The impact of rainfall in the North West province on the summer grain markets

JM Maritz

orcid.org 0000-0003-1562-3748

Mini-dissertation submitted in partial fulfilment of the requirements for the degree *Master of Business Administration* at the North-West University

Supervisor: Prof Christo Bisschoff

Graduation May 2018
Student number: 26947587

ABSTRACT

Drought has been noted as having severe impacts on the agricultural sector of South Africa. The vulnerable populations of the country are the ones that are impacted the most by the occurrence. Maize is the staple food of most individuals in the southern African region and as a result the reliance on rain-fed agriculture is tremendous. Rainfall variability in the region also has serious consequences for agriculture and for food security. The onset of a drought is generally the trigger required to cause large-scale food shortages in the southern African region.

The interaction between the ocean and the atmosphere have a major impact on the weather and climate. It takes several months before one big event will happen. The Ocean and the atmosphere are closely related. They are both components of the climate and together form a system called the climate system. The Indian Ocean Dipole, or IOD, is one of the key drivers of Australia's climate, and there is a likelihood it has an impact on South Africa's weather as well. The Sea-surface temperature, or SST, in the Niño region in the Pacific Ocean is very crucial for determining a La Niña, El Niño of neutral conditions around the world.

Sporadic rainfall in South Africa is the main reason for these cycles not to have been determined yet. Annual patterns have been identified however, where it has been established that little or no rainfall is recorded in the winter and most rain occur in the summer and mid-summer, with drought generally being prevalent during December, January, or February. New developments in the field of weather research in recent years can aid considerably in more accurate seasonal predictions.

This dissertation will consider the impact of rainfall in the North West province and the impact it has on the South African summer grain markets, especially White Maize and Sunflower prices. Before the 2016/17 season, the average rainfall for the previous five seasons was only 416 mm according to data provided by the South African Weather Services, only 77% of the long-term average.

Keywords: NIŇO3, Rainfall, North West province, Grain prices, South Africa

ACKNOWLEDGEMENTS

- I would like to firstly thank my wife, Doré Maritz for her unending support, patience, encouragement and understanding during the time it took to do my dissertation. You have really supported me so much and I cannot thank you enough.
- Then I would like to thank the Lord for giving me the abilities, strength, concentration, brain power and determination to pull through and finish what I have started. Without You Lord this would not have been possible. To quote Rom. 8:28, "And we know that God causes all things to work together as a plan for good for those who love God, to those who are called according to His plan and purpose."
- I would also like to thank the South African Weather Services for supplying me with the data and support with rainfall figures for the North West province. It has helped enormously.
- Thank you also to Prof Christo Bisschoff and the NWU School for Business and Governance for their support and opportunity to submit my dissertation.
- Furthermore, I would like to thank Mr. Sakkie Nigrini, National Weather guru in South Africa for the past 35 years. It was he who motivated me enormously to pursue this title because I wanted to learn more and expand my knowledge on weather. On the night of 27 March 2018, Mr. Nigrini passed away in his sleep. He has left a massive legacy behind with his weather knowledge, outlook and forecasts on Southern Africa weather. This dissertation is dedicated to you Mr. Nigrini. May you rest in peace and thank you for all that you have taught me. We will miss you a great deal.
- A word of thanks also to the NWU Statistical Consultation Services Department, in specific Prof. Suria Ellis for the data analysis that was done.
- Lastly, I would like to extend a special thanks to Francois Stevens and Johan Botha for ensuring the language and editing was checked and reviewed to be at an acceptable standard.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

DEFINITION OF KEY TERMS

The following abbreviations will be used in this document.

Table 1: Abbreviations used in this dissertation

Abbreviation	**Meaning**
t/ha	Tonnages of the commodity produced per hectare
R/ton	Rand price per ton of the commodity
Mm	Amount of rainfall / precipitation over a set period of time
Ha	A unit of measurement on an area of land (10 000 m^2)
hPa	Unit of measurement for air pressure
IOD	Indian Ocean Dipole
SST	Sea surface temperatures
ENSO	El Niño-Southern Oscillation

CHAPTER 1:

Chapter 1 consist of an Introduction, Problem statement and core research question, the research objective formulations and specific research questions, the objectives and benefits of the proposed study and the division of chapters, as well as the delimitations and assumptions of the proposed study.

1.1. NATURE AND SCOPE OF THE STUDY

1.1.1. INTRODUCTION

Agriculture delivers around 2.5% to the Gross Domestic Product (GDP) of the economy in South Africa. (Greyling, J. 2015) and grain production forms part of this percentage. The fact that grain production in South-Africa forms part of agriculture's contribution (2.5%), does not reveal the true picture of the sector's impact on the country's economy as a whole. Grain production does not operate in a vacuum. Inputs are bought from the manufacturing sector, raw materials are provided for manufacturing and purchases of a whole host of services. Statistics on agricultural employment differ according to definition and source, but it is safe to say that that the sector employs around 700 000 workers (Greyling, J. 2015).

With the above in mind, consideration should be given to factors which could either have an adverse or positive impact on the grain production industry's contribution to the economy. These include actual and expected rainfall-data and strategies regarding the risk-management approach. The latter could have a major impact on which strategies are implemented by the farmer, the buyer, the country and all businesses involved with agriculture. Rainfall, for one, plays a critical part in determining the price of grain, because farmers are dependent on rain to productively manage their fields and land for planting. The plants rely on rainfall for effective growth and more importantly during the crucial pollination phase. The pollination stage of Maize and Sunflowers is vital, as it determines the potential yield that can be produced.

According to Standard Bank (2010?), the identification of rainfall cycles over the past 100 years has often been a topic of discussion. Several studies have been conducted by the likes of the

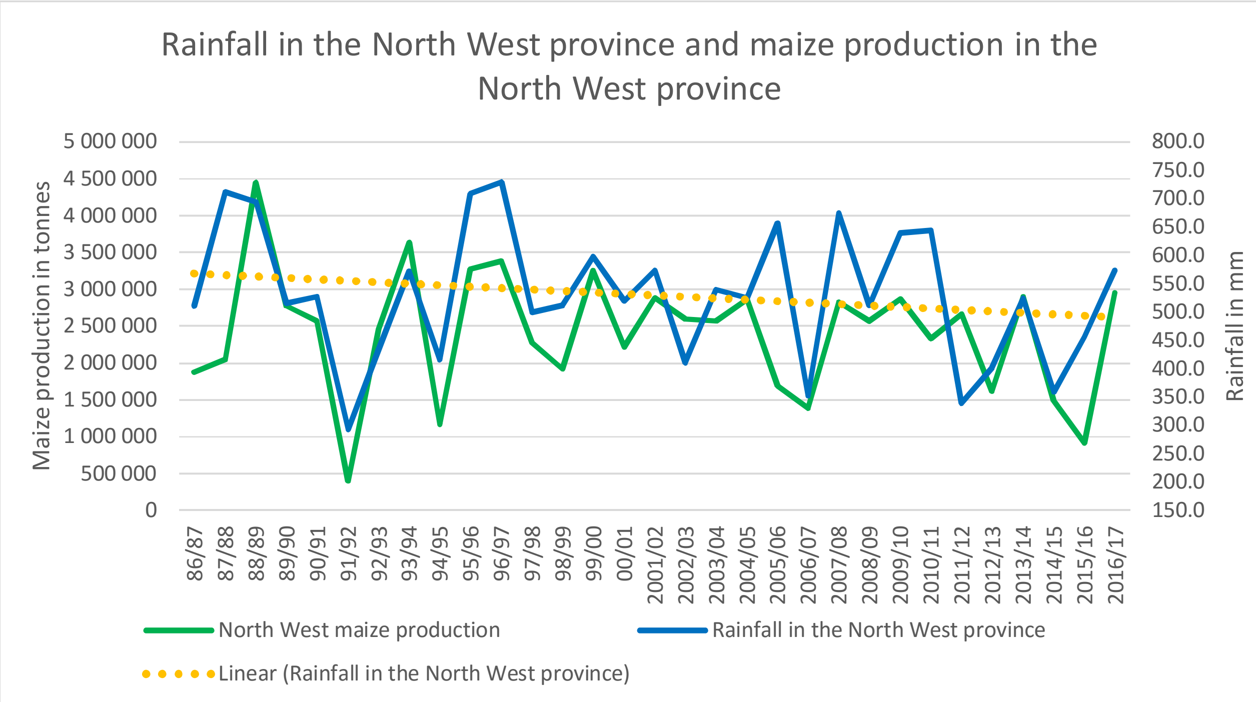
Witwatersrand University, University of Pretoria and the University of Cape Town on the rainfall cycles across seasons. Sporadic rainfall in South Africa is the main reason for these cycles not to have been determined yet. Annual patterns have been identified however, where it has been established that little or no rainfall is recorded in the winter and most rain occur in the summer and mid-summer, with drought generally being prevalent during December, January, or February. These patterns are repeated year after year, but the intensity differs. (Standard Bank, 2010?). Seasonal rainfall is a very complex concept, and virtually impossible to be predicted with dependable accuracy. However, new developments in this field in recent years can aid considerably in more accurate seasonal predictions. This can aid farmers in deciding when and how much to plant in their specific area (Standard Bank, 2010?).

This dissertation will consider the impact of rainfall in the North West province. This area consists of 90 to 95% dry land farming with very few irrigation fields. The study will also take into account the South-African grain markets, with the focus mainly on White Maize and Sunflower markets. The main aim will be to establish the correlation between rainfall in the North West province and the White Maize and Sunflower markets in South Africa. There are considerable risks involved in farming: price movement of grain, as well as the production possibilities contribute to these risks. Farming activities in this area are heavily dependent on the annual rainfall. According to the Department of Agriculture, Forestry, and Fisheries (2015), the North-West province is the second biggest provincial producer of Maize and Sunflower behind the Free State. White Maize forms an integral part of most South Africans' daily diet, and if production discrepancies can be noticed beforehand, plans can be made to change strategies, alleviate potential pressure on food availability and clients can be better advised on pricing risk for the future production of their commodities.

When the potential harvest is determined, price risk can be controlled more effectively. The most common variables in the South African grain markets are rainfall, price movements of commodities, potential production, expected yield per hectare, and hectares planted. Knowing the possible impact that rainfall has on price movement and potential production, makes it possible to improve hedging for farmers and buyers of grain. Figure 1 below summarises the rainfall in the North West province as well as Maize production since the 1986/1987 season. A season runs from 1 July to 30 June the following year. The logic behind this is that the crops are planted from November to January each year and is harvested the predominantly during June and July.

The average rainfall in a season for the North West province from 1 July 1986 to 28 February 2017 is 529.70 mm. Figure 1 illustrates that in seasons where rainfall was below normal, yields were impacted negatively, and in seasons where normal to above normal rainfall were recorded, yields correlated mostly positive with the rainfall. A linear trend line for rainfall was inserted and this trend line reflects a negative curve, which translated into the premise that seasonal rainfall in the province has decreased over the past 30 years.

Figure 1: Rainfall in the North West province and Maize production since 1986/1987



Source: South African Weather services (2017) and SAGIS (2017)

What is also interesting to note is that during seasons when a La Niña was experienced, the seasonal rainfall total was higher than in seasons where neither a La Niña or El Niño was experienced. An average of 586 mm of rain fell during the eight La Niña seasons since 1986. However, not all La Niña years yielded higher seasonal rainfall for the North West province.

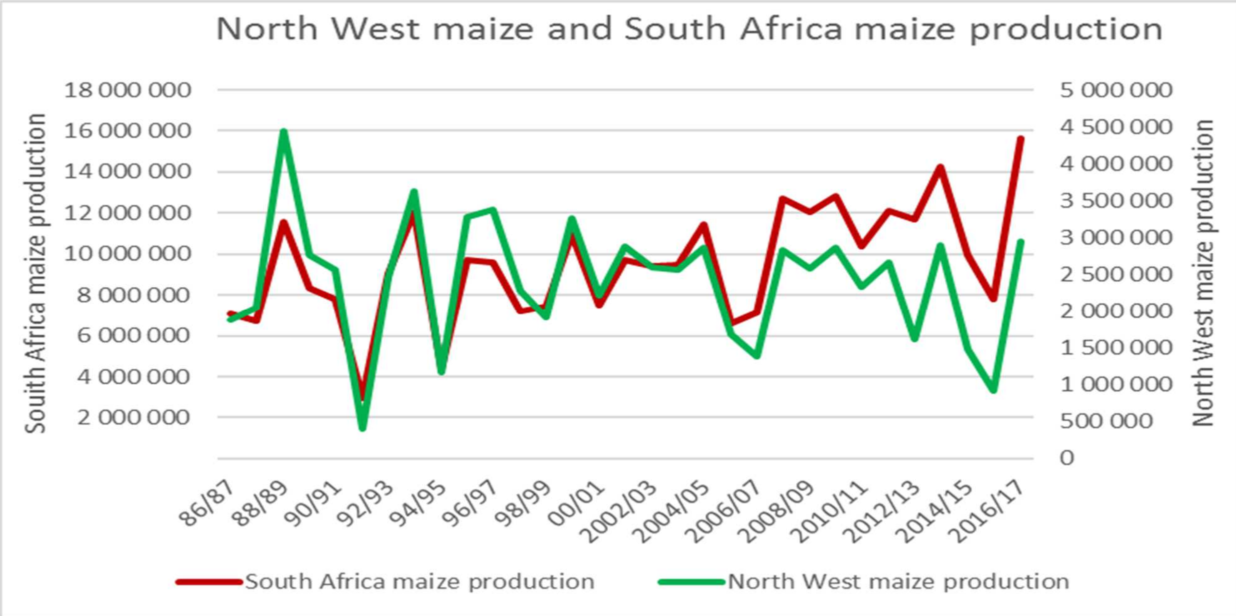
The 2011/2012 season was the only La Niña season where less than 500 mm of rain fell, when only 339 mm fell. During an El Niño season, the average rainfall in the North West province is only 481 mm, around 50 mm less than the long-term average. There have been ten El Niño seasons since 1986, with only the 1987/88 and 2009/10 yielding above average rainfall for the province.

