, it was concluded that there is a varying trend of precipitation across the stations in the study site in general and with a varying magnitude in at ENSO phases in particular. On the other hand crop production and rainfall pattern are highly interlinked. As we have noticed from the analysis, both El Niño and La Niña phase affected crop productivity by deficiency and a surplus of rainfall respectively. During deficiency of moisture, total failure/complete absence of crop production were recorded and during surplus of moisture lesser production with less quality output was reported. Among the five chosen crop for this investigation two of the crops were seriously affected during El Niño and La Niña. From this investigation one can conclude that the overall cereal crop productivity was decreased and ENSO phase has a negative impact on concentration of precipitation and productivity of major Agriculture. El Niño cause comprehensive droughts in Ethiopia in general and the study site in particular and result in food shortage. So, having the information on ENSO phase in advance helps to select crop types and varieties to maximize agricultural rain fed cereal crop productivity while minimizing the crop risk associated with seasonal rainfall and ENSO phases.

### 5.2. Recommendation

Based on the results obtained from this investigation the following recommendations were forwarded:

- People should be aware of ENSO information and should shuffle the planting time for crops like maize wheat, Barely sorghum and Enset Proper design of soil and water conservation structures should be performed with caution in order to combat moisture stress.
- Hybridizing modes of life from sole mixed cultivations to other means if not able to cope up with ENSO disasters.
- Further studies focusing on extreme rainfall analysis and it's relationships with ENSO phase, should be performed in the areas where unexpected rainfall and flooding is common and accordingly proper design of flooding and soil and water conservation structures could be adopted and those farmers who are more vulnerable to crop failure due to ENSO must develop new means of coping up the disasters.

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**Table 1: Illustrates the Mann- Kendall trend test with significance level 0.05**

| Mann-Kendall trend test | | | P-value | | | |
|---|---|---|---|---|---|---|
| Test | Angecha | Doyogena | Durame | Kedidda | Hadero | Mudulla |
| Kendall's tau | -0.20 | -0.44 | -0.32 | -0.52 | -0.36 | -0.49 |
| S | -95.00 | -203.00 | -149.00 | -243.00 | -169.00 | -229.00 |
| Var(S) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| P-Value | 0.11 | 0.00 | 0.01 | <0.0001 | 0.00 | <0.0001 |

**Table 2. Illustrates Inter-seasonal to Seasonal rainfall Coefficient of variation (CV %)**

| Station | Belg/spring | Kiremit/summer | Winter/Bega | **Annual** |
|---|---|---|---|---|
| Angecha | 42 | 38 | 28 | **33** |
| Doyogena | 44 | 34 | 58 | **29** |
| Durame | 43 | 48 | 32 | **28** |
| Kedida | 45 | 32 | 79 | **35** |
| Hadero | 44 | 49 | 61 | **34** |
| Mudulla | 49 | 34 | 81 | **36.4** |

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**Table 3: The impact of ENSO phases on the productivity of crops site wise**

