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Impacts of Various ENSO Phases on Cereal Crop Productivity in the Upper Awash Basin, Central High Land of Ethiopia

Abdisa Alemu[1*], Dirba Korecha[2], Muktar Mohamod [3]

[1, 3] Haramaya University, Diredawa, Ethiopia

[2]USGS/Famine Early Warning Systems Network, Addis Ababa, Ethiopia

Corresponding Author:** ***Abdisa Alemu, *Haramaya University, Diredawa, Ethiopia*

Abstract: *El Niño-Southern Oscillation (ENSO) has different impacts on seasonal agricultural systems in Ethiopia. In order to characterize effects of ENSO, this paper is therefore aimed to determine the impacts of various ENSO phases on cereal crop in Upper Awash Basin region of central Ethiopia. Here we used the rainfall data covering the period from 1980 to 2014 while selecting more reliable and continuous data from the Upper Awash Basin. Climato logical pattern of rainfall and its variability, areal rainfall anomalies were evaluated with respect to global sea surface temperature. Multivariate statistical methods were employed to quantify relationship exist between regionalized rainfall index and Sea Surface Temperature anomalies (SSTa). The results of this study revealed that SSTa as recorded over Nino regions have strong signal in explaining regional rainfall variation than other ocean fields. In particular, Nino regions SSTa have negatively correlation with kiremt rainfall and vice versa in the case of belg rains. Computed weighted average rainfall for each homogenous zone of Upper Awash Basin and CDF with zonal cereal crop yield data, particularly for Teff, Wheat, Maize and Sorghum crops were analyzed. Risk analysis was computed against the ENSO-based approach using cumulative density function. The results showed that, preferable yield value and less crop risk were identified during non-ENSO years both by first and second stochastic dominance senses. Hence, non-ENSO phase is therefore found to be the best risk efficient set identified in Upper Awash Basin for crop productivity. In contrast, overall cereal crop yields were decreased in regionalized area three of Upper Awash Basin by 16% and 5.3% during El Niño and La Niña episodes, respectively. El Niño shocks are likely to cause a reduction in cereal crop production but it is relatively better than La Niña episodes for wheat crop production in regionalized area one of Upper Awash. So, having the information of ENSO phase in advance will improve agricultural practices such as selection of crop varieties and thus to maximize agricultural rain feed cereal crop productivity and minimize crop risk associated with fluctuation of seasonal rainfall under various ENSO phases. The results of this study would therefore be utilized by farmers and agricultural societies in the provision of alternate use of ENSO forecasts for further insightful decision, particularly on crop risk planning and management strategies.*

Keywords: *Cereal crop, ENSO, Regression, Stochastic dominance and variability.*

1. INTRODUCTION

The El-Niño-Southern Oscillation (ENSO) is the most important coupled oceanatmosphere 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. ENSO is characterized by a varying shift between a neutral phase and two extreme phases such as El Niño and La Niña. The El Niño phase is marked by a deep layer of warm ocean water across the eastern and central equatorial Pacific. 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. Monthly spatially SST anomaly 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. If the SST index values are 0.5 or greater, between -0.5 and 0.5, and -0.5 or less for a consecutive months over central and eastern and Pacific Ocean, ENSO phase is categorized as El Niño, Neutral and La Niña respectively (Goddard et al., 2001).

The most important feature of sea surface temperature variability that can cause large scale weather disruptions is El Niño and its counterpart La Niña (Goddard et al., 2001). According to Nicholls, 1991 ENSO and local rainfall relationship extensive use has been made of correlation and regression methods in attempting to establish evidence of “teleconnections” that affects local rainfall patterns.In

Ethiopia, many authors have documented how ENSO events have strongly linked with various atmospheric system and rainfall distribution like (Korecha and Barnston, 2007). The principal cause of drought in Ethiopia is asserted to be the fluctuation of the global atmospheric circulation, which is triggered by sea surface temperature (SST) anomalies, occurred according to ENSO events. The phenomena have significant impact on displacement and weakening of the rain producing system in the seasons. ENSO episodes and other regional systems have impact on seasonal rainfall performance and rainfall variability over Ethiopia is due to remote tele connections system (NMSA, 1996; Tsegay, 1998; 2001; Gissila, 2001; Korecha, 2002; Korecha and Barnston, 2007).

Hence, most of the drought years were recorded during *Kiremt* season El Niño episode. Since Agriculture is heavily reliant on rainfall andproductivity and production are stronglyinfluenced by climatic and hydrologicalvariability due to ENSO phases that are reflected as dry spells, droughts and floods.In Ethiopia the degree of crop yield variability over time is changed not only by the amount of seasonal rainfall, but also by the pattern and frequency of the rainfall cycle (Adugna, 2005).According to evaluation of Fraisse *et al.*, 2006ENSO-based seasonal climate affects the crop yield reduction by ENSO phase phenomenon.

The Upper Awash River rises from the high plateau of central Ethiopia near Ginchi town, west of Addis Ababa extends *Koka* dam and based on physical and socio-economic factors the UAB is part of lands where all digital elevation map are located about 1500 m above sea level (Taddese *et al.*, 1998). Based on FAO (1998) the dominant soil types are Cambisols and Vertisols. The chief agricultural crops grown in Upper Awash River Basin are cereal crops, pulse and oil seeds. Cereal crops are Teff, Barley, Wheat, Maize and Sorghum. Out of Oil seed Nueg is commonly grown and other crops accustomed in the region are Pulses such as broad Beans, Horse beans, Chickpeas, Peas, lentils and Guaya, which are widely grown in rotation with grain crops and Oil seeds (CSA, 2014).

The rainfall type of UAB is bimodal type one, which are two rainy seasons and one dry season, namely *belg (FMAM)* small rainy However, the rainfall is highly characterized by inter annual and inter seasonal variation. Major rain bearing systems during the *belg* season are the development of thermal low over South Sudan, generation and propagation of disturbances over the Mediterranean Sea, sometimes coupled with easterly waves, development of high pressure over the Arabian Sea, the interaction between mid-latitude depressions and tropical systems accompanied by troughs and the subtropical jet and occasional development of the Red Sea convergence zone (RSCZ) (NMSA, 1996; Gonfa, 1996).While *kiremt (JJAS)*main rainy season, that covers the period from June to September. Major rain producing systems during *Kiremt* season includes; Northward migration of ITCZ, development and persistence of the Arabian and South Sudan thermal low along 20^{o}N latitude, development of quasi-permanent high pressure systems over south Atlantic and south Indian Oceans, development of tropical easterly jet and the generation of low level Somali jet that enhance low level south westerly flow (NMSA, 1996; Segale and Lamb, 2005).