As discussed previously, most of the planting done by farmers in the North West province, is dry land, so the dependency on rainfall is very important when looking at the following part. During the 1990's, the average Maize production in the North West province was 2.435 million tons, 2.448 during the 2000's, and thus far during the 2010's the average is down to 1.985 million tons (excluding the 2016/17 season). The Crop Estimate Committee estimated during September 2017 that the Maize crop harvested during 2017 in the North West was 3.135 million tons. This crop will be the second biggest Maize crop for the province in the last 20 seasons. During the 1999/00 season, the farmers harvested 3.256 million tons of Maize. The National Crop Estimates committee estimate that the national Maize crop for 2016/2017 season will be 16.744 million tons, the biggest crop ever produced in South African history. The second biggest crop was during 1980/81 season when 15.030 million tons was produced, and the third biggest crop was during the 2013/14 season when 14.982 million tons was produced.

Figure 2 below shows the Maize production totals for South Africa and the North West province since the 1986/87 season. The national Maize production is the red line, and on the left axis is South Africa's production total and on the right axis is the North West production totals. At first glance, spikes in the North West province Maize crops, correlates well with increases in the national Maize production total. What is of a concerning factor for national Maize production, is the decline in the North West province's Maize production, over the past 10 years. The two lines in the graph does not move that close anymore.

All the summer grain products are traded on the Agricultural Derivatives market, a subsidiary of the Johannesburg Stock Exchange (JSE). They include White Maize, yellow Maize, Sunflower and soybeans. A background on the trading side of the market will be discussed next to show what happens to grain once it has been harvested and delivered directly to the market, or to a silo nearby for storage.

Figure 2: North West Maize and South Africa Maize production since 1986/87



Source: SAGIS (2017)

Prior to the deregulation of the market mechanism, the Maize Board regulated the Maize price and was the sole buyer and seller of Maize in South Africa, which led to a market that was relatively free from price risk (Krugel, 2003: 52). During 1996, the South African agricultural market was deregulated. The Agricultural Derivatives, a subsidiary of the Johannesburg Stock Exchange (JSE), was founded and provides a platform for price discovery and efficient price risk management for the grain market in South Africa and Southern Africa (JSE: 2016). Trading on a formal exchange market that connects buyers and sellers, provides transparent price discovery and all transactions are assured through the Derivatives clearing structure (JSE: 2016).

Prices have been very volatile since deregulation and producers are faced with the necessity to hedge against adverse price movements. The JSE offers two main types of contracts, futures and options. The major commodities traded are White Maize, yellow Maize, wheat, Sunflower, soya beans and sorghum. Contracts are traded in South African Rand per ton. Future contracts have an expiry date and the expectation is that all parties involved in the transaction have to honour the prevailing position at the traded price on or before the expiry date. Contracts can be physically settled should the futures position be held on until the last trading day. Option contracts give buyers the opportunity to secure a floor price (Put Option) or a ceiling price (Call Option) at the cost of an agreed premium. The sellers must take on the opposite position if the buyer wishes to exercise their option. Buyers don't have to exercise their option (JSE: 2016)

Nelson and Siegel (1987) explains that it is important to have background information on forward contracting as far as futures contracts are concerned. Futures contracts are fundamentally similar to forward contracts in that they too establish a price today for a transaction that will take place in the future. Nelson and Siegel (1987) define the forward contract as an agreement between buyer and seller that has the following characteristics:

- It specifies a quantity and type of commodity or security to be bought or sold at a pre-specified future date.
- It specifies a delivery place.
- It specifies a price.
- It obligates the seller to the buyer subject to conditions and it obligates the buyer to buy.
- No money changes hands until the date of sale, except perhaps for a small service fee.
- The two parties to the deal negotiate the terms of the forward contract and each side must trust that the other will not default on the contract.

Often one or both parties will perform a credit check on the other party before entering into the contract. While futures and forward contracts are fundamentally similar, there are still some important differences between the two types of contracts. Firstly, futures contracts specify standardised quantities and delivery dates, while forward contracts are customized to meet the needs of the two parties (Chance, 2003:3). Secondly, futures contracts are traded in centralised and established exchanges (in South Africa on SAFEX), while forward contracts are traded between dealers. Thirdly, to enter into a future contract, one must, in conjunction with a broker, simply allocate a certain percentage of the face value into an account, called a margin account. In order to enter into a forward contract, a credit line has to be set up with the dealer. Finally, a futures contract is regulated, while a forward contract is unregulated.

The Agricultural Derivatives markets are mainly utilised by commercial producers, consumers, millers and speculators (JSE: 2016). Buyers and Sellers of grain want to hedge their stock against adverse price movement in the physical agricultural commodities market by using futures and/or options. Commercial producers, can employ a short hedge to lock in a selling price and end-users can use a long-hedge to secure a purchase price (JSE: 2016). According to Investopedia (2017a), a long hedge is a situation where an investor has to take a long position in futures contracts in order to hedge against future price volatility. It is beneficial for a company that knows it has to purchase an asset in the future and wants to lock in the purchase price.

A short hedge is an investment strategy that is focused on mitigating a risk that has already been taken, with short referring to the act of shorting a derivative like White Maize, that hedges against potential losses in an investment that is held long (Investopedia, 2017b). Commercial producers mainly aim to hedge their expected harvest at the highest possible price to ensure maximum return on investment. The opposite is true for consumers and millers: they want to buy their expected production/processing stock at the lowest possible price. Because of the strong competition in South Africa in the different segments of the market, price is crucial for any miller and consumer. Price risk in the White Maize market in South-Africa is significantly higher compared to any other agricultural commodity traded on the South African Futures Exchange (SAFEX). (Geyser, 2013:39).

This is due to the price inelasticity of the White Maize market, caused by the small number of substitutes available for this commodity (Bown et al., 1999:277-278; van Zyl, 1986: 53-54). Another explanation is that the increased price volatility was caused by the deregulation of the agricultural commodities market in the mid-1990's (Groenewald et al., 2003). White and yellow Maize has a contract size of 100 metric tons, while Sunflower has a contract size of 50 metric tons. The major trading months on all three commodities are March, May, July, September and December. The other months of the year is also tradeable, but the volumes are much lower than the five major trading months. The expiry date of a futures contract is on the sixth last business day of the month (JSE, 2016).

The minimum price movement on all three contracts is 20c / ton, while the maximum movement per day on White Maize and yellow Maize is R100/ton, whilst the movement for Sunflower is R150/ton. The JSE booking fee for futures for White Maize, yellow Maize and Sunflower is R14/contract, or 14c/ton, whilst on options the booking fee is 7c/ton. Trading hours are weekdays from 09h00 to 12h00. For every position that is traded and not closed by the end of trading on the same day, an initial margin per contract is payable before 10h00 the following day by the member who is holding the position (JSE, 2016).

The current initial margins as at 9 January 2017 applicable to positions held by members are as follow:

White Maize for July 2017 delivery:	R31 800 / contract
Yellow Maize for July 2017 delivery:	R18 700 / contract
Sunflower for May 2017 delivery:	R18 100 / contract

The JSE offers two types of trading features: end of day trading and intraday trading. End of day trading is when a position is held overnight or longer in order to realize profits. An initial margin is payable by the member holding the position. Booking fees are applicable in the case of end of day trading. These customers have a long-term view about the market.

When engaging in intraday trading, a member enters and exits the market on the same day and does not carry the position over to the next day. The only fee applicable here is the booking fee payable to the JSE, as well as the trading house facilitating the trade. These customers have a short-term view, or they want to participate in the market, but does not have the deposit to carry an overnight position and act upon this view via intraday-trading.

1.1.2. PROBLEM STATEMENT AND CORE RESEARCH QUESTION

This study aims to investigate the relationship between rainfall in the North West province and the summer grain markets in South Africa, with the main focus on White Maize and Sunflower markets.

This study will focus on rainfall in the North West province and the number of hectares planted; eventual yield realised; production totals and how this correlates with the national averages and price movement. The other major factor that could potentially have an impact on the North West province and South Africa's rainfall outlook and precipitation, is the sea surface temperature in the El Niño region and the Indian Ocean Dipole (IOD). The study will also attempt to determine whether a La Niña and El Niño can be expected during the upcoming summer or not by using the data available from the sea temperatures.

The sea surface temperature data was sourced from the Climate Prediction centre for each year since 1990 and will be correlated with the rainfall in the North West province. It is obvious that not only the sea surface temperatures in the Niño region impacts rainfall in South Africa. But what will be done is to take the weekly sea surface figures for the current year, and correlate them with previous years to see if a resemblance is there or not. My aim will be to see in September or October each year which years correlate the best with the current year, and price management and planting summer grains is the option or not. Price data was sourced from the Thomson Reuters Portal and when the years that mostly correlate with the current year is available, more informed decisions can be made regarding price management, and potential yields that can or cannot be realized.

1.1.3. RESEARCH OBJECTIVES FORMULATIONS AND SPECIFIC RESEARCH QUESTIONS

The main question will be to find out what is the relationship between rainfall in the North West province and the South African summer grain markets.

Research objectives: The number of hectares planted, the total production, and the yield per hectare will be analysed against the rainfall data and price movement of White Maize, yellow

Maize and Sunflower contracts. The El Niño and La Niña phenomenon (via weekly sea surface temperatures in the Niño region and the IOD) will also be analysed and their impact on the rainfall totals and price movement of White Maize and Sunflower contracts.

1.1.4. OBJECTIVES AND BENEFITS OF THE PROPOSED STUDY

- The following benefits and importance can be highlighted from the proposed study.
- The need for the study exists because management of agricultural and financial providers, specifically in the North West province need a thorough background when making decisions about loans to farmers and budgeting purposes for the grain season ahead.
- Farmers need assistance when to plant or not to plant because of rainfall patterns in the province.
- To reduce the risk involving price movement on the South-African Futures Exchange (Safex).
- To provide better advice to clients trading on the South-African Futures Exchange (Safex).

1.1.5. DIVISION OF CHAPTERS

To fulfil the objective of this study, the study has been divided into five chapters and include:

Chapter 1: Chapter 1 consist of an introduction and the problem statement that was put out, and the core research question was stated: What is the relationship between rainfall in the North West province and the South African summer grain markets?

The introduction starts off with the background on agriculture in South Africa, and moving towards factors that could have an adverse or positive impact on the grain production in South Africa. One of these factors are actual and expected rainfall data and strategies towards managing price risk. Rainfall, for one, plays a critical part in determining the price of grain, because farmers are dependent on rain to productively manage their fields and land for planting. The average rainfall for the North West province is discussed in normal, dry and wet years and analysed. The production figures of Maize and Sunflower of the North West province and South Africa are discussed, and the chapter finishes off with a discussion and explanation of the pricing mechanism on Safex.

Chapter 2: Chapter 2 consist of the literature study needed to explain the different terms, and give background on them. The chapter also provides insight on the relevant keywords, NIŇO3, Rainfall, North West province, Grain prices, South Africa and how they are interconnected. The different divisions in chapter 2 are: Background on drought, Background on rainfall, Weather forecasting and interpretation, Sea surface temperatures, The Indian Ocean Dipole, El Niño and La Niña, The rainfall impact on South Africa and the North West province, Grain price background, Maize planting in the North West province.

Chapter 3: An empirical study where data was collected on a quantitative basis through research. Chapter 3 consist of the research methodology, the description of the overall research design, the data collection method, and the data analysis that was done.

The steps in the data analysis were the following:

Step 1 - Calculating the average rainfall per month for the North West province.

Step 2 - Can the NIŇO3 and IOD SST's individually or together predict rainfall for the North West province?

Step 3 - Doing the correlation between the NIŇO3 and IOD SST's and rainfall for the North West.

Step 4 - Calculating the correlation between the monthly rainfall in the North West province and the prices of White Maize and Sunflower.

Step 5 - Evaluating the results.

Chapter 4: Conclusion, summary, and discussion on all the data and results gathered in the study.

Chapter 5: Chapter 5 consist of six conclusions and six recommendations for the results based on all the data gathered for this dissertation. The chapter starts off with an introduction.

This is followed by the six conclusion and six recommendations, areas for further study are outlined and finally ends off with a summary for the dissertation and the major highlights.

1.2. DELIMITATIONS AND ASSUMPTIONS

1.2.1. DELIMITATIONS (SCOPE)

There are no delimitations to the study.

1.2.2. ASSUMPTIONS

The assumptions made will be that each variable will be tested individually and that no other factor can impact price. If further research is needed, the variables will be tested together to determine price movements in the South African Maize and Sunflower markets.

CHAPTER 2:

Chapter 2 consist of the literature study needed to explain the different terms, and give background on them. The chapter also provides insight on the relevant keywords, NIŇO3, Rainfall, North West province, Grain prices, South Africa and how they are interconnected.

The different divisions in chapter 2 are: Background on drought, Background on rainfall, Weather forecasting and interpretation, Sea surface temperatures, The Indian Ocean Dipole, El Niño and La Niña, The rainfall impact on South Africa and the North West province, Grain price background, Maize planting in the North West province.

