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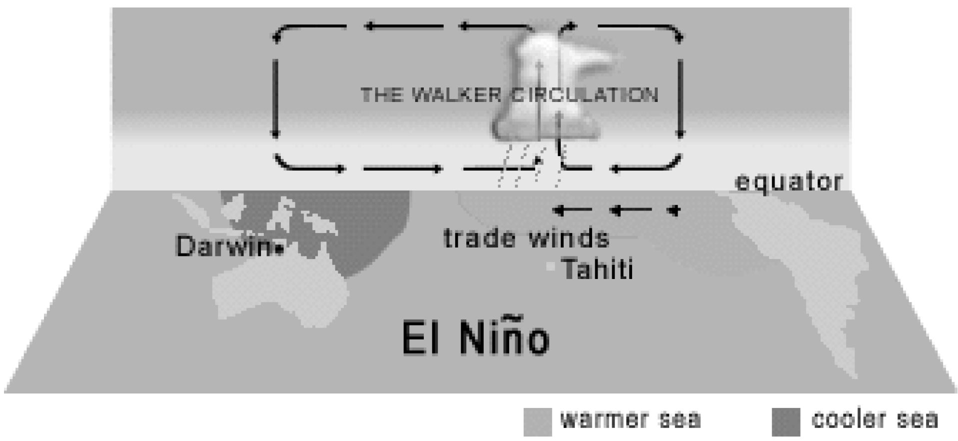
The impact of the El Niño Southern Oscillation on rainfall variability in Timor-Leste

Samuel Bacon, Florindo Morais Neto,
Isabel Soares Pereira and Robert Williams[1]

The El Niño Southern Oscillation (ENSO) is an established climate phenomenon occurring across the Pacific Ocean. This well-documented climate phenomenon is known to have an impact on climate variability in Timor-Leste. Historical rainfall data from the Portuguese period of Timor-Leste was analysed together with historical data on the Southern Oscillation Index. Averages for each month when these events occurred were collated and compared with the overall average rainfall pattern. This analysis was done for the thirteen district centres to assess the historical impact of ENSO on the annual rainfall patterns across Timor-Leste. For the 13 district centres, the annual total rainfall for Timor-Leste is 1583mm on average. During a La Niña event this rises to 1885mm (19.1% increase). During an El Niño event, rainfall fell to 1313mm (17.0% decrease). ENSO had a greater impact on rainfall during the transition periods between the wet season and dry season. Finally the Southern Oscillation Index was compared to maize and rice production.

Introduction

The El Niño Southern Oscillation affects many regions around the world, including Timor-Leste. (Ropelewski & Halpert, 1987). The El Niño Southern Oscillation refers to the oscillation in air pressure across the Pacific Ocean resulting in two weather phases called El Niño and La Niña. In the Pacific Ocean, strong easterly trade winds lead to the development of ocean currents flowing east to west across the tropical Pacific. The easterly trade winds are part of a circulation of air currents known as the Walker Circulation (BOM 2005) (see Figure 1). During El Niño, the easterly trade winds weaken and there is a warming of the central and eastern regions of the tropical Pacific Ocean leading to a shift in the low pressure area of the Walker Circulation towards the east. This leads to lower rainfall throughout the western Pacific including Timor-Leste. During La Niña, the Walker Circulation shifts to the west leading to higher rainfalls in the western Pacific (BOM 2013).



[1] Seeds of Life, Division of Research and Special Services, Ministry of Agriculture and Fisheries

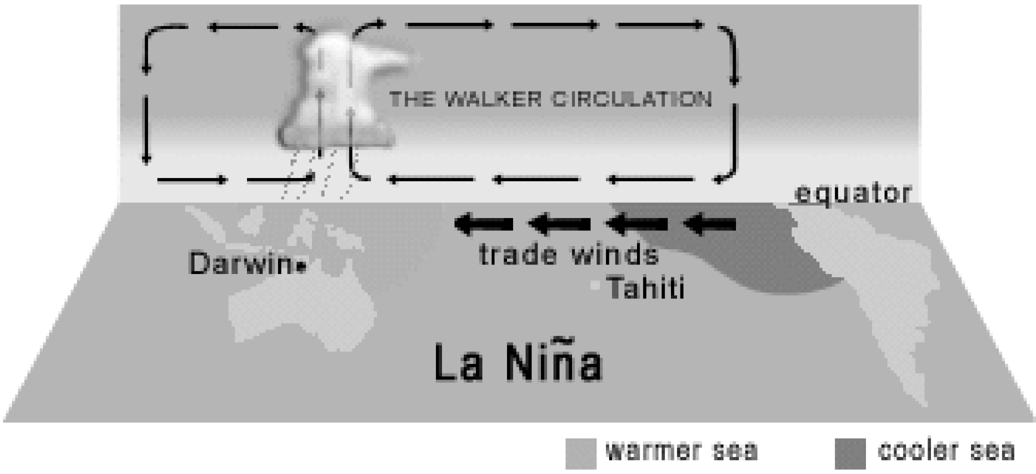


Figure 1 - The relationship between the Walker Circulation and ENSO as sea temperatures change (BOM 2013)

The Southern Oscillation Index (SOI) is a standard indicator used to identify phases of the ENSO cycle. SOI compares the difference in air pressure measured in Tahiti in the central South Pacific Ocean and Darwin in northern Australia. The SOI is defined as ten times the standardised value of the mean sea level pressure in Tahiti minus the mean sea level pressure in Darwin (Troup, 1965). Sustained positive values of the SOI above +8 may indicate a La Niña event, while sustained negative values below −8 may indicate an El Niño event. Studies have been conducted on the impact of rainfall during El Niño for Dili indicating that, when the SOI is negative, dry season rainfall is below normal and the wet season onset is later than normal (CAWCR 2004). Timor-Leste's rugged landscape results in very different climates from north to south and from low altitudes to high altitudes. The main ridgeline of mountains running east-west along the length of the country results in drier conditions on the northern side and wetter conditions on the southern side which also has a bi-modal wet season. Inter-annual variation in rainfall due to ENSO can have a significant impact on livelihoods. ENSO is also known to affect other aspects such as health especially with increased rains during La Niña (Kovats, et al., 1999). This paper explores the impact of ENSO across the nation to understand how it affects different regions of different climatic conditions.

