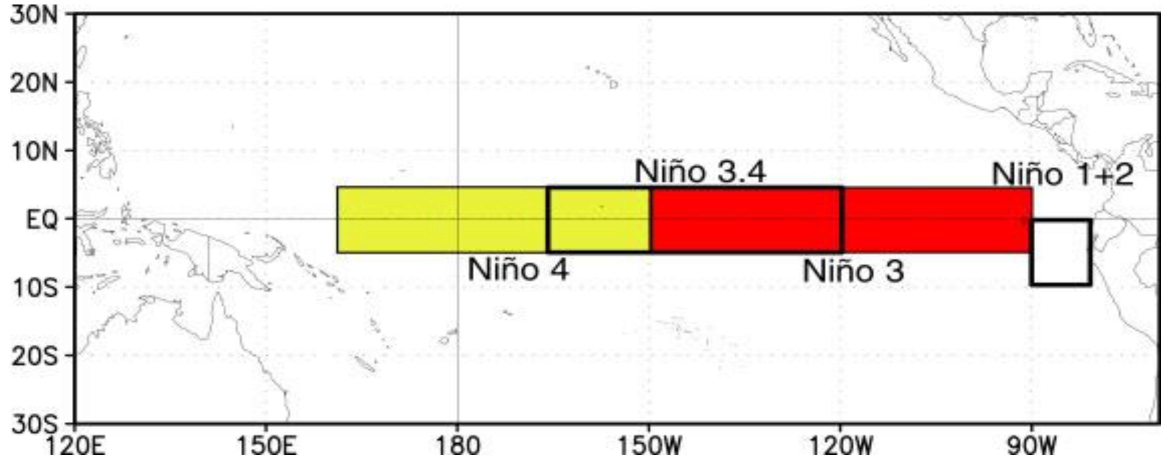
EL NIÑO SOUTHERN OSCILLATION (ENSO) EVOLUTION AND ITS INFLUENCE ON RAINFALL OVER TANZANIA



By

Peter Enos

Reg No: I45/84345/2012

Department of Meteorology

School of Physical Sciences

University of Nairobi

P.O.Box 30190-00100

Nairobi-Kenya

A project submitted to the Department of meteorology, University of Nairobi in partial fulfilment for the award of postgraduate diploma in Meteorology.

Nairobi University 31 July 2013

Declaration

This project is my original work and has never been presented for examination in any other this university or elsewhere.

Signature: ------------------------------ Date: -------------------------------

Peter Enos
Department of Meteorology
University of Nairobi

This project has been submitted for examination with our approval as University Supervisors

Signature: ------------------------------ Date: -------------------------------

Prof: J.M.Ininda
Department of Meteorology
University of Nairobi

This project has been submitted for examination with our approval as University Supervisors

Signature: ------------------------------ Date: -------------------------------

Dr:J.N.mutemi
Department of Meteorology
University of Nairobi

Abstract

The relationship between seasonal rainfall and various Niño indices is investigated in this study. Rainfall used covered eighteen gauge stations distributed throughout Tanzania. The data for both rainfall and ENSO evolution phases were monthly in nature covering the periods 1982 to 2012. Seasonal rainfall totals for both March-April-May and October-November-December are calculated from the raw rainfall data and then standardised to remove the mean. The same is done for the Niño indices. Simple linear correlation and regression techniques are then applied to the data to get the linear relationships inherent in the data. It is found that most of the stations during the season of March to May are not affected by El-Nino evolution phases as most of them registered a p-value higher that 0.05 which is the significant level set for this study. This was mainly during a one season lag (January to February). During lag 0, stronger correlations are observed which also failed to reach a cut-off point of less than 0.05 in terms of the p-value. However, October to December season performed better than the season of March to May with some stations registering highs of 0.5 in terms of the correlation coefficients. Nevertheless, most of the correlations were still poor and could not allow for regression model building. Bukoba rainfall station was the only synoptic rainfall station that could have allowed for model construction during the season of March-April-May while Kigoma and Arusha permitted model construction during the season of October to December season. It was found that Niño 3.4 was the only index that accounted for more than 10% of rainfall variability in the 3 stations mentioned above. It is concluded that if the relationship between ENSO and rainfall over Tanzania is **linear in nature** then, there is no connection between seasonal rainfall and ENSO over Tanzania.

Acknowledgements

I would like to express my special thanks of gratitude to the almighty God for giving me health, strength and guidance for the entire period of my course. I also wish to acknowledge with thanks the Tanzania Meteorological Agency (TMA) for providing me with this golden opportunity to do this wonderful course of meteorology, I real appreciates for its financial support and the data they provided me. I thank my parents, brothers, sisters, my fiancé Rebecca Amos and all my friends for being patient during my absence, keeping me harmonious and for their kind cooperation and constant encouragement which has helped me in completion of this project. I will be grateful forever for their love.

I also take this opportunity to express my profound gratitude and deep regards to my supervisors Prof J.M.Ininda and Dr J.N.Mutemi for their tireless exemplary guidance, monitoring and constant encouragement throughout the course of this project. The blessing, help and guidance given by them time to time shall carry me a long way in the journey of life on which I am about to embark. In addition, I thank Prof J.N.Muthama who introduced to me the research method skills, as well as necessary information regarding the project and whose enthusiasm for the underlying structures had lasting effect.

Furthermore I would also like to acknowledge with much appreciation the Chairman Department of Meteorology Dr A.O.Opere who have invested his full effort in guiding the team in achieving the goal. I also appreciate the guidance given by other supervisors as well as the panels especially in my project presentation that has improved my presentation skills, their comments and advices were vital for the betterment and success of this project. I am also obliged to my lecturers, for their valuable information provided by them in their respective fields as well for the support on the way, I am grateful for their cooperation during the period of my study and I would like to extend my sincere thanks to all of them.

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CHAPTER FIVE

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Abbreviations

AN: - ABOVE NORMAL

BN: - BELOW NORMAL

ENSO: - EL-NINO SOUTHERN OSCILLATION

0 SEASON LAGS: - PREVIOUS SEASONS (JANUARY-FEBRUARY FOR MAM AND JUNE-JULY-AUGUST FOR OND)

1 SEASON LAGS: - MARCH-APRIL-MAY SEASON AND OCTOBER NOVEMBER-DECEMBER SEASON

MAM:- MARCH-APRIL-MAY SEASON

ME:- MODERATE EL-NIÑO

ML: - MODERATE LA-NINA

NC: - NEUTRAL CONDITION

NN: - NEAR NORMAL

OND: - OCTOBER-NOVEMBER-DECEMBER SEASON

P-VALUE: - PROBABILITY VALUE

SE: - STRONG EL-NIÑO

SL: - STRONG LA-NINA

TMA: - TANZANIA METEOROLOGICAL AGENCY

WE: - WEAK EL-NIÑO

WL: - WEAK LA-NINA

CHAPTER ONE

1.0 Background

ENSO is a phenomenon that has been known to characterize seasonal rainfall over East Africa for a long time (Camberlin et al., 2001). Its importance lies in its ability to predict rainfall reasonably well during the seasons of October to December. Rainfall over the East African region is however difficult to predict due to the complexity in regional topographical characteristics. Research is still being carried out to find out how all these complexities can be represented in regional models to enhance rainfall predictability. This is because; precipitation is a fundamental parameter due to the regional dependency on rain-fed agriculture. Economies over the East African region are fully, if not totally, dependent on precipitation. The various cash crops grown over the region including millet, sorghum, maize, beans, coffee, tea, pyrethrum, sisal, sugarcane among others are foreign exchange earners given that the region is non-oil producer. As mentioned earlier, it would be important to know the distribution of precipitation as a weather parameter both spatially and temporally and in a lead time so that planning can be effected on how the next season fairs in terms of output. Being one of the countries lying within the East African region, Tanzania is heavily dependent on agriculture as a foreign exchange earner. Floods and drought affect the country every year necessitating the need for accurate hourly, daily, weekly, monthly, seasonal and yearly forecasting to avert the dangers therein including hunger and malnutrition as well as the dangers associated with floods, including loss of life and destruction of property.

Tanzania is characterized by two distinct seasons north of 8˚S and one prolonged season to the south of the same latitude. Rainfall variability over Tanzania has been extensively covered under the banner of rainfall variability over East Africa by many authors including Camberlin et al., (2001), Nicholson and Kim, (1997). The work carried out by these researchers indisputably connects the regional rainfall variability to the sea surface temperature evolution of the Pacific Ocean known as the El-Niño Southern Oscillation (ENSO). There are two major types of ENSO namely El-Niño and La-Niña. During a La-Niña episode, the eastern central Pacific region remains cool while the western counterpart remains warm. This in essence would render the eastern part of the central pacific a sinking end of the Walker circulation. Walker circulation is a zonal circulation in the tropical pacific named after its founder.

Thus a La-Niña episode would therefore constitute a normal phenomenon as expected. However an intensified La-Niña would have far-reaching ramifications across the globe as figure 1 indicates. El-Niño phase occurs when the eastern Pacific Ocean warms above average reversing what would normally constitute the walker circulation. Thus, the western part of the central equatorial Pacific Ocean would act as a sink while motion will rise over the eastern central pacific. Again, this process has consequences as the global walker circulations in figure 1 indicate. This ENSO phenomena have been quantified in the past and indices invented. Pacific Ocean is thus divided into four regions. Each region acts an ENSO characterizer or a NINO region. Figure 2 illustrates the various regions.

The indices of ENSO have been used for rainfall prediction purposes across the globe. The physical interpretation of the global effect of ENSO is well explained by figure 1.

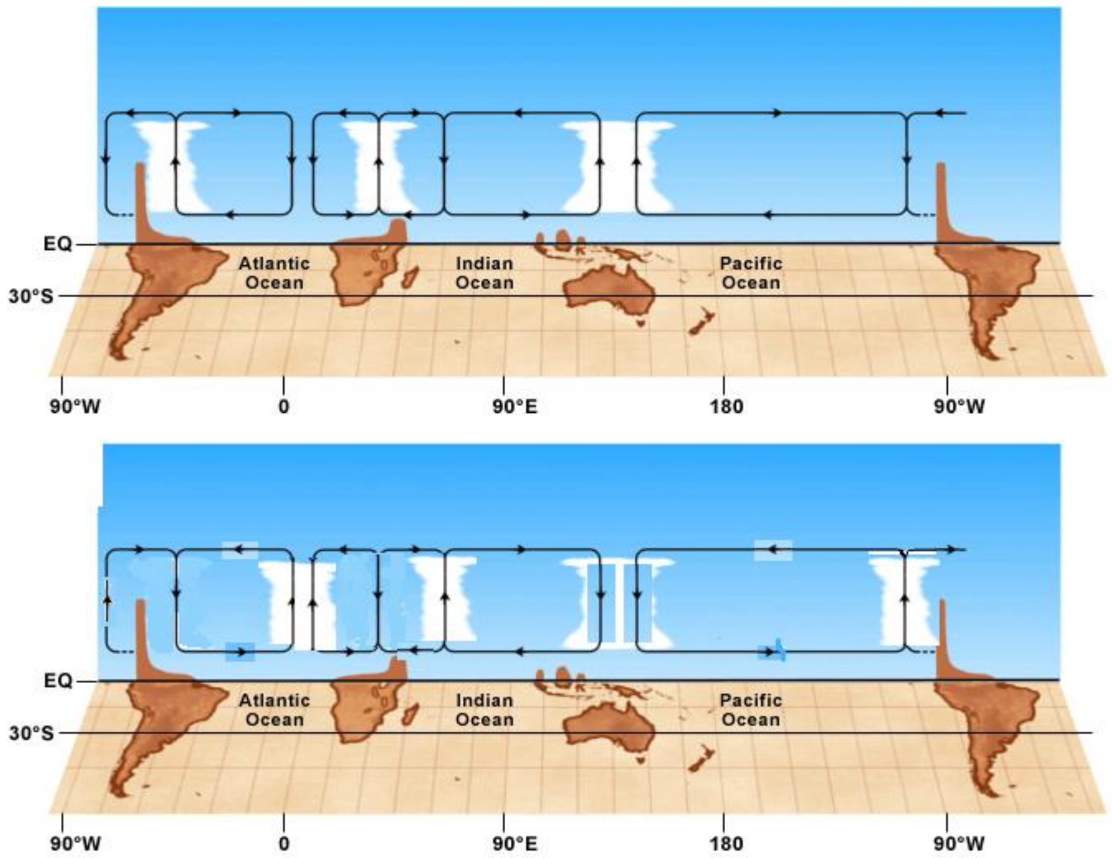

Figure 1: Walker circulations across the globe with La-Nina event (Top panel) and El-Niño event (Bottom panel).