2. LITERATURE STUDY

2.1. BACKGROUND ON DROUGHT

Wilhite (2000:3) state that there are four main categories of drought, namely meteorological, agricultural, hydrological and socio-economic.

- "A ***meteorological drought*** is expressed solely on the basis of the degree of dryness and the duration of the dry period due to a deficiency in precipitation" (Wilhite, 2000:4).
- "***Agricultural drought*** links meteorological to agricultural impacts such as soil moisture and crop yield, and the impacts are crop specific, for example, with Maize there is impaired growth and reduced yields." (Wilhite, 2000:6).
- "A ***hydrological drought*** is associated with the effects of periods of precipitation shortfall on surface or sub-surface water supply and water storage systems." "Hydrological droughts are usually out of phase or lag the occurrence of meteorological and agricultural droughts." (Wilhite, 2000:8).
- "A ***socio-economic drought*** associates supply and demand of some economic good or service with the drought and the impacts on human activities" (Wilhite, 2000:11). A drought-related shortage of crops marks a drought condition according to human needs. Humans can also create a drought situation by means of land-use choices or excess demand for water (Wilhite, 2000:13).

Severe agricultural losses to commercial and subsistence farmers, reductions in reservoir levels and an increase in the plight of rural communities are regular impacts of drought in South Africa (Wilhite, 2000:5). Another impact of drought on the economy is the increase in food prices, which has major implications for food security. Maize is a very important staple food for low-income people and they are therefore seriously affected by price volatility during a drought.

Malnutrition and hunger for these low-income groups occur during periods of high prices as they cannot afford the higher prices of food (Wilhite, 2000:7). The volatility in price changes can arise mainly because of two factors. The first is due to variability in natural conditions such as weather, disease and pests reducing the total crop yield thereby increasing prices. The second occurs as a result of a lag between planting decisions and the harvesting of crops. Government intervention to curb price fluctuations is therefore common in industrialized and developing countries due to the natural instability of agricultural markets (Wilhite, 2000:7).

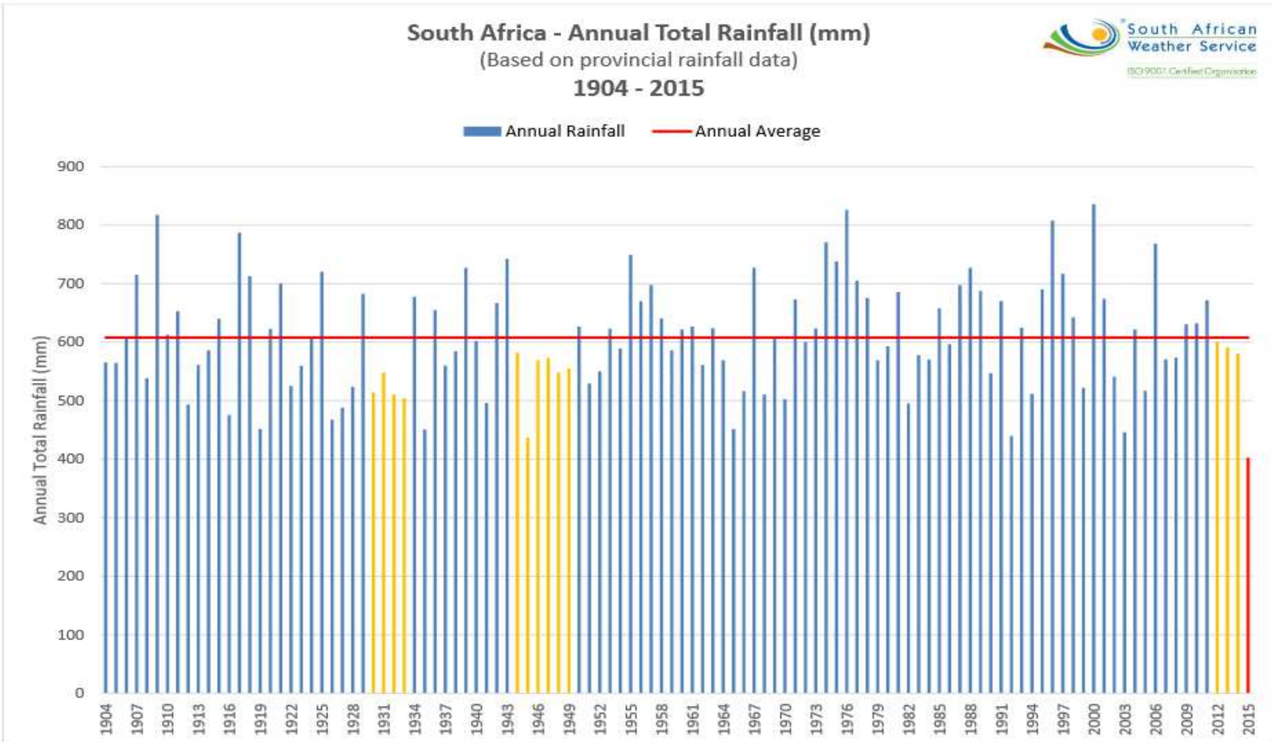
Drought has been noted as having severe impacts on the agricultural sector of South Africa (Wilhite, 2000:6). The vulnerable populations of the country are the ones that are impacted the most by this occurrence. Maize is the staple food of most individuals in the Southern Africa region and as a result the reliance on rain-fed agriculture is tremendous (Wilhite, 2000:6). Rainfall variability in the region also has serious consequences for agriculture and for food security. The onset of a drought is generally the trigger required to cause large-scale food shortages in the southern African region (Wilhite, 2000:8).

The performance of Maize is highly sensitive to the intra-seasonal distribution of rainfall, particularly at the time of flowering, which generally occurs around February. Any extended halt in rainfall can cause a considerable reduction in grain formation and a result, Maize yield that is substantially smaller (Clay et. al., 2003). The onset date of the rainy season is also crucial to subsistence farmers as they need to decide when to plant their Maize. Frequent dry spells may occur if planting is too early and intense rains washing seeds away could occur if planting is too late (Reason et al, 2005). The variability in seasonal rainfall characteristics such as onset, cessation and dry spell frequency are harmful to the agricultural sector and especially to the staple food of most South Africans (Tadross et. al., 2005).

2.2. BACKGROUND ON RAINFALL

According to De Jager (2016), since records started way back in 1904 by the South African Weather Service, the average annual rainfall in the country has been 608 mm. In 2015 only 403 mm of rain fell, the lowest annual amount of rainfall since 1904 and 205 mm below the long-term average. The three years prior to 2015, an average of 591 mm rain fell. The second lowest amount was recorded in 1945 when 437 mm fell, and the third lowest annual total was set in 1992 when 440 mm fell. The fourth lowest total was recorded in 2003 when 446 mm fell, and the fifth lowest was 1935 when 451 mm of rain fell. The yearly (Calendar years – January to December) totals as compiled by De Jager (2016) can be seen below in figure 3.

Figure 3: South African yearly rainfall since 1904



Source: De Jager, E. (2016)

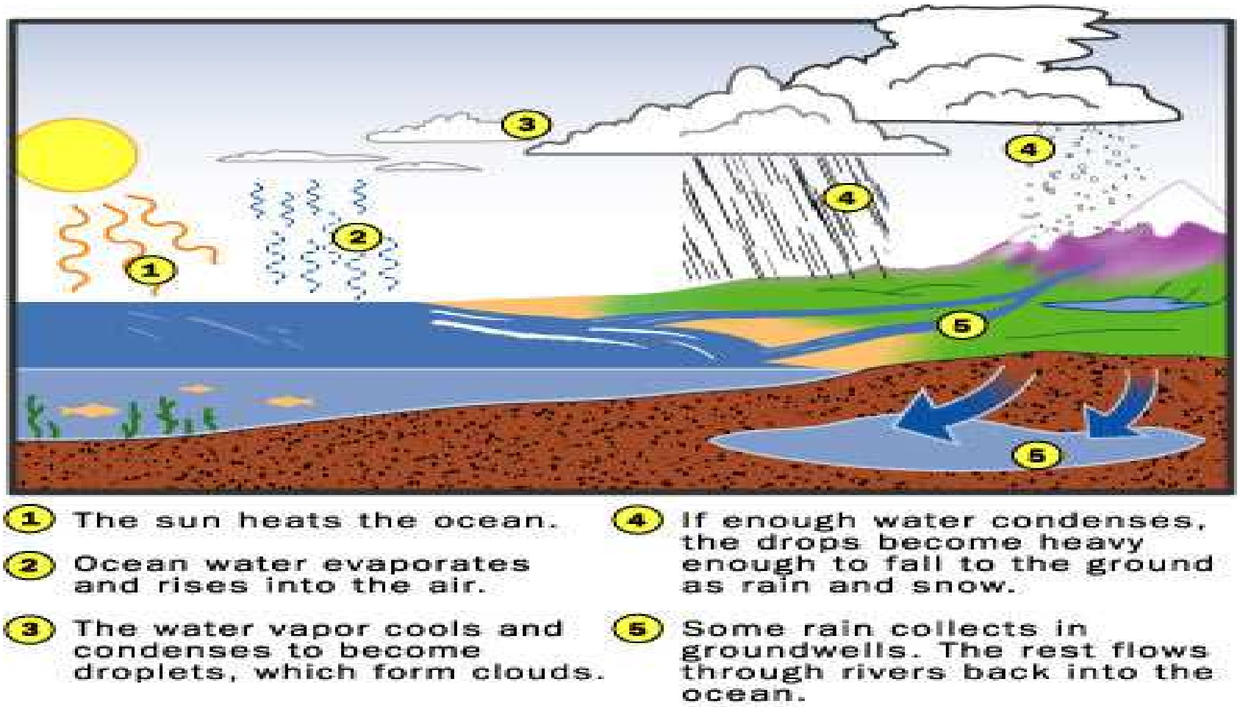
What is important to note is that the background on the weather systems and in particular precipitation is needed to understand how everything fits into one another. The following part will provide background on weather terms, precipitation, weather forecasts and the El Niño and La Niña phenomenon.

“Precipitation – rain, snow, sleet and hail, is associated with areas of rising air and low pressure. When air rises, it cools, and the moisture it contains condenses out as clouds, which eventually produce precipitation. In regions of high pressure, air is descending and the atmosphere is stable, the skies are usually clear and precipitation is rare.” (Ecoca, 2016). Places like the Arctic and Antarctica, precipitation is usually low because air is too cold to contain much vapour, whilst over hot and cold deserts, high pressure limits the cloud formation and precipitation. Over western facing coastlines like Africa, Asia and Northern America, the interior landmasses receive less rain as the air moves further away from the ocean, the source of moisture. According to Ecoca (2016), around the equator in the tropics, there is a very strong heating of the sun, and this creates significant vertical uplift of air and formation of prolonged heavy showers and frequent thundershowers. Rainfall in these areas can reach 2500 mm annually.

Chuey and Nelson (2017) state that clouds are condensed droplets or ice crystals from atmospheric water vapour. Clouds form by the rising and cooling of air caused by convection, topography, convergence and frontal lifting. Convection occurs when the Sun’s radiation heats the ground surface, and warm air rises, cooling as it goes. The counter clockwise motion of a low-pressure centre draws air inward and the convergence forces the air upward. Air also is lifted and cooled along either a cold front or a warm front. A cold front is the leading edge of an air mass that is colder than the air it is replacing. The front forms a wedge that pushes under the warmer air ahead, lifting it. A warm front is the leading edge of an air mass warmer than the air it is replacing. As the air mass pushes forward, the warm air slides up over the wedge of cold air ahead of it. The varying intensities of rainfall have specific names.

Liquid precipitation is of a longer duration and of a larger drop size and is called rain. When it falls in shorter spurts it is called a shower. Rain typically falls from low level stratoform clouds with greater vertical extent. When the drops are very small, rain is called a drizzle according to Chuey and Nelson (2017). Thunderstorms are when clouds build well above the freezing level in the air where the temperature of the rising air has cooled to water’s freezing point. The precipitation particles grow larger and become heavier. The rising air cannot hold them up and they begin to fall. The particles drag some of the air along with them, creating a downdraft. The updraft pulls more dry air into the cloud, and the air cools, making it colder and heavier than the surrounding air. This causes the thunderstorm to increase its downdraft and dissipation starts. The process can be seen clearly below in figure 4.

Figure 4: The cycle of rain



Source: Lamb, R. (2008)

2.3. WEATHER FORECASTING AND INTERPRETATION

Weather services around the world publishes synoptic charts on their website, social media, newspapers and television every day. A synoptic chart is the scientific term for a weather map according to (Skwirk, 2016?). Synoptic charts provide information on the distribution, movement and patterns of air pressure, rainfall, wind and temperature. This information is conveyed using symbols, which are explained in a legend. Synoptic charts are used to report on current weather and to predict future weather patterns. (Skwirk, 2016?).