Method

We used historical monthly rainfall data for Timor-Leste collated by the Australian National University (Santika, 2004). This data ranges from 1914 through until 1998. There are 64 sites with historical rainfall data which have on average 22 years of data. Homogeneity testing was not applied as previous studies note that possible break points around ENSO events displayed by homogeneity testing may in fact be a genuine climatic process being identified as an inhomogeneity (Caesar, et al., 2011). It should be noted that the Inter-decadal Pacific Oscillation (IPO) phase was negative during the period of 1954-1974 which have the most complete sets of data. The ENSO-hydroclimate relationship is a lot stronger when the IPO phase is negative compared to when it is positive. (Chiew & Leahy, 2004) For the district of Emera, a combination of data from Gleno and Emera town was used.

ENSO events were classified according to the Australian Queensland Government's *Long Paddock* documentation which states that El Niño years were determined when the average SOI from June to November was less than or equal to -5.5, and La Niña years were determined when the average SOI was greater than or equal to +5.5 (QG 2011).

Location	Period	Mthly Data	Latitude	Longitude	Alt. (m)
Manatuto	1917-1974	415	-8.30	126.08	4
Dili	1914-1998	787	-8.60	125.60	5
Oecussi	1916-1998	480	-9.12	124.22	10
Liquica	1916-1974	359	-8.38	125.20	25
Maliana	1953-1974	262	-8.59	125.14	278
Baucau	1917-1998	546	-8.28	126.20	350
Gleno	1914-1919* 1968-1974	72 84	-8.43	125.27	770
Aileu	1916-1974	243	-8.45	125.35	930
Ainaro	1928-1974	412	-9.01	125.30	809
Same	1916-1974	373	-9.05	125.47	544
Los Palos	1953-1974	264	-8.32	127.01	394
Suai	1916-1974	192	-9.21	125.18	71
Viqueque	1916-1974	440	-8.50	126.28	46

Table 1 - Monthly rainfall data for the 13 district centres of Timor-Leste. *adjusted data based on the nearby town of Emera.

A typical ENSO phase begins around April and lasts for approximately 14 months but the beginning, duration and ending of an ENSO phase can vary widely. For this study, where an El Niño year has been classified, the El Niño event is taken to start at the beginning of a consistent set of negative SOI values for that period and end at the last consistent negative SOI value for that period. The same method was applied for the calculation of La Niña rainfall during years classified as La Niña years based on positive SOI values. SOI data was sourced from the Australian Bureau of Meteorology. (BOM 2013)

The Southern Oscillation Index was compared with maize and rice production. For maize, this used the average of the SOI for November to January. For rice, the comparison was made using the SOI average for December to February. This was correlated with production, yield and area harvested. Crop data was sourced from statistics from the Food and Agriculture Organisation of the United Nations (FAO). (FAO, 2013)

Wet season onset is defined as occurring when rainfall exceeds 50mm in two successive 10-day periods where each month is be divided into three periods of 10 days each. (CAWCR 2004) For this data set, the wet season onset was defined as that date at which 100mm of rainfall was accumulated in the first month after August using a simple linear analysis of the monthly rainfall data.

Results

The average of the total annual rainfall, as measured in 13 district centres, is 1583mm. During an El Niño event the annual rainfall falls by 17.0% to 1313mm on average. During a La Niña event the annual rainfall rises by 19.1% to 1885mm on average. This change in rainfall is not consistent over all months (Figure 2). There is a significant change in rainfall during the months of April and May.