(http://t0.gstatic.com/images?q=tbn:ANd9GcQoiyJ6zEUwlExKus2AO8zpTMdMbQNvCeqn6ayjD2DMTNPrHLtKfg)

During La-Nina, there is sinking motion over the eastern African coast while during an El-Niño event, there is rising motion over the Indian Ocean. Thus, rising motion would usually be associated with enhanced convection while sinking motion would be associated with depressed or no convection (dry episodes). However, even if this is the case, the East African region is a highly variable region due to the physical features that characterize and usually, these local topographic features dominate the synoptic and large scale features. Thus, it's not surprising to find that during an El-Niño year, several parts of the region record minimal or no rainfall at all while during a la-Nina year, enhanced convection is recorded over several parts. The nearness to Lake Victoria and the close proximity to the Indian Ocean coupled with the orography and also the presence of the Ethiopian highlands makes the region unable to respond to the large scale climate drivers as would be expected.

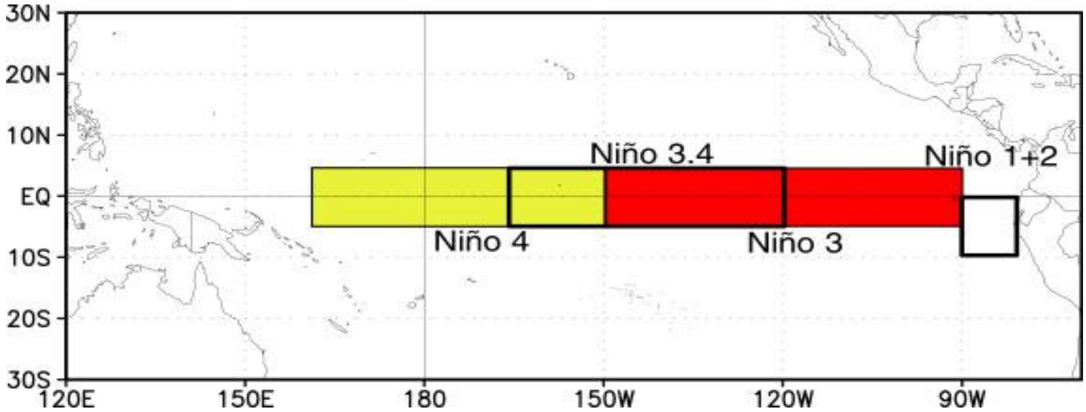

Figure 2: The various Niño regions over the Equatorial pacific

(http://t0.gstatic.com/images?q=tbn:ANd9GcQoiyJ6zEUwlExKus2AO8zpTMdMbQNvCeqn6ayjD2DMTNPrHLtKfg)

1.1 Statement of the Problem

There is need to enhance predictability of rainfall over Tanzania for the reasons enumerated in the preceding section. Since it has been hypothesized in the past that rainfall over the East African region and, Tanzania in particular, is modulated by ENSO, this study seeks to endorse the theory using current and up to-date data on ENSO. The stability of the ENSO phenomena is crucial to planning for the major sectors of the Tanzanian economy given the erratic nature of weather and the corresponding demand for better and accurate skill in prediction for a sustainable agricultural output. ENSO is a good predictor of wet weather especially in the short rains season.

1.2 Hypothesis

If there is an ENSO evolution over the Pacific Ocean, there is no corresponding influence on seasonal rainfall over Tanzania.

1.3 Objectives of the study

The overall aim of this research is to establish the relationship between El-Niño Southern Oscillation and rainfall over Tanzania on a seasonal basis. To achieve this objective, several specific objectives will be pursued. They include;

i) To determine rainfall trends over Tanzania.

ii) To investigate the relationship between the ENSO indices and seasonal rainfall over Tanzania.

1.4 Justification of the study

Due to the rising need to enhance agricultural production over Tanzania, accurate lead time forecasting of precipitation on a seasonal basis is instrumental to provide actionable climate information for early actions, for example agricultural preparations that can lead to bumper harvests. This will also go a long way to alleviate food insecurity associated with less rainfall than predicted. At the same time, accurate rainfall prediction will alert the various divisions responsible for national planning for socio-economic development.

1.5. Area of Study

The study is conducted over Tanzania. The country forms one of the East African countries. It lies within the geographical coordinate's 12S-1S and 29E-42E as shown in figure 3. It's surrounded by Burundi and Rwanda to the North West, Uganda to the North and Kenya to the North East, Mozambique to the South East, Dr Congo to the West and Zambia and Malawi to the South West. It has a land mass area of 945203 Km^2. As mentioned earlier, the major socio-economic activity over Tanzania is Agriculture.

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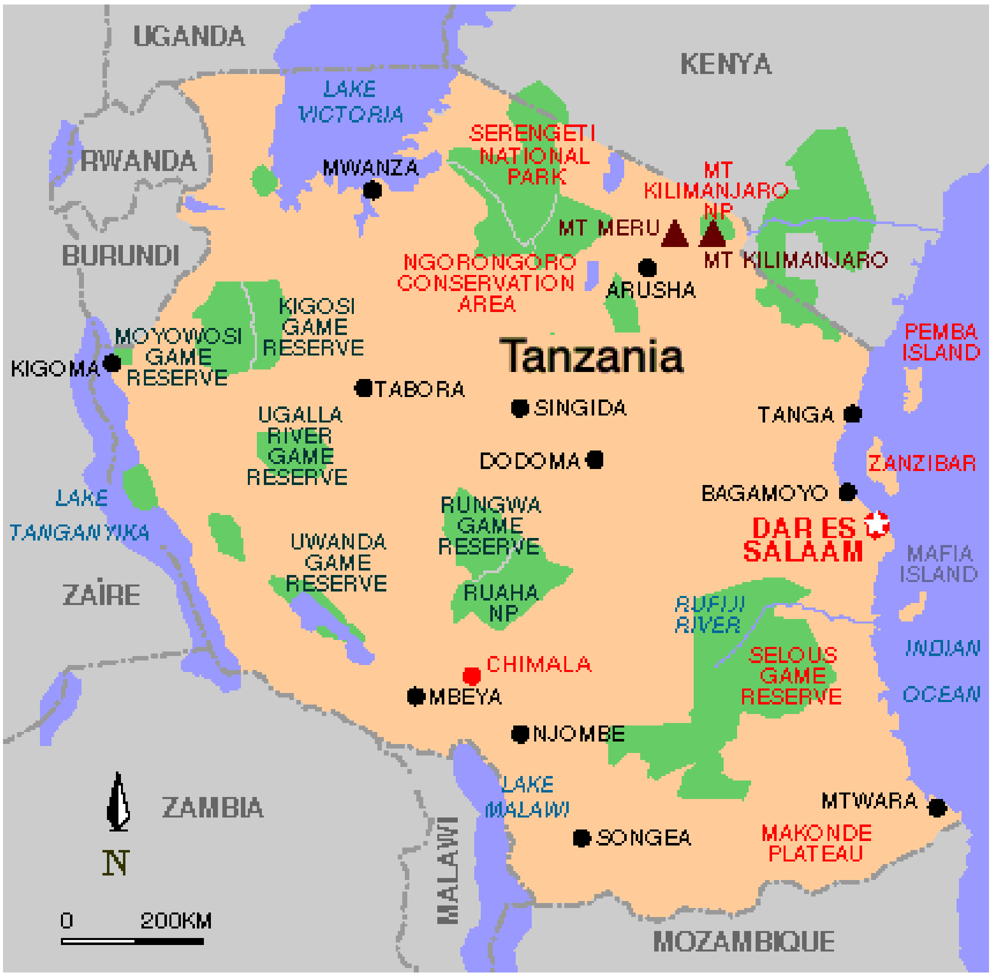

Figure 3: The domain of study

CHAPTER TWO

2.0 Literature Review

El-Niño Southern Oscillation is planetary scale dominant mode of inter-annual climate variability that has a periodicity of 2 to 7 years characterized by a warming/cooling in the Pacific Ocean near the Peruvian coast. During the period when the central-eastern Pacific Ocean warms up above average, heavy rainfall is experienced over Northern Peru and Ecuador Ropelewski and Halpert (1987, 1989). The evolution of these warm waters is referred to as El-Niño. La-Niña is the term that corresponds to a cooling below average across the Central eastern Pacific waters. The warming/cooling of the Pacific Ocean to the East coupled with cooling/warming to the west is associated with air pressure differences between two centres, one located at Darwin (Australia) and the other at Tahiti (Central Pacific). The see-saw pressure difference is known as the Southern Oscillation (SO). The El-Niño/La-Niña phenomenon together with the Southern Oscillation is termed the El-Niño Southern Oscillation, hence the term ENSO (Nicholson and Kim, 1997).

There are four Niño regions across the central Pacific namely Niño 1+2, Niño 3, Niño 3.4 and Niño 4 as shown in figure 1. Niño Indices are computed as the area-averaged sea surface temperature anomalies for each of the four Niño regions. Niño 1+2 region covers the extreme eastern equatorial Pacific between 0˚-10˚S, 90˚W-80˚W. Niño 3 covers the eastern equatorial Pacific between 5˚N-5˚S, 150˚W-90˚W. Niño 3.4 region covers the east-central equatorial Pacific between 5˚N-5˚S, 170˚W-120˚W. Niño 4 region spans the date line and covers the area 5˚N-5˚S, 160˚E-150˚W (Smith and Reynolds, 1998).

CHAPTER THREE

3.0. Data and Methodology

This section presents the data and the methods used to address the objectives of the study.

3.1. Data

The gauge rainfall data used were obtained from Tanzania Meteorological Agency (TMA) eighteen stations spanning the period 1982 to 2012 were selected for analysis since they had continuous quality records. The data were averaged on a seasonal basis to capture the various seasons both to the north of 8˚N which prides two distinct rainfall seasons (March to May and October to December seasons) and to the south of 8˚N which is characterized by one distinct season which spans from December to May, and. the ENSO data spanning from the period 1982-2012 covering Niño 1+2 region, Niño 3.0 region, Niño 3.4 region and Niño 4.0 region were obtained from the Climate Prediction of the National Oceanic and Atmospheric Administration as Niño indices which are archived on a monthly basis.

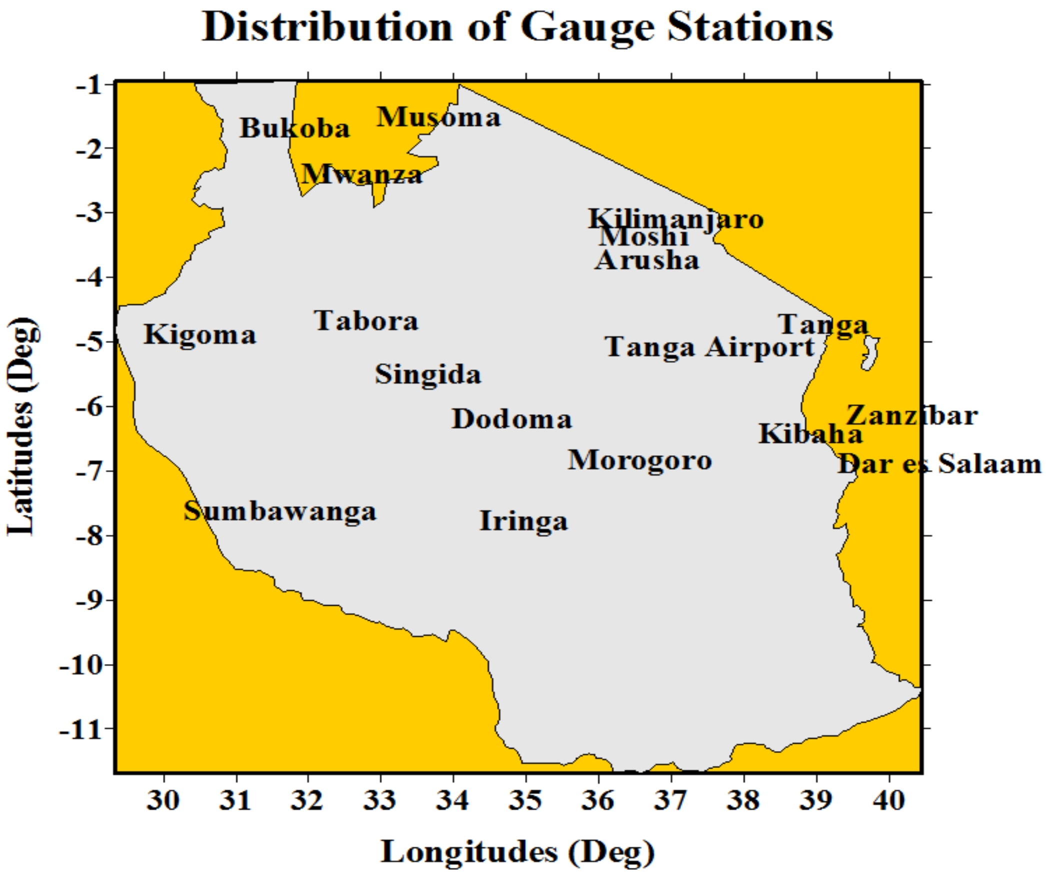

Figure 4: A Map of Tanzania Showing the Distribution of Gauge Stations used

3.2 Methodology

Several methods were undertaken to pursue the objectives of the study. They include the use of Spearman rank correlation method and linear regression analysis.