| Site | Crop type | Average Productivity in Qt. | El Niño | | La Niña | |
|---|---|---|---|---|---|---|
| | | | Δproductivity | Δchange in % | Δ productivity | Δ change in % |
| **Angecha** | Maize | 25805.9 | -0.16 | -16 | -0.65 | -65 |
| | Wheat | 77398.9 | -0.47 | -47 | 0.91 | - 91 |
| | Barely | 9723.27 | 0.63 | 63 | -0.13 | -13 |
| | Sorghum | 9106.11 | 0.54 | 54 | 0.65 | 65 |
| | Enset | 117921.4 | 0.51 | 51 | 0.71 | 71 |
| **Doyogena** | Maize | 1973.95 | -0.26 | -26 | -0.36 | -36 |
| | Wheat | 77398.91 | -0.17 | -17 | 1.14 | 11.4 |
| | Barely | 9723.27 | 1.16 | 11.6 | 0.59 | 59 |
| | Sorghum | 8939.25 | -0.56 | -52 | -0.59 | -59 |
| | Enset | 117921.4 | 0.67 | 67 | 0.68 | 68 |
| **Kedida G** | Maize | 23692.26 | 0.12 | -12 | -0.69 | -69 |
| | Wheat | 77398.91 | -0.66 | -66 | -0.86 | -86 |
| | Barely | 9723.27 | -0.47 | -47 | -0.58 | -58 |
| | Sorghum | 8939.25 | -0.11 | -11 | -0.16 | -16 |
| | Enset | 117921.4 | 0.01 | 1 | -0.06 | -6 |
| **Hadero** | Maize | 35022.61 | 0.04 | -4 | -0.43 | -43 |
| | Wheat | 77398.91 | -0.6 | -6 | -0.53 | -53 |
| | Barely | 117012.4 | -0.67 | -67 | -0.64 | -64 |
| | Sorghum | 8939.25 | -0.73 | -73 | -0.94 | -94 |
| | Enset | 117921.4 | -0.58 | -58 | -0.47 | -47 |
| **Mudulla** | Maize | 60722.79 | 0.08 | 8 | -0.16 | -16 |
| | Wheat | 117012.4 | -0.62 | -62 | -0.58 | -58 |
| | Barely | 9723.27 | -0.83 | -83 | -0.9 | -9 |
| | Sorghum | 8939.25 | 1.63 | 16.3 | -0.04 | -4 |
| | Enset | 117921.4 | -0.81 | 16.3 | -0.178 | -17.8 |
| **Kachebira** | Maize | 52591.74 | 0.12 | -12 | -0.53 | -53 |
| | Wheat | 117012.4 | -0.65 | -65 | -0.34 | -34 |
| | Barely | 9723.27 | -0.02 | -2 | -0.35 | -35 |
| | Sorghum | 8939.25 | -0.89 | -89 | -0.93 | -93 |
| | Enset | 117921.4 | 0.25 | 25 | 0.63 | 63 |

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Table 4. Rainfall distribution and its trend from in past thirty years

| station | Seasons | Obsn | Min | Max | Standard deviation (n) | CV | Skewness (Pearson) | Kurtosis (Pearson) |
|---|---|---|---|---|---|---|---|---|
| Angecha | Spring | 31 | 58 | 786.8 | 189.4 | 0.42 | 0.09 | -0.72 |
| | Summer | 31 | 292 | 1149.9 | 239.2 | 0.38 | 0.64 | -0.62 |
| | Winter | 31 | 0.0 | 530.9 | 106.5 | 0.61 | 1.03 | 1.96 |
| | Annual | 31 | 594.7 | 1976.5 | 387.1 | 0.32 | 0.22 | -0.85 |
| Doyogena | Spring | 31 | 23 | 702.1 | 141.2 | 0.44 | 0.00 | 0.32 |
| | Summer | 31 | 57.5 | 806.3 | 177.8 | 0.34 | -0.89 | 0.25 |
| | Winter | 31 | 17.8 | 544.2 | 120.6 | 0.58 | 0.56 | 0.24 |
| | Annual | 31 | 299 | 1556.4 | 299.4 | 0.29 | -0.81 | -0.07 |
| Durame | Spring | 31 | 37.7 | 712.3 | 162.9 | 0.43 | 0.00 | -0.53 |
| | Summer | 31 | 179.6 | 997.2 | 203.7 | 0.48 | 1.08 | 0.41 |
| | Winter | 31 | 9 | 514.5 | 110.4 | 0.52 | 0.30 | 0.13 |
| | Annual | 31 | 277 | 1635.9 | 283.5 | 0.28 | -0.37 | 0.52 |
| Kedida | Spring | 31 | 52 | 913.3 | 214.5 | 0.45 | 0.18 | -0.52 |
| | Summer | 31 | 95 | 1066.6 | 211.5 | 0.32 | -0.09 | 0.08 |
| | Winter | 31 | 9 | 768.8 | 167.9 | 0.79 | 1.80 | 3.48 |
| | Annual | 31 | 159 | 2522.8 | 470.8 | 0.35 | 0.21 | 0.98 |
| Hadero Tunto | Spring | 31 | 38 | 916.8 | 184.8 | 0.44 | 0.04 | 0.79 |
| | Summer | 31 | 123.8 | 997.2 | 180 | 0.49 | 1.54 | 2.89 |
| | Winter | 31 | 0.00 | 470.7 | 114.8 | 0.61 | 0.17 | -0.36 |
| | Annual | 31 | 181.8 | 1841.3 | 328.8 | 0.34 | -0.43 | 1.66 |
| Tembaro/ Mudulla | Spring | 31 | 43.8 | 913.3 | 233.7 | 0.49 | 0.11 | -0.81 |
| | Summer | 31 | 144 | 1066.6 | 218.2 | 0.34 | 0.19 | -0.50 |
| | Winter | 31 | 8.9 | 768.8 | 170.8 | 0.81 | 1.66 | 3.11 |
| | Annual | 31 | 209 | 2522.6 | 482.8 | 0.36 | 0.26 | 0.62 |