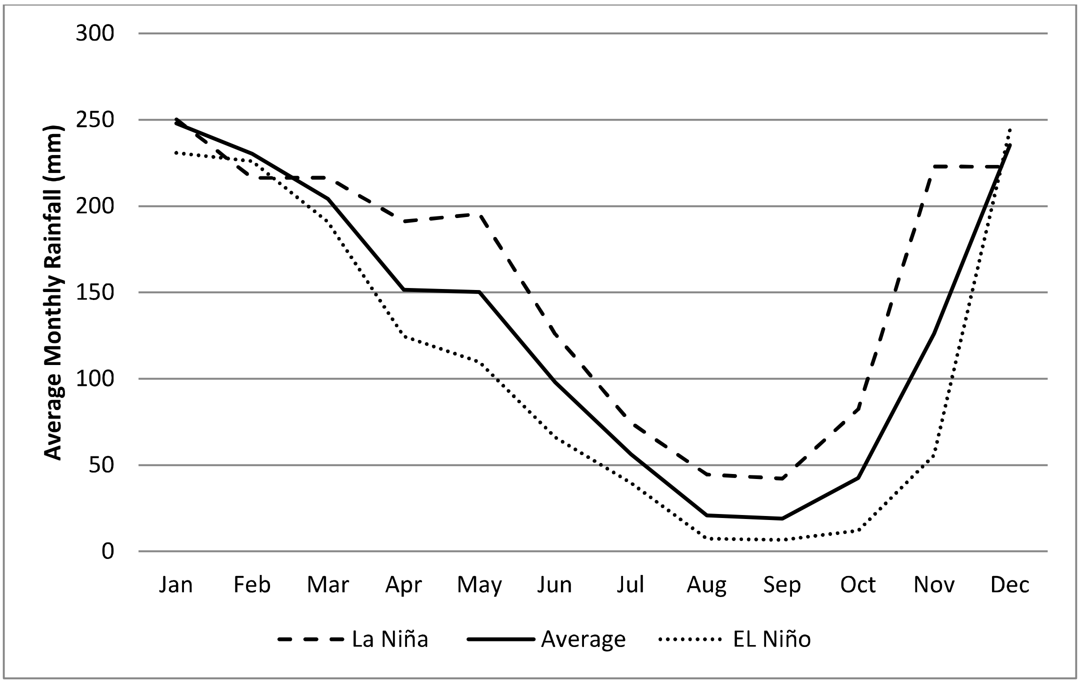
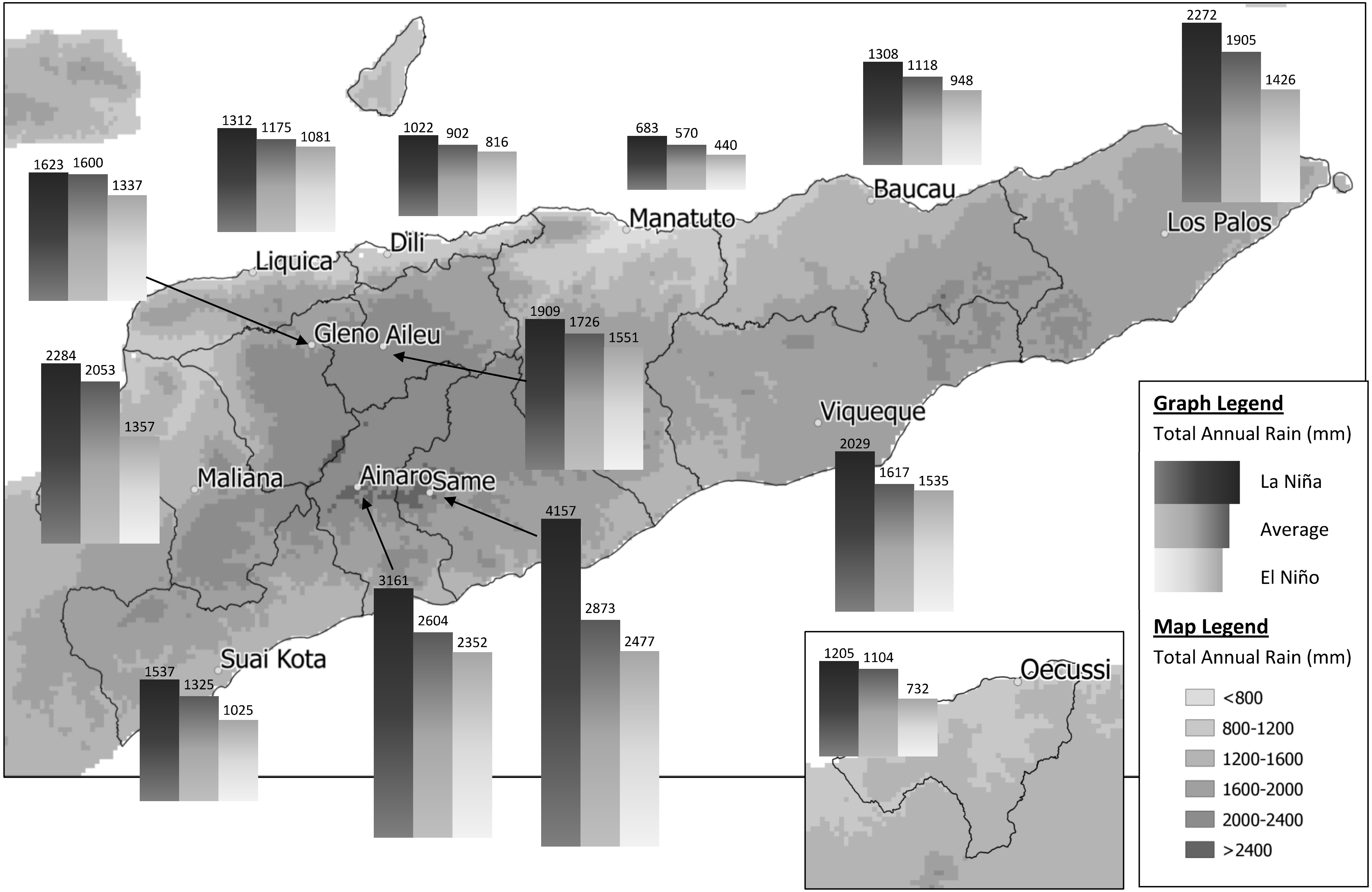


Figure 2 - El Niño and La Niña in Timor-Leste based on monthly averages of 13 district centres.

Figure 3 - Map of Timor- Leste showing rainfall distribution with the total annual rainfall received during La Niña, Neutral and El Niño ENSO phases



During La Niña, the wet season extends into June**.** During El Niño, the wet season ends earlier in the month of April. In the month of May La Niña results in 195mm on average whereas El Niño results in 110mm on average. Similarly, large differences in rainfall are experienced in November when La Niña results in 223mm compared with El Niño rainfall of 56mm. It is at these two periods, the change between wet season and dry season that ENSO has the greatest impact. During El Niño there is less rainfall annually and it is concentrated heavily into the wet season months of December to February. During La Niña there is more rainfall annually but it is distributed more broadly from the months of November through to June the following year.

An ENSO event has a comparatively greater impact on rainfall during the late wet and dry season months with less impact during the wet season. (Table 2) Rainfall in November has high variation from -56% (El Niño) to 77% (La Niña) combined with substantial monthly rainfall averaging 126mm. The impact is particularly large in April, June and November when some regions are still experiencing significant amounts of rainfall

Month	Rainfall (mm)	El Niño (%)	La Niña (%)
January	248	-7%	1%
February	230	-2%	-6%
March	204	-7%	6%
April	151	-18%	26%
May	150	-27%	30%
June	98	-33%	28%
July	56	-29%	32%
August	21	-65%	113%
September	19	-65%	121%
October	43	-71%	94%
November	126	-56%	77%
December	235	4%	-5%

Table 2 - Monthly rainfall anomaly during ENSO showing change in rainfall from the average due to El Niño and La Niña. (negative values indicate below average rainfall, positive values indicate above average rainfall)