3.2.1. Estimation of Missing Data

Arithmetic mean ratio method was employed to estimate the missing rainfall records. This involved comparing of the correlation coefficients found between stations of similar climate with complete data and the station with missing data. The station that depicted the highest value of the correlation coefficient was then used to calculate and replace for the corresponding missing record to the station with missing data. The arithmetic mean ratio formula used is given by the equation 1 below;

$$x_m = \frac{\bar{x}}{\bar{y}} . y_a \quad \text{(1)}$$

3.2.2. Pearson Product Moment Correlation Analysis

Rainfall and Nino indices are correlated on seasonal lag basis to establish the relationship between the two variables. This method attempts to establish a linear relationship between two variables. The student t-test is used to test the significance of the derived correlation. Equation 2 shows the formula for calculating the simple correlation while equation 3 shows the formula for computing the student t. The values for the t are then compared with the tabulated values for student t. In case the computed t is bigger than the tabulated t, then one is required to reject the null hypothesis and adopt the alternative one that there is a relationship between the Niño indices and rainfall.

$$r_{sg} = \frac{\sum_{i=1}^{n} \{(s_i - \bar{g}_i)(s_i - \bar{g}_i)\}}{\sqrt{n \sum_{i=1}^{n} \{(s_i - \bar{g})^2 (s_i - \bar{g})^2\}}} \quad \text{(2)}$$

Where; $-1 \le r_{sg} \le +1$

$$t_{n-2} = r_{sg} \sqrt{\frac{n-2}{1-r_{sg}^2}} \quad \text{(3)}$$

3.2.3. Linear Regression Analysis

Linear regression analysis will be employed to develop linear models that will further the linear relationship established through the correlation analysis between rainfall and the Nino indices.

$$y_i = a_o + \sum_{i=1}^{n} b_i x_{ij} + e_i \quad \text{..........} \quad (4)$$

Where a_o and b_i are the intercept and regression coefficients for the predictors, x_i. The variance of the error term e_i, in this case is $S^2 = \frac{SSE}{n-(k+1)}$ while a test of the adequacy of the model is done by computing R^2 (the multiple coefficient of determination) given by $R^2 = 1 - \frac{SSE}{\sum_{i=1}^{n}(Y-\overline{Y})^2}$. For $R^2 = 0$, it implies Lack of fit, while $R^2 = 1$ implies perfect fit.

Linear regression analysis in this study is used to determine a linear relationship between Niño indices and the rainfall at different time lags.

CHAPTER FOUR

4.0. Results and Discussion

This chapter presents and discusses the results obtained from the analysis.

4.1. Testing of Data Homogeneity

Before the rainfall data was used for analysis, it was subjected to data quality control. Single mass curves were adopted for this exercise. The degrees of deviation from a straight line in the plots of cumulative were found to be within acceptable range. The slight deviations were however corrected to account for error which might have compromised the quality of the data in the analysis. Figure 5 below shows single mass curves for selected stations.

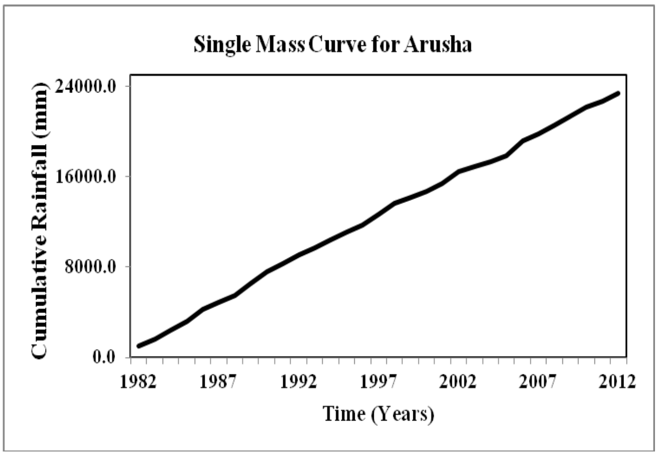

Figure 5(a): Single Mass curve for Arusha

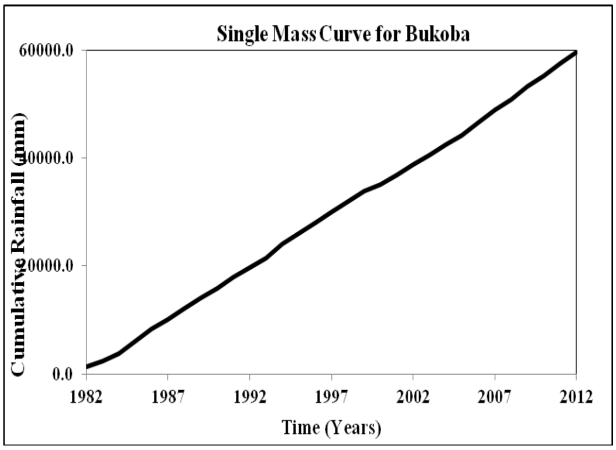

Figure 5(b): Single Mass curve for Bukoba

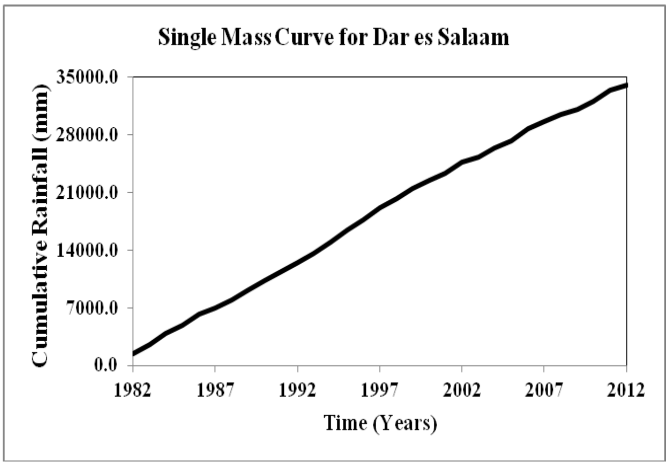

Figure 5(c): Single Mass curve for Dar es Salaam

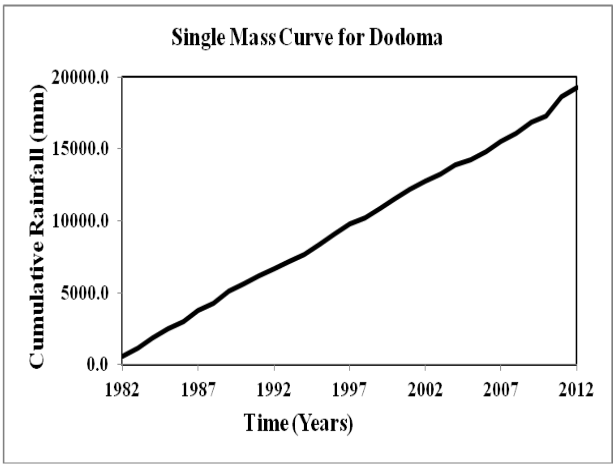

Figure 5(d): Single Mass curve for Dodoma

4.2. Trends in Rainfall

This section examines rainfall trends over Tanzania on seasonal and annual basis. Generally, it was found that March to May seasonal rainfall totals are higher than October to December seasonal rains. Annual rainfall over Northern parts of the country especially near the Lake region was found to be gradually increasing with time. Figure 6a and 6b shows rainfall trend over Bukoba and Mwanza representing Northern parts of Tanzania and the lake region. Seasonal rainfall in both long and short rains increases gradually but at a slower rate compared to the annual rainfall near the Lake region. However, over the central parts of the country, the trends in rainfall were found to remain nearly at a constant rate with March to May rains still registering higher values in terms of totals as compared to the October to December rains. Figure 6c and 6d shows the trends in rainfall over the central parts of Tanzania represented by Singida and Dodoma. Towards the Southern parts of the country including the coastal regions, there was observed a generally gradual decrease in rainfall at annual and seasonal time scales. Figure 6e, 6f, 6g, and 6h shows the gradual decrease in rainfall over Dar esSalaam, Kibaha, Iringa and Morogoro in both the 2 time scales mentione

