Samoa's 102 year meteorological record and a preliminary study on agricultural product and ENSO variability

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ABSTRACT
This paper seeks to find a relationship between the El Nino/Southern Oscillation (ENSO) variability and crop production. Precipitation and mean temperature were examined first to establish an ENSO relationship while primary sector macroeconomic and crops data were analyzed to note any significant variations in output linked to ENSO impacts of significant occurrence. Institutional strengthening and improved access to markets, both local and regional, and sector development programmes however have made this assessment difficult. Subsistence agriculture (and fisheries), said to the backbone and economic mainstay of Samoa's primary sector, ideally the best source of ENSO impacts unfortunately remains the data poor sector.

1 INTRODUCTION

The Samoa Meteorology Division located on the Mulinu'u peninsula two kilometers west of the capital of Apia has achieved a milestone of great importance to various users of weather and climate data; it has completed more than a hundred years of continual atmospheric recordings consistently without a single shift in it's original location.

Official observations began at its existing location in June 14th of 1902, when Dr. Otto Tetens arrived from Gottingen University, Germany, under orders to begin geophysical observations in the South Pacific that were to run concurrently with similar expeditions in Europe, Africa, South America, and the Antarctic. Meteorological observations were part of the sundry scientific observations that also included an investigative expedition to the larger island of Savai'i when a volcano erupted in 1903 forcing nearby villages to flee it's massive lava flow. After Dr. Teten's initial tenure, replacements from Germany carried on the various observations, a notable atmospheric scientist amongst them being a young Dr. Franz Linke whose later work in atmospheric science and meteorology earned him honor as one of the founding fathers of modern numerical prediction. Operation of the Apia Observatory, as it was known then, passed from German to New Zealand scientists at the conclusion of World War I, and its continued work in meteorological observations coupled with accumulating knowledge of tropical weather and climatology at the time also saw a role as central forecasting office for the Allied Forces during the World War II Pacific theatre. Official handing over to the Samoan Government was in 1962 on achievement of Samoa's independence although management was shared with various New Zealand geophysical and meteorological agencies until the mid-eighties.

While the length of data records is impressive and covers high resolution observation intervals (from hourly to daily values), access to the data presents a current challenge to a recently re-instituted climate section component of the Division. Records of various atmospheric variables ranging from daily sunshine recorders to hourly autographic rainfall and barometric charts are yet to be fully digitized, analyzed and entered into a database management system. Currently, a "strong room" of solid concrete has managed to safeguard the fragile original paper records from damage to recent severe tropical cyclones. Summary data of low resolution (examples are monthly rainfall totals and monthly mean temperatures) have been extracted from summary sheets and digitized while the more "value rich" daily, synoptic and hourly weather data remain until solid rescue, preservation and digitization solutions have been found for the paper records. Low-resolution data nevertheless can initiate some investigative studies of recent topics of climate variability and change and their local impacts, and the use of the available data has led hence to investigating an initial link between ENSO and local agricultural product in Samoa.

Samoa, as with many of the other Pacific Island states, has the primary sector as its national economic mainstay and the backbone upon which other sectors build upon. Primary sector outputs and performances certainly do not rely solely on the resource availability itself nor upon the raw materials and the essential tools of its trade; external factors such as those of the global market, free trade, and others of economic nature, plus internal factors such as technological capacity, infrastructure, institutional capability and the social and cultural environment provide non-climatic causal factors counting for or against overall production performance. However, relative to these non-climatic factors, climate variability still largely determines the levels of output and successes of agricultural sector production.

Understanding agricultural performance in terms of its outputs or production levels in relation to El Niňo is important not only for understanding the nature of perhaps the largest single determinant of overall agricultural output, but also possible mitigation strategies in the face of extreme events such as drought and tropical cyclones.

2 OBJECTIVES

This paper seeks to establish a relationship between rainfall and mean temperature (as measured in Apia) and ENSO first. Second, a relationship between agricultural sector outputs and the interannual variability (El Niňo and La Niňa) by comparing some key indicators of agricultural production to variations in the SOI (Southern Oscillation

Index; a measure of ENSO's current state). The terms 'production levels' and 'outputs' refer to simple measurable values of agriculture related data used for basic analytical purposes of the objectives aimed at here.