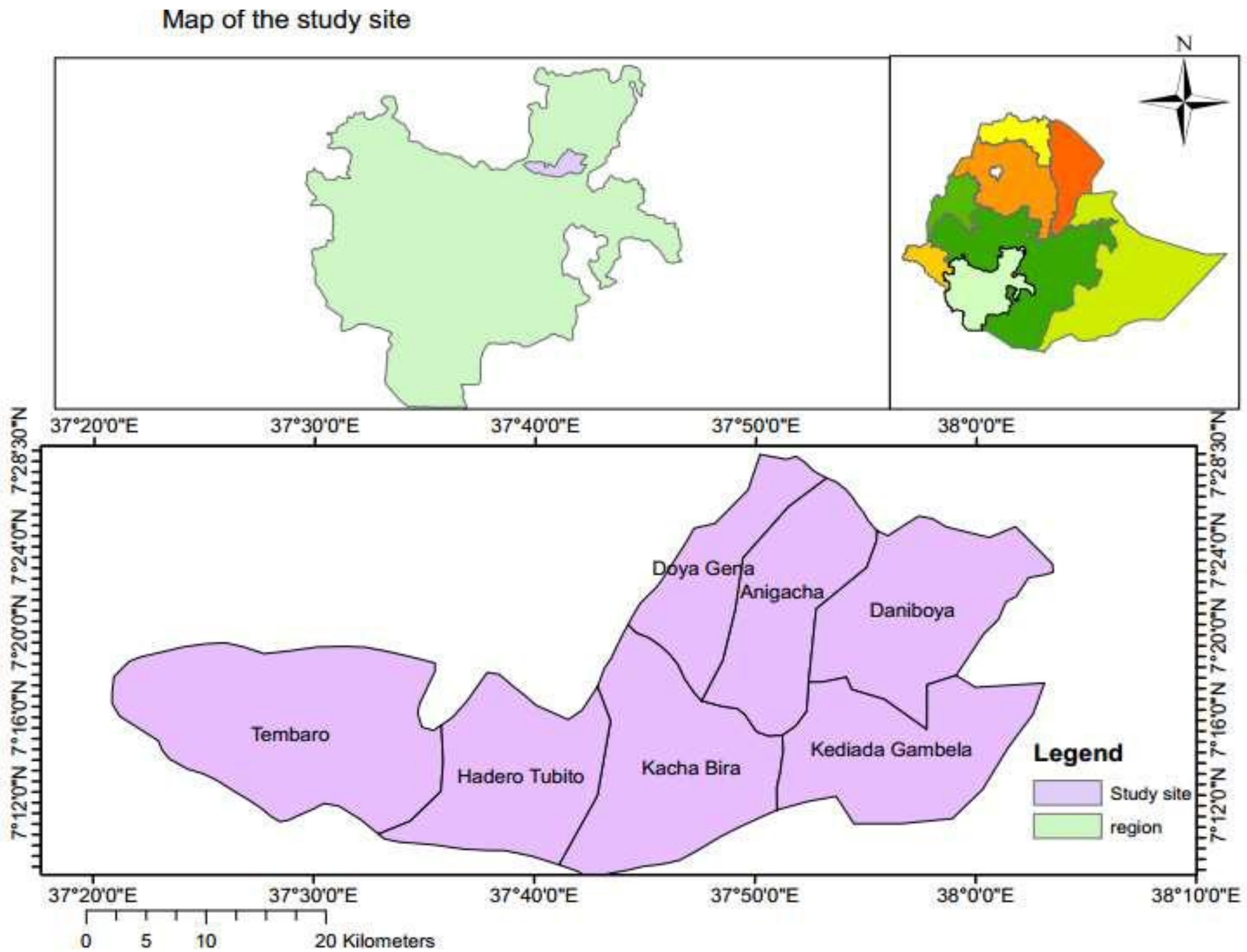


Figure 1. Map of the study site

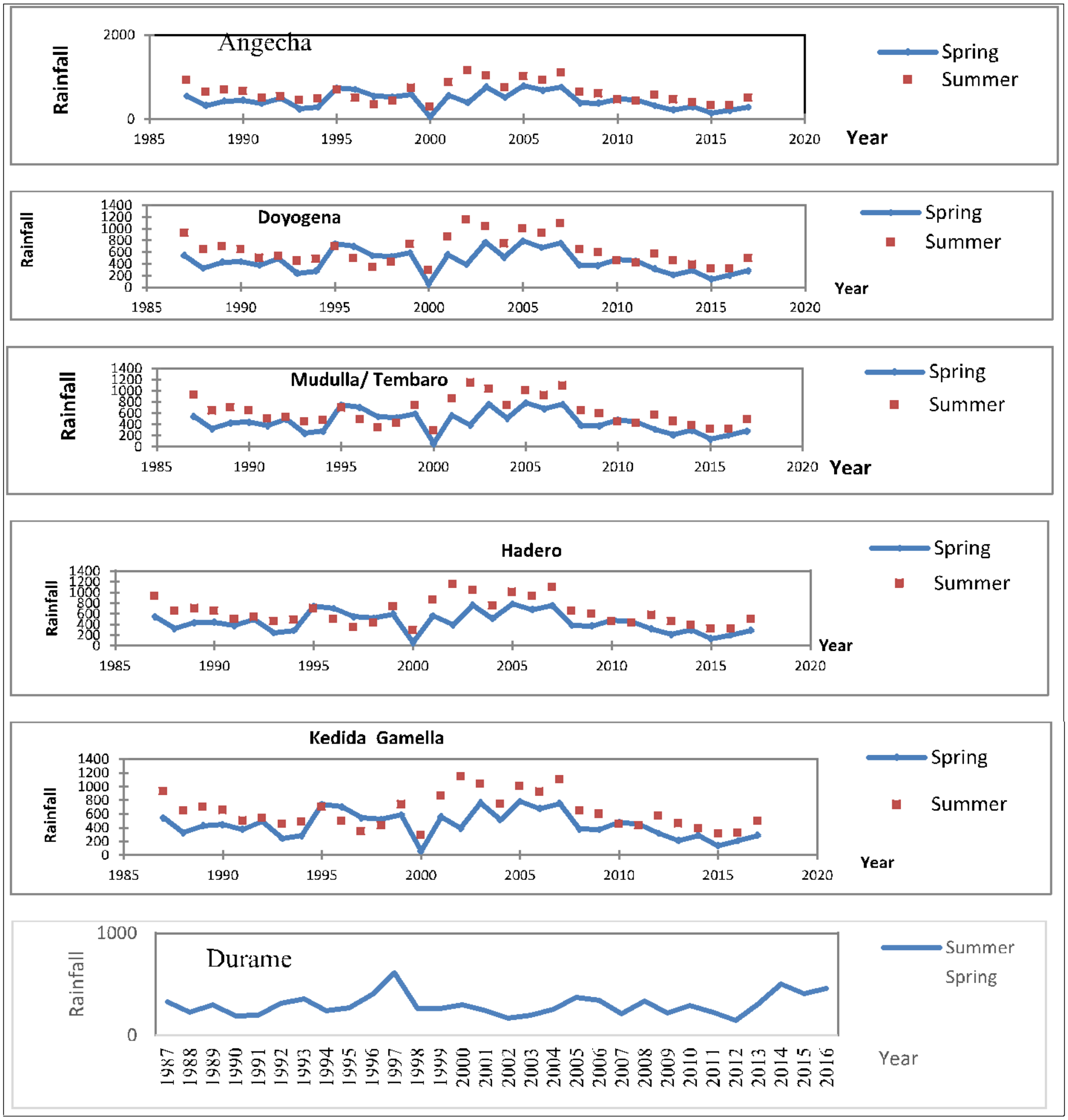


Figure 2. Seasonal & Annual distributions RF Kembata Tembaro zone southern Ethiopia.