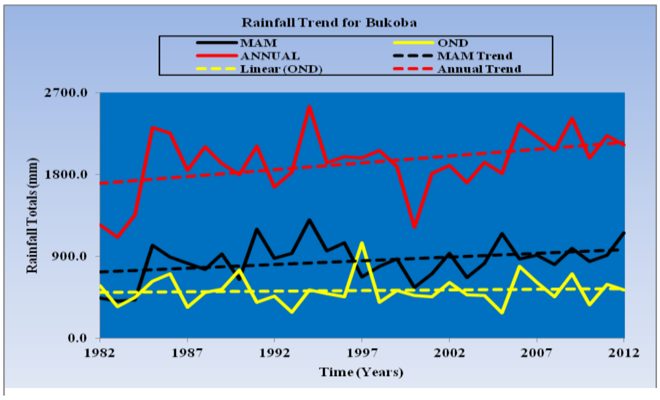

Figure 6(a): Interannual variability of rainfall over Bukoba

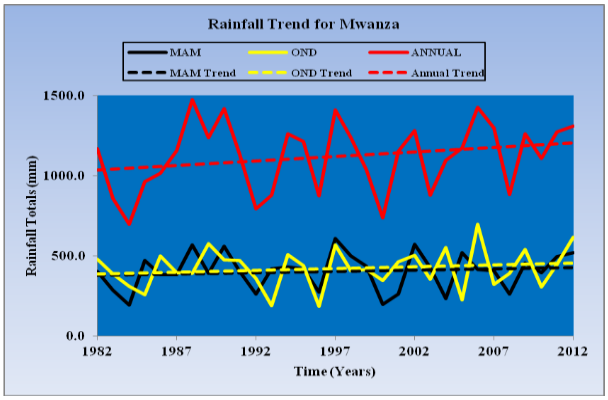

Figure 6(b): Interannual variability of rainfall over Mwanza

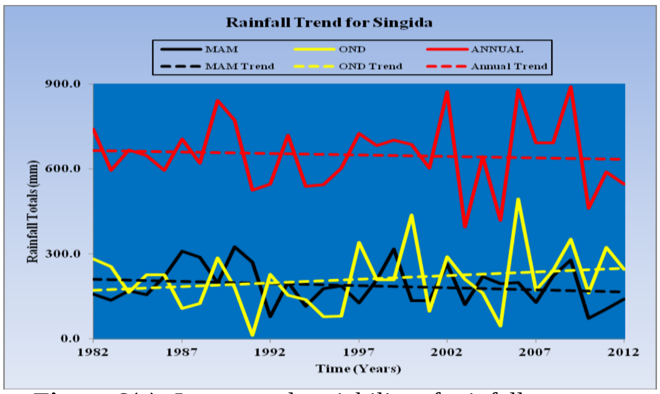

Figure 6(c): Interannual variability of rainfall over Singida

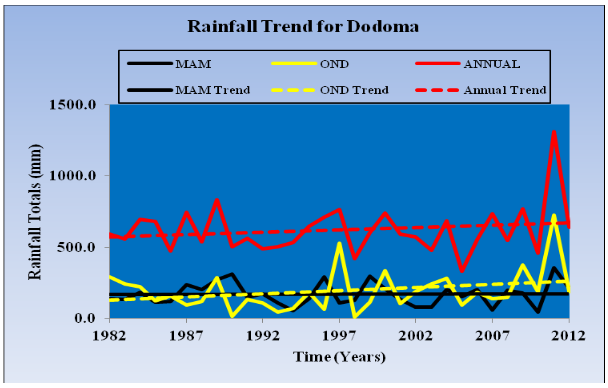

Figure 6(D): Interannual variability of rainfall over Dodoma

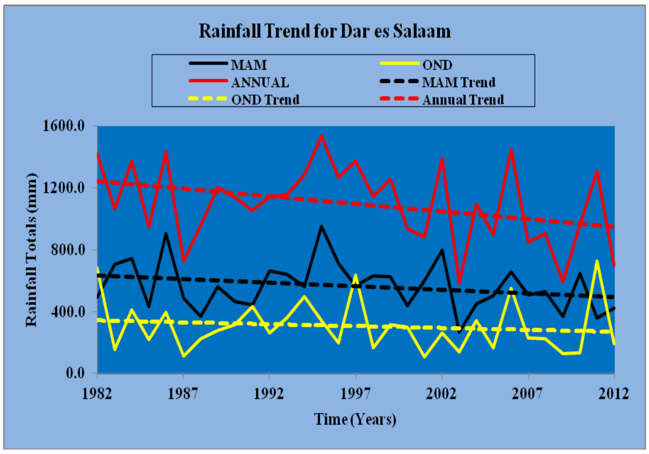

Figure 6(e): Interannual variability of rainfall over Dar-es-Salaam

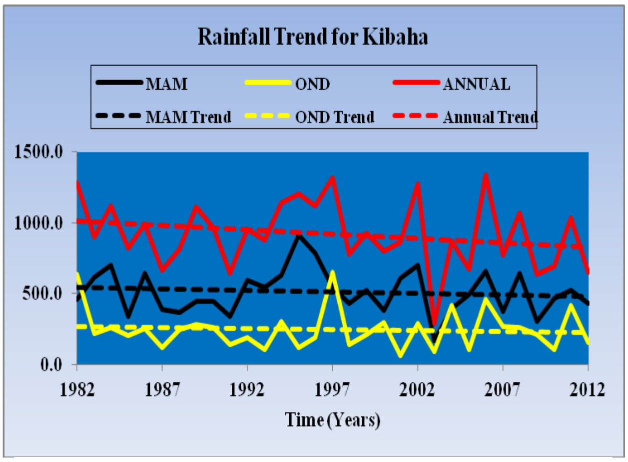

Figure 6(f): Interannual variability of rainfall over Kibaha

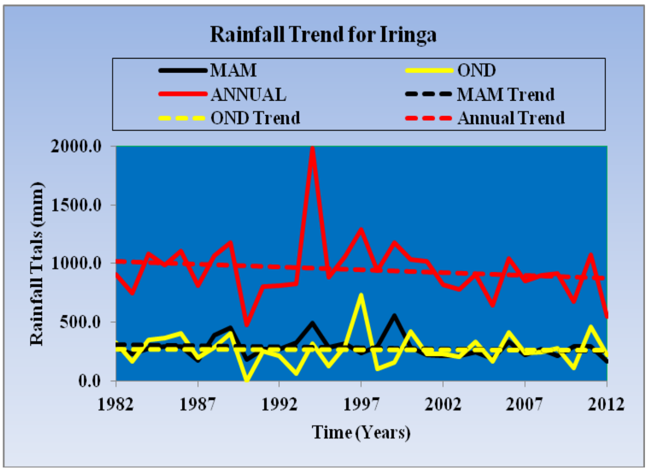

Figure 6(g): Interannual variability of rainfall over Iringa

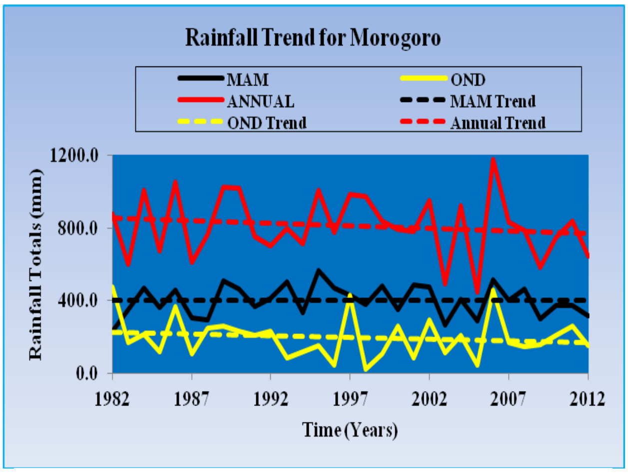

Figure 6(h): Interannual variability of rainfall over Morogoro

4.3. Results from Correlation Analysis

This section presents results obtained from correlation analysis between rainfall at stations and the various Niño indices adopted for the study. In general, the correlations were found to be low in both lag 0 and lag 1 correlation. However, the lake region registered significant positive correlations at both lag 0 and lag 1.

4.3.1. Lag 0 correlations for March to May Season

Figure 7 shows lag 0 correlations between the 4 Niño indices employed and with March to May rainfall. High positive correlations are observed to the Southern part of the country in Niño 1+2 and 3.0 indices, though not significant. Highly positive and significant correlation is also observed to the north western part of the country between the two Niño 3.4 and 4.0 indices and the March to May rains. The rest of the country show low non-significant correlations with all the Niño indices considered.

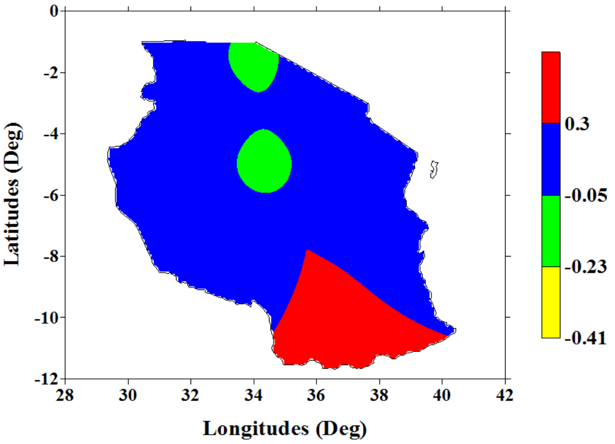

Figure 7a: Correlations between Nino 1+2 and March to May rainfall at 0 season lag.

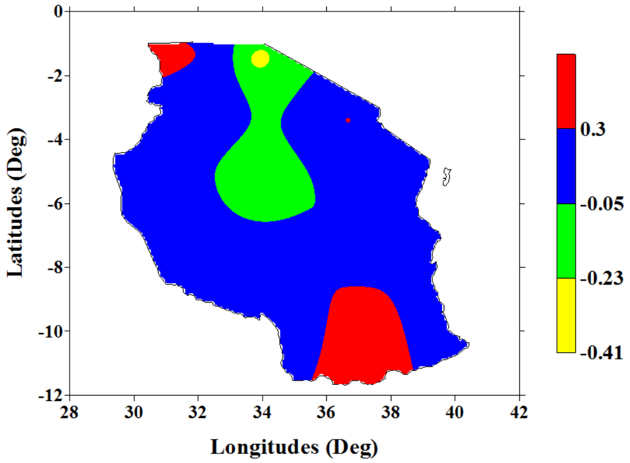

Figure 7b: Correlations between Nino 3.0 and March to May rainfall at 0 season lag.

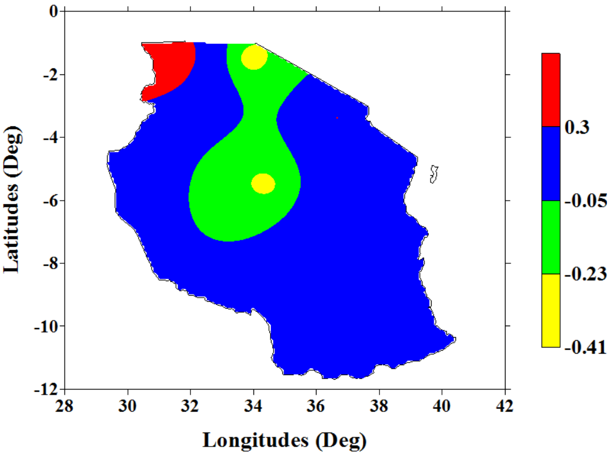

Figure 7c: Correlations between Nino 3.4 and March to May rainfall at 0 season lag.

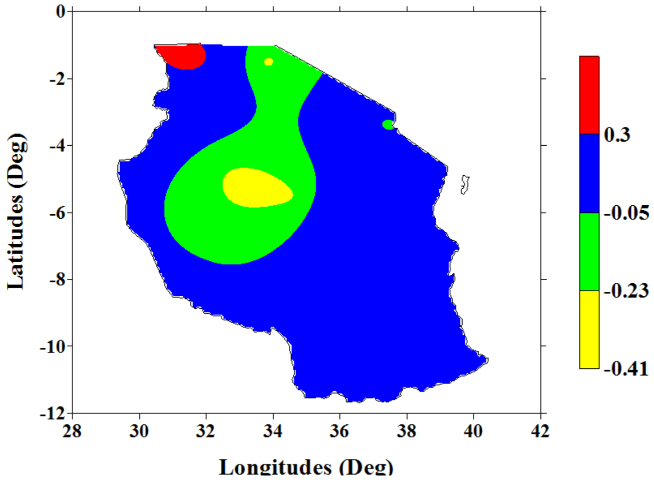

Figure 7d: Correlations between Nino 4.0 and March to May rainfall at 0 season lag.

4.3.2. Lag 1 correlations for March to May Season

Figure 8 shows lag 1 correlation between the 4 Niño indices employed and with March to May rainfall. The entire country showed low non-significant correlations. However, the eastern part and the south eastern part of the country showed appreciable negative correlations between Niño 1+2, Niño 3.0 indices and MAM rains though not significant at the 95%.

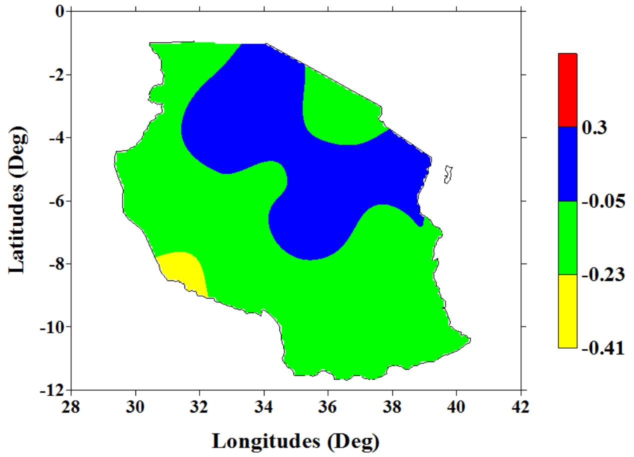

Figure 8a: Correlations between Nino 1+2 and March to May rainfall at 1 season lag.

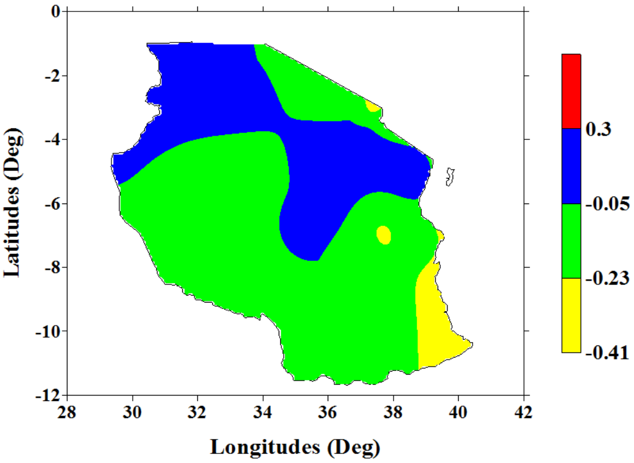

Figure 8b: Correlations between Nino 3.0 and March to May rainfall at 1 season lag.

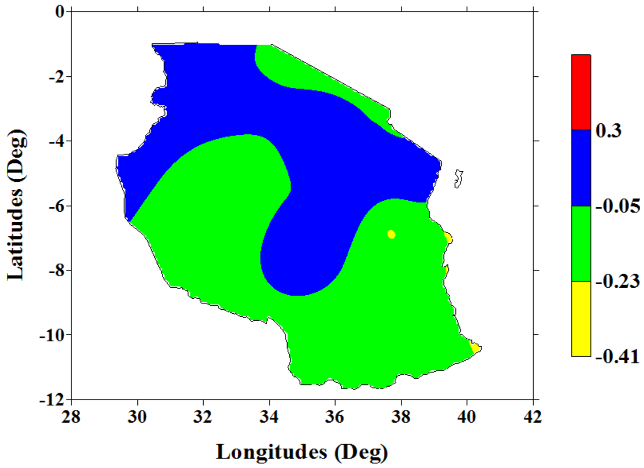

Figure 8c: Correlations between Nino 3.4 and March to May rainfall at 1 season lag.