3 METHODOLOGY

3.1 METEOROLOGICAL ANALYSIS

Climate variability in the region is best identified by fluctuations of a notable degree in seasonal and annual precipitation amounts with large variations having potential for adverse socio-economic impacts on several key economic sectors.

The first part of this paper aimed to establish a pattern of variability in Samoa with ENSO phases (El Niňo, La Niňa or neutral). This was achieved through the analysis of precipitation and temperature records at Apia against the Southern Oscillation Index (SOI), the Tahiti minus Darwin mean sea-level (msl) pressure difference, normalized with a base period of 1933 – 1992 (*Troup,* 1965). A software tool, the MDA (Monthly Data Analyzer), [a Microsoft Excel based program written to homogenize, quality control, and analyze monthly data of any given atmospheric variable] was used extensively in this part of the analysis. The MDA was used to calculate trend and correlation values for two meteorological variables: precipitation and average temperature. Selection of the two variables was based on the following characteristics:

Precipitation

- High response and variation characteristics to ENSO perturbations and rainfall indices are typically used to study ENSO phase responses for climate predictions.
- In Samoa (and Fiji), much of the rainfall received normally correlates highly with the position of the South Pacific Convergence Zone (SPCZ) which in turn has its position strongly influenced by regional sea-surface temperatures and atmospheric pressure (Folland *et al.* 2002).
- Seasonal rainfall is of high importance as a determinant factor for productivity and management to the agriculture sector and water resource sector.

Mean temperature

- Air temperatures recorded at Apia (and at other Pacific Island meteorological services) reflect changes in the predominantly maritime climate.
- SSTs (sea surface temperature) and ambient air temperatures recorded at island stations correlate well. The Apia Observatory is located on a peninsula with the weather observation field well exposed to the sea less than twenty meters away.

3.2 CROPS DATA ANALYSIS

Agricultural sector performance indicators from the summary of FAO (Food and Agriculture Organisation) statistics and surveys of quantities of produce supplied to market by the MoA (Ministry of Agriculture) and the Ministry of Commerce, Industry and Labour were sourced to establish trends and then pinpoint likely fluctuations (either negative or positive) associated with well known large ENSO events (such as the 1982-83, 1991-1993, and the 1997-1998 El Niňo, and the 1998-1999 La Niňa).

3.3 DATA COLLECTION

Meteorological data were sourced from the Meteorology Division of the Ministry of Agriculture. The Division, formerly known as the Apia Observatory, is in its 102nd year of operation officially although the first meteorological observations were begun in 1890 at a site two kilometres away from its current location. These observations (made between 1890 and 1902 have been homogenised and incorporated into the data set for the analysis. Monthly data indices for precipitation, mean temperature and the SOI were used in this part of the analysis with data statistically homogenised for removal of biases and outliers.

Crop data were relatively more difficult to access to for many reasons. With agriculture being mostly subsistence in the past few decades, movement towards cash cropping systems have been slow and recent development in this area has only taken place within the last two decades. Data and assessment reports are not easy to locate in any central location within the MoA and thus FAO statistics of agricultural performance were sourced for Samoa to provide a background of the development of the overall primary sector. Market surveys undertaken by the Ministry of Commerce, Industry and Labour of supplied quantities to market were used to examine significant changes in figures in recognized ENSO phases of known extreme.

4 RESULTS

4.1 PRECIPITATION AND MEAN TEMPERATURE

Samoa's meteorological trends and variability in response to ENSO show definite correlation. Preliminary results of the analysis find that since 1890, average temperature has increased by 0.231° Celsius, and precipitation has increased in total amount by 228.8 mm. By separate periods beginning from the first 35 years and subsequent 25 year breaks, average temperature rises rapidly and falls almost negligibly in the latter years. Precipitation fluctuates throughout in rates of increase but is overall not significant with respect to the entire record.

Figures 1 and 2 illustrate an example of the calculation of trends and correlations, as in the case of Figures 1 and 2 below of the percentage of the calculated 30 year normal for precipitation against the annual average SOI from 1970 to 2000.

The MDA correlates monthly values of mean temperature and total rainfall with SOI indices for ENSO analysis. This part of the analysis figures into assessing what Samoa's climate variability is within these two phenomena, and the results are given in Table 1.