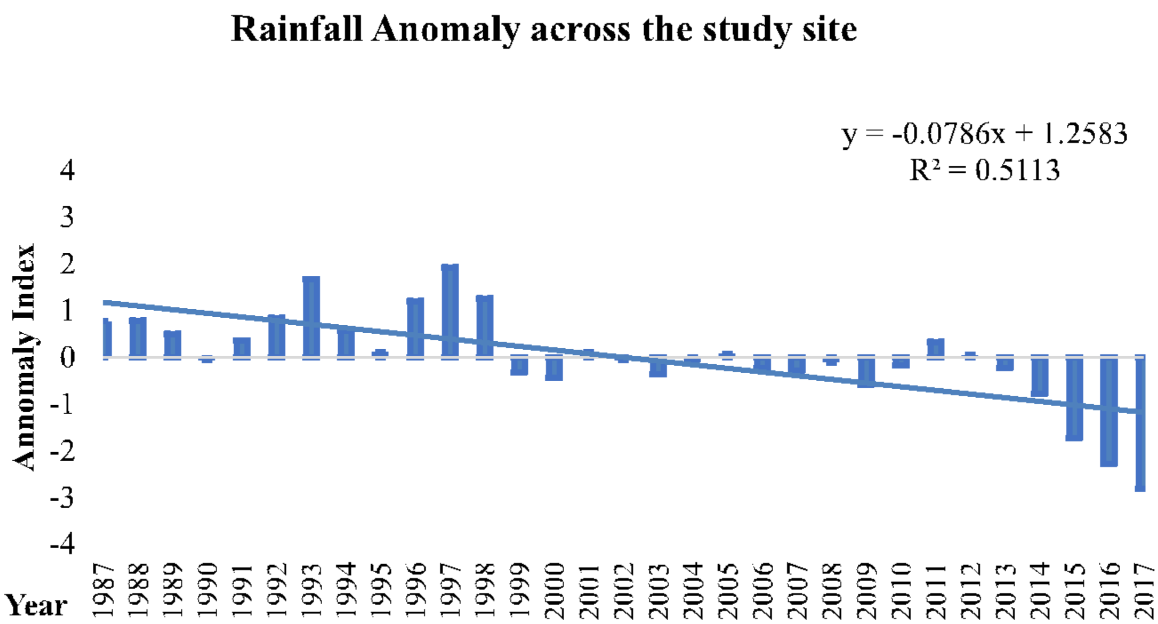


**Figure 3. The Entire anomaly of rainfall from 1987-2017**

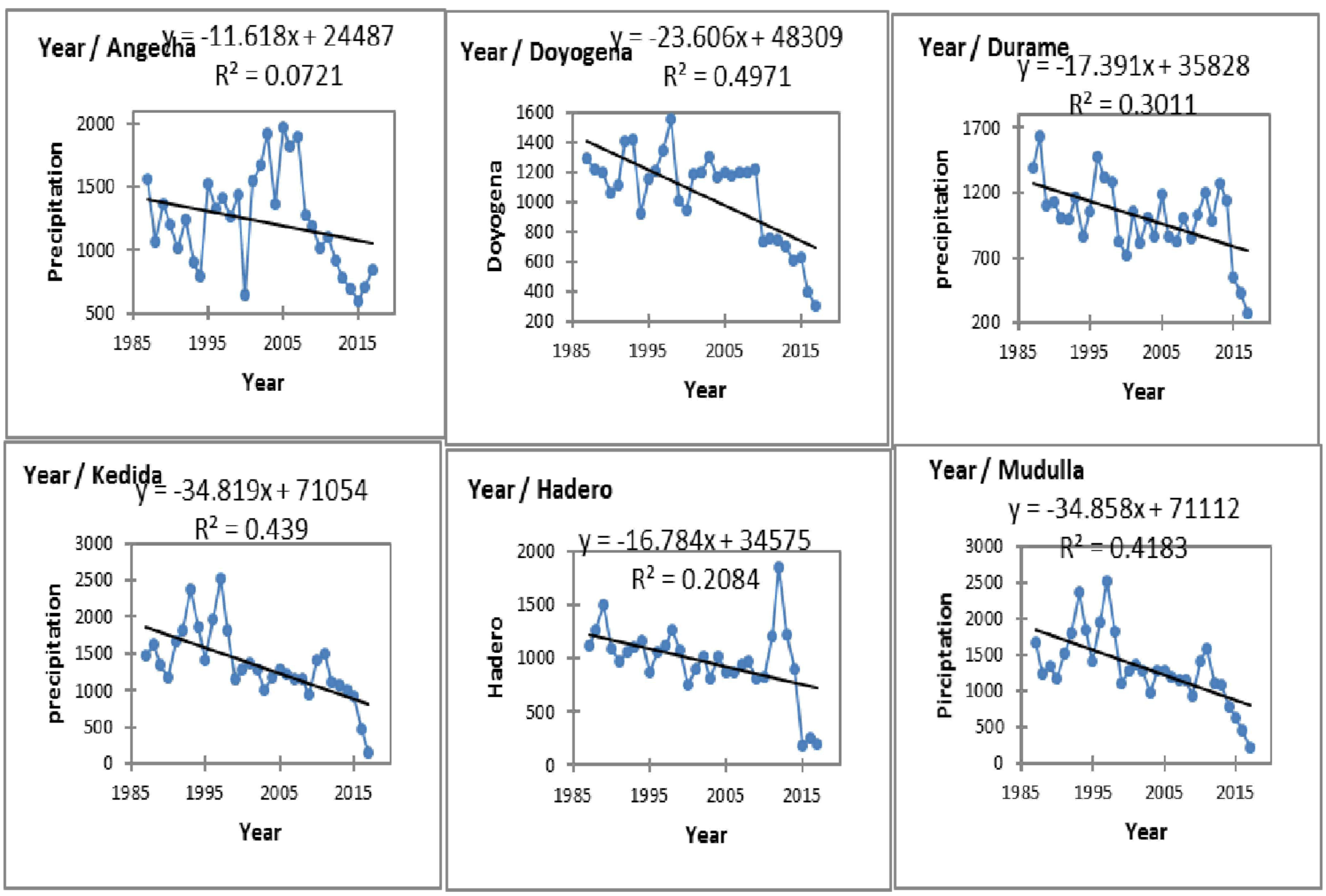