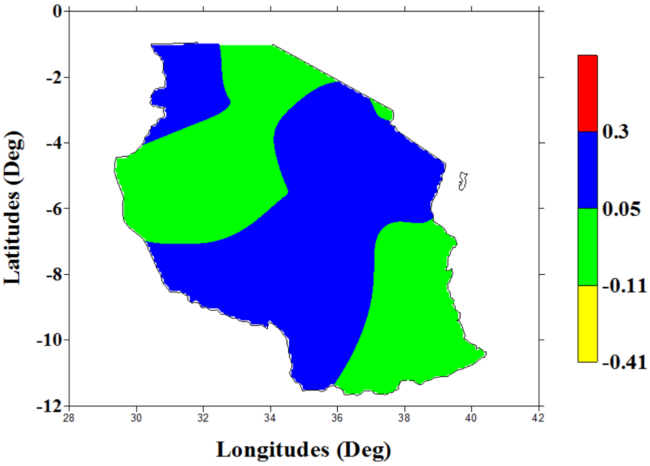

Figure 8d: Correlations between Nino 4.0 and March to May rainfall at 1 season lag.

4.3.3. Lag 0 correlations for October to December.

Figure 9 shows lag 0 correlations between the 4 Niño indices employed and October to December rainfall. The entire country showed low non-significant correlations between the four Niño regions and the October to December rains. However, the western part registered highly positive correlations between the Niño 1+2 and 3.0 and the October to December rain. Also the north eastern highland of the country showed highly positive but significant correlations between the three Niño 3.0, 3.4 and 4.0 indices and the October to December rains.

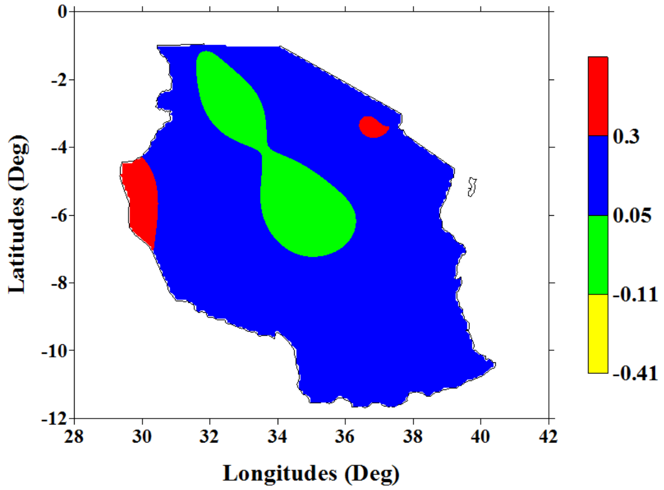

Figure 9a: Correlations between Nino 1+2 and October to December rainfall at 0 season lag.

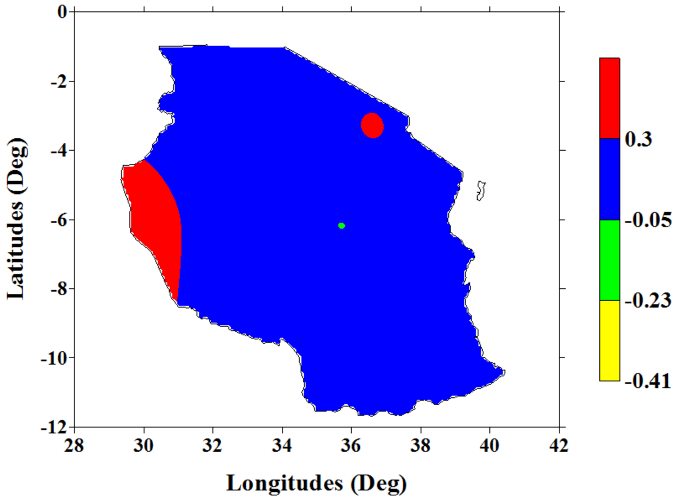

Figure 9b: Correlations between Nino 3.0 and October to December rainfall at 0 season

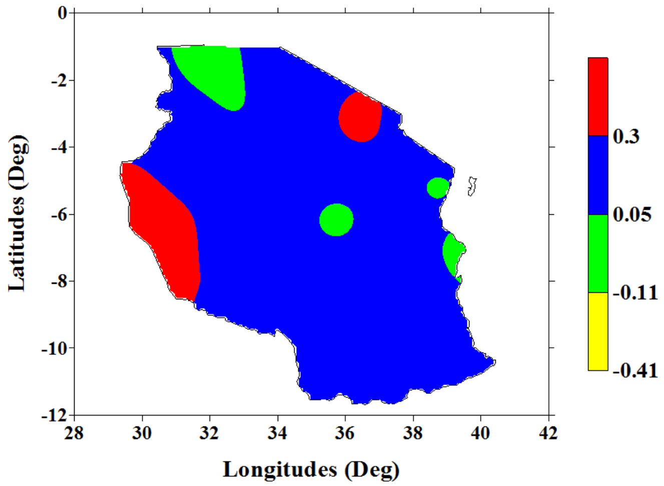

Figure 9c: Correlations between Nino 3.4 and October to December rainfall at 0 season lag.

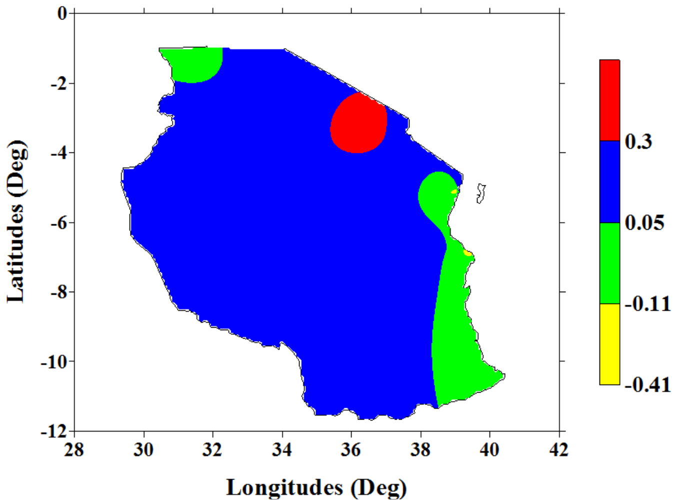

Figure 9d: Correlations between Nino 3.4 and October to December rainfall at 0 season

4.3.4. Lag 1 correlations for October to December Season

Figure 10 show lag 1 correlations between the 4 Niño indices employed and October to December rainfall. High negative correlations are registered in the southern part and the north eastern part of the country between Niño 1+2, 3.0 and the October to December rains. Also high negative correlations are showed in the western part of the country between the Niño 3.4 and Niño 4.0 indices and the October to December rains. Highly negative but significant correlations are registered in the western part between Niño 3.0, 3.4 and 4.0 indices and the October to December rains and the. The rest of the country show low non-significant correlations with all the Niño indices considered.

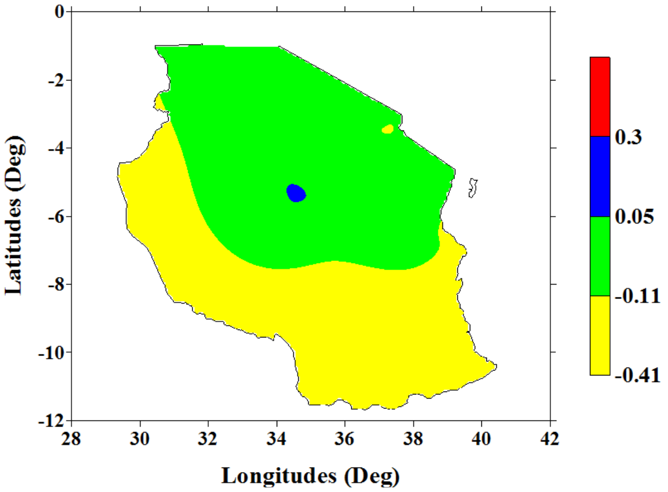

Figure 10a: Correlations between Nino 1+2 and October to December rainfall at 1 season

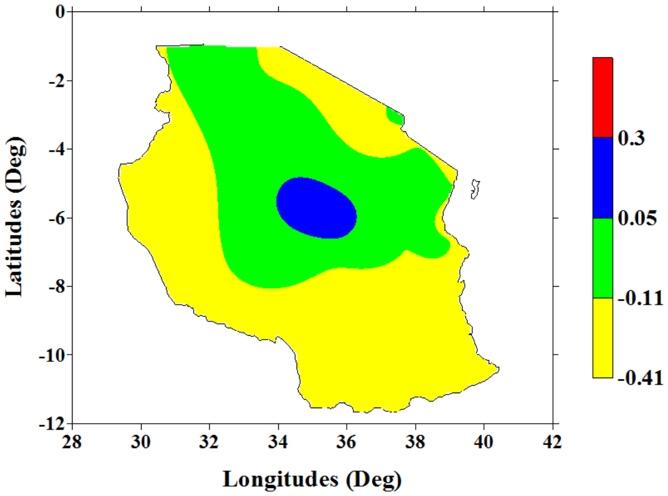

Figure 10b: Correlations between Nino 3.0 and October to December rainfall at 1 season

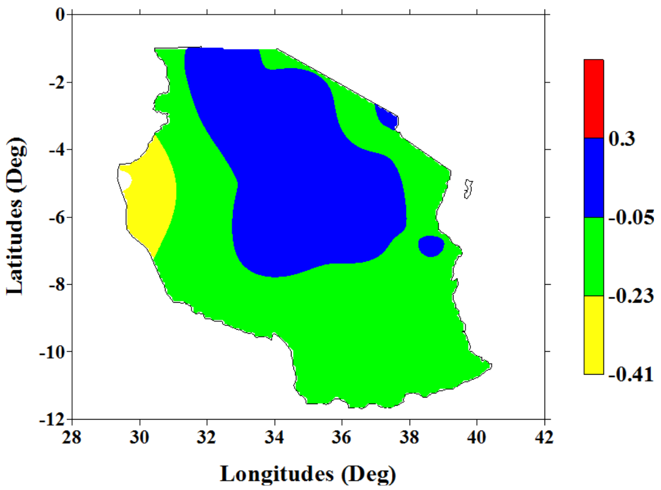

Figure 10c: Correlations between Nino 3.4 and October to December rainfall at 1 season

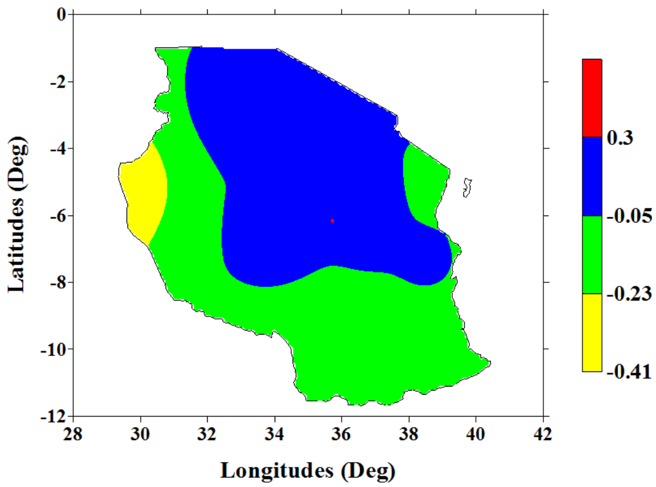

Figure 10d: Correlations between Nino 4.0 and October to December rainfall at 1 season

Table 1 (a) and (b) below summarises the correlations between station seasonal rainfall and Niño indices at both lag 0 and 1