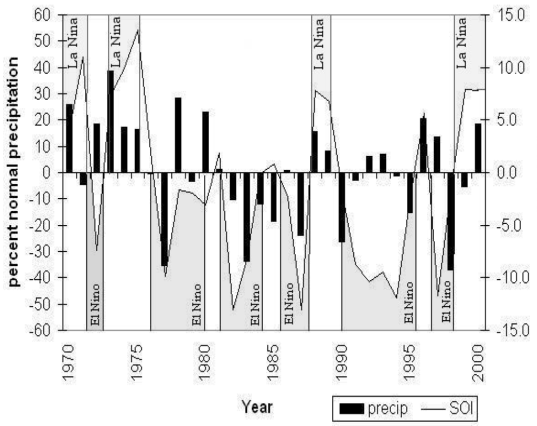

Figure 1. Percentage of annual normal precipitation against annual average SOI from 1970 to 2000. Graph shows general below normal rainfall during negative SOI years (EL Niňo) and above average in positive SOI years (La Niňa).

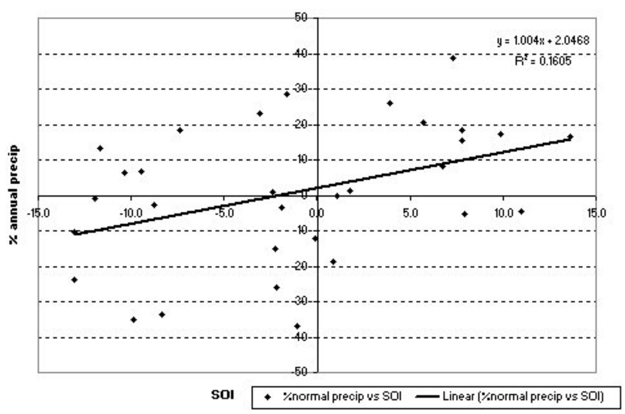

Figure 2. Scatter-plot for the 1970 - 2000 percentage normal annual rainfall and SOI indicating a positive relationship (positive x co-efficient) and reasonable correlation (R value).

Table 1. Trends and correlations derived from the MDA of precipitation and mean temperature to the SOI from scatter-plot analysis. (R = correlation value, M = gradient sign indicating relationship)

	Precipitation		Mean Temperature	
Period	R	M	R	M
1890 – 2000	0.494	+	0.107	-
1890 – 1925	0.493	+	0.095	-
1926 – 1950	0.619	+	0.522	-
1951 – 1975	0.591	+	0.294	-
1976 – 2000	0.340	+	0.080	+

Precipitation emerges as having a positive correlation with the SOI; at negative SOI values less than –5.0 (Australian Bureau of Meteorology calculated SOI indices), indicating an El Niňo phase, precipitation tends towards suppressed levels. The opposite occurs for positive SOI values greater than 5.0 indicating a La Niňa phase (Salinger *et al.* 2001). Temperature by comparison has weak, almost ambiguous, trends and correlations to the SOI. This latter finding may be attributable to the geographic location of the island group, on examination of the climatologies of the sea-surface temperature regions, in relation to the extremities and transitions of ENSO events (Manton *et al*. 2001).

4.2 CROP PERFORMANCE INDICATORS

The selected study of gross domestic output production indicators are not a perfect for the many non-climatic factors that include its arrival at the final figures; inflation and currency fluctuations, local and global market prices and consumer demand, import and export market opportunities all have some influences on macroeconomic data. However, it is reasoned here that these indicators are sufficient for the scope of this study as severe ENSO impacts on Samoa (having a relatively smaller economy and fewer coping mechanisms) should register at least some correlation to fluctuating gross output on interannual time scales. Agricultural performance indicators (Figure 3 and Figure 4) from summary FAO statistics and from selected few sources in the primary sector overall indicate an increasing specialization and diversification in the production of crops (for increased productivity), the increase in plantation or monoculture cash crops while maintaining a small (household) subsistence based production. In particular, the early export industries of many Pacific Islands of the 1960s and 1970s, Samoa included, had mostly to do with either coconut or cocoa or both, and in some cases were the only products with a significant export market at all; partially explaining the agricultural contribution sometimes of near 100% of total national export. In Samoa, the coconut plantations of the 70s and early 80s were in full production with incentives acquired for the industry (provided by guaranteed minimum prices) by trade agreements covering coconut oil. Coconut plantations at the time accounted for much of the large-scale agricultural products of the time in terms of land use and direct and indirect employment (from coconut collectors to the transport industry set up to ferry and ship desiccated coconut).