**Figure 4. Trends (Mann-Kendal trends) in Rainfall distribution**

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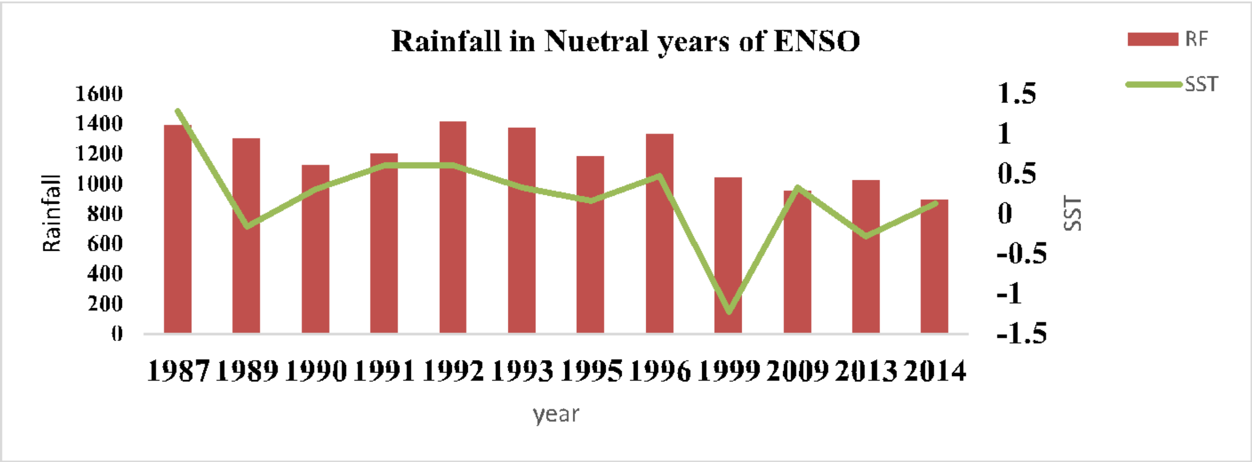