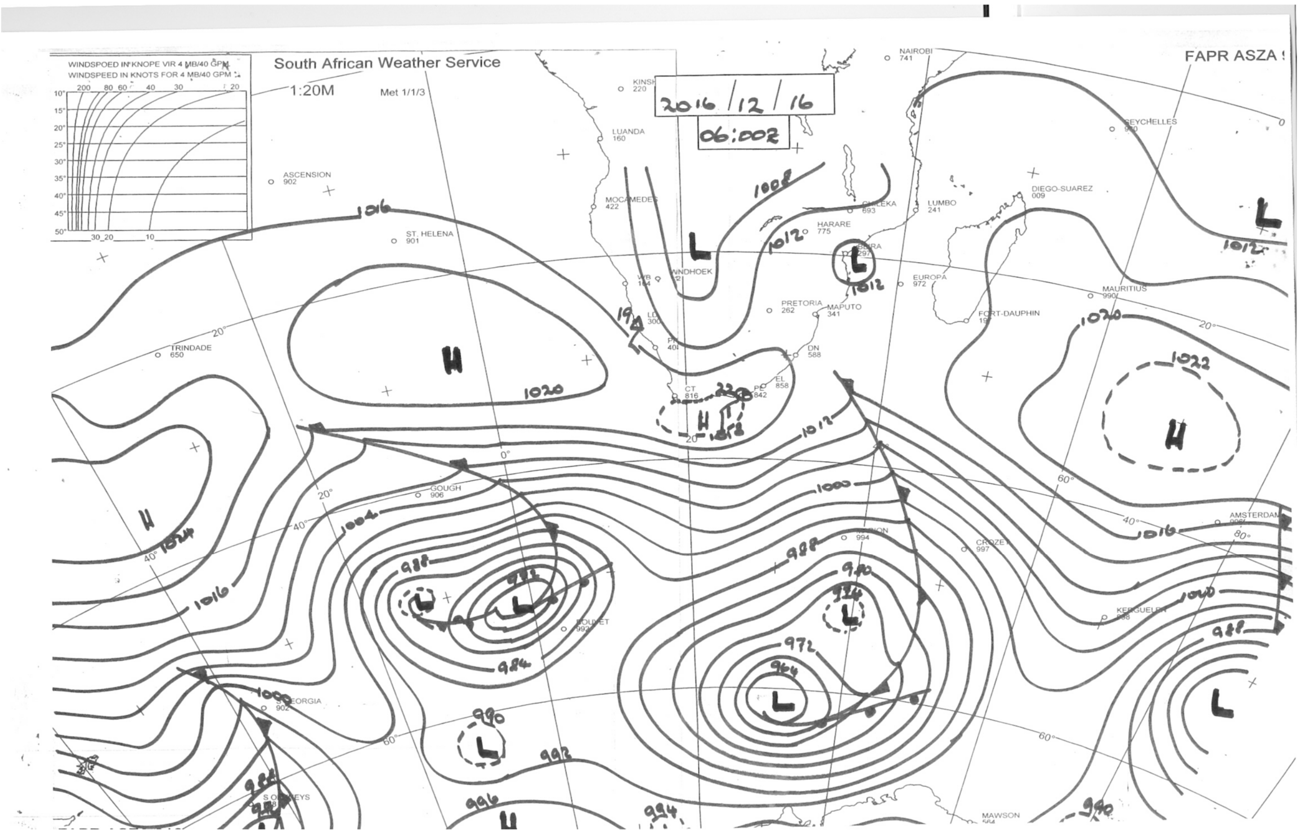
The most important feature of a synoptic chart is the fine black lines called isobars. While isobars are similar to contour lines, they provide different information than them. Contour lines connect points which share the same atmospheric air pressure. The closer the contour lines are, the steeper the slope is and the closer the isobars are, the stronger winds are. (Skwirk, 2016?)

Air pressure is essentially the weight of the air. Air pressure is measured by a barometer and the unit of measure is hectopascal. These measurements can be seen on synoptic charts. Air pressure systems usually move from west to east, but change shape and position as they move. The average air pressure at sea level is 1013 hPa. Any measurement above 1013 hPa is called a high-pressure system and is considered to be an area of sinking air. A high-pressure system generally means that the weather is fine and settled. It is marked by a ‘H’ on the synoptic chart. Winds in a high-pressure system move anti clockwise in the Southern Hemisphere and clockwise in the Northern Hemisphere. (Skwirk, 2016?). During a high-pressure system, winds in South-Africa blow anti-clockwise and air is descending. The surface temperature also tends to rise creating higher maximum temperatures during the day. (Nigrini, 2016). Low pressure areas are associated with rising air, causing the formation of clouds with possible precipitation (SAWS, 2016). Conversely any measurement below 1013 hPa is called a low-pressure system and is thought to be an area of rising air. Low pressure systems usually mean unsettled weather, which could turn into rain. On a synoptic chart, it is marked by an ‘L’. Winds move clockwise in the Southern Hemisphere and anti-clockwise in the Northern Hemisphere. (Skwirk, 2016?).

When two masses air with differing characteristics (warmer and colder) collide with one another, it is called a front. A warm front brings the increase in temperatures and light showers. A cold front can lead to cooler temperatures and rain. (Skwirk, 2016?). Precipitation includes snow, hail and dew. The most common form of precipitation is rainfall. Rainfall on a synoptic chart is shown using a shading. Wind generally refers to the horizontal movement of air. The earth produces local winds, which include land and sea breezes, as well as permanent global winds, called Trade Winds and Polar Easterlies. Wind direction can be measured using a weather vane, which is a device that turns on an axis to point the direction of the wind. Wind speed can be measured using an anemometer, which is a device that uses rotating cups of pressure differences to determine speed. (Skwirk, 2016?).

Figure 5 below show a synoptic chart for South-Africa on 16 December 2016. The low-pressure and high-pressure systems can be clearly seen below, as well as a cold front approaching South-Africa from the west over the Atlantic Ocean.

Figure 5: A synoptic chart for South-Africa for the 16th of December 2016



Source: South-African Weather Services. (2016)

The South-African Weather service publishes an interpretation of a synoptic chart on their website, www.weathersa.co.za. Below are some of the important highlights relevant to this dissertation (SAWS, 2016).

“When looking at a synoptic chart the first thing to take note of are the isobars. These are lines joining places of equal pressure. Areas with high numbers are known as areas of high pressure and low-pressure areas are indicated by lower numbers. Wind blows from high-pressure areas to low-pressure areas. However, due to the Coriolis force, wind doesn’t blow in a straight line from high- to low-pressure areas but blow in a clockwise direction around a low-pressure area and in an anti-clockwise direction around a high-pressure area (in the Southern Hemisphere).

Winds thus tend to blow sub-parallel to the isobars and from the isobar patterns on a synoptic chart it is possible to estimate from which direction the wind will be blowing at any location. The closer the isobars are together, the steeper the gradient between areas of high and low pressure and the stronger the wind. By studying the patterns shown by isobars, forecasters can make predictions about how the weather conditions will develop.

Troughs of low pressure and ridges of high pressure can also be identified. Ridges are areas of high pressure that generally result in dry conditions in their immediate vicinity. A ridge of high pressure may be associated with coastal showers when it brings onshore winds along the east coast in advance of the ridge itself. These onshore winds can produce widespread coastal showers. The zone of interaction of the ridge with nearby areas of low pressure or troughs can be unstable and produce storms or rain in any area. Troughs are regions of relatively low pressure which often precede a cold front. These areas of relatively low pressure are unstable and tend to have high moisture associated with them. Consequently, they are good sources of thunderstorms.

Temperatures from a large number of weather stations are also plotted on the synoptic chart. This information is used to determine the location of fronts. By seeing where temperature changes significantly across a small area, it is possible to locate the position of these fronts. Cold fronts have triangles along the line indicating the position of the front and warm fronts have half-circles. Fronts occur at the boundaries of converging air masses which come together from different parts of the world. Since air masses usually have different temperatures, they cannot mix together immediately owing to their different densities. Instead, the lighter, warmer air mass begins to rise above the cooler, denser one.

Fronts are usually associated with regions of low pressure, also known as depressions. As the sector of warm air is forced to rise, the cold air begins to engulf it. The leading edge of the warm air is marked by the warm front. The cold front marks the rear edge of the warm air and the leading edge of the ensuing cold air. When the warm air is completely lifted off the ground and is no longer in contact with the surface of the earth, this may be marked on a synoptic chart by an occluded front. Fronts are usually accompanied by clouds of all types, and very often by precipitation. Precipitation is usually heavier although less prolonged at cold fronts than at warm fronts, since the uplifting of warm air is more vigorous due to the undercutting of cold air, resulting in increased atmospheric instability."

2.4. SEA SURFACE TEMPERATURES (SST) AND CORRELATIONS

The interaction between the ocean and the atmosphere have a major impact on the weather and climate. It takes several months before one big event will happen. Ocean and atmosphere are closely related. They are both components of the climate and together form a system called the climate system according to Randriamahefasoa, (2013). Randriamahefasoa, (2013), state that the wind coming from the atmosphere drives the sea water. Then the oceans move, and the ocean currents appear and transport the heat from solar radiation which is absorbed by the sea water. The circulation of the oceans, in turn, influences the atmosphere. The ocean circulation is much slower than the atmospheric circulation according to Randriamahefasoa, (2013).

As mentioned previously, the SST in the Niño region is very crucial for determining a La Niña, El Niño of neutral conditions around the world. The Climate Prediction Centre produces their weekly SST's, which is measured by buoys in the Niño region and captured into a computer.

This weekly data has been collected since 1990. The correlation between the current year or season and all the seasons beforehand can be drawn up and the three seasons with the closest correlations are identified. In the example below, the 2016/2017 season's SST was analysed. The Niño 3 region's SST is the most common of the Niño regions that impacts South African rainfall patterns according to Nigrini (2016). The three years that most closely correlate with 2016's Niño 3 SST in chronological order, is the 1998/99, 2010/11 and the 2007/08 seasons. Although 2016 has not been declared an official La Niña, the weekly SST's were in La Niña range for a while, but not long enough to be declared an official La Niña. The three most corresponding years were all moderate La Niña events, meaning the Niño 3.4 SST exceeded 1.0 Celsius for three or more consecutive months.

Table 2: The top three results from correlating the weekly SST Niño 3 with 2016

WEEKLY SST NIŇO 3	Moderate La Niña 98/99	Moderate La Niña 07/08	Moderate La Niña 10/11
CORRELATION - 2016			
	1998	**2007**	**2010**
Begin March	95%	94%	70%
Begin June	91%	79%	87%
Begin October	94%	86%	91%
Begin November	94%	86%	90%
Begin December	94%	86%	90%
3rd week Dec	94%	86%	90%

Source: Climate Prediction Centre and own compilation

2.5. THE INDIAN OCEAN DIPOLE (IOD)

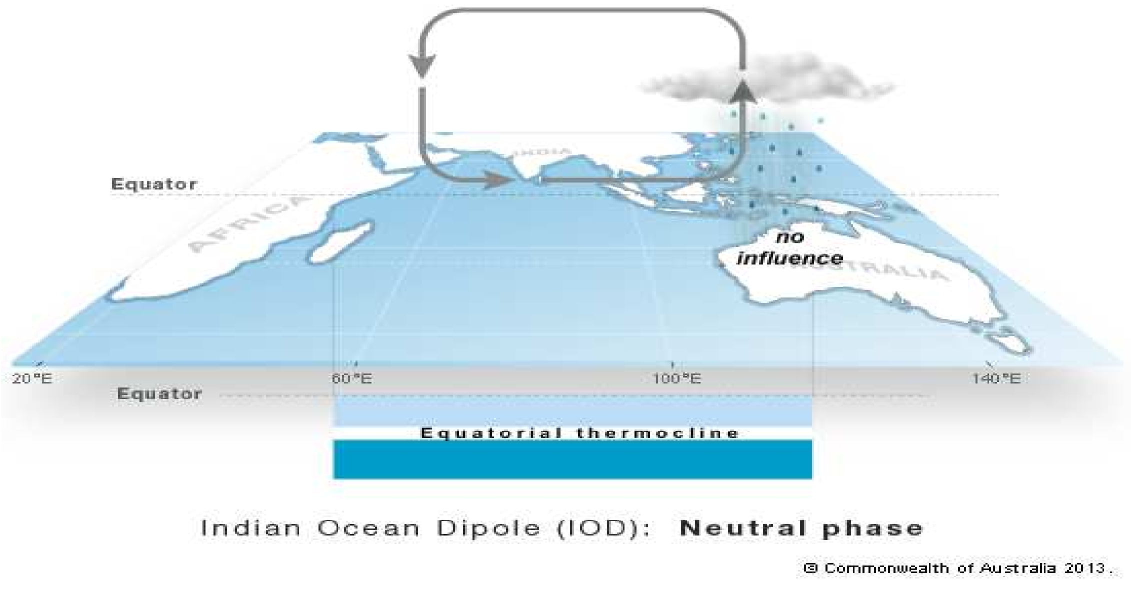
The Indian Ocean Dipole, or IOD, is the sustained changes in the difference between sea surface temperatures of the tropical Western and the Eastern Indian Ocean according to The Australian Weather Bureau (2017). The Indian Ocean is the ocean basin bounded to the north by the Asia continent, to the south by the Southern Ocean, to the west by Africa and to the east by Australia according to Randriamahefasoa (2013). The Indian Ocean is the smallest ocean compared to the Atlantic, Pacific and Southern Oceans. It is also the warmest ocean on earth according to Randriamahefasoa (2013).

The IOD is one of the key drivers of Australia's climate, and there is a likelihood it has an impact on South Africa's weather as well. It has a key impact on the Australian Agriculture. In Australia, it coincides with the winter crop growing season like wheat and barley, and because Australia is a major exporter of wheat, it has a global impact as well on prices according to the Australian Weather Bureau (2017). The IOD has three phases, neutral, positive, and negative. Events start around May or June, and peak between August and October. The IOD is unable to form between December and April. To explain these three phases, graphs were added.