This study uses a combination of extensive climatic and crop yield datasets spanning the years 1995-2013 to empirically measure the impact of ENSO on Wheat, Maize, Sorghum and Teff crop productivity. According to Anderson and Dillon (1992) CDF is likely to be the first and most understandable graph of the distribution, in which it is possible to compare the dynamic values of random variables for risk assessment. Under such circumstances Crop yield values of each year in UAB and associated ENSO phase were incorporated into a simple tool that allows users to customize the output of its specific situations. The overall objective of this paper is to determine the impacts of ENSO on cereal crop productivity. Specifically, the research study was conducted with the following objectives:

- To determinethe influences of ENSO on the local areal rainfall pattern
- To determine impacts of ENSO phase on major cereal crop productivity

2. MATERIALS AND METHODS

2.1. Description of the Study Area

This study was conducted in the Upper part of the Awash River Basin in Ethiopia, which is located between 8°16’N - 9° 18’ N and 37° 57’E - 39°17’E. It covers about 7240 km² and all topographic lands lie between 1500 m to 3419m above sea level. The physical settings of the study area are characterized by the heterogeneity of the large topographic systems such as orographic groups, the high plains, mountains and plateaus (Figure 1). Based on physical and socio-economic factors the Upper Awash Basin is topographic level of all lands above 1500 m (Taddese*et al*., 1998).

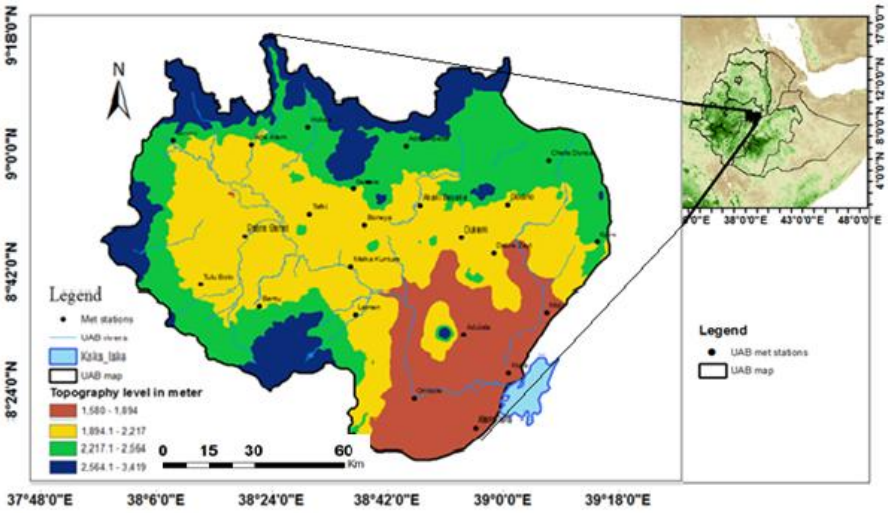


Figure1. *The Study Area of Upper Awash River Basin and its Topographic features*

The land use pattern of UAB consists mainly of cultivated agricultural land, grass land and shrub land, which cover 93.2% of the total area; about 3.6% is covered by sparse trees and the remaining 3.2% comes from the other land cover types (Mussa, 2011). According to Koei (1996) and FAO (1998) soil classification, the UAB soil types are pellicvertisol, verticcambisol, Chromic luvisols, luvicphaeozems and lithosols. However, the dominant soil types are Cambisols and Vertisols. Hence, Vertisols are unique group of soils, often described as black cotton soils and heavy, usually dark colored, clay soils that form deep cracks when they dry out, and difficult to cultivate when dry, and become very sticky when wet Andrew (1995; Deckers *et al*., 2001).

2.2. Types and Sources of Data And Methods of Data Collection

Various types of data were obtained from different sources in order to analyze andexamine the impacts of ENSO phase on crop production in the study area. Daily rain gauge data from 1980 to 2014 were obtained from National Meteorological Agency (NMA) of Ethiopia; Missing data were filled with gridded data taken from NMA. Major crop yield data were obtained from Central Statistical Agency (CSA).Global and regional SST data and atmospheric indices were taken from NOAA-CIRES climate diagnostics center (http://www.cdc.noaa.gov/).SST over Nino regions data were taken from CPC https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/.

2.3. Methods of Data Analysis

There are numbers of standard climatic data analysis methods for climatic variability and examining the impacts of ENSO phase on crop production for decision supporting in relation to seasonal climate performance. Characteristics of areal rainfall analysis, rainfall pattern and its variabilityas well as its relation with global SST have been analyzed. The seasonal and annual spatial rainfall distributions were computed based on historical rainfall data using various spatial analysis tools in ArcGIS software version 10.1 and presented spatially.

2.4. Seasonal Climate Variability Analysis

Kiremt seasonal rainfall data ranging from 1980 to 2014 of meteorological stations have been selected from the Upper Awash Basin in order to show inter-seasonal to seasonal rainfall anomaly and variabilityfor rainy season. The coefficient of variation of seasonal and inter-seasonal rainfall variability and anomaly were analyzed by:

$$CV = \left(\frac{SD}{\overline{X}}\right) * 100 \text{ Where } \overline{X} = \frac{\sum Xi}{N} \text{ and } SD = \frac{\sqrt{(Xi - \overline{X})^2}}{N - 1} \quad (1)$$

$$RAi = \frac{\mathrm{Xi} - \overline{\mathrm{X}}}{\mathrm{SD}} \qquad (2)$$

Where SD is standard deviation $\overline{X}$ is long year mean and N is total number of year taken, Xi is rainfall of each month or season and RAi is rainfall anomaly of each year. If RAi is more than 0.5 between -0.5 and 0.5 and less than -0.5 is meteorologically the season is wet, normal and dry respectively.

2.5. Areal Regional Rainfall Analysis

Regional local level rainfall variability has been analyzed so that, the local climatepatterns can be well characterized. Rk, which is zonal rainfall anomaly for kth homogeneous rainfall zone calculated by the (Equation 3). This computation was made for each of the threehomogenous rainfall regime of UAB during the *belg* and *kiremt* seasons that enabled to show the degree of long term temporal Zonal rainfall variability. Regional rainfall index R_k is calculated using the following formula:

$$R_k = \sum_{i}^{m} \mathrm{Wi}\,x\left(\frac{R_{k,i} - \overline{m}}{\mathrm{SD}}\right) \qquad (3)$$

Where Rk is regional level areal rain fall index, Wi is a weighted applied to the ith of n stations, Rk,i is the rainfall at ith station during year k, and SD are the average and standard deviation of the station’s rainfall. If Rk is more than 0.5, between -0.5 and 0.5 and less than -0.5 are meteorologically the zonal seasonal rainfall categorizedunder wet, normal and dry season respectively.