**Figure 5. Distribution of Local rainfall during neutral phase of ENSO**

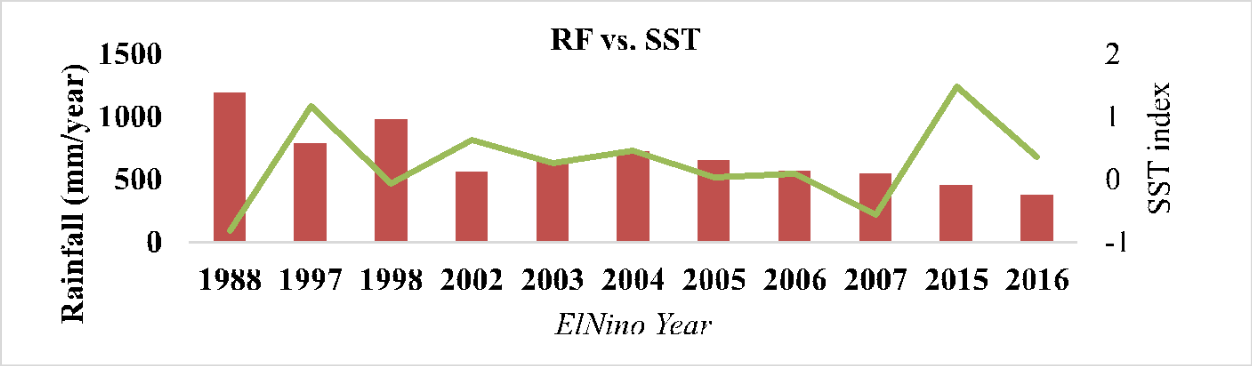


**Figure 6.the impact of En Nino on the distribution of local rainfall**

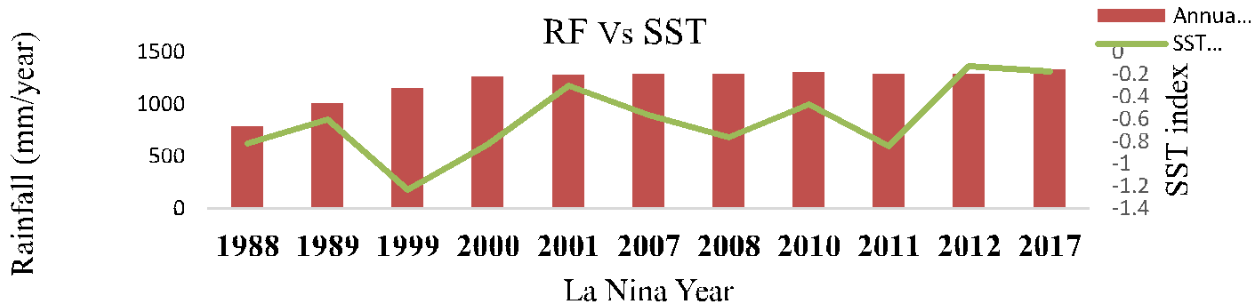