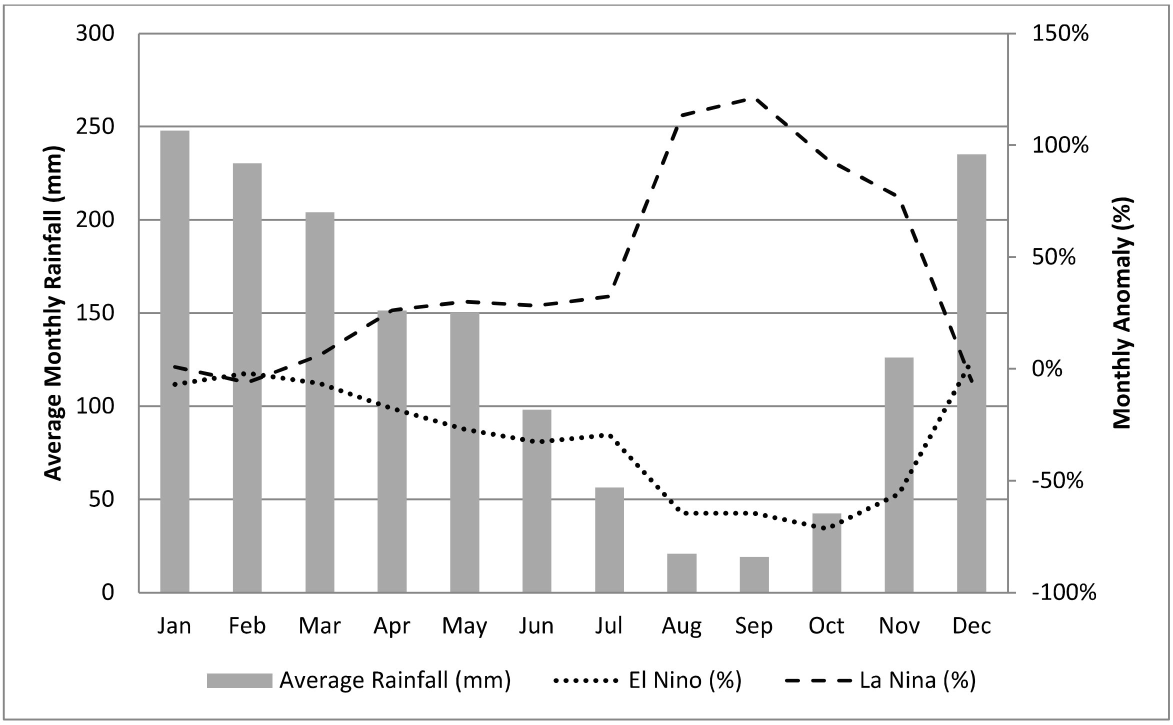
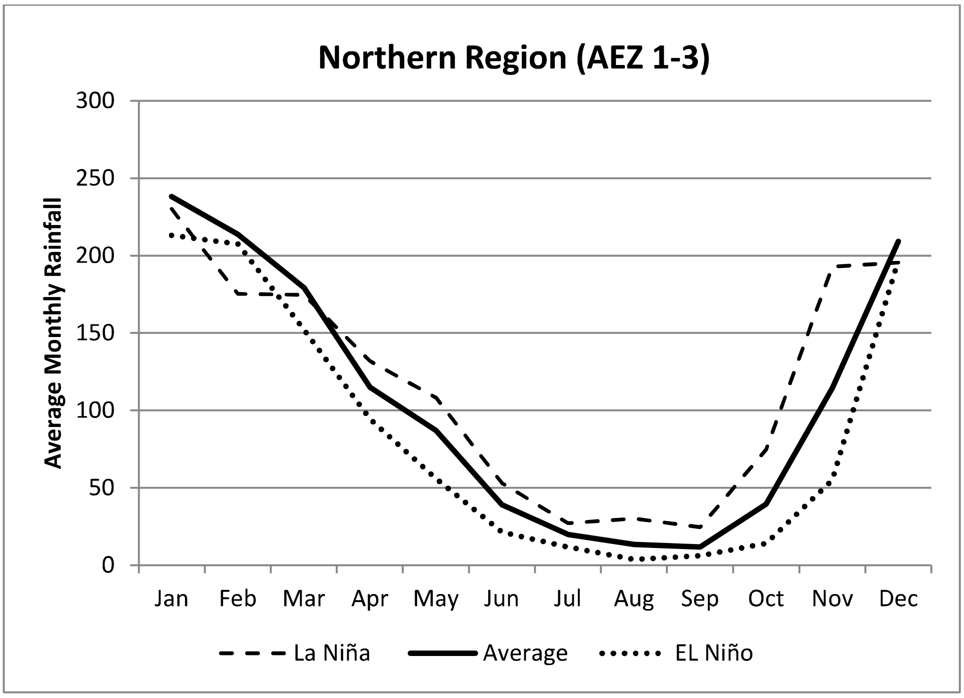


Figure 4 - Graph of ENSO anomaly with monthly rainfall indicating that the greatest digression from normal rainfall occurs during the dry season.

Location results

The monthly rainfall results for La Niña, El Niño and the average for each of the 13 district centres are shown in Figure 5. These have been categorised into northern and southern regions to reflect the different climatic conditions on either side of the main ridgeline. Total annual rainfall in the northern region is 1281mm and increases by 10.7% during La Niña and decreases by 19.4% during El Niño. From this we can see that El Niño has the greatest impact on rainfall for the north. The main impact on the northern region is during the late dry when there is an early start to the wet season during La Niña and a delayed start to the wet season during El Niño. During the late wet season period of March through to May, El Niño influences rainfall more than La Niña. Wet season rainfall from December through to January is below average for both El Niño and La Niña.

Total annual rainfall in the southern region is 2065mm and increases by 27.4% during La Niña and decreases by 14.6% during El Niño. In contrast to the northern region, it is La Niña that has the greatest impact on rainfall for the south. La Niña delivers above average rainfall for all months except December. The greatest increases are during the late wet season months of April to June as well as the late dry/early wet season months of October and November.



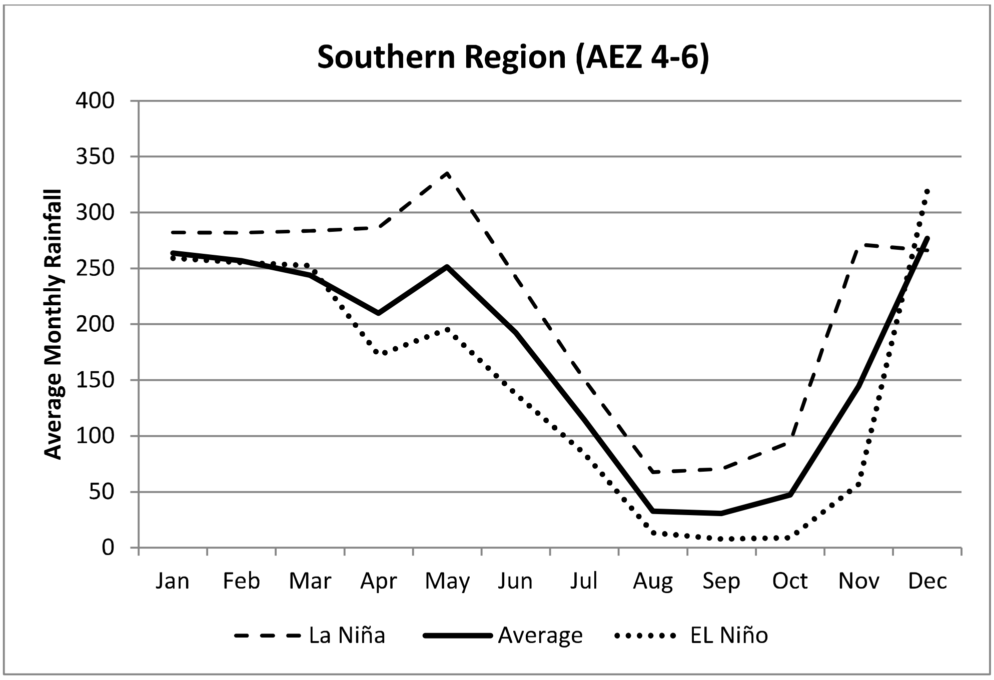


Figure 5 - Change in average monthly rainfall during La Niña and El Niño for two broad regions: Northern (AEZ 1-3) and Southern (AEZ 4-6)

Graphs of rainfall for individual district locations are shown in Figure 6 (Northern Region) and Figure 7 (Southern Region). The results of this analysis demonstrate that the impact of ENSO is different in different locations.