2.6. Correlation between SST and Regional Local Areal Rainfall

Identifying the relationship between zonal rainfall anomaly and SSTs which, is the most predictive skill comes from information contained in the initial states of the coupled ocean–atmospheric system, for ocean initialization the emphasis is on the initialization of the upper ocean thermal structure, particularly inscribed tropical area, where observational information about SST is essential. Local based regional rainfall index of each homogenous rainfall regime was evaluated and canonical correlation analysis (CCA) technique using R-Gui software version 2.10 to estimated patterns of correlated with pre-seasonal data between Ocean fields of 40 N to 40 S degree extensions SST and long year’s regionalized rainfall index (Rk).Parts of the oceanic surface having good correlation with the delineated zones were then identified. The predictors which have significant correlation with seasonal rainfall anomaly has been identified by those oceanic areas having a strong relationship with the respective rainfall zones for a target month, in which a threshold correlation (r) value of $\geq |0.3|$ has been taken into account, which amounts to a minimum 10% of the variance being explained (Tanco and Berri, 2000). CCA uses linear statistical techniques to find optimum relationships among multivariate sets of independent and dependent variables, which is an extension of a multiple regression technique to the case of the vector-valued predictor-predict and relationship (Land man and Goddard, 2002).And Empirical correlation between zero lead time Nino region SST anomaly and regionalized rainfall anomaly using SPSS software has been done. Therefore, Canonical correlation is calculated by

$$C = Ryy^{-1} Ryx\ Rxx^{-1} Rxy \qquad (4)$$

Where: C = matrix of singular value decomposition

Ryy = Correlations between Y variables

Ryx = Correlations between Y and X variables

Rxx = Correlations between X variables

Rxy = Correlations between X and Y variables

2.7. Cumulative Density Functions (C Dfs) and Stochastic Dominance (SD) Analyses

Stochastic dominance (SD) means the cumulative density function (CDF) of the best alternative must always lie below and to the right of the CDFs of the other distribution curves (Hardaker *et al*., 1998; Mamo, 2005). For instance, a CDF ‘A’ lies entirely below and to the right of another CDF ‘B’, then ‘A’ dominates ‘B’ in the first-degree sense (FSD). ‘A’ would be preferred by any individual who prefers more of the performance measure to less, regardless of whether they are risk averse. On the other hand, decisions are more difficult to resolve by FSD when the CDFs interact (cross-over) such as ‘A’ cross ‘B’. Second degree stochastic dominance is applied based on the area under the CDF. If the area under CDF of ‘A’ is less the area under CDF ‘B’ at every point along the x-axis, under such circumstances, neither of them totally dominates in the sense of FSD, indicating the limited discriminatory power of the FSD (Mc Carl, 1996). Then ‘A’ is said to dominate ‘B’ in the second-degree sense. Activity ‘A’ would be preferred by any individual to any risk-averse for all values of the performance measure (Levy 1992, 1998).

Cross-over implies that one strategy could dominate the other at the lower points (bottom tail) of the distribution, but could be dominated at the upper values (top tail) in the distribution or vice versa. Crop yield and associated rainfall values for UAB were incorporated into a simple tool that allows users to customize the output to their specific situations.

Average Zonal crop yields for their specific fields with *Kiremt* homogenous Zonal rainfall data for the period from 1995 to 2013 were classified into three ENSO episodes, namely El Niño, La Niña and Neutral, based on Oceanic Nino region index value. ENSO phase classification are 0.5 or greater, between -0.5 and 0.5 , and -0.5 or less for consecutive months over central and eastern and pacific ocean during crop growing season, ENSO phase is categorized as El Niño, Neutral and La Niña respectively. Stochastic dominance (SD) analysis of Teff ,Wheat, Maize and Sorghum cereal crop with different ENSO Phase such as *ElNiño, La Niña* and normal phenomena were analyzed for risk analysis and to answer which ENSO phase has contribute for better yield performance.

Stochastic dominance rules assume that farmers must decide whether to invest crop production during *La Niña* ,f, or an alternatively *ElNiño* events ,g, and normal condition ,h, with crop yield cumulative density functions given by F(x), G(x) and H(x) respectively. Then by taking those three SST phase such as la Niña,El Niño and normal phase year with corresponding crop yield alternatively analyzed by first and second -order stochastic dominance (FSD) or SSD sense. Using a statistical technique known as (CDF) as stated in(Equation 6), by R-Gui software version 2.10.1, used for stochastic dominance rules that assume farmers should decide whether to invest crop production during la Niña phase “F” or an alternative El Niño phase “G” and Normal phase “H”.Decision rule of First Stochastic Dominance (FSD) if and only if

$$G(x)-F(x)\geq 0\ \forall x\ \varepsilon\ R \tag{5}$$

And the cumulative density function can be calculated by

$$\begin{aligned}&\mathrm{F(x)}=\int_{0}^{\mathrm{X}}\mathrm{F(X,\mu,\delta)dx},\\&\mathrm{whereF(X,\mu,\delta)}=\frac{1}{\sqrt{2\pi\delta^{2}}}\exp\left(-\frac{(\mathrm{x}-\mu)^{2}}{2\delta^{2}}\right)\end{aligned} \tag{6}$$

Where F(x), G(x) and H(x) are crop yield cumulative density functions given during *La Niña, ElNiño* and Normal phase respectively. Given ‘X’ represent crop yield in quintal per hector during each ENSO phase and μ and δ mean and standard deviation of yield respectively.

2.8. Yield Reduction Due to ENSO Phases

Since higher cereal crop yield with lower risk have been observed in the normal ENSO phase in the Upper Awash basin (Figure 6 and 7), which is relativelyhigher potential crop yield has been harvested during in this phase. For a given year ofEl Niño orLa Niñaepisode, a percentage crop yield deviating from normalaccustomed yield obtained during Neutral ENSO phase is yield reduction due to ENSO variability, which is calculated by the following methods.

$$R=\left(\frac{\Delta P}{\overline{Yn}}\right)*100 \tag{7}$$

$$\overline{Yn}=\frac{1}{i}\sum_{1}^{i}Yn \quad \text{If and only if } -0.5<ONI<0.5 \text{ during crop growing season} \tag{8}$$

$$\overline{Yla} = \frac{1}{j}\sum_{1}^{j} Yla \quad \text{If and only if ONI} \leq \text{-0.5during crop growing season} \qquad (9)$$

$$\overline{Yel} = \frac{1}{k}\sum_{1}^{k} Yel \quad \text{If and only if ONI} \geq \text{0.5 during crop growing season} \qquad (10)$$

$$OR = \frac{1}{N}\sum_{1}^{N} R \qquad (11)$$

Where R and ORare reduction of each crop yield and over all crop yield reductionin percentage respectively and whereas N is number of cereal crop grown in the same year.In this regard, four number of major cereal crop grown in the study area such as Teff, Wheat, Maize and Sorghum were considered.