**Figure 7. The characteristics of rainfall during La Niña Years**

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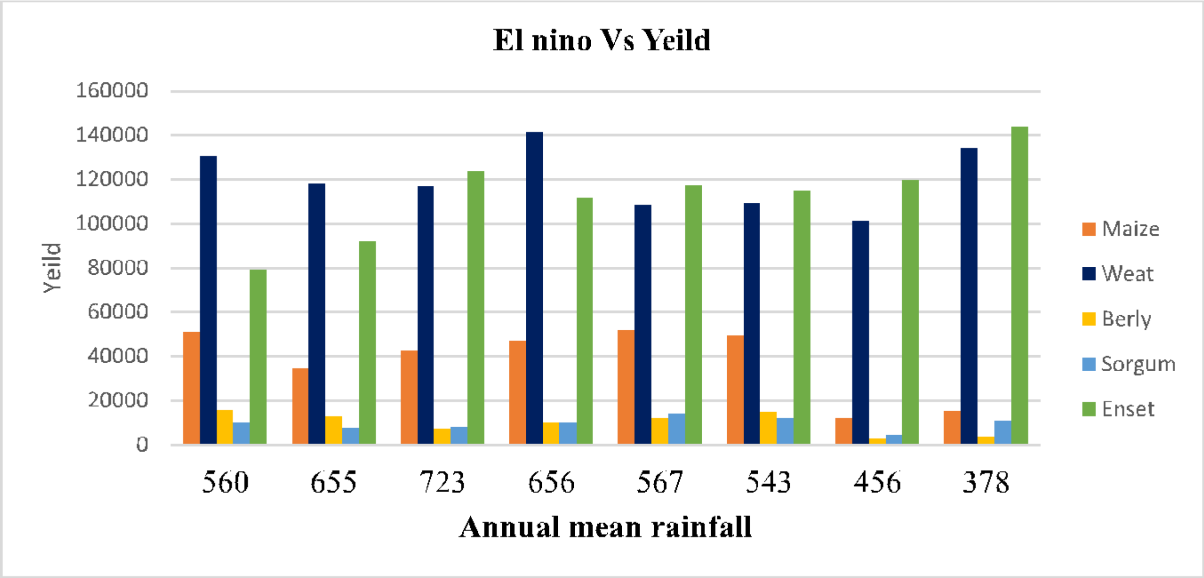


**Figure 8. The impact of La Niña on major crops**

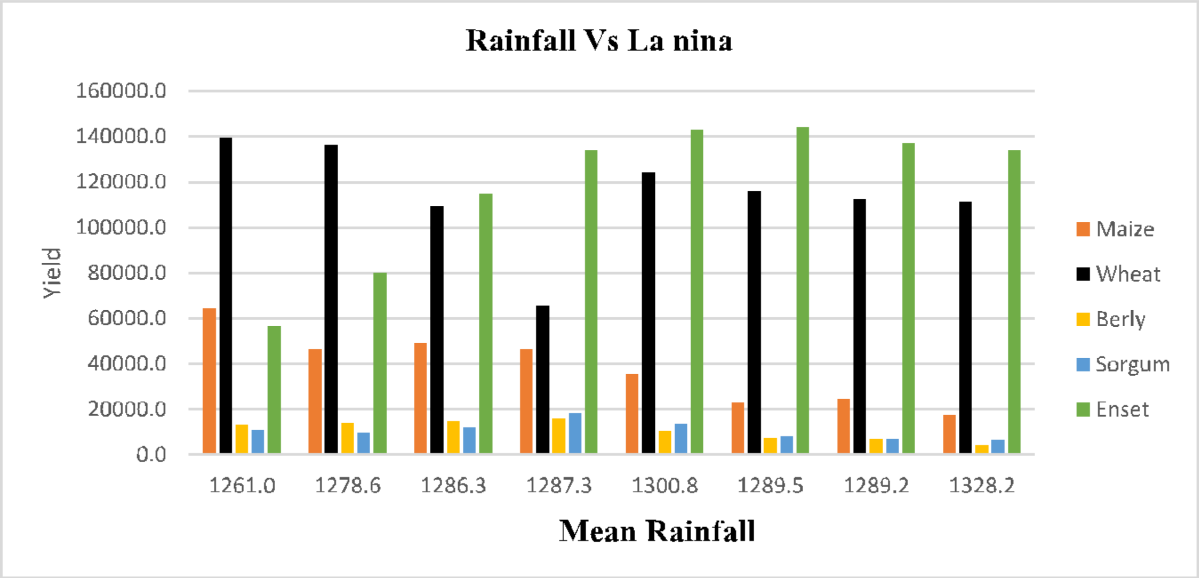


**Figure 9. The impact of El-Nino on major crops**