Table 1(a): March to May (MAM) Correlations

Stations	Lon	Lat	JF Niño 1+2	JF Niño 3.0	JF Niño 3.4	JF Niño 4.0	MAM Niño 1+2	MAM Niño 3.0	MAM Niño 3.4	MAM Niño 4.0
Arusha	36.68	-3.37	0.1077	0.3200	0.3121	0.2747	-0.1649	-0.0529	0.0487	0.2768
Bukoba	31.82	-1.33	0.1046	0.3262	0.4146	0.3468	-0.2274	0.0234	0.0854	0.1253
Da es Salaam	39.28	-6.82	0.1661	0.1782	0.1494	0.1601	-0.1612	-0.2308	-0.2335	-0.0764
Dodoma	35.74	-6.19	0.0817	-0.0353	0.0329	0.1369	0.2344	0.0628	0.1302	0.2161
Iringa	35.69	-7.77	0.3011	0.2762	0.1849	0.1768	-0.0417	-0.0487	0.0023	0.1668
Kibaha	38.92	-6.77	0.1148	0.2631	0.3058	0.2951	-0.0347	-0.1093	-0.1049	0.0189
Kigoma	29.63	-4.88	0.0956	0.2360	0.1963	0.0418	-0.10767	-0.0314	-0.0120	0.0411
Kilimanjaro	37.35	-3.08	0.2125	0.0380	-0.0220	0.0161	-0.1166	-0.2724	-0.2222	-0.0281
Morogoro	37.67	-6.82	0.2116	0.2317	0.1525	0.1298	-0.2150	-0.2606	-0.2473	-0.0179
Moshi	37.33	-3.35	0.0471	0.1293	0.0345	-0.0910	-0.1102	-0.0836	-0.0775	0.0910
Musoma	33.8	-1.5	-0.1305	-0.2789	-0.3063	-0.2522	0.0248	-0.0494	-0.0716	-0.0960
Mwanza	32.75	-2.75	0.0491	0.0892	0.1422	0.0937	0.0800	0.0367	0.0310	0.0533
Singida	34.5	-5.5	-0.1196	-0.2061	-0.2773	-0.2564	-0.0942	-0.0812	-0.0734	0.0457
Sumbawanga	31.62	-7.97	0.1785	0.1287	0.0123	-0.0002	-0.2537	-0.1469	-0.0846	0.0725
Tabora	32.8	-5.02	-0.0108	-0.0866	-0.1470	-0.2770	-0.0412	-0.1503	-0.1472	-0.0282
Tanga Airport	39.07	-5.08	0.1046	0.1375	0.1134	0.1736	0.1775	0.0751	0.0774	0.2718
Tanga	39.1	-5.07	0.2687	0.1683	0.0695	0.0741	-0.0244.	-0.0723	-0.0149	0.1456
Zanzibar	39.22	-6.22	-0.0406	0.0341	0.0520	0.0814	-0.0494	-0.1268	-0.1239	0.0136

Table 1 (a): Tabulated Rainfall and Niño indices correlations for March to May season

Table 1(b): October to December (OND) Correlations

Station	lon	Lat	JJA Niño 1+2	JJA Niño 3.0	JJA Niño 3.4	JJA Niño 4.0	OND Niño 1+2	OND Niño 3.0	OND Niño 3.4	OND Niño 4.0
Arusha	36.68	-3.37	0.3383	0.3538	0.3947	0.3900	-0.1099	-0.2169	-0.1247	-0.0373
Bukoba	31.82	-1.33	0.0400	-0.0154	0.0026	0.0282	-0.0219	-0.0375	-0.0107	-0.0217
Da es Salaam	39.28	-6.82	0.1916	0.0530	-0.0366	-0.1310	-0.1246	-0.1734	-0.1369	-0.0839
Dodoma	35.74	-6.19	-0.0274	-0.0613	-0.0176	0.0908	0.0443	0.1231	0.2339	0.3091
Iringa	35.69	-7.77	0.1038	0.1493	0.1740	0.1178	-0.1767	-0.1667	-0.1422	-0.1204
Kibaha	38.92	-6.77	0.0943	0.0610	0.0547	0.0286	-0.1156	-0.0836	-0.0082	0.0670
Kigoma	29.63	-4.88	0.3778	0.3778	0.3315	0.1340	-0.3150	-0.4082	-0.4299	-0.3930
Kilimanjaro	37.35	-3.08	0.2145	0.2259	0.2569	0.2465	-0.0509	-0.0729	-0.0038	0.0632
Morogoro	37.67	-6.82	0.1963	0.2118	0.2282	0.2122	-0.0658	-0.1084	-0.0711	-0.0398
Moshi	37.33	-3.35	0.3004	0.2154	0.2068	0.2049	-0.1208	-0.1405	-0.0556	-0.0241
Musoma	33.8	-1.5	0.1601	0.0927	0.1143	0.1395	-0.0352	-0.1366	-0.0587	-0.0245
Mwanza	32.75	-2.75	-0.0278	-0.0346	0.0294	0.0998	0.0309	-0.0266	0.0673	0.1252
Singida	34.5	-5.5	-0.0433	0.0245	0.1438	0.2612	0.0541	0.1059	0.1888	0.2174
Sumbawanga	31.62	-7.97	0.2393	0.2760	0.3030	0.2711	-0.1950	-0.1520	-0.1052	-0.0824
Tabora	32.8	-5.02	0.1130	0.2148	0.2733	0.2454	0.0225	-0.059	-0.0658	-0.0302
Tanga	39.07	-5.08	0.1257	0.0628	-0.0257	-0.1463	0.0324	-0.0689	-0.1475	-0.1946
Tanga Airport	39.1	-5.07	0.1021	0.1824	0.2321	0.2046	-0.1063	-0.1911	-0.1725	-0.1487
Zanzibar	39.22	-6.22	0.1335	0.1345	0.1158	0.0181	-0.1769	-0.2145	-0.2044	-0.2049

Table 1 (b): Tabulated Rainfall and Niño indices correlations for October to December season

4.4. Results from Linear Regression Analysis

This section presents results obtained after regression models were fit between seasonal rainfall and Niño indices at one season lag. It should be noted that due to the low correlations obtained between the two variables in most of the stations considered, most of the regression models constructed were far from being optimal. However, a few stations showed good models explaining more than 10% of variability.

4.4.1. March to May Regression Model

Only Bukoba rainfall station registered appreciable correlations leading to its adoption for linear regression modelling. Figure 11a illustrates the model constructed. The coefficient of determination was above 10% implying that Niño 3.4, which correlated highly with the station, explains about 10% of the variability of rainfall for this station. For the other stations, none of them registered a p-value less than 0.05 and were therefore ignored during regression model building.

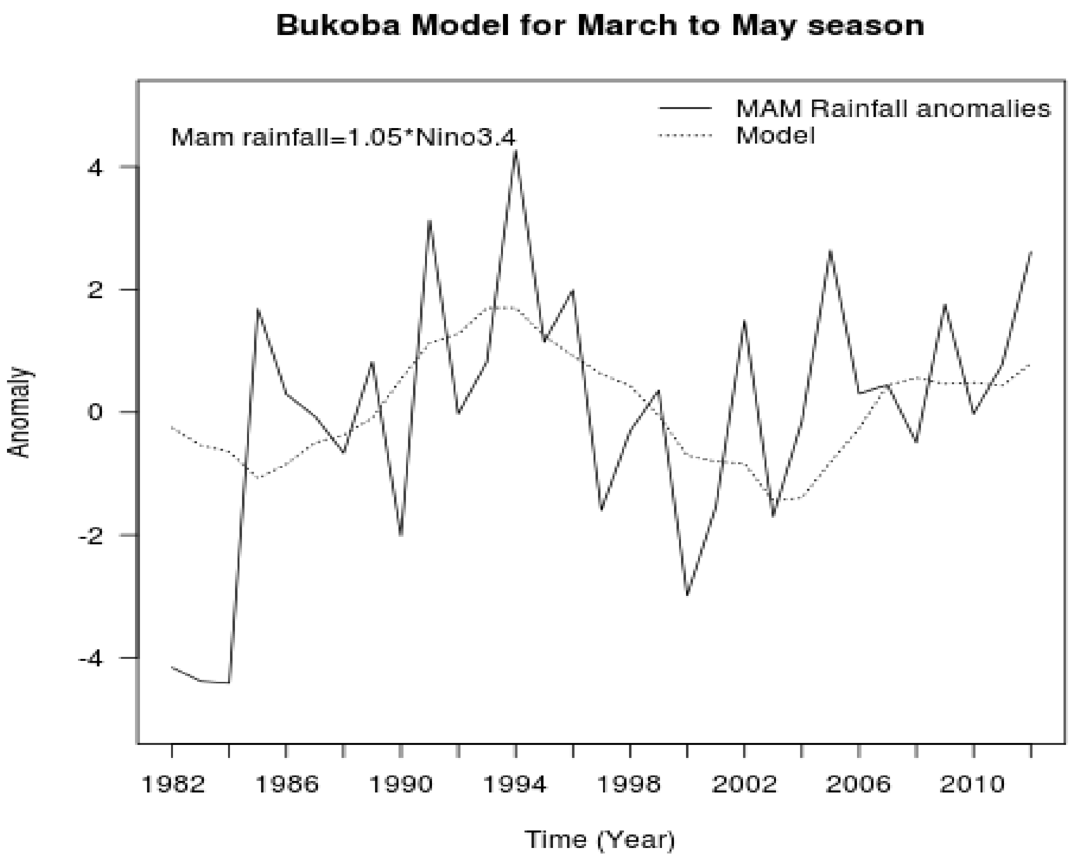

Figure 11(a): A model for March to May season

4.4.2. October to December Regression Models

October to December season performed much better than the March to May rainfall season in terms of the response to the indices. However, the stronger correlations registered were not able to attain the 0.05 p-value threshold required for a model to be adequate in most stations. In this regard only 2 stations whose p-value was less than 0.05 were adopted for modelling. Arusha and Kigoma rainfall stations did well when correlated with the Niño 3.4 index while the correlations with other indices, though high, never reached the cut-off point of 0.05 in p-value. However the model was not able to capture the peaks observed in the observed data. The results are shown in figure 11b and 11c below