Neutral IOD phase

Water from the Pacific Ocean flows between islands of Indonesia, keeping the sea temperature warm toward north-west Australia. Air rises above this area and falls over the western half of the Indian Ocean, blowing westerly winds across the equator. This will keep sea temperatures normal across the Indian Ocean, with no major impacts on Australia's weather according to the Australian Weather Bureau (2017). Figure 6 below show a neutral Indian Ocean Dipole, meaning that the western and eastern half of the Indian Ocean's temperature show little deviation from normal.

Figure 6: The neutral Indian Ocean Dipole phase



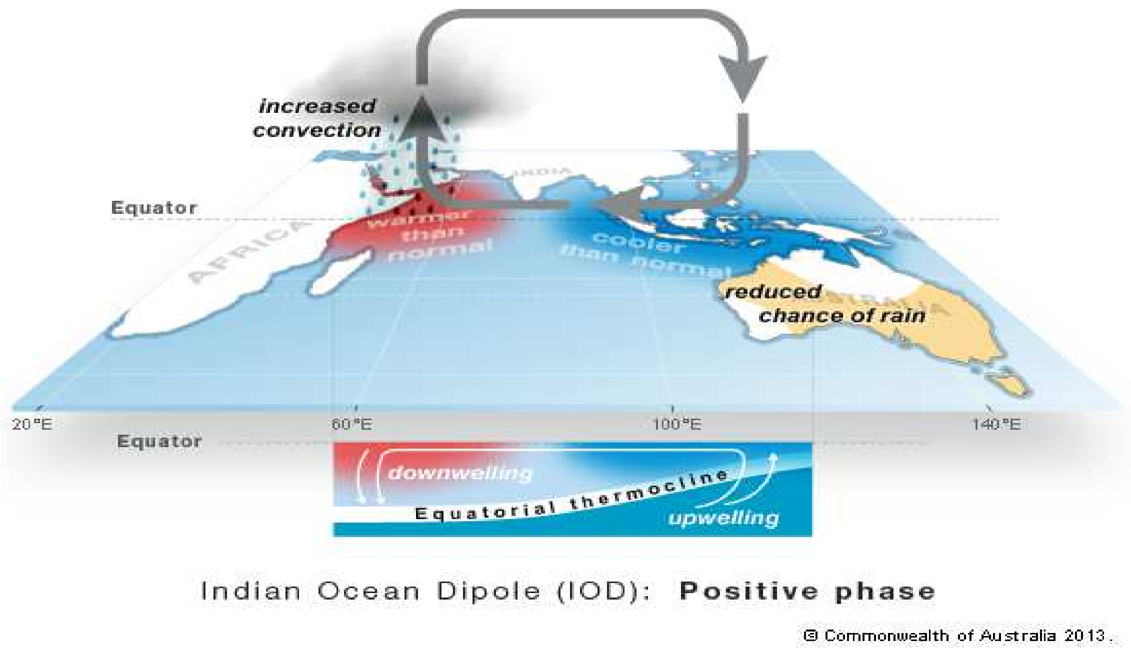
Source: Australian Weather Bureau (2013)

Positive IOD phase

Westerly winds weaken along the equator allowing warm water to shift towards Africa's East Coast. Changes in the winds also allow cool water to rise from the deep ocean in the Eastern Indian Ocean. This sets up a temperature difference across the tropical Indian Ocean with cooler than normal water in the east and warmer than normal water in the west according to the Australian Weather Bureau (2017).

Generally, this means there is less moisture than normal in the atmosphere to the northwest of Australia. This changes the path of weather systems coming from Australia's west, often resulting in less rainfall and higher than normal temperatures over parts of Australia during winter and spring according to the Australian Weather Bureau (2017). Figure 7 below show the positive Indian Ocean Dipole where the warmer than normal sea temperature in the Western Indian Ocean must be noted, as well as the cooler than normal sea temperature to the north-west of Australia. An upwelling of cooler water across the Australian and Asian coast is clearly visible.

Figure 7: The positive Indian Ocean Dipole phase



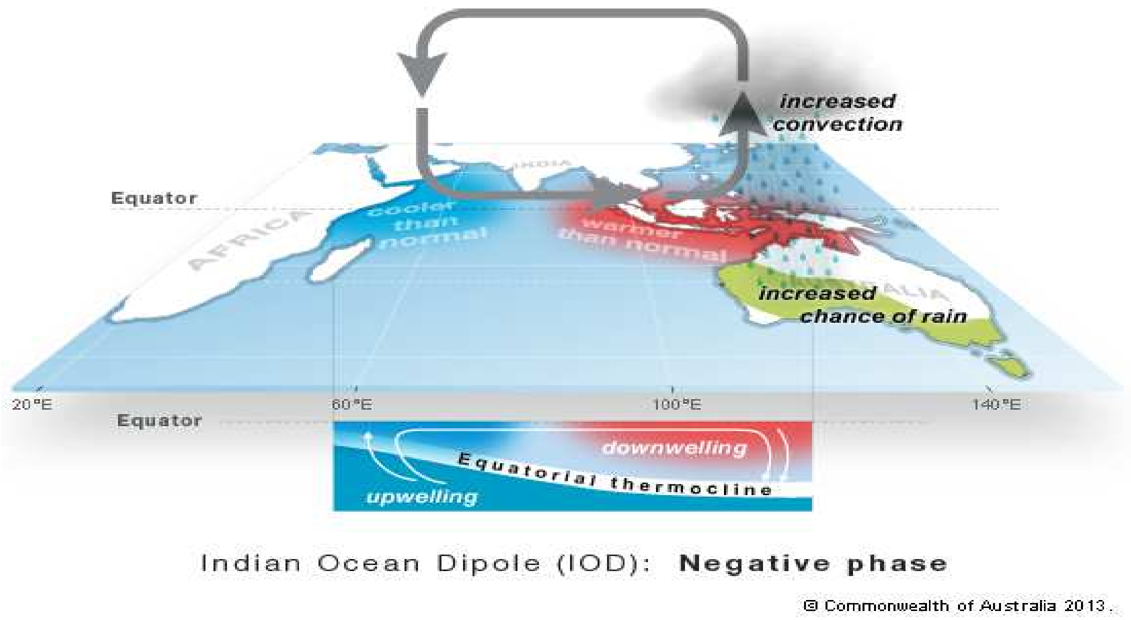
Source: Australian Weather Bureau (2013)

Negative IOD phase

Figure 8 below show that westerly winds intensify along the equator, allowing warmer waters to concentrate near Australia. This sets up a temperature difference across the tropical Indian Ocean, with warmer than normal water in the Eastern Indian Ocean and cooler than normal water in the Western Indian Ocean according to the Australian Weather Bureau (2017).

A negative IOD typically results in above-average winter and spring rainfall over parts of southern Australia as the warmer waters off northwest Australia provide more available moisture to weather systems crossing the country according to the Australian Weather Bureau (2017). Olivier (2016) state that the tendency of cooling over the South-Western Indian Ocean south of Madagascar, may create favourable conditions for rainfall activities over South Africa, partly corresponding with the IOD's impact on Australia for above normal rainfall. The question however is what is the time after the IOD impacts Australia, how long until the impact will be felt in South Africa?

Figure 8: The negative Indian Ocean Dipole phase



Source: Australian Weather Bureau (2013)

2.6. EL NIǸO AND LA NIǸA

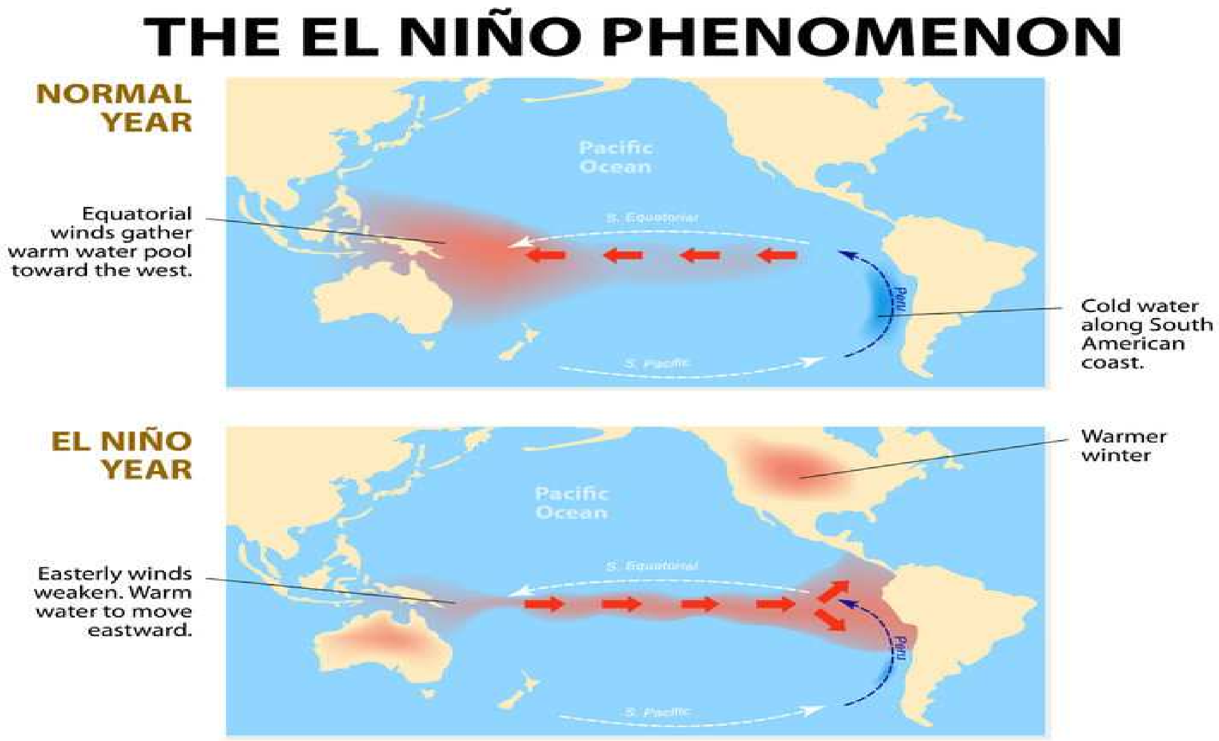
The strong weather phenomenon, El Niño, was on the lips of everybody and the whole world knew a record El Niño has been forecasted for the 2015/2016 South African summer, but nobody knew what exactly the impact will be on the world, especially South-Africa. For a background on El Niño, an explanation will be needed.

Garner (2015) state that," an El Niño occurs every two to seven years when an unusually large pool of water, sometimes two to three degrees Celsius higher than normal, develops across the Eastern Pacific Ocean to create a natural short-term climate change event". According to Reuters (2017), El Niño can be described as a warming of the ocean current along the coast of Peru and Ecuador in South America that is generally associated with dramatic changes in the weather patterns of the region. It occurs every 3 to 7 years according to Reuters with changes in weather patterns worldwide is associated with it. El Niño and La Niña are a naturally occurring phenomena that result from interactions between the ocean surface and the atmosphere over the Pacific. Changes in the ocean surface temperatures affect tropical patterns and atmospheric winds over the Pacific Ocean which in turn impact the ocean temperatures and currents. It causes changes in global weather patterns according to the National Weather Service (2016).

Nigrini (2016) states that historically El Niño reaches its maximum around Christmas on the 25^{th} of December each year. Satellites have been monitoring the sea temperatures in the ocean between South-America and Australia, but they could not say how cold the water beneath the surface was. Since 1990, buoys have been installed every few kilometres apart by the European countries and the United States of America. These buoys measure the sea temperature depth every few kilometres and give accurate readings which is sent to research centres for monitoring and observations. When the trade winds start to blow, the sea water that is displaced can be measured and monitored to give predictions and sound warnings across the world.

According to Guru Mavin (2015), during a neutral year, trade winds blow from east to west, causing warm sea water to migrate from South America towards Asia, and cool water from the south converges off the South American coast. The Niño 3.4 region then have a neutral or cooler than normal water temperature. Stable atmospheric conditions are produced, causing a normal year in terms of rainfall throughout the world. During an El Niño year, trade winds blow from west to east that can be seen in figure 9 below. In some years these winds don't blow that strong. Warm water from Asia flow eastwards towards the South American coastline across the Niño region, or stay idle here. Because trade winds can collapse, there is very little flow of cold water from the South Pole to replace this warmer water. This warm water then condenses along the coast and can flow further eastwards towards Africa, causing increased convection in the air, and anomalies in the rainfall patterns across the world. High pressure builds over the Pacific Ocean and can cause drought over Asia and Africa according to Guru Mavin (2015).