ΔP is change in productivity of crop yield in quintal per hector (Qt/ha) from Neutral year due toLa Niña or El Niño episode.

$\overline{Yn}$, $\overline{Yla}$ and $\overline{Yel}$ are the average of crop yield in Qt/ha for the entire years in Neutral, La Niña and El Niño years respectively; i, j and k are the number of Neutral, La Niña and El Niño years, respectively whereas Y_n, Yla and Yel are the amount of crop yield harvested in (Qt/ha) during Neutral, La Niña and El Niño years and (i+ j+ k=19 years of cropping season has been taken in this study which is from 1995 to 2013); and ONI is the Oceanic Niño Index value for the reproductive growth period of the cropping season in the respective year.

3. RESULTS AND DISCUSSION

3.1. Rain Fall Climatology of the Study Area

Upper Awash Basin is part of Central highlands of Ethiopia, which covers areas with high potential for crop production with attributed rainfall variability. The annual rainfall reaches 649-1222 mm of which the western mountain chains receives an annual rainfall ranging from 1000 to 1200 mm, while the southern ,south eastern and central regions of UAB receive between 700 to 900 mm (Figure 2c). Seasonally, 183 to 310 mm and 465 to 906 mm contribution come from small and main rainy seasons, respectively (Figures 2a and b). The fact that the study area is characterized by the presence of hills/peaks of undulating nature implies that orography plays an important role in the rainfalldistribution over the region. The quantum of rainfall is found to be highest in the western high land or Zone one and lowest in the lower altitude or zone three. Therefore the climate of UAB is influenced by undulated mountain chains and thecirculatory systems that interact with Oro graphy, cross equatorial wind system and ITCZ.

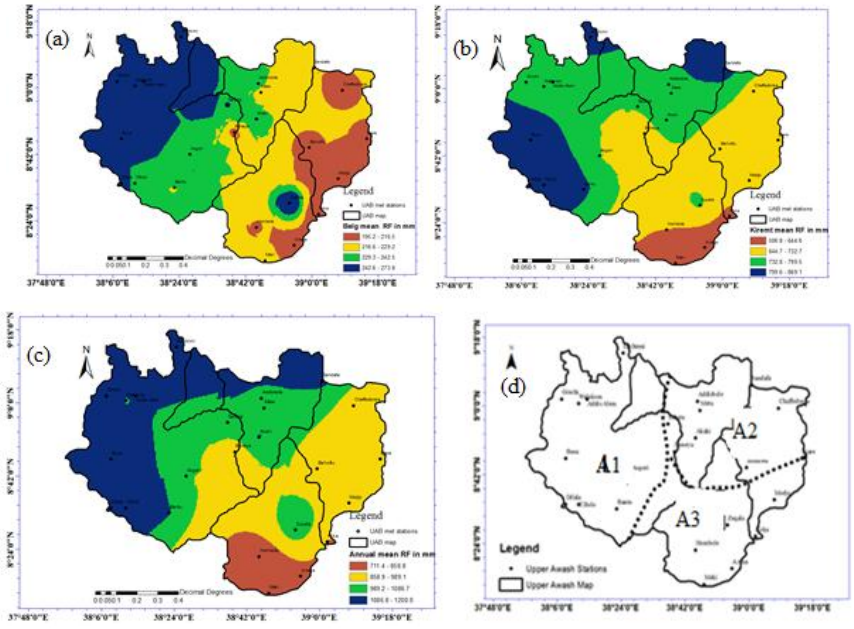


Figure2. *Seasonal and annual spatial mean rainfall distribution of Upper Awash*

3.2. Inter-Seasonal to Seasonal Rainfall Variability

The rainfall variability resulted by coefficients of variation (CV) of inter seasonal to seasonal rainfall over UAB during *Kiremt* season and annual totals have shown that there existed less spatial and temporal variability, while monthly and *belg* season rainfall patterns have possessed high spatial and temporal variability (Table 3). Having this information of seasonal and inter-seasonal rainfall variability is very important for short and long term planning of farming system, through which cropping patterns, sowing period and selection of crop variety.

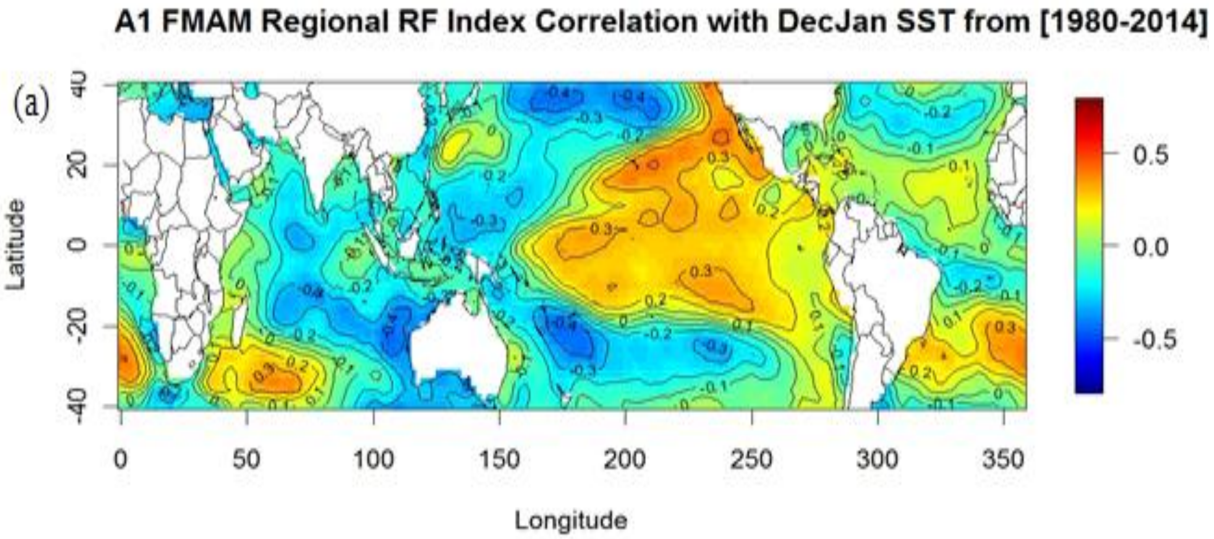
Table1. *Inter-seasonal to seasonal rainfall coefficient of variation of some selected stations*