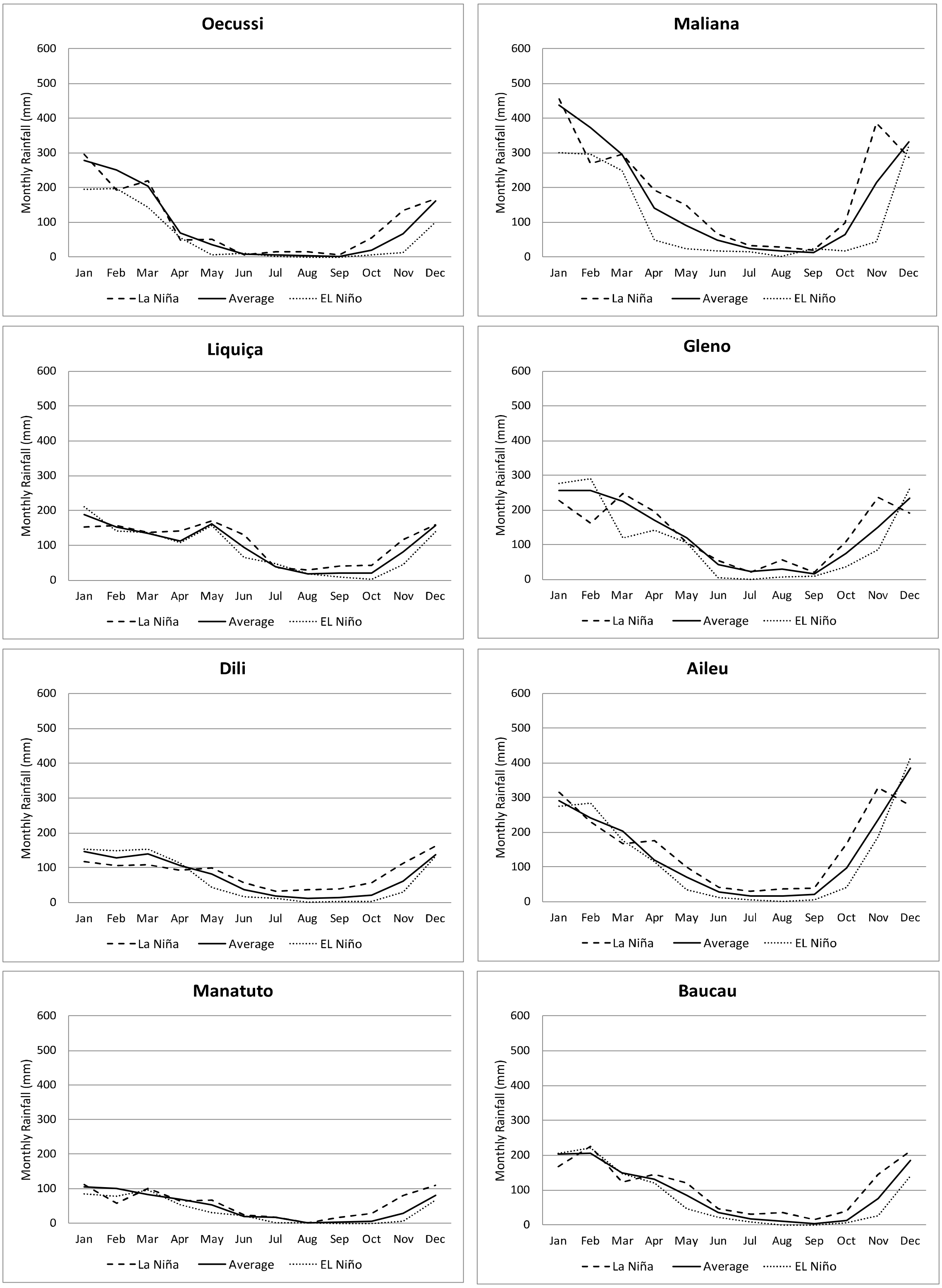


Figure 6 - Change in average monthly rainfall during La Niña and El Niño for district centres in northern agro-ecological zones.