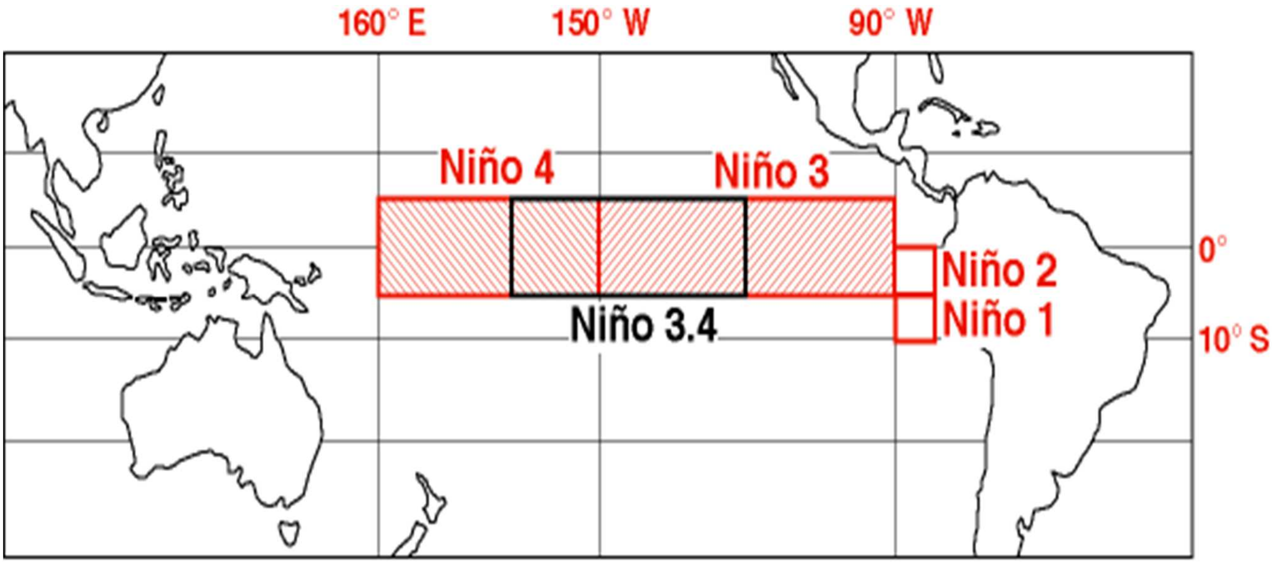
Figure 9: The El Niño phenomenon versus a normal year



Source: Kaskus (2016)

Reuters state that ENSO is short for El Niño-Southern Oscillation, a reference to the state of the Southern Oscillation and sea-surface temperatures, or SST's. ENSO is a climate phenomenon generally defined by sea surface temperatures in the central and eastern Pacific Ocean between Australia and South-America. The most common SST used to determine and monitor ENSO status (El Niño, La Niña or neutral conditions), is the Niño 3.4 region. The specific regions are shown below in figure 10 to enhance the illustration.

Figure 10: The three Niño regions in the Pacific Ocean west of South America



Source: Ucar (1998)

To count as an *El Niño* event, the 3-month average sea surface temperatures in the Niño 3.4 region departure predicted must meet or exceed + 0.5°C in the east-central equatorial Pacific Ocean to the west of South America according to the National Weather Service (2016).

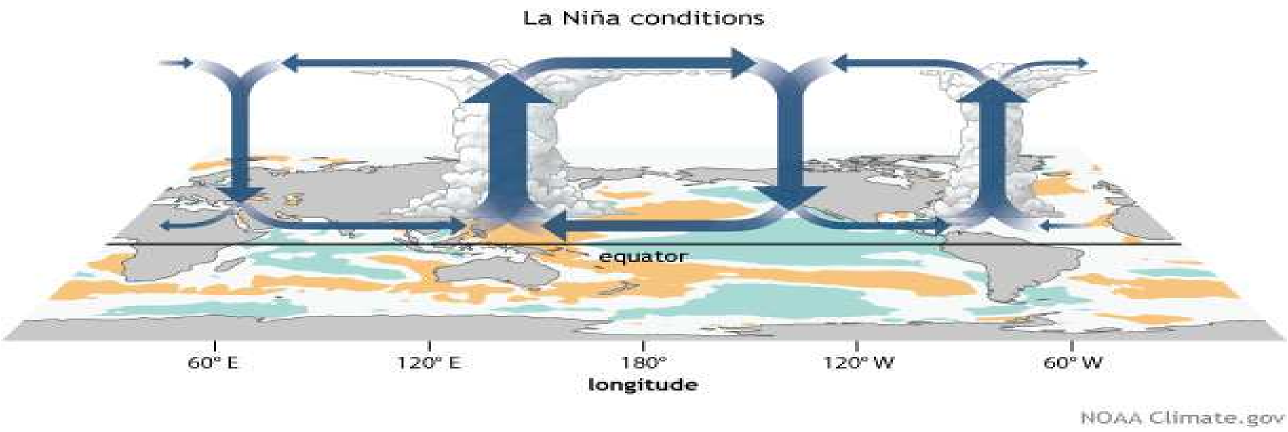
According to the National Weather Service (2016), the term El Niño refers to the large-scale ocean-atmosphere climate phenomenon linked to a periodic warming in sea-surface temperatures across the central and east-central equatorial Pacific. El Niño represents the warm phase of the ENSO cycle, and is sometimes referred to as a Pacific warm episode. According to Reuters, an El Niño is characterized by the unusual weakening of trade winds blowing over the Pacific Ocean, sometimes blowing west to east and this causes movement of warm water from the western Pacific to the Eastern Pacific. The result is a fundamental shift in the transfer of energy from the tropical areas to the non-tropical areas, which can change weather patterns worldwide.

Halpert, M. (2014) state that an El Niño event can have three episodes, namely Weak, Moderate and Strong. A weak episode of El Niño is when the Oceanic Niño Index (ONI) is greater than, or equal to 0.5 ˚C, but less than 0.9 ˚C. A moderate El Niño episode is when the peak ONI is greater than or equal to 1 ˚C and less than or equal to 1.4 ˚C. A strong El Niño episode is when the peak ONI is greater than or equal to 1.5 ˚C. Typical results of El Niño worldwide include drier conditions in South Africa, Australia, India and Southeast Asia, whilst wetter weather can be expected in South America and wetness over the southern parts of the United States of America according to Reuters.

La Niña, the opposite of El Niño, refers to the periodic cooling of ocean surface temperatures in the central and eastern-central equatorial Pacific that occurs every 3 to 5 years or so according to the National Weather Service (2016). La Niña represents the cooling phase of the ENSO cycle, and is sometimes referred to as a Pacific cold episode. To count as a La Niña event, the 3-month average sea surface temperatures departure exceeds -0.5ºC in the east-central equatorial Pacific Ocean to the west of South America according to the National Weather Service (2016).

According to Reuters, La Niña is characterized by the unusual strengthening of trade winds blowing from east to west, and this causes water to move from the eastern Pacific towards the Western Pacific. Figure 11 below illustrates the La Niña conditions. The result is that there is a fundamental shift in the transfer of energy from the non-tropical areas to the tropical areas. Common results from a La Niña event worldwide is good rainfall over India, cool and wetter weather over Australia, South Africa, and Southeast Asia, but warm and hot weather over South America, and dryness over the southern parts of the United States of America.

Figure 11: La Niña conditions illustration



Source: NOAA (2016)

Below in table 3, the rainfall for the North West province during El Niño and La Niña events since 1971 and the rainfall that fell during the specific episode in that season, is illustrated. As mentioned before, an El Niño and La Niña can be either a weak, moderate or strong episode. During a weak El Niño or La Niña, the average deviation from the long-term average is not that much. The deviation comes in when the episode is moderate or strong. During a strong La Niña, the average rainfall increase to 230 mm above the long-term average, while during a strong El Niño the deviation is 84 mm below the long-term average. There have been a total of 14 La Niña and 15 El Niño events since 1971.

Table 3: Rainfall for the North West province in El Niño and La Niña events since 1971

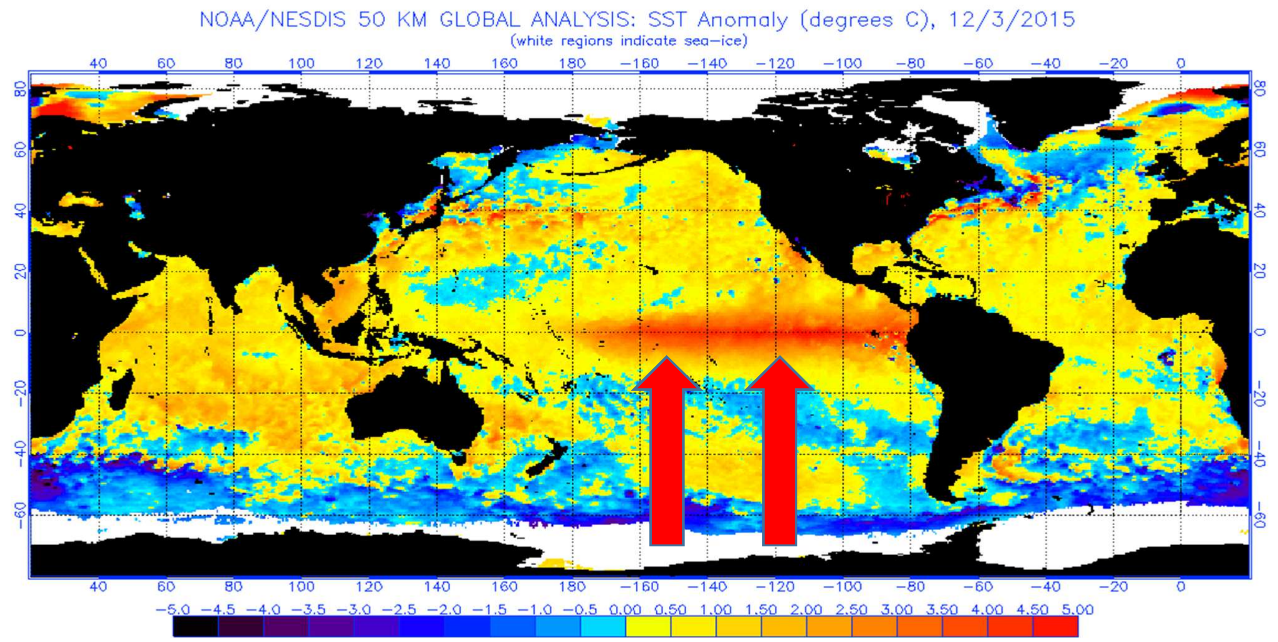
Rainfall for the North-West province in El Nino and La Nina events since 1971 (mm)												
Episode	El Nino	Deviation from avg	Events below normal rainfall	Events above normal rainfall	Event count	Last event	La Nina	Deviation from avg	Events below normal rainfall	Events above normal rainfall	Event count	Last event
Weak	530	-10	3	3	6	2006/07	538	-2	4	3	7	2011/12
Moderate	495	-45	4	2	6	2009/10	607	67	1	3	4	2010/11
Strong	456	-84	3	0	3	2015/16	770	230	0	3	3	1988/89
Total			**10**	**5**	**15**				**5**	**9**	**14**	
Average	501		67%	33%			607		36%	64%		
Long-term average	540						540					
Deviation	**-39**						**67**					

Source: SAWS (2017) and NOAA (2017)

On average, during an El Niño season, 39 mm less than the long-term average can be expected in the North West province. During the strong El Niño episode, it is where the most deviation can be expected. Since 1971, three events have occurred with the previous event occurring in the 1997/98 season, before the record strong 2015/16 event. In zero out of the 3 events, above normal rainfall was experienced.

On average, during a La Niña event, 67 mm more rain can be expected in the North West province with the episode producing the most deviation, being a strong La Niña event. The last Strong La Niña event occurred during the 1988/89 season and since 1971 there has been 3 events. During a weak La Niña, there have been 4 instances where below average rainfall has been experienced, while 3 have events have produced above average rainfall. Only in one instance, has below average rainfall been experienced during a moderate La Niña, while 3 events have produced above average rainfall. In figure 12 below, it can be clearly seen the warm to much warmer water in the Niño region on the 3rd of December 2015 which impacted South-Africa during the summer of 2015/2016.

Figure 12: The sea temperature anomaly in the Niño region on 3 December 2015

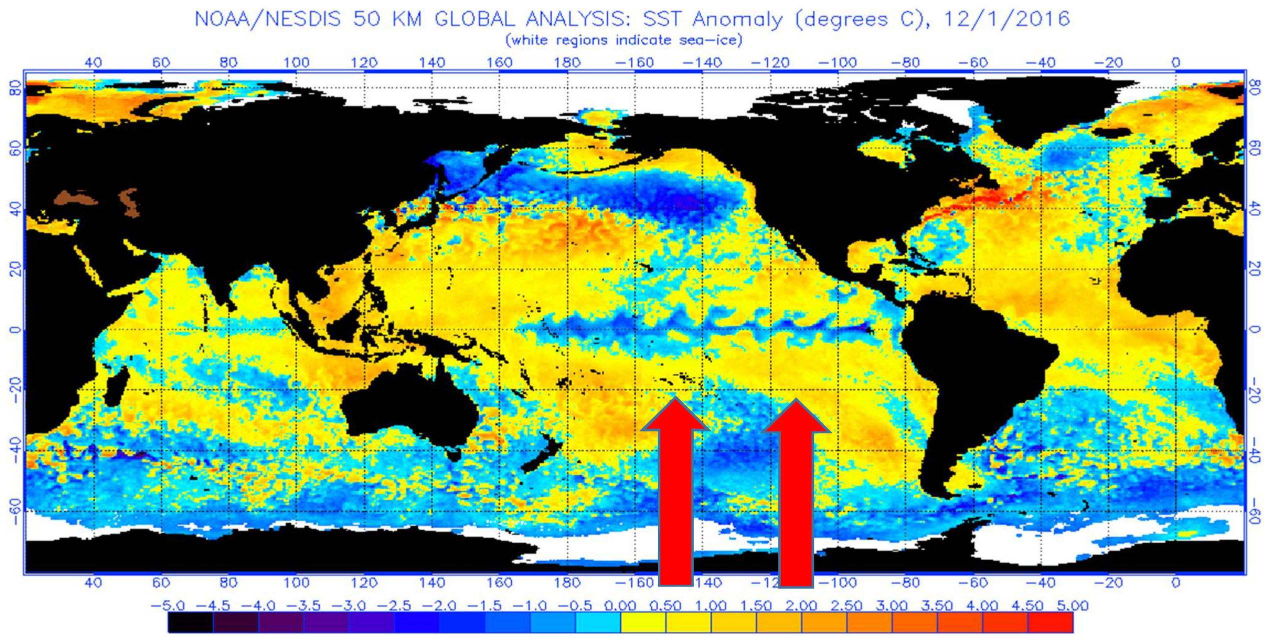


Source: NOAA (2016)

The warmer water in the Niño region caused the strongest El Niño on record to be recorded and force South Africa into a catastrophic drought with the lowest yearly rainfall figures over the most parts of the country.