Stations	Jun CV%	July CV%	Aug CV%	Sep CV%	*Belg* CV%	*Kiremt* Cv%	Annual Cv%
Busa	42	31	38	55	55	29	28
A/Ababole	47	21	22	31	40	16	15
A/Tena	59	42	31	50	43	22	13
Bishoftu	48	30	28	40	55	19	19
Ginchi	35	22	25	34	43	15	16
Akaki	50	35	42	52	44	36	30

3.3. Spatial Correlation between SST and Regionalized Rainfall Index

The interpretation of regional rainfall index (R_k) value is important to consider that wetness and dryness are relative to historical average for the regional rainfall index, which was explained in (equation 3) correlations with pre-seasonal SST data results shown that,rainfall during JJAS and FMAM have strong relationship with the global SSTs such as Nino regions, the Indian Ocean dipole and (IOD). This index expresses the magnitude of excess or stress rainfall relative to normal. The results of a statistical technique known as (CCA), which was stated in (Equation 5), with SST Anomalies over most of the Pacific Ocean tend to be inversely correlated with zonal rainfall of UAB during *kiremt* season (Figure 3b), while directly proportional with *belg* rainfall index (Figure 3a).

During *belg*season, Zone one regional rainfall index correlated result with mean of December and January Spatial globalsea surface temperature results shown that, relatively the best correlated area (r) value of ≥ |0.3| are Nino regions such as Nino 4 and Nino 3.4, part of Nino 3 and North eastern Pacific ocean and some parts of southern Atlantic and south western Indian ocean, which are positive correlation while western Pacific and most of Eastern Indian ocean have a negative correlation with Zone One and also positive IOD has more significant with zone one (Figure 3a).*Kiremt*regional rainfall index of Zone one correlated with mean of April and may Spatial global sea surface temperature results shown that, the best correlated area which has (r) value of ≥ |0.3| are some part of North eastern pacific, which are positive correlation with Zone one (Figure 3a). The IOD phase is not significant relation with *kiremt* zonal rainfall (Figure 3b).



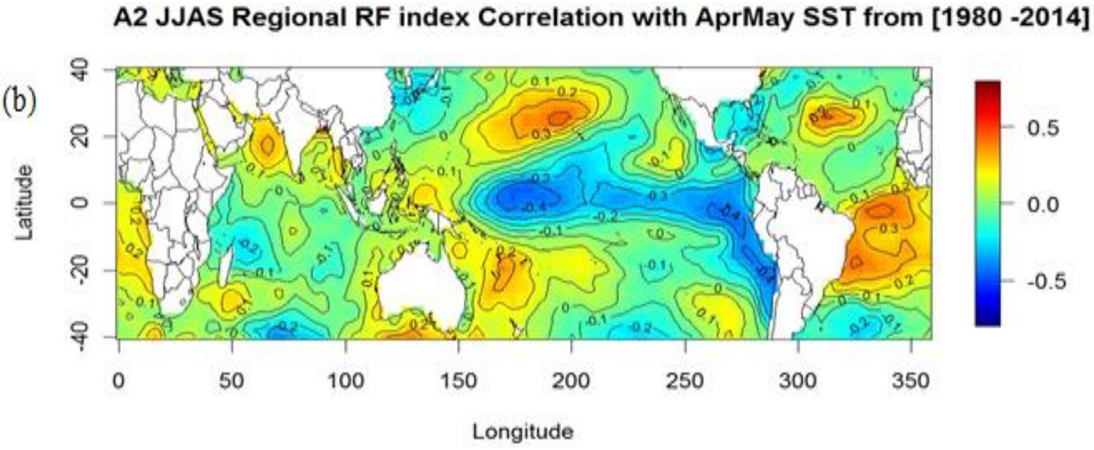


Figure3. *Regional R_K index correlation with global spatial SSTa*

3.4. Relationship between Zero Lead Time Nino Regions SST With Regional Rainfall Index

Empirical correlations between Nino regions SSTa and regionalized rainfall anomaly suggest that ENSO variability is closely linked to variability in rainfall in Upper Awash basin.According to long years' correlation analysis of zero lead time Nino region SST and seasonal regional rainfall index for each Zone results shown that, observation described during *belg* season rainfall anomaly and related Nino regions are positive correlated, while during *kiremt* season rainfall anomaly and SST are opposite sign (Table2a and b). In other words positive SST anomaly is related to increasing sea surface temperature than normal while negative SST anomaly is related to coldness of sea surface than normal condition, Which resulted to increase rainfall activity in the kiremt rainy season during La Niña years/cold phase (Figure 4). The result of zero lead time of the Nino region SST anomaly correlation with *kiremt* regional rainfall index as explained in (Table 2), all Nino regions have negative correlation with *kiremt* rainfall index, while all Nino regions have positive correlation with *belg* regional rainfall index (Table 3). Nino 3 and 3.4 SST regions have more significant correlationwith Zone one and two regional rainfalls, while Nino 4 and 3.4 SST have more significant correlation with Zone three kiremt regional rainfall index (Table 2). But Nino 3.4 region has more significant correlation with all three regional rainfall indexes during belg season (Table 3).

Table2. *Zero lead time Nino region SSTa correlation with Zonal rainfall index of Kiremt*

Correlation Matrix							
(a) **Correlation during kiremt**	**JJAS nino4**	**JJAS nino3.4**	**JJAS nino3**	**JJAS nino1+2**	***Kiremt* A1**	***Kiremt* A2**	***Kiremt* A3**
JJAS nino4	1.000	0.898	0.700	0.326	-0.209	-0.501	-0.341
JJAS nino3.4		1.000	0.909	0.562	-0.368	-0.610	-0.331
JJAS nino3			1.000	0.827	-0.427	-0.631	-0.251
JJAS nino1+2				1.000	-0.321	-0.502	-0.078
KiremtA1					1.000	0.695	0.390
KiremtA2						1.000	0.503
KiremtA3							1.000

Table3. *Zero lead time Nino region SSTa correlation with Zonal rainfall index of belg*