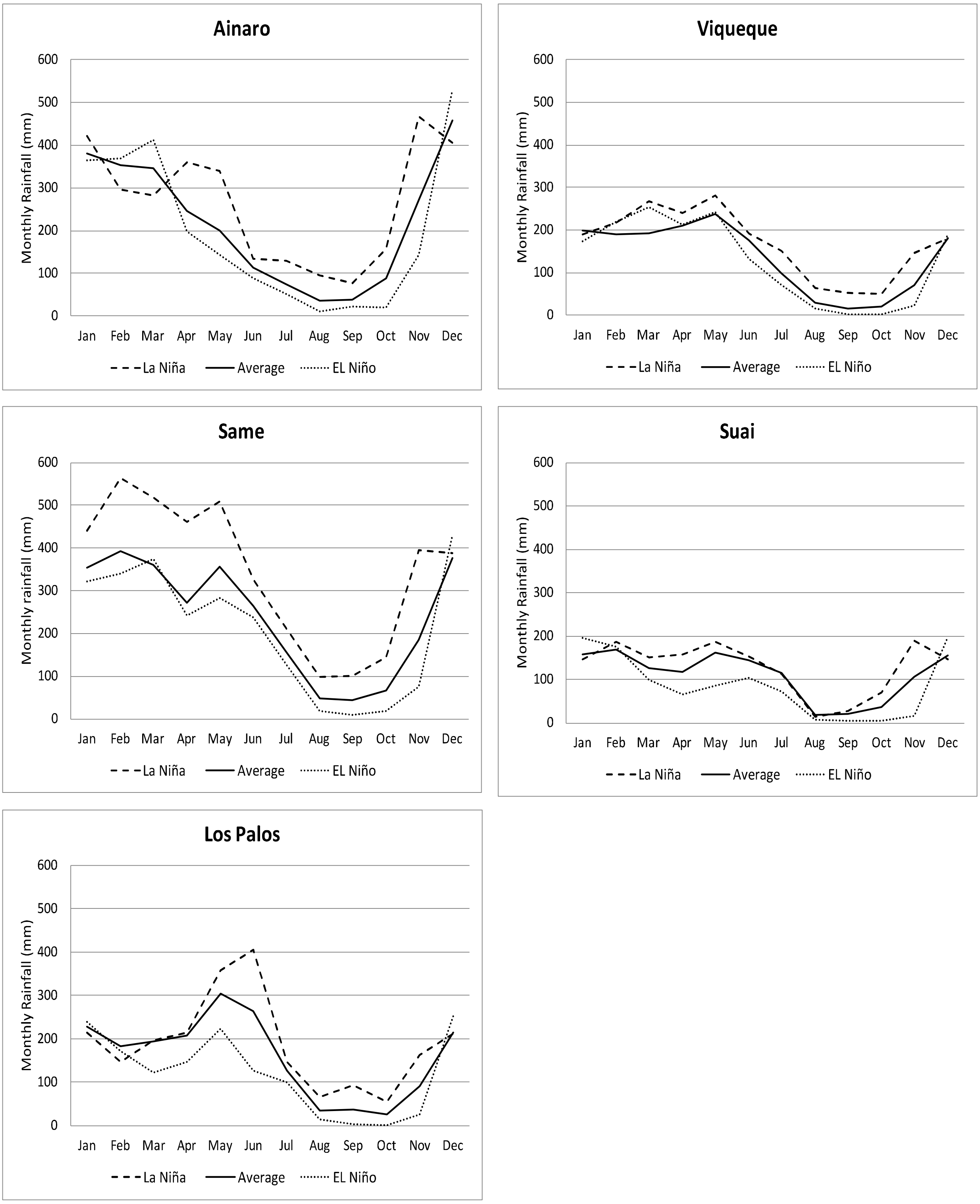


Figure 7 - Change in average monthly rainfall during La Niña and El Niño for district centres in southern agro-ecological zones.

High rainfall locations such as Same, Ainaro and Los Palos received proportionally even more rainfall during La Niña than low rainfall locations. (R = 0.53*, Figure 8).

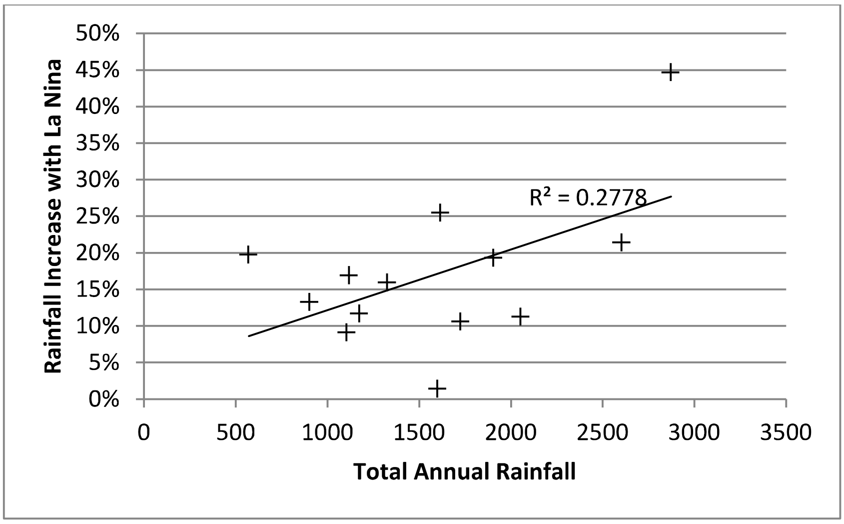


Figure 8 - Increase in rainfall due to La Niña correlated with the average of the total annual rainfall for that location.

Wet Season Onset Anomaly

One of the important aspects of the impact of ENSO on Timor-Leste farming is the onset of the wet season. (Table 3) During La Niña, the wet season starts 22 days earlier on average. During El Niño, the wet season starts 15 days later on average. In locations at higher altitudes, the wet season begins earlier than those locations at lower altitudes (Figure 9).

Location	La Niña	Average	El Niño
Manatuto	34 days early	23rd January	Not achieved
Dili	23 days early	16th December	5 days late
Oecussi	24 days early	11th December	20 days late
Liquica	16 days early	8th December	7 days late
Maliana	7 days early	7th November	29 days late
Baucau	20 days early	7th December	13 days late
Gleno	13 days early	10th November	22 days late
Aileu	16 days early	1st November	11 days late
Ainaro	24 days early	2nd November	18 days late

Same	51 days early	8th November	24 days late
Los Palos	19 days early	2nd December	8 days late
Suai	19 days early	27th November	17 days late
Viqueque	22 days early	8th December	6 days late

Table 3 - Average date to accumulate 100mm of rainfall at the onset of the wet season and changes in the wet season onset during La Niña and El Niño.

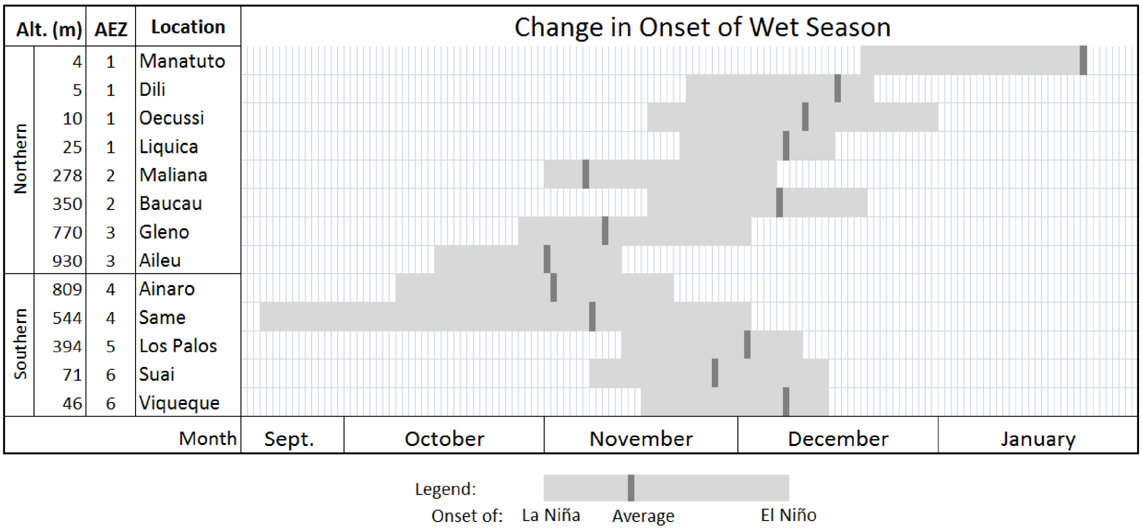


Figure 9 - A comparison of the change in the onset of the wet season for the 13 district centres arranged according to agro-ecological zones.