When a comparison is done between the SST's in the Niño region between 2015 and 2016, quite the opposite is seen below in figure 13 compared to figure 12 above. The cooler than normal sea surface temperatures on 1 December 2016 in the Niño region off the coast of South-America can be seen. It is not cold enough to be declared an official La Niña, but at least normal to La Niña like conditions can be expected over South Africa during the summer of 2016-17. The water along the Cape Town coast is more or less the same warmth during 2016 than it was in 2015. What is also very interesting to note is that off the coast of KwaZulu-Natal, the water is much cooler during December 2016 than it was during December 2015. This is positive news for South Africa's summer production areas regarding rainfall expectation during December, January and February. Cooler water along the KwaZulu-Natal coast means that it is difficult for low-pressure systems and tropical cyclones to form which causes rain to fall over the ocean, instead of the land.

Figure 13: The sea temperature anomaly in the Niño region on 1 December 2016

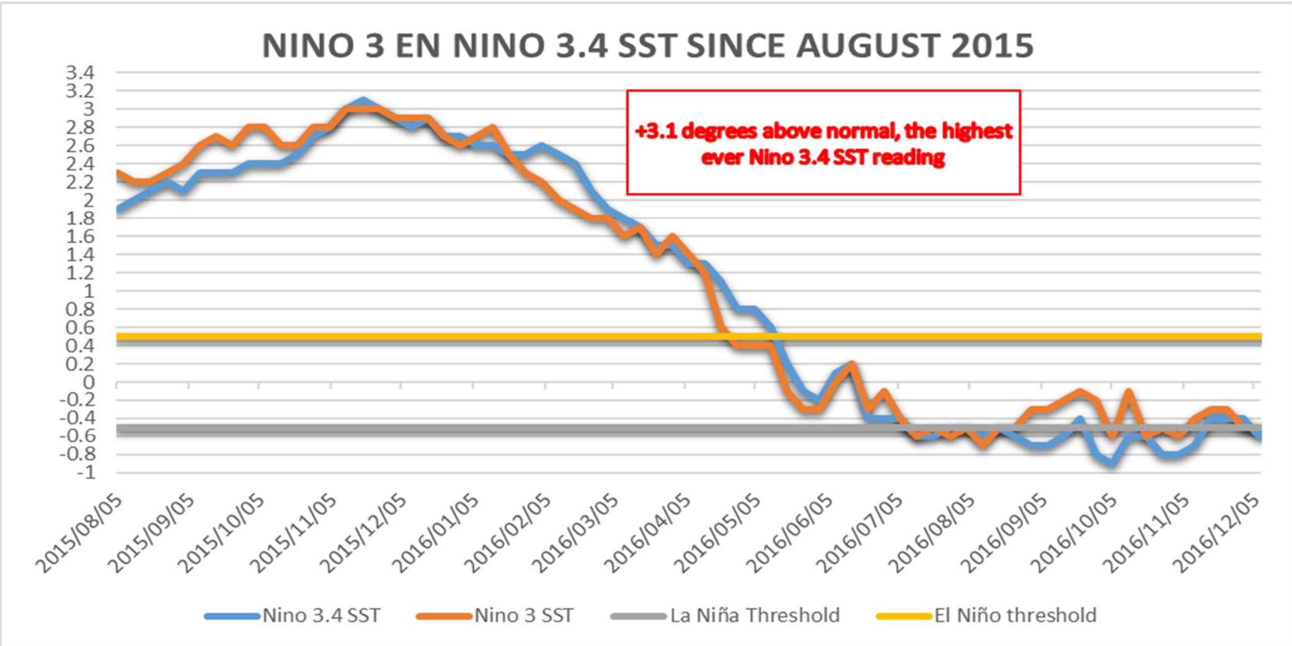


Source: NOAA (2016)

According to the Agency for Marine-Earth Science and Technology (2016), the Niño 3.4 SST anomaly reached its maximum level of 3.1 degrees Celsius above normal during the week of 18 November 2015, the highest reading ever recorded.

Figure 14 below shows how the NIŇO3.4 SST temperatures kept increasing since August 2015. The Niño 3.4 SST stayed almost 3 degrees hotter than normal during December and January. The Niño 3.4 SST started declining during the week of 3 February 2016 and reached neutral levels of zero degrees Celsius during the week of 25 May 2016. The Niño 3.4 SST kept at these neutral to negative readings until the end of 2016.

Figure 14: The ENSO 2015 and 2016 SST readings for NIŇO 3.0 and 3.4 region



Source: Climate Prediction Centre (2016) and own compilation

According to NOAA (2016), to constitute a La Niña, the threshold of -0.5 degrees must be met or exceeded and the forecast must be for the La Niña to persist for 3 months ahead.

To conclude above comparisons, it is explained what impact the Sea Temperature in the Niño region has on the conditions and rainfall in South Africa and the North West province. 2015 was a very dry year, while 2016 was a very wet year. During 2015, the Niño SST was very high, which had a devastating impact on South-Africa's and specifically the North West province's rainfall. During 2016, the opposite happened, with much cooler SST's in the Niño region, as well as along the South-African coastline. More explanation on the above statement will follow next.

2.7. RAINFALL IMPACT ON SOUTH AFRICA AND THE NORTH WEST PROVINCE

The year 2015 started off on a dry note in the North West province after a normal start to the rainfall season was recorded from October 2014 through to December 2014 when the average amount of rainfall in the province was around 185 mm as seen from data received from the South African Weather Bureau. This figure equates to 96% of the long-term average for this specific period. The long-term average for the months, January to March (when water is crucial for Maize and Sunflower because this is their pollination stage) is around 265 mm, but in 2015 the total for this three months was only 144 mm, or 54% of the long-term average. This lead to lower levels of soil moisture for the Maize and Sunflower to fully pollinate and lower harvests was realized in the North West province according to the Department of Agriculture, Forestry and Fisheries (2015). During the January to March period for 2016, 224 mm of rain fell, or 85% of the long-term average, still lower than the long-term average. Rainfall data has been provided since 1970 by the South African Weather Bureau, but for this dissertation the focus will mostly on the past 30 years.

To get a better indication of the past few seasons and the below average rainfall that was received in the North West province, historical rainfall need to be evaluated and reviewed. From Table 4 to 6 below, it can clearly be seen that there has been a steady decline in rainfall during the past 5 years in the North West province. For the July to December timeframe in table 4, the 5-year average is only 160.68 mm, whilst the 30-year average is 211.77 mm, a decline of 51.09 mm, or 24% versus the long-term average. Just to note, the 2-year average is for the 2014/2015 and 2015/2016 season.

Table 4: The average rainfall totals for the North West province for July to December (mm)

SEASON	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL	NOTE
30-year average	1.26	3.93	14.43	43.06	63.23	85.86	211.77	excl. 16/17
20-year average	1.65	3.92	11.83	37.41	61.07	86.45	202.33	excl. 16/17
10-year average	1.85	3.27	12.80	31.51	56.01	77.35	182.78	excl. 16/17
5-year average	1.34	1.24	10.55	20.81	46.54	80.21	160.68	excl. 16/17
3-year average	1.92	1.98	12.75	12.69	47.80	73.53	150.67	excl. 16/17
2-year average	2.09	2.82	18.87	6.75	53.85	60.10	144.47	excl. 16/17

Source: SAWS (2017), Compilation: own

October has been very dry over the past couple of years and is 36.31 mm below the 30-year average. This month is crucial for farmers to prepare fields for the planting of summer grains. November is more or less in line with the five-year average of 46.54 mm. However, the 30-year average is 63.23 mm. December's rainfall was at only 60.10 mm for the past two seasons, excluding 2016/2017, while the 5-year, 20-year and 30-year average is above 80 mm.

Table 5 below shows that during January, when rainfall is crucial for the pollination of Maize (pod filling), a decline in the 5-year average to 73.66 mm from the 108.51 mm long term average was seen. The 10-year average is 107.68 mm. The 2-year average is only 79.75 mm, almost 30 mm, or 26% below the long-term average.

Table 5: The average rainfall totals for the North West province for January to July (mm)

SEASON	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	TOTAL	NOTE
30-year average	98.34	81.88	75.21	39.31	15.10	6.64	316.47	excl. 16/17
20-year average	103.09	74.71	76.91	40.00	18.48	7.72	320.93	excl. 16/17

10-year average	107.68	60.70	71.68	41.27	13.64	12.45	307.42	excl. 16/17
5-year average	73.66	62.97	71.22	34.77	7.26	5.62	255.49	excl. 16/17
3-year average	78.72	72.68	85.90	39.84	11.73	6.96	295.83	excl. 16/17
2-year average	79.75	33.62	70.79	52.46	16.24	10.36	263.22	excl. 16/17

Source: SAWS (2017), Compilation: own

The five-year average for February month is 62.97 mm versus the long term average of 81.88 mm, but during the past two years, the average was only 33.62 mm, or 54% of the long-term average, whilst temperatures soared during this time as well, negatively impacting Maize yields in the province. When the seasonal totals (July to June) is compared in table 6 below, it shows the decline of 124.13 mm in the 5-year average from the long term average stands out very clearly. What is even more evident of lower yield during the past two seasons (harvesting during 2015 and 2016), is the total seasonal rainfall was only 407.69 mm, or 80% of the long-term average, and a total of 132.62 mm below the long term average, and even 8.49 mm below the 5-year average.

Table 6: The seasonal average rainfall totals for the North West province (mm)

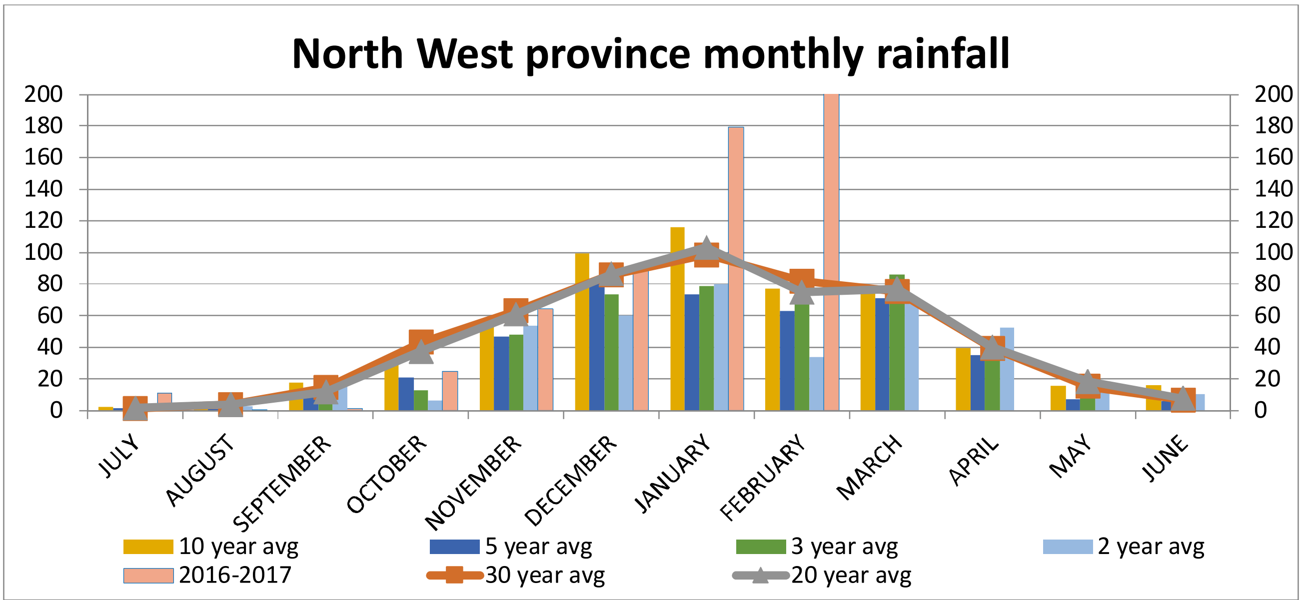
SEASON	TOTAL (mm)	DIFFERENCE FROM LONG-TERM (mm)	NOTE
30-year average	528.25		excl. 16/17
20-year average	523.26	-4.99	excl. 16/17
10-year average	490.20	-38.05	excl. 16/17
5-year average	416.18	-112.07	excl. 16/17
3-year average	446.49	-81.75	excl. 16/17
2-year average	407.69	-120.55	excl. 16/17

Source: SAWS (2017), Compilation: own

It can clearly be seen from figure 15 below, that lower rainfall fell across the North West province and it had an impact on the amount of Maize that was harvested during July 2015 and July 2016. The 2016/2017 season until 28 February 2017 was also included in this graph, to illustrate that this season's rainfall corresponds with predictions of normal to La Niña like conditions. During October, November and December of 2016, the two, three, five and ten-year averages were exceeded, whilst the total for the July to December timeframe, 2016's rainfall is very close to the 20 and 30 year-year averages.