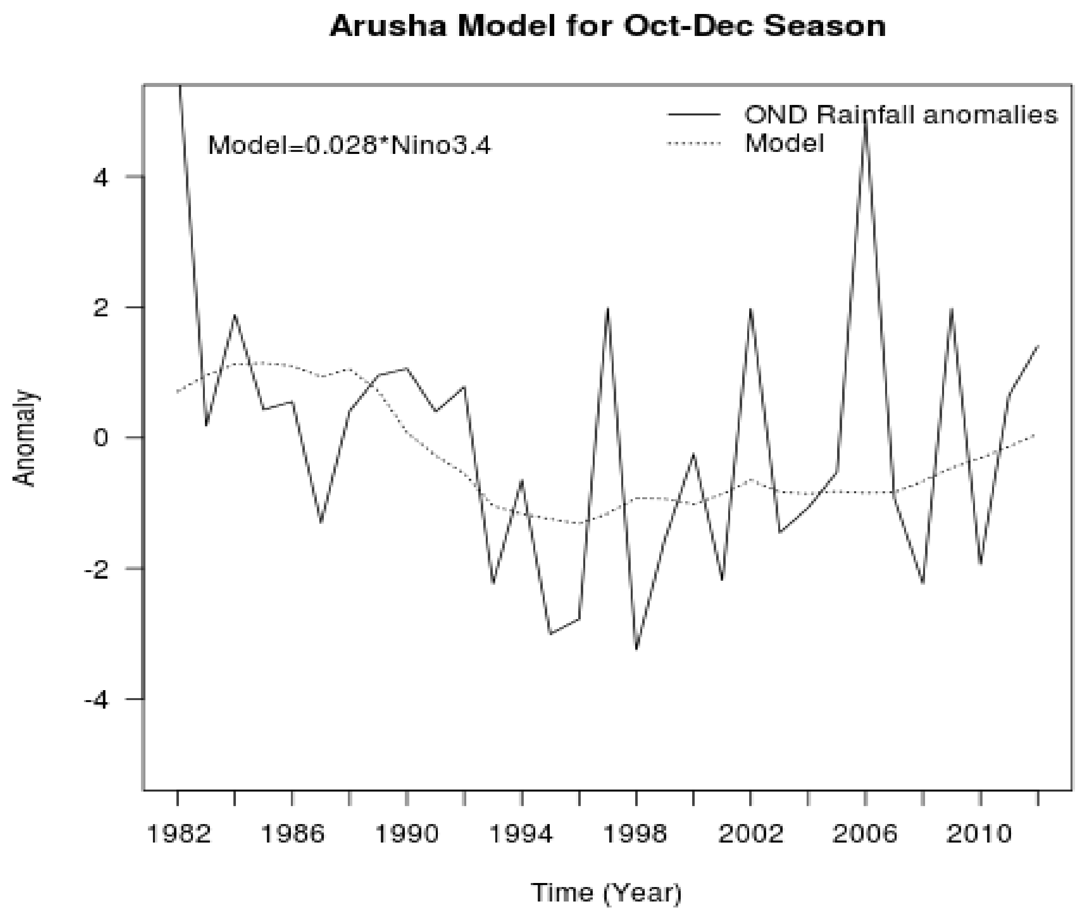

Figure 11(b): A model for October to December

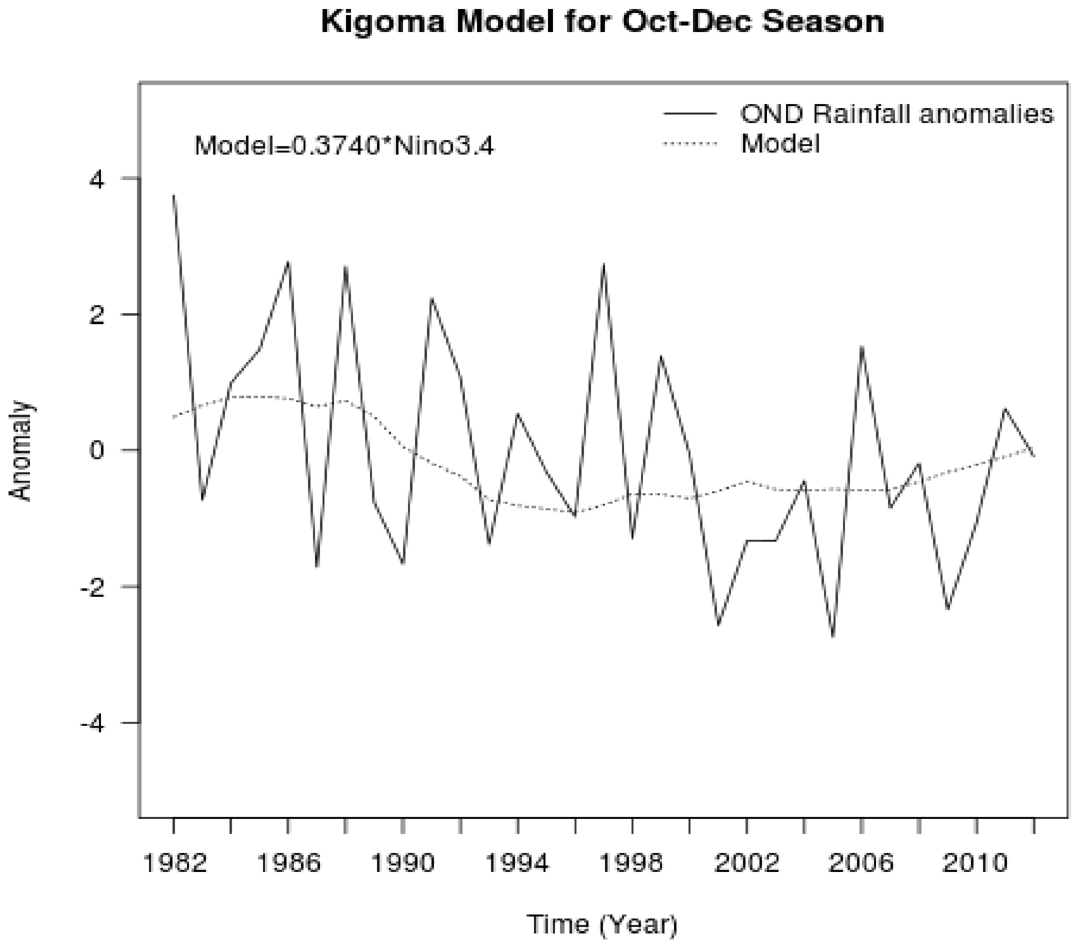

Figure 11(c): A model for October to December

4.5. Results from El-Niño/La-Nina Events against Rainfall Patterns

This section presents the seasonal El-Niño/La-Nina event patterns as compared with the seasonal rainfall patterns over Tanzania for a period 1982 to 2012 for the stations adopted.

4.5.1. Results from El-Niño Events against Rainfall Patterns

The 1982/1983 El-Niño was accompanied by rains above normal in most of the stations considered in 1982 at both the October to December season lags, whereby the March to May season generally registered rainfall near normal in most of the stations considered in the year 1982. The 1987 El-Niño was generally accompanied with rainfall near normal in all seasons considered at that year. The 1992 El-Niño also accompanied with rains near normal in most of the stations adopted in the analysis at that year. The 1997/1998 El-Niño associated with above normal in most of the stations in the March to May rains at 0 season lag in 1998 and in the October to December rains at 1 season lag in 1997, while in other seasons below normal and near normal dominated in most of the stations in 1997/1998. The 2009/2010 El-Niño was also dominated by rains below normal and near normal in most of the stations used in the analysis. The results also show above normal rains in the March to May rains at 1 season lag in 1990 and in the October to December rains at 1 season lag in 2006 and 2011 and at 0 season lag 1999, though were not the El-Niño years.

4.5.2. Results from La-Nina Events against Rainfall

The 1988/1989 La-Nina was found to be accompanied by rains above normal in few stations in the march to May rains at 1 season lag, though in most of the stations near normal rains dominated in all of the seasons considered. The 1999/2000 la-Nina was found to be dominated by rains near normal in all of the rain seasons except the October to December rains at 0 season lag in 1999 which was dominated by above normal rains. The 20007/2008 La-Nina dominated by near normal rains in all of the stations. Also below normal rains dominated for the March to May rains in 2012 at 1 season lag and in the October to December rains at 1 season lag in 1993, 1998 and 2005 though were not the La-Nina years.

A table showing El-Niño/La-Nina Event Patterns

YEARS	JF Nino 1+2 EVENT	JF Nino 3.0 EVENT	JF Nino 3.4 EVENT	JF Nino 4.0 EVENT	MAM Nino 1+2 EVENT	MAM Nino 3.0 EVENT	MAM Nino 3.4 EVENT	MAM Nino 4.0 EVENT	JJA Nino 1+2 EVENT	JJA Nino 3.0 EVENT	JJA Nino 3.4 EVENT	JJA Nino 4.0 EVENT	OND Nino 1+2 EVENT	OND Nino 3.0 EVENT	OND Nino 3.4 EVENT	OND Nino 4.0 EVENT
1982	ML	WE	WL	WL	ML	ME	WE	WE	ME	ME	ME	WE	SE	SE	SE	ME
1983	SE	SE	SE	ME	SE	SE	SE	WE	SE	SE	WE	WL	ME	ML	SL	ML
1984	ML	WL	WL	ML	ML	WL	WL	ML	ML	ML	WL	WL	WL	ML	SL	ML
1985	SL	ML	ML	ML	SL	ML	ML	ML	SL	SL	ML	ML	ML	ML	WL	WL
1986	WL	ML	ML	WL	ML	WL	WL	WL	WL	WL	WE	WE	WE	ME	ME	ME
1987	ME	SE	SE	ME	SE	SE	ME	WE	ME	SE	SE	ME	ME	SE	SE	ME
1988	WL	WE	ME	ME	ML	ML	WL	WL	SL	SL	SL	WL	ML	SL	SL	SL
1989	WL	SL	SL	SL	WL	ML	ML	ML	ML	WL	WL	WL	WL	WL	WL	WL
1990	WL	WL	WE	WE	WL	WL	WE	WE	WL	WE	WE	WE	ML	WL	WE	WE
1991	WL	WE	WE	ME	WL	WE	WE	WE	WE	ME	ME	WE	ME	ME	SE	ME
1992	WE	SE	SE	ME	SE	SE	SE	ME	WE	WE	WE	WE	WL	WL	WL	WE
1993	WE	WE	WE	WE	ME	ME	ME	WE	ME	WE	WE	WE	WE	WE	WE	WE
1994	WL	WL	WE	WE	ML	WL	WE	WE	ML	WL	WE	ME	ME	ME	SE	ME
1995	WE	ME	ME	ME	ML	WL	WE	ME	ML	WL	WL	WE	ML	ML	ML	WL
1996	ML	ML	ML	ML	SL	ML	WL	WL	SL	WL	WL	WL	SL	ML	WL	WL
1997	ML	ML	WL	WE	SE	WE	WE	ME	SE	SE	SE	ME	SE	SE	SE	ME
1998	SE	SE	SE	ME	SE	SE	ME	WE	SE	WL	ML	ML	WL	ML	SL	SL
1999	WL	SL	SL	SL	ML	ME	ML	ML	ML	ML	SL	ML	ML	SL	SL	SL
2000	ML	SL	SL	SL	WL	WL	ML	SL	ML	NL	ML	WL	ML	ML	ML	ML
2001	WL	WL	ML	ML	WE	NC	WL	WL	ML	WL	WE	WE	SL	ML	WL	WE
2002	WL	WL	WL	ME	ME	WE	WE	ME	WE	ME	ME	ME	ME	SE	SE	ME
2003	WE	ME	ME	ME	WL	WL	WL	WE	WL	WE	WE	WE	ME	ME	WE	WE
2004	`WE	WE	WE	WE	ML	WE	WE	WE	ML	WE	ME	ME	ME	ME	ME	ME
2005	ML	WE	WE	ME	ML	WE	WE	ME	ML	WE	WE	WE	SL	ML	ML	NC
2006	WE	ML	ML	WL	ML	WL	WL	WL	WE	WE	WE	WE	SE	SE	ME	ME
2007	SE	ME	WE	ME	ML	ML	WL	WE	SL	ML	WL	WL	SL	SL	SL	ML
2008	WL	SL	SL	SL	WE	WL	ML	ML	ME	WE	WL	ML	WL	WL	WL	ML
2009	ML	WL	ML	ML	NC	WL	WL	WL	SE	ME	ME	WE	WE	SE	SE	SE
2010	WE	ME	SE	SE	WE	WE	ME	ME	ML	ML	ML	ML	SL	SL	SL	SL
2011	WL	SL	SL	ML	WL	WL	ML	WL	WL	WL	WL	WL	ML	SL	ML	ML
2012	WL	WL	ML	ML	ME	WE	WL	WL	ME	WE	WE	WL	ML	WL	WE	WE

Table 2(a): El-Niño/La-Nina Event Patterns

Rainfall Patterns for March to May at 0 Season lag

Year	ARS	BKB	DSM	DDM	IRI	KBH	KGM	KLM	MRG	MSH	MSM	MZA	SGD	SMW	TBR	TNG ARP	TNG	ZNZ
1982	BN	BN	BN	NN	NN	BN	NN	BN	BN	NN	NN	NN	NN	NN	BN	NN	NN	NN
1983	NN	BN	NN	NN	NN	BN	NN	NN	BN	NN	NN	BN	NN	NN	BN	NN	BN	NN
1984	NN	NN	NN	NN	NN	NN	BN	NN	AN	NN	NN	NN	AN	NN	NN	NN	NN	NN
1985	NN	NN	AN	AN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1986	NN	AN	BN	NN	NN	NN	AN	AN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN
1987	NN	AN	BN	AN	NN	NN	BN	NN	NN	NN	NN	NN	NN	BN	AN	NN	NN	NN
1988	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	AN	NN	NN	NN
1989	NN	NN	AN	NN	NN	AN	NN	NN	NN	NN	NN	NN	AN	BN	NN	NN	NN	NN
1990	AN	NN	AN	NN	NN	AN	AN	NN	AN	NN	NN	AN	NN	BN	NN	AN	BN	NN
1991	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	AN	NN	BN	NN
1992	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	BN	NN	NN	NN	BN	NN	NN	NN
1993	AN	NN	NN	NN	NN	NN	NN	AN	NN	AN	NN	NN	AN	NN	NN	NN	AN	AN
1994	NN	NN	NN	AN	AN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	AN	NN
1995	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	AN	AN	NN	AN	NN
1996	AN	NN	AN	NN	NN	NN	AN	NN	NN	NN	NN	NN	AN	NN	NN	NN	AN	NN
1997	BN	BN	BN	BN	NN	BN	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN
1998	AN	AN	AN	NN	NN	NN	NN	AN	AN	AN	AN	NN	NN	NN	AN	AN	AN	AN
1999	BN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN	BN	BN	NN	AN	NN
2000	NN	BN	BN	NN	NN	BN	NN	NN	NN	NN	NN	NN	BN	NN	BN	NN	NN	BN
2001	AN	AN	NN	NN	NN	AN	NN	AN	NN	AN	NN	AN	AN	AN	NN	NN	AN	NN
2002	AN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN
2003	NN	BN	NN	NN	NN	BN	AN	NN	NN	NN	BN	BN	BN	BN	NN	NN	NN	BN
2004	NN	NN	AN	NN	NN	NN	NN	AN	AN	NN	NN	NN	NN	NN	NN	AN	NN	AN
2005	BN	NN	NN	BN	NN	NN	NN	NN	NN	NN	AN	NN	NN	BN	NN	NN	BN	NN
2006	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN
2007	NN	NN	NN	AN	NN	NN	BN	NN	NN	NN	NN	AN	AN	NN	AN	NN	NN	NN
2008	NN	AN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN
2009	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	AN	NN	NN	AN
2010	AN	AN	NN	NN	NN	NN	BN	NN	NN	NN	AN	AN	NN	NN	NN	AN	BN	NN
2011	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN	BN	BN	BN	NN	NN	NN	NN
2012	NN	NN	BN	NN	BN	NN	BN	NN	NN	NN	NN	BN	BN	AN	NN	NN	NN	NN