SOI and food production

Annual maize production reported by FAO from 1990 to the present was compared with SOI values from November to January when maize is being planted. Figure 10 indicates that when the SOI is either strongly positive (La Niña) or strongly negative (El Niño) around the time of planting and early crop growth then total maize production is reduced. ($R = 0.55^*$ for $P<0.01$) There is a drop in production of 11.5% during El Niño (if the 2010 production of 149000 t is considered an outlier (Young, 2013)). During La Niña, the production falls by 17.2%. This drop in production was found to be associated with less area being harvested rather than a drop in yield (Figure 11, 12). (SOI correlated with area harvested, $R=0.61^*$ for $P<0.01$). Rice production, including area harvested and yield was not found to be correlated with SOI.

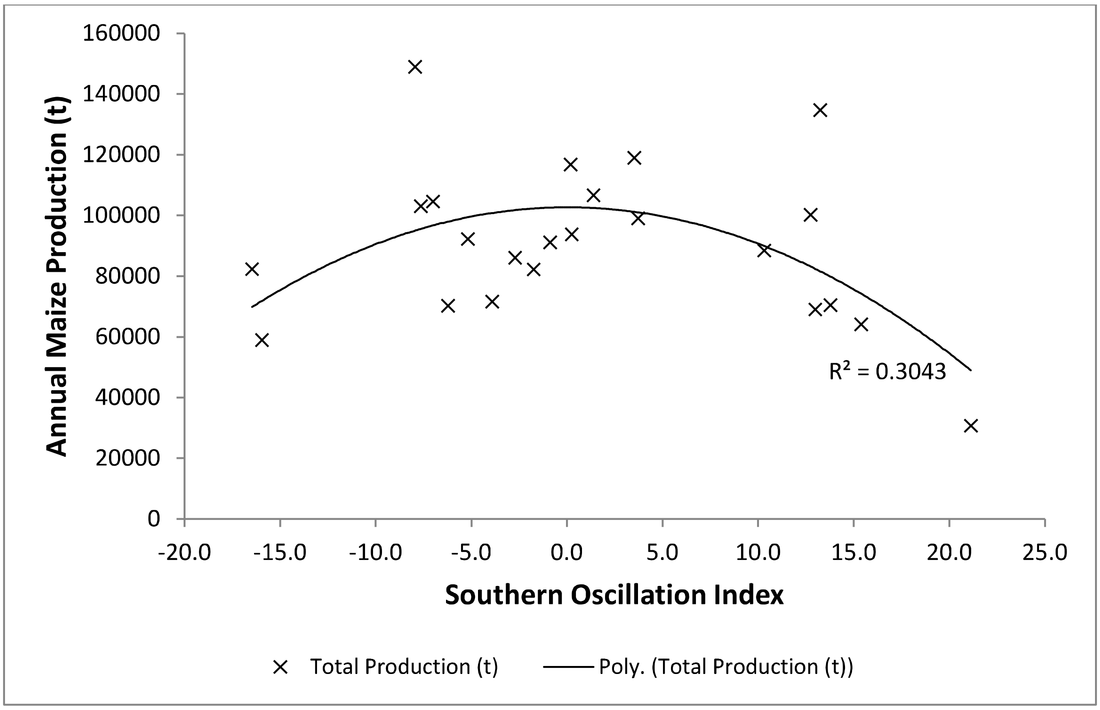


Figure 10 - Annual maize production versus average SOI Nov-Jan from 1990-2012.