Correlation Matrix							
(b) Correlation during belg	**FMAM nino1+2**	**FMAM nino3.4**	**FMAM nino4**	**FMAM nino3**	***Belg* A1**	***Belg* A2**	***Belg* A3**
FMAM nino1+2	1.000	0.675	0.388	0.890	0.247	0.087	0.214
FMAM nino3.4		1.000	0.869	0.894	0.474	0.312	0.429
FMAM nino4			1.000	0.613	0.380	0.245	0.350
FMAM nino3				1.000	0.427	0.268	0.407
Belg Z1					1.000	0.787	0.799
Belg Z2						1.000	0.797
BelgZ3							1.000

3.5. Regionalized Rainfall and Nino Regions Sst Anomaly During Rainy Seasons

Rainfall anomaly is used to compare the long-term variation of rainfall at individual year. This gives an estimate of the degree to which rainfall recorded during the months of season is either stable or changing. The result of regional rainfall anomaly has shown that those extreme seasons of wet or dry season, whereas value more than 0.5 and less than -0.5 with associated years of belg and kiremt season were extreme wet and dry season respectively (Figure4a and b).According to the historical SST anomalies in the Niño 3 and3.4 regions results revealed that rainfall amounts of major rainy season became very high in La Niña but low in El Niño years. Conversely, during small rainy season, comparatively high rainfall amounts were observed when El Niño was apparently establishedand low rainfall has been observed during La Niña episode (Figure 4b).

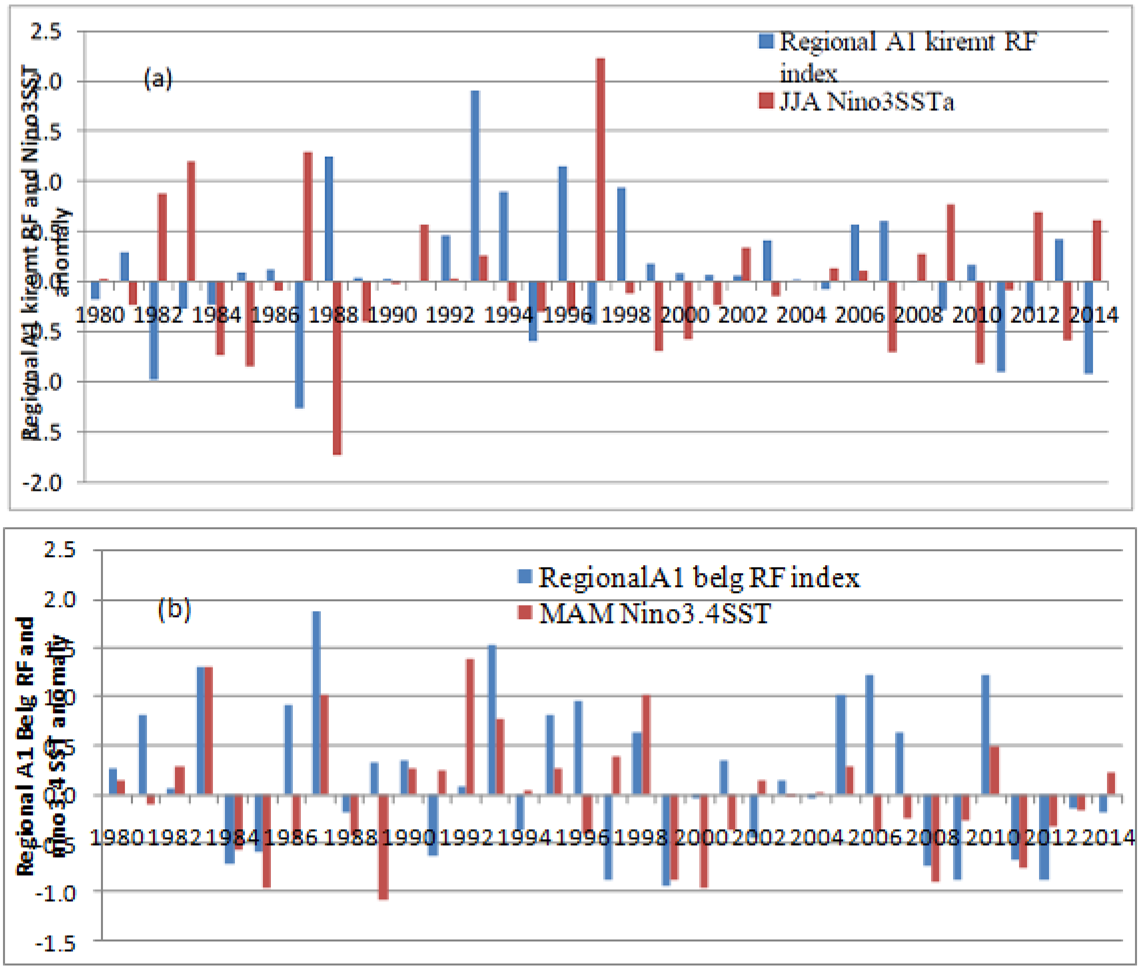
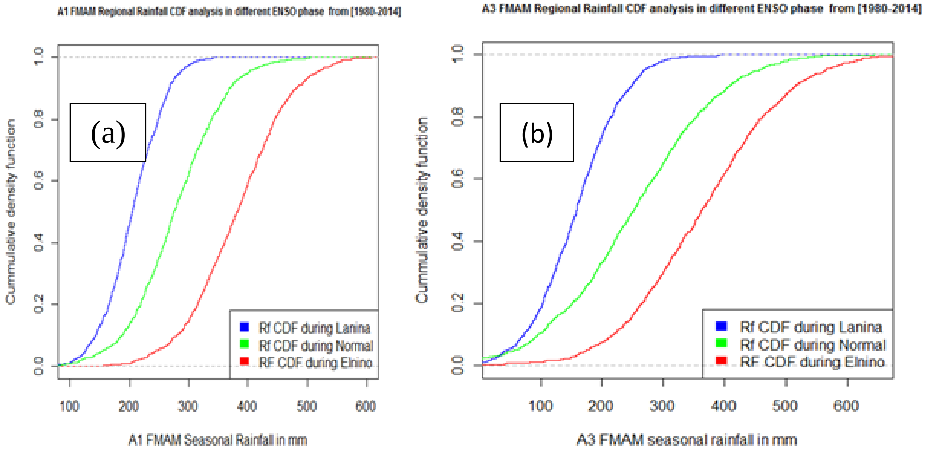