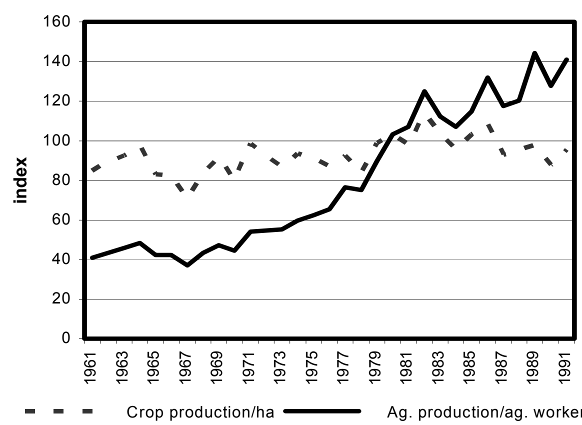

Figure 3. Production Indices indicating crop production per hectare and agricultural production per worker show an average increasing trend particularly in the latter.

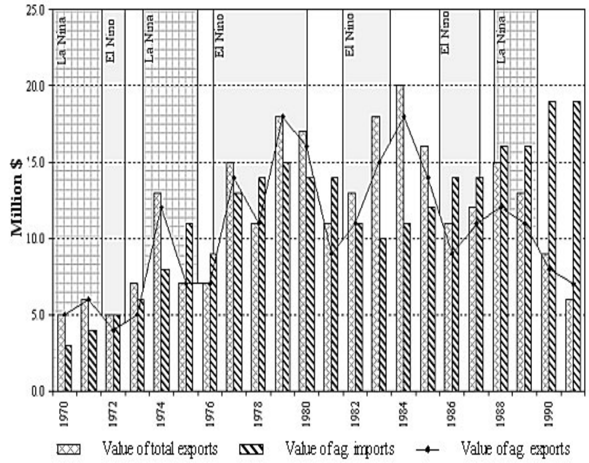

Figure 4. Trade and Agriculture macroeconomic performance indicators, overlaid with El Nino and La Nina years, from 1970 – 1991.

Analysis of more recent market supply data for rainfall dependent crops (either sown or grown to harvest during wet-season months) such as Head (or English) and Chinese cabbages (Figure 5), cucumber, and tomatoes (Figure 6) against wet-season months finds El Niňo and La Niňa effects of below normal rainfall impacting the market with lower numbers supplied per month and for the whole year in total. The effects of El Niňo and La Niňa events through drier than normal wet-season months and dry-season months through a time-lag analysis of monthly data of the quantity supplied of these produce seem to indicate a definite link although more data is needed for more clearer results. The larger extreme weather events such as tropical cyclones and flash floods did not occur in Samoa in the late 1990s or the more recent years (save this year's Tropical Cyclone Heta). Confirmed drought events such as the 1997-1998 El Niňo induced drought certainly had an impact on the forestry sector causing widespread forest fires that took weeks to put out but not before a substantial amount was lost.

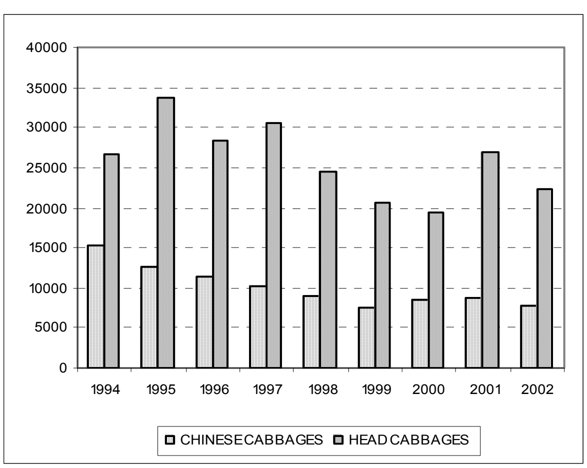

Figure 5. Total unit quantity supplied to market of cabbages of the English and Chinese variety.