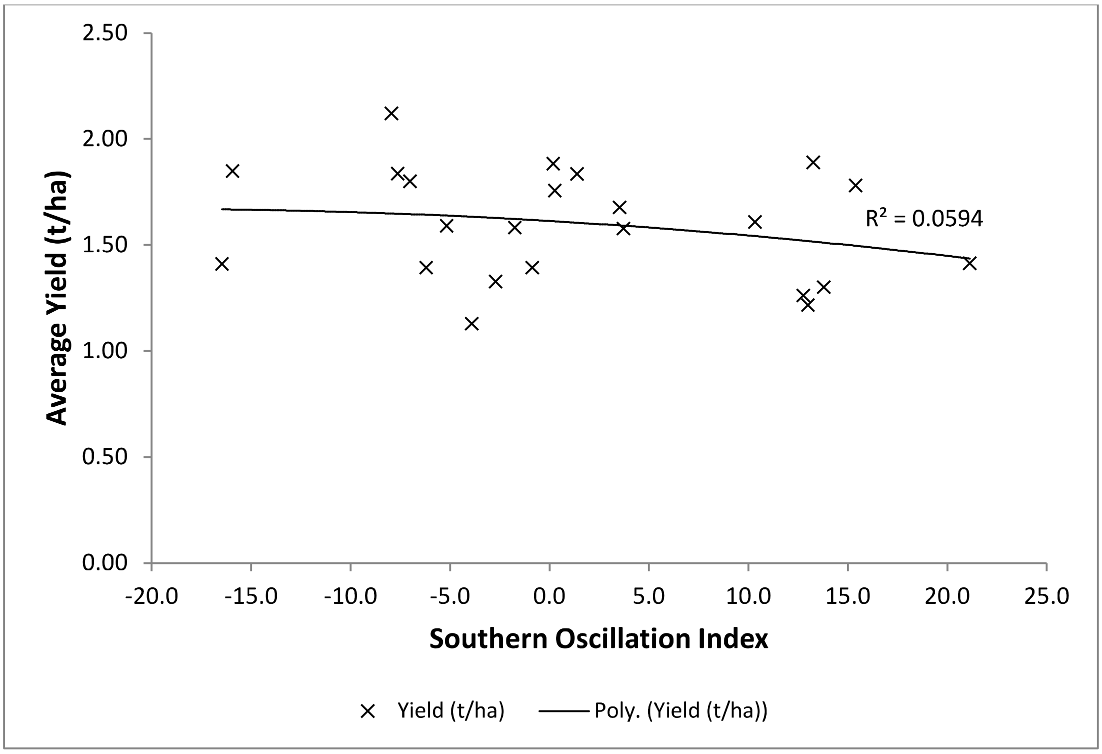


Figure 11 - Average maize yield versus average SOI Nov-Jan from 1990-2012

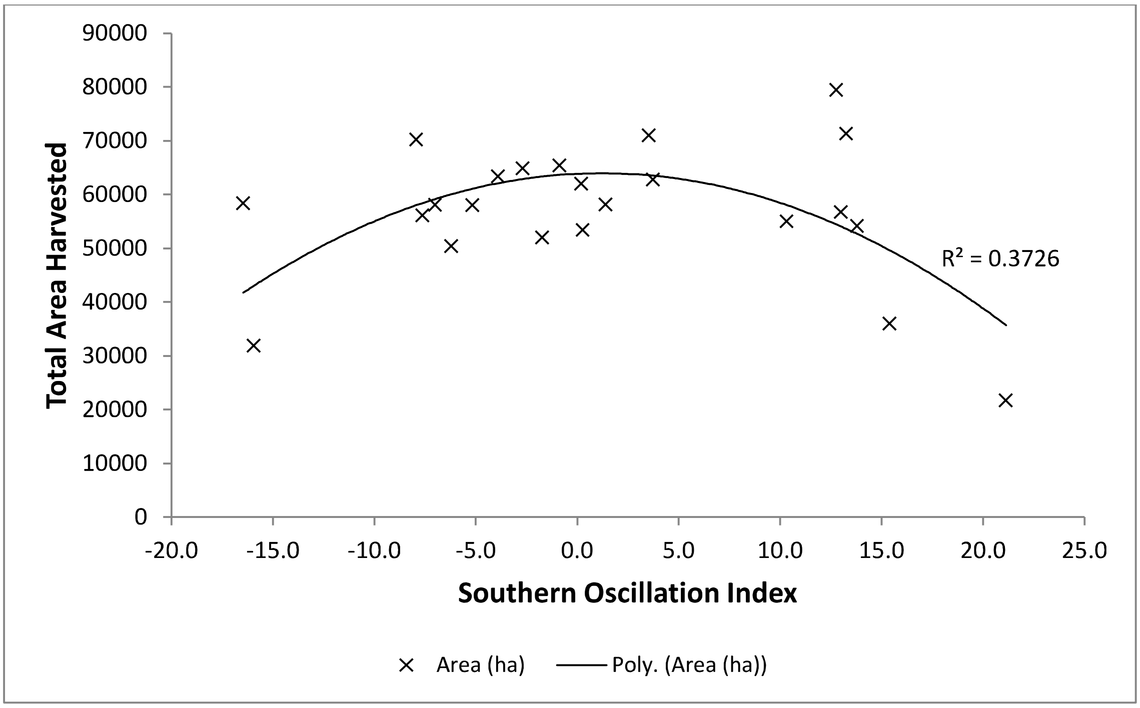


Figure 12 - Average maize area harvested versus average SOI Nov-Jan from 1990-2012

Discussion

The analysis of the data shows that an El Niño event results in less rainfall overall for Timor-Leste. El Niño means a late start to the wet season and an early finish with a contraction of the total rainfall into a shorter period over the wet season often leading to higher rainfall in January during El Niño. Planting too early may lead to crop failure with plants dying due to a false start in the wet season. Caution should be taken when considering planting a second crop in those areas with a bimodal rainfall pattern.

A La Niña event results in more rainfall overall for Timor-Leste. The impact on rainfall is greatest in the transition between the wet season and dry season. La Niña tends to mean an extended wet season and higher rainfall throughout the dry season. This can create problems during harvest and drying of crops with the risk of storing the grain with moisture levels that are too high. It can also allow planting of a second crop in areas where only a single crop is planted.

Region specific impact of ENSO

The ENSO cycle affects the rainfall of different regions across Timor-Leste in different amounts and at different periods during the year. In the region of the southern and eastern slopes, Timor-Leste experiences a bimodal wet season allowing two crops to be grown. The main wet season is affected by the movement of the monsoonal trough south of the equator. The second peak in rainfall around March to June is due to the development of south-east trade winds delivering rain to Timor-Leste from the Timor Sea. In these areas, La Niña has an impact on the second peak in rainfall.

Wet season onset

La Niña consistently leads to an early onset of the wet season while El Niño leads to a delay in the onset of the wet season. It can also be seen from the results that this change in the wet season onset is not the same in each location. In Same, it could be difficult to identify the start to the wet season as relatively high rainfall can be experienced throughout the year. Most locations experience a 4-6 week variation in the wet season onset from La Niña to El Niño. Locations at higher altitudes tend to have an earlier start to the wet season than locations at lower altitudes.

SOI and food production

The Southern Oscillation Index is correlated with annual maize production. The greatest impact on maize production occurs during La Niña. This is related to the reported figures of the amount of area harvested rather than yield which may mean farmers plant fewer crops during La Niña or there is a greater incidence of crop failure. Further complications can also be experienced with increased disease lowering yield in the moist, wet conditions and damaging stored food.

There also appears to be an association with low SOI values (such as during El Niño) and food production. This may be due to germination failure and early crop failure. Areas that usually produce a second crop may not be successful in establishing the second crop during periods of negative SOI.

The drop in maize production correlated with ENSO (El Niño, 11%; La Niña, 17%) is greater than the predicted drop in maize production due to climate change. A 1.5^{o}C rise in temperature may result in a drop in maize production of 6% by 2050. (Molyneux N, 2012) However, if these two factors are compounded Timor-Leste may experience falls in production of up to 23% in the future.

Conclusion

The El Niño Southern Oscillation cycle has a significant impact on the rainfall patterns of Timor-Leste. El Niño results in less rainfall for Timor-Leste with the greatest impact on the contraction of the wet season. La Niña leads to more rainfall with the greatest impact on the late wet season especially in locations with a bimodal rainfall pattern. It is important that agricultural workers and farmers have an understanding of how this cycle can affect crops and food production in their specific location of Timor-Leste.

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