Figure4. *Regional rainfall and Nino regions SST anomaly during rainy seasons*



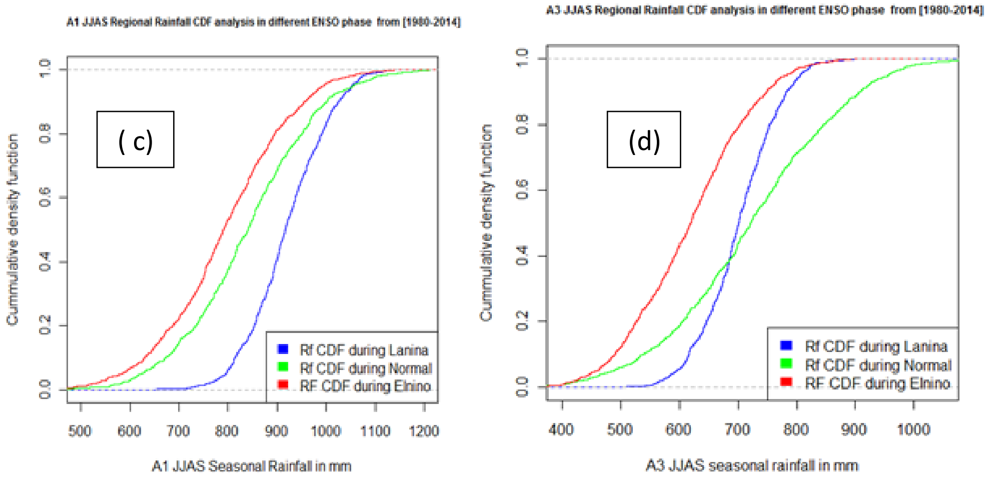


Figure5. *Comparison of cumulative seasonal rainfall at various ENSO phases*

3.6. Crop Yield Risk Analysis by Using ENSO Phase

According to crop risk analysis based on 19 years of crop data associated with seasonal ENSO phase of 4 ElNiño years, 4 La Niña years, and 11 Neutral years result, by the First order stochastic dominance (FSD) shown that, the dominating variable would be preferred by any decision maker who prefers “more” to “less”, regardless of the attitude towards risk. Normal phase is preferable, since CDF of plot of line of crop yield during normal phase is to the right of CDF plot of during El Niño phase, as described in crop yield CDF production in (Figure 6a,b) and (Figure 7a and c), which illustrates that, those CDFs of crop yield during ‘Normal’ SST phase and ‘La Niña’ SST phase are dominant relative to crop yield CDF of during ‘El Niño’ SST phase in the FSD sense. This means that for every risk percentile point on the Y axis, a farmer gets at least x amount of more crop yield from CDF of 'Normal' or ‘La Niña’ SST phase as compared to the yield obtained from CDF during ' El Niño ' SST phase. At Zone one during ‘El Niño’ phase has better wheat crop yield production than during La Niña’ by FSD sense (Figure 6b). The seasonal climate information may further support in the selection of crop variety/types, fieldallocation and other strategic management activities with respect to less crop risks.

The cross-over between CDF during ‘la Niña’ phase and CDF during ‘Normal’ phase implies in (Figure 7b), that curves meet the requirements for Second order stochastic dominance (SSD) and the comparison should be handled using the higher order stochastic dominance techniques to be the first choice as described by (McCarl, 1996). CDF of wheat crop yield during ’Normal phase’ lies to the left of CDF during ‘la Niña’ at the lower level of the yield data series, meaning that the during ‘La Niña phase’ alternative is better choice in this range of the yield data distribution, while CDF during ‘La Niña’ lies to the left of CDF during ‘Normal’ at the upper tail of the series, meaning that during ‘Normal’ phase is a better and less risky choice in the upper range of the wheat yield at Zone three(Figure 7b).

Comparing the total area under the CDF of (Figure 7b), during ‘Normal’ phase is bigger than CDF during ‘La Niña’ phase at upper percentile points. SSD requires that the area under the cumulative density function during normal SST phase at lowertail is smaller than the area under the cumulative density function for the during La Niña phase at upper tail as described in (Figure 7b).Therefore, during ‘Normal’ phase standard algorithms for identifying stochastic dominance utilize pair-wise area comparisons of wheat yield sorted series of net revenue distributions CDF during ‘La Niña’ and ’Normal’ phase for wheat production yield at Zone three has better performance. Every risk-averse, farmer therefore prefers Normal phase alternative that dominated by SSD. Therefore, Normal phase is found to have the best riskefficient set identified for each three Zones crop productions planning. Crop yield has good performance during Normal SST phase than El Niño and La Niña phase; users can make comparisons based on alternate ENSO forecasts for further insight for crop risk planning and management strategy. farmer targeting 12Qt/ ha of Teff crop yield at Zone three cropping seasons could achieve the desired quantity, but the associated risk level is of the highest order of 40% as described in resulted from (Figure 7 a).

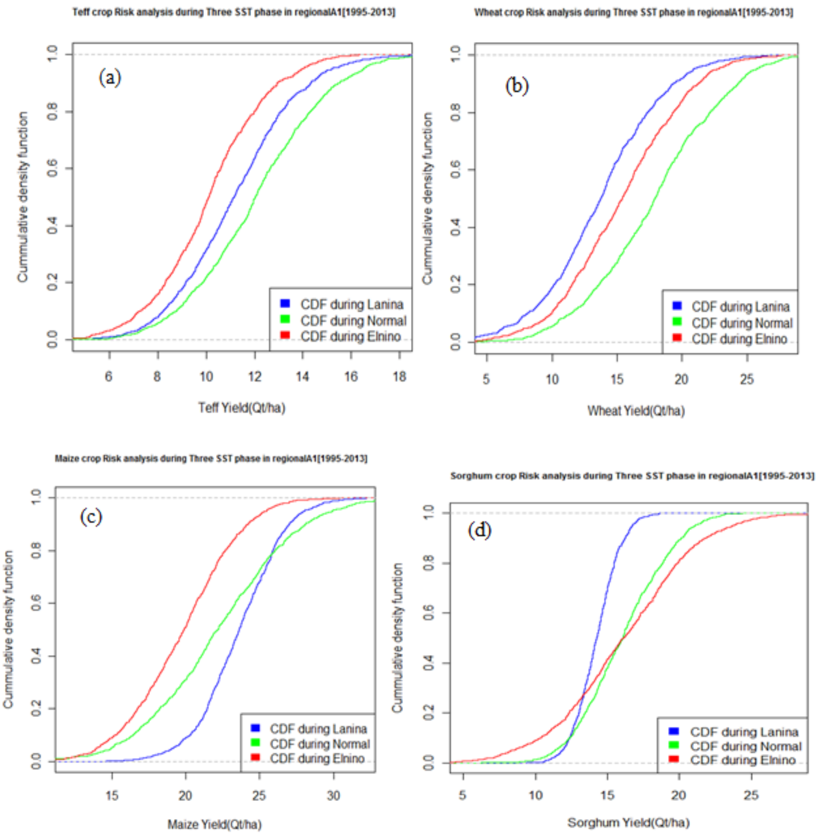


Figure6. *Cumulative Density function for cereal crop yield of Zone one with three SST phase*