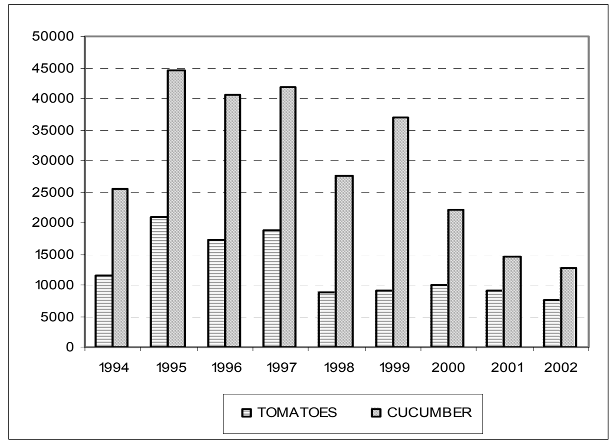

Figure 6. Tomato and cucumber quantities supplied to market.

5 DISCUSSION

ENSO impacts are at least traceable in meteorological variables, particularly through precipitation. It is Samoa's geographical location however, which perhaps has the controlling determining in the intensity of an ENSO effect. This is because Samoa lies on the boundary of (identified visually) ENSO phases. The weak correlation of the positive trends between precipitation and ENSO certainly does exist although the reflection of severe events such as the 1997-1998 drought does not show in the agricultural sector performance. This is thought to be attributable to recent sector development work improving agricultural output indicators regardless.

At the higher resolution more dry periods may show up simply because of the nature of the rainfall (e.g. high intense, short-period rainfall); monthly average value might show an average rainfall month but perhaps 80% of that rainfall may only come in 1 evening. Unfortunately, this high-resolution data is not digitally available for analysis.

Agriculture sector performance responses are difficult to relate (at this level) to ENSO variability, the main reason being that consistent information on the supply to markets is not available. A survey organised by the Ministry of Agriculture (MoA) and the Ministry of Commerce, Industry and Labour (MCIL) reviewing household agriculture shows that at the household level production and own consumption (subsistence) remains high, reflecting a typical (and healthy) subsistence agricultural production. Cash crops are only a small percentage of the total produce overall. Hence, the variability in market quantities are also at the whim of traditional and socio-cultural needs and not necessarily El Niňo related. The lack of consistently collected and reported data that can be readily analyzed means that this sector is difficult to assess.

Overall, the ENSO effects on the agricultural sector are difficult to identify at the level this paper attempted to look at. What has emerged is that a strongly subsistence based primary sector and governed to some extent by traditional and socio-cultural needs introduce some variability into the market supplied quantities, introducing some uncertainty into the crop variability and ENSO link. Also, the weak link that does exist may explain more mismatches in surplus rainfall and the onset of more products available on the market in a supposedly dry El Niňo year.

6 CONCLUSION

The growth of the sector in the past two decades through concerted government policy and multi-lateral development assistance programmes has meant that, in what was probably the most climatically active in recent decade and human history, the primary sector has strengthened its intrinsic coping mechanisms (via traditional farming system) and improved its overall efficiency and production. In the fisheries case with the tuna industry in particular, this sectoral improvement and market influences may indeed have led it to a negative impact on the local tuna resource. However, without regard of these factors it is still without challenge that agricultural sector production still is influenced and dictated to some degree by its climate and environment. At the data level this paper endeavoured to examine the relationship between climate variability through ENSO and agricultural sector production variability, more research into specific areas of the primary sector and better data collection is needed. It may very well be that it is at the household level rather than the national indicator level (through economic performance indicators) that the burden or benefit of ENSO variability is felt.

REFERENCES

1. Folland, C.K., Renwick, J.A., Salinger, M.J.and Mullan, A.B. Relative influences of the IPO and ENSO on the South Pacific Convergence Zone, *Geophysical Research Letters*, **29 (13),** 21-1 – 21-4, 2002
2. Manton, M. J., Della-Marting, P.M., Haylock, M.R., Hennessy, K.J., Nicholas, N., Chambers,L.E. Collins, D.A., Daw, G. and Finet, A. 2000., Trends in extreme daily rainfall and temperature in South-East Aasia and the South Pacific: 1961-1998*, International Journal of Climatology,* **21**, 269-284.
3. Salinger, M.J, Renwick, J.A. and Mullan, A.B. 2001. Interdecadal Pacific Oscillation and South Pacific Climate, *International Journal of Climatology*, **21**, 1705-1722.
4. Troup, A.J. 1965. The Southern Oscillation, *Quarterly Journal of the Royal Meteorological Society*, **91**, 490-506.