Table 2(b): Rainfall Patterns for March to May at 0 Season lag

Rainfall Patterns for March to May at 1 Season lag

Year	ARS	BKB	DSM	DDM	IRI	KBH	KGM	KLM	MRG	MSH	MSM	MZA	SGD	SMW	TBR	TNG ARP	TNG	ZNZ
1982	NN	BN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	AN	NN	NN
1983	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	BN	NN	NN	NN	NN
1984	NN	BN	AN	NN	NN	AN	BN	NN	NN	NN	BN	BN	NN	NN	NN	NN	NN	NN
1985	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN
1986	AN	NN	AN	NN	NN	NN	BN	NN	NN	AN	NN	NN	NN	AN	NN	AN	NN	AN
1987	NN	NN	NN	NN	BN	NN	NN	NN	BN	BN	NN	NN	AN	NN	NN	AN	BN	NN
1988	NN	NN	BN	NN	AN	NN	NN	NN	BN	AN	AN	AN	AN	NN	NN	NN	AN	BN
1989	AN	NN	NN	AN	AN	NN	NN	NN	AN	NN	BN	NN	NN	AN	NN	NN	AN	NN
1990	AN	NN	NN	AN	BN	NN	AN	AN	NN	AN	NN	AN	AN	AN	AN	NN	BN	NN
1991	NN	AN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	AN	NN	BN	NN	NN	NN
1992	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	BN	BN	NN	NN	NN	NN	AN
1993	NN	NN	NN	NN	NN	NN	NN	BN	AN	BN	NN	NN	NN	NN	BN	NN	NN	BN
1994	NN	AN	NN	BN	AN	NN	NN	NN	NN	NN	NN	NN	BN	NN	BN	NN	NN	NN
1995	AN	NN	AN	NN	NN	AN	NN	NN	AN	AN	AN	NN	NN	BN	NN	NN	NN	NN
1996	NN	NN	NN	AN	NN	AN	NN	NN	NN	NN	BN	BN	NN	AN	NN	NN	NN	NN
1997	AN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	AN	NN	BN	NN	NN	NN	NN
1998	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	AN	NN	NN
1999	NN	NN	NN	AN	AN	NN	NN	AN	NN	NN	AN	NN	AN	NN	NN	NN	AN	NN
2000	BN	BN	NN	NN	NN	NN	NN	BN	NN	NN	BN	BN	NN	NN	NN	NN	NN	NN
2001	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	AN	BN	NN	NN	NN	NN	NN	NN
2002	NN	NN	AN	BN	NN	AN	AN	NN	NN	NN	NN	AN	AN	NN	AN	NN	NN	NN
2003	BN	NN	BN	BN	NN	BN	NN	NN	BN	NN	NN	NN	NN	BN	NN	BN	NN	BN
2004	BN	NN	NN	NN	NN	NN	BN	BN	NN	BN	NN	BN	NN	BN	NN	BN	NN	NN
2005	NN	AN	NN	NN	BN	NN	BN	NN	BN	NN	NN	AN	NN	NN	NN	NN	BN	AN
2006	AN	NN	NN	NN	NN	NN	AN	NN	AN	NN	AN	NN	NN	AN	NN	NN	NN	NN
2007	NN	NN	NN	BN	NN	NN	NN	NN	NN	BN	BN	NN	NN	NN	BN	AN	NN	AN
2008	AN	NN	NN	NN	NN	NN	NN	AN	NN	AN	NN	BN	NN	NN	NN	BN	NN	NN
2009	NN	NN	BN	NN	NN	BN	AN	BN	BN	BN	NN	NN	AN	AN	NN	BN	NN	BN
2010	NN	NN	NN	BN	NN	NN	AN	NN	NN	NN	AN	NN	BN	NN	NN	NN	NN	NN
2011	BN	NN	BN	AN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN
2012	NN	AN	NN	NN	BN	NN	BN	NN	NN	BN	BN	AN	NN	BN	NN	BN	BN	BN

Table 2(c): Rainfall Patterns for March to May at 1 Season lag

Rainfall Patterns for October to December at 0 Season lag

Year	ARS	BKB	DSM	DDM	IRI	KBH	KGM	KLM	MRG	MSH	MSM	MZA	SGD	SMW	TBR	TNG ARP	TNG	ZNZ
1982	AN	NN	AN	NN	NN	AN	NN	AN	AN	AN	NN	NN	NN	NN	NN	AN	NN	AN
1983	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	AN	AN	NN	NN	NN	NN	NN	NN
1984	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	AN
1985	BN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	BN	NN	NN	NN	AN	NN	NN
1986	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	BN	BN	NN	NN	NN	BN	NN	BN
1987	AN	NN	NN	NN	NN	NN	NN	AN	NN	AN	NN	AN	NN	NN	NN	NN	NN	NN
1988	NN	NN	NN	NN	NN	NN	AN	NN	AN	NN	NN	AN	NN	NN	NN	AN	NN	AN
1989	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1990	BN	BN	NN	NN	NN	BN	NN	BN	NN	NN	BN	BN	NN	NN	NN	BN	NN	NN
1991	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN
1992	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1993	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1994	NN	AN	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1995	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1996	BN	NN	NN	NN	NN	BN	NN	BN	BN	NN	NN	AN	NN	NN	NN	NN	NN	BN
1997	NN	BN	AN	NN	NN	AN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1998	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1999	AN	BN	AN	NN	AN	AN	NN	AN	AN	AN	BN	NN	NN	NN	NN	AN	AN	AN
2000	NN	BN	AN	NN	NN	AN	NN	AN	AN	NN	NN	BN	NN	NN	NN	AN	NN	AN
2001	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	AN	NN	AN	NN	NN	NN
2002	NN	BN	NN	NN	NN	AN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN
2003	NN	AN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	AN	NN
2004	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN	AN	NN	NN	NN	NN
2005	NN	NN	NN	NN	NN	NN	NN	AN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN
2006	NN	NN	AN	NN	NN	AN	NN	NN	AN	NN	NN	NN	AN	NN	NN	NN	NN	AN
2007	AN	AN	NN	NN	AN	NN	NN	NN	NN	NN	NN	AN	AN	NN	AN	NN	AN	NN
2008	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN	AN	BN	NN	NN	NN	NN	NN	NN
2009	NN	NN	BN	NN	NN	NN	NN	NN	NN	AN	NN	BN	NN	NN	AN	NN	NN	NN
2010	BN	NN	NN	NN	NN	NN	NN	BN	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN
2011	BN	NN	NN	AN	NN	BN	NN	BN	NN	BN	AN	AN	NN	NN	NN	BN	NN	NN
2012	NN	NN	NN	NN	AN	NN	AN	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	BN

Table 2(d): Rainfall Patterns for October to December at 0 Season lag

Rainfall Patterns for October to December at 1 Season lag

Year	ARS	BKB	DSM	DDM	IRI	KBH	KGM	KLM	MRG	MSH	MSM	MZA	SGD	SM W	TBR	TNG ARP	TNG	ZNZ
1982	AN	NN	AN	NN	NN	AN	AN	AN	AN	AN	NN	NN	NN	AN	AN	NN	NN	NN
1983	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN
1984	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1985	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN
1986	NN	AN	NN	NN	NN	NN	AN	NN	AN	NN	AN	NN	NN	AN	AN	NN	AN	AN
1987	NN	BN	BN	NN	NN	NN	BN	NN	NN	BN	BN	NN	NN	NN	BN	NN	NN	NN
1988	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1989	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	AN	NN	NN	NN	NN	NN	NN
1990	NN	AN	NN	BN	BN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN
1991	NN	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	BN	NN	BN	NN	NN	NN
1992	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
1993	BN	BN	NN	BN	BN	BN	NN	NN	NN	NN	BN	BN	NN	BN	BN	NN	BN	NN
1994	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN
1995	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	BN	BN	NN	BN	BN
1996	BN	NN	NN	NN	NN	NN	NN	NN	BN	BN	BN	BN	BN	NN	NN	BN	NN	BN
1997	NN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	NN	AN	AN	AN
1998	BN	NN	NN	BN	BN	NN	NN	BN	BN	BN	BN	NN	NN	BN	BN	NN	BN	AN
1999	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN
2000	NN	NN	NN	NN	AN	NN	NN	NN	NN	BN	NN	NN	AN	AN	NN	NN	AN	NN
2001	NN	NN	BN	NN	NN	BN	BN	NN	NN	NN	NN	NN	BN	NN	NN	NN	NN	BN
2002	NN	NN	NN	NN	NN	NN	NN	AN	NN	NN	AN	NN	NN	NN	NN	NN	NN	NN
2003	NN	NN	BN	NN	NN	BN	NN	NN	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN
2004	NN	NN	NN	NN	NN	AN	NN	NN	NN	NN	NN	AN	NN	NN	AN	NN	NN	NN
2005	NN	BN	NN	NN	NN	NN	BN	NN	BN	BN	BN	BN	BN	NN	BN	NN	NN	BN
2006	AN	AN	AN	NN	AN	AN	AN	AN	AN	AN	NN	AN	AN	NN	AN	NN	AN	AN
2007	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
2008	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
2009	NN	AN	BN	AN	NN	NN	BN	NN	NN	NN	AN	NN	AN	NN	NN	NN	NN	NN
2010	NN	NN	BN	NN	BN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	BN	NN
2011	NN	NN	AN	AN	AN	AN	NN	NN	NN	NN	AN	NN	AN	AN	NN	AN	AN	NN
2012	AN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	AN	NN	BN	NN	NN	BN	NN

Table 2(e): Rainfall Patterns for October to December at 1 Season lag

CHAPTER FIVE

5.0. Summary, Conclusion and Recommendations

This section summarises, concludes and gives recommendations from the study being adopted.

5.1. Summary

The study was dedicated intofocused on establishing the degree of relationship between Tanzanian seasonal rainfall and ENSO evolution phases. The question being addressed in this particular study therefore was; Does El-Niño clearly implies rainfall in Tanzania? To pursue this question, Niño indices from NOAA were acquired through the NOAA website and standardise to remove the mean. Gauge rainfall data from stations spread across the country were also standardised to ensure that similar constructs were compared. The Niño regions which are defined in literature as Niño 1+2, Niño 3.0, Niño 3.4 and Niño 4 were then directly correlated with seasonal rainfall both at one and zero seasonal lag. The idea was to find out whether there was any predictive influence that these Niño indices can have on the overall seasonal rainfall in the stations spread across the country. This would then lead to models being constructed to that effect. However, since most of the stations demonstrated rather weak correlations with each of the indices adopted for the study, then the question of whether El-Niño implies rainfall over Tanzania is still remains open.

5.2. Conclusion

Many researchers in the past have associated ENSO evolution phases to extreme wetness and/or dryness over the country, some results which indicated this connection were also obtained in this study over Bukoba station during the March to May rainfall season, Arusha and Kigoma stations during the October to December rainfall season. These results suggested that "ENSO can weakly influence rainfall over these stations within Tanzania. The results also show that, in most cases the El-Niño events associated with rains below and near normal were dominant. Above normal rains were observed in 1982 at both the October to December season lags. The La-Nina events were also associated with rains above normal and below normal, though near normal rains were dominant. Generally the weak results of this study might be due to reasons including the authenticity of the data collected from stations which in most times are somehow interfered during transit to the author. Therefore, the study does not authoritatively claim that the country is unaffected by ENSO but leaves the question open for further interrogations.

5.3. Recommendations

The study recommends that any further work on this topic should strive to ensure that the data collected from the stations are homogenized using state-of-the-art statistical techniques so that the non-climatic variations are removed which might interfere with the main signal being sought. The other recommendation being put forward is that other more robust statistical and dynamical methods should be adopted for a similar study since the assumption that has been made in this particular study is that the relationship between seasonal rainfall and ENSO evolution phases can only be **linearly** related. For stations like Arusha, Kigoma and Bukoba which showed quite significant correlations, more study is needed to ensure that the relationship shown here are verifiable through other robust techniques. However, the results of this study can be implemented by various sectors of the economy including Agriculture, water, Livestock, and humanitarian sectors. Going by the findings of this study, caution should be exercised to ensure that sensational information is not disseminated to the public because of an El-Niño signal registered in the Pacific.

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