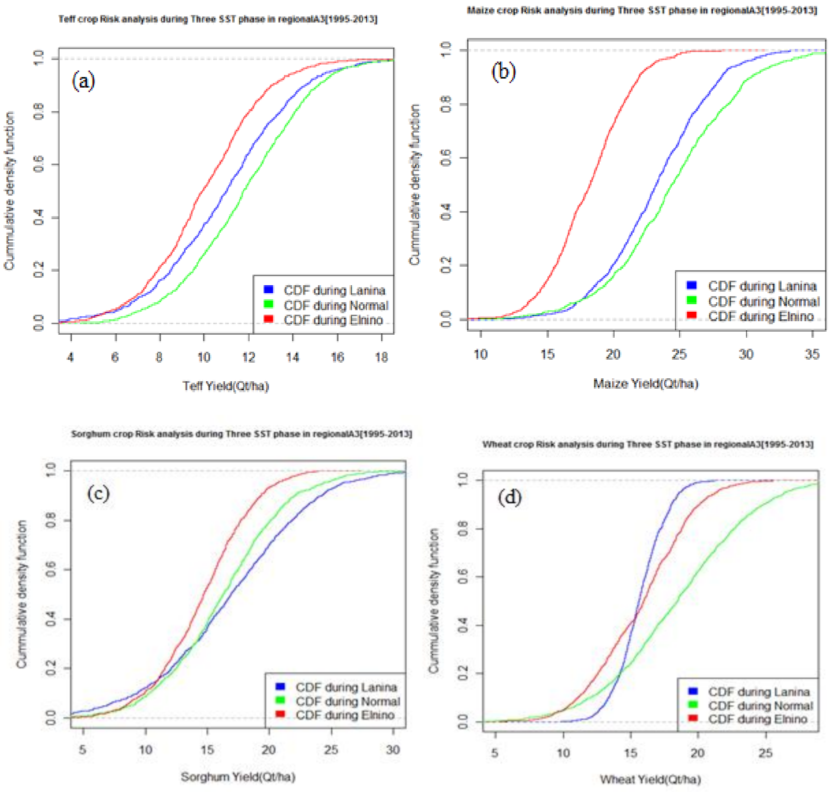


Figure7. *Cumulative Density function for cereal crop yield of Zone three with three SST phase.*

3.7. Cereal Crop Yield Reduction Due to Various ENSO Phases

Due to ENSO phase changes from normal situation, the major cereal crop productivity has been decreased by Overall of cereal crop yield in regionalized area one of Upper Awash Basin by 10.1%

and 9.1% due to El Niño and La Niña episode respectively(Table 4). While Overall reduction of cereal crop yield in regionalized area three of Upper Awash Basin by 16% due to El Niño episode while by 5.3% due to La Niña episode (Table 5). The results show that cereal crop production in regionalized area three is more vulnerable to El Niño episode while reduction during La Niña episode is less in regionalized area three than regionalized area one. El Niño shocks are likely to cause on average a reduction in cereal crop production but it is relatively better than La Niña episodes for wheat crop production in regionalized area one (Figure 6b).

Table4. *Impact of ENSO events on crop productivity in Regionalized area A1*

Cereal Crop	**Average Productivity (Qt/ha)**	**El Niño**		**La Niña**	
		Δ productivity (Qt/ha)	**Percentage change**	**Δ productivity (Qt/ha)**	**Percentage change**
Teff	12.17	-2.0	-16.49%	-0.96	-7.90%
Wheat	17.9	-2.47	-13.77%	-4.12	-23.02%
Maize	22.2	-2.60	-11.72%	1.46	+6.56%
Sorghum	16.13	+0.26	+1.64%	-1.97	-12.19%

Table5. *Impact of ENSO events on crop productivity in Regionalized area A3*

Cereal Crop	**Average Productivity (Qt/ha)**	**El Niño**		**La Niña**	
		Δ productivity (Qt/ha)	**Percentage change**	**Δ productivity (Qt/ha)**	**Percentage change**
Teff	11.65	-1.69	-14.50%	-0.77	-6.59%
Wheat	18.42	-2.53	-13.72%	-2.7	-14.65%
Maize	24.52	-6.42	-26.17%	-1.48	-6.02%
Sorghum	16.15	-1.50	-9.31%	+0.97	+5.99%

4. CONCLUSION AND RECOMMENDATION

According to the result output established between zonal rainfall index and global sea surface temperature correlations, which are mostly manifested as ENSO phenomenaand IOD phase. It has been found that, SST anomalies of the Nino regions and IOD phase have relatively strong correlated with all zonal rainfall indices during *belg* season, while Nino regions are the mostly identified effective area where upsetsrain bearing system during *kiremt* season. Hence, seasonal climate pattern in UAB is affected by the El Nino-Southern Oscillation (ENSO) phases and there is a close relationship between the increase and decrease of rainfall depending upon the warm or cold phases of the phenomenon. The results revealed that rainfall amounts of major rainy season became very high in La Niña but low in El Niño years. Conversely, during small rainy season, comparativelyhigh rainfall amounts were observed when El Niño was apparently established.Therefore the variability of rainfall patterns during the major and small rainy seasons as well as annual totals rainfall at UAB were strongly linked to ENSO phases.

A stochastic dominance analysis using cumulative density function (CDF) of crop yield based on different ENSO phase has identified as the treatments that would be preferred by individuals within a range ofpreferences. It described the weight of risk on crop yield in comparing alternative cropping systems on the risks producers of different ENSO phase. According to Teff, maize, wheat and sorghum cereal crops risk analysis result showed that, crop yield has good performance and less risk during non-ENSO years than El Niño and La Niña phases.Hence, using CDF tools is recommended to evaluate crops yield risk analysisfor applications that allow a user to examine the rainfall forecast for individual cropping Zone based on the ENSO phase.

Due to ENSO phase changes from normal situation, the major overall cereal crop productivity has been decreased in regionalized area three than regionalized area one of Upper Awash Basin. El Niño shocks are likely to cause on average a reduction in cereal crop production but it is relatively better than La Niña episodes for wheat crop production in regionalized area oneof Upper Awash Basin.So, having the information of ENSO phase in advance for the study area can take comparisons based on alternate ENSO forecasts for further insight to select types and varieties of crop to maximize agricultural rain feed cereal crop productivity while minimizing the crop risk associated with seasonal rainfall and ENSO phases.

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