A good graphical illustration can be seen of low rainfall during the start of 2015 and 2016 with the light blue bars clearly identifying this. The contrasting part is the record amount of rain that fell during January and February 2017, standing out clearly below. The North West province has exceeded all long-term averages and stood at 573.2 mm on 28 February 2017 of rainfall that fell since 1 July 2016. It could very well prove to be the best season the province has seen since the 729 mm that fell during the 1996/97 season. The most recent season with rainfall close to 700 mm, was during the 2007/08 season when 674 mm of rain fell. During the 1996/97 season neither a La Niña or El Niño was experienced, whilst during the 2007/08 season, a moderate La Niña event was experienced.

Figure 15: Graphical rainfall records for the North West province for the past 30 years



Source: SAWS (2017), Compilation: own

To ensure the seasonal averages is in-line to work with, the median for the same periods as earlier was determined. Researchers argue that it is much safer to work with the median of seasons instead of averages.

Table 7: The seasonal median and average rainfall totals for the North West province (mm)

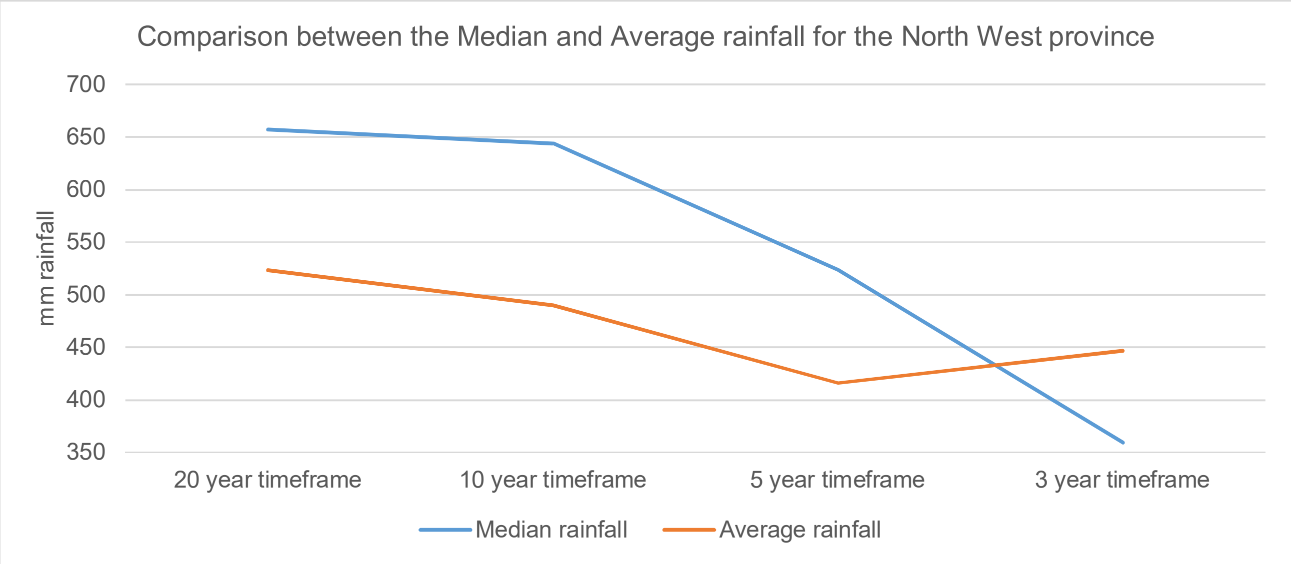
North West Province rainfall	SEASON TOTAL-MEDIAN (mm)	DIFFERENCE FROM 30-YEAR MEDIAN (mm)	SEASON TOTAL-AVERAGE (mm)	DIFFERENCE FROM 30-YEAR AVERAGE (mm)	MEDIAN DIFFERENCE TO AVERAGE
30 year timeframe	520		528.25		
20 year timeframe	657	137.00	523.26	-4.99	133.74
10 year timeframe	644	124.00	490.20	-38.05	153.80
5 year timeframe	524	4.00	416.18	-112.07	107.82
3 year timeframe	359	-161.00	446.49	-81.75	-87.49

Source: South African Weather Services (2017), Compilation: own

Table 7 above show the comparison of the median and the average seasonal rainfall in the 30-, 20-, 10-, 5- and 3-year timeframe. In only two instances, the 3- and 30-year timeframe, the median is lower than the average. In all the other instances, the median is higher and in some cases much higher than the average rainfall.

The data from table 7 above has been graphed below in figure 16 for easy reading. The difference between the mean and the average can be clearly seen, with the median almost constantly higher than the average most periods evaluated.

Figure 16: Comparison between the median and average rainfall for the North West province.



Source: SAWS (2017), Compilation: own

The 2015 calendar year has seen South-Africa gripped by the worst drought in 23 years. Scientists have determined that 2015 was the warmest year in South Africa since records began in 1880. Five provinces including KwaZulu-Natal, Free State, North West, Limpopo and Mpumalanga have been declared disaster areas after this major event according to Times Live (2016). Water levels in dams used for irrigation of grain and the spread of rainfall has had a massive impact on the whole agricultural sector, and indirectly on the whole economy as well.

The sea surface temperatures around the South African coast and in the Niño region plays a very big part in determining what type of season can be expected in the South African summer each year when summer grain crops are planted. When looking back at the summer of 2015/2016, then it was quite a unique situation that played off in South Africa.

A very good explanation on South-African weather impacts from the Niño region was given by Nigrini (2016). The process that determines the sea water temperature in the Niño regions are called the eastern trade winds. When these trade winds start to blow from east to west, they move the warmer water along the South-American coast further westwards towards Asia, and an upwelling of colder water takes place in the Niño region. This causes a La Niña to develop.

The opposite is also true, that when trade winds weaken in the Niño region, the warmer water stays in the Niño region, or drift eastwards, and prevents the upwelling of colder water. The upwelling of warmer water in the Niño region causes sea temperatures to rise to above normal levels and this causes an El Niño to develop according to Nigrini (2016).

According to Nigrini (2016), two of the most important factors for summer rainfall in South Africa is the seawater temperature in the Niño 3 region, as well as the sea water temperature along the KwaZulu-Natal coast. It is true that the warm Mozambique stream is flowing along the coast from north to south, but when the water gets too warm caused by trade winds blowing in warmer than normal water from the western and southern coast of South-Africa, it can lead to the forming of tropical cyclones. What happens when tropical cyclones form in the Indian Ocean off the KwaZulu-Natal coast, is a low-pressure system emerge, and "pulls" most of the moisture that is over South Africa to over the ocean, and causes rain to fall over the sea, not over land according to Nigrini (2016).

An Indian Ocean high pressure system forming over KwaZulu-Natal coast, is one of the most important elements needed for rain across the interior parts of South Africa where summer grains are planted. When a high-pressure system forms over KwaZulu-Natal during the South African summer months, it creates the north-eastern wind to blow in/channel moisture from the tropics over the interior of South Africa.

When the north-eastern wind blows, it keeps the warmer water on South African east coast in a narrow band, and forces it to flow in a southern direction, creating an upwelling of cooler water either side of it according to Nigrini (2016). The cooler the water, the better the chances are of a surface high developing, and that increases the chances for rain over the interior. When a high-pressure system on the eastern part of the country is in place, and a low-pressure system (upper-air low) forms over the central and western parts of the country, conditions for widespread rainfall increases. As stated previously, in a high-pressure system, air is flowing anti-clockwise, and this process is what pushes colder air from the ocean to the interior parts of South-Africa. If this high-pressure system is not in place, the amount of cold air pushed over the interior diminishes and lowers the chances of rainfall according to Nigrini (2016).

During summer months, moisture is transported from the Inter tropical convection zone along the equator in Africa. The trade winds allow this moisture to flow southwards towards the Southern Africa regions. When a high-pressure system forms on the east coast of South Africa, cooler air is flowing towards the central parts of South Africa, and with the moisture coming from the Inter tropical convection zone, a rise of moistures occurs creating favourable rainfall conditions for the summer rainfall regions. It is true that high moisture from the inter tropical convection zone can be present over South Africa, but without a good and solid burst of cold air from the north-eastern parts of South Africa, only heat storms and thunderstorms will occur, and be sporadic, not widespread rainfall that is needed to aid crops according to Nigrini (2016).

2.8. GRAIN PRICE BACKGROUND

According to Mofokeng (2012), "Futures markets are important for the hedger, because they are used to reflect expected future prices." Mofokeng (2012) also added that "According to theory, markets for futures transactions are markets for contracts to future spot transactions." Burns (1979) reported that such markets entail a means of effective contracts to future transactions in commodities as well as a way of collecting and disseminating information on the terms of such contracts. Burns (1979) added that "Market forces determine both the types of contracts for future transactions and the maturity limits of those contracts. It should be recognized that market forces operate in a particular institutional framework, including regulatory and other governmental policies." Burns (1979) defines a futures contract as an agreement between two parties, one to buy and the other to sell a stated quantity of a commodity of given quality for delivery at a future date (or over a period of time) at a specified price and at a specified location.

Groenewald et al. (2003:106) and Giddy (2015) outlined the six important steps below, which are designed to help risk managers determine whether or not their companies stand to benefit from a hedging program or not.

“Step one: Identify the risk”

“Before management can begin to make any decision about hedging, they must first identify all of the risks to which the enterprise is exposed. These risks will generally fall into two categories, i.e. operational risk and financial risk.”

“Step two: Distinguish between hedging and speculating”

“According to the Chicago Board of Trade (1998), the reason that risk managers are sometimes reluctant to hedge is because they associate the use of hedging tools with speculation. Speculation is the mechanism in which traders try to profit from buying or selling futures and/or options contracts by anticipating future price movements. They believe hedging with futures introduces additional risk, while in reality the opposite is true. A properly constructed hedge always lowers risk. It is by choosing not to hedge that managers regularly expose their companies to additional price risk.”

“Step three: Decide how much to hedge”

Hedgers may not be able to eliminate all the price risk by hedging; they also have to keep in mind that there is quantity risk (uncertainty over the size of the grain crop that is involved. Therefore, they have to decide on how much to hedge. According to Edward and Ma (1992), this decision depends upon a hedger’s risk preference.

“Step four: Evaluate the cost of hedging in light of the costs of not hedging”

The cost of hedging can sometimes make risk managers reluctant to hedge. Yet the alternative has to be considered. Derivatives tend to be cheaper because of lower transaction costs that exist in highly liquid forward and option markets (Edward and Ma, 1992:163; Groenewald et al., 2003).

“Step five: Do not base a hedging programme on market view”

Giddy (2015) states that many corporate risk managers attempt to construct hedges on the basis of their outlook for interest rates, the exchange rate or some other market factors.

However, the best hedging decisions are made when risk managers acknowledge that market movements are unpredictable. A hedger should always seek to minimize price risk. It should not represent a gamble on the direction of market prices.

"Step six: Understand the Hedging tools"

According to Edward and Ma (1992), lack of familiarity with derivative products was found to be the factor that contributes most to the reluctance to use forward contracts. Some managers view derivatives as instruments that are too complex to understand. The fact is that most derivative solutions are constructed from two basic instruments: forwards (Swaps, Futures, etc.) and options (Caps, Floor, Calls, Puts, etc.)

According to Mofokeng (2012), "the price of Maize is normally determined by the world Maize price, the exchange rate, stock levels and the relative size of the domestic Maize crop. Maize that is located in different countries has different values. For example, Maize in the United States of America (USA) does not have the same value as Maize in South Africa; hence the price of Maize in different markets must be adjusted to take account of differences in transport costs, exchange rates, etc. in order to make comparisons possible. The adjusted price is called a parity price, which is calculated with respect to a reference point and a specific point in time." In South Africa, the reference point for commodities trading on SAFEX (excluding soybeans) is Randfontein (Mofokeng, 2012)."

According to the NDA (2007), the price that farmers receive if they sell their Maize on the international market is known as the export parity price. To calculate this, the international commodity price is adjusted by a factor to account for the difference between the location and the quality of Maize, as well as the costs that are incurred to export the Maize from Durban. The figure is then converted to local currency using the current exchange rate. The import parity price reflects the price that Maize millers, traders and feed manufacturers would pay if they had to buy imported Maize.

According to NAMC (2008) in theory, import parity is referred to as the ceiling price – if the domestic price increases above this level, millers will rather import. Export parity, on the other hand, is where Maize producers will sell their Maize to foreign millers until domestic buyers are willing to bid up the domestic price to this level of parity. If the domestic buyers lower their price below this level of parity, exports will resume. Therefore, in theory the export parity is referred to as a floor price.

Mofokeng (2012) states that in South Africa the prices of commodities trading on SAFEX are adjusted to the parity price by adjusting the international commodity price (Free on board – (FOB) Gulf price) by taking into account all the costs incurred in bringing the Maize to Durban. This price is called the CIF (Cost Insurance Freight) price, and is adjusted to the local currency using the current exchange rate. Once this is done, all local Rand based costs (including off-loading, interest, insurance, local transport costs and any tariff applicable) can be added, resulting in a final local price per ton at the reference point.

Mofokeng, (2012) also states that "the futures price, or the price at which buyers and sellers are prepared to buy and sell Maize futures contracts for a future month reflects a consensus of market opinion." "For example, it combines the opinion of a producer in the Free State who expects his crop to be smaller because of damage caused by wind and heavy rains, with the opinion of a Mpumalanga producer who expects a bumper crop, with the opinion of a feed manufacture who expects demand for Maize to be higher because of herd expansion after good rains and the opinion of a grain trader who expects a good US crop and changes in the statutory Maize marketing scheme (SAFEX APD 2002:74)." This shows that the futures price is a forecast of what the cash price of Maize will be for a given future month based on currently available information. Futures prices will change (move up and down) as the current available information changes. Furthermore, the futures price for each successive month in the production season will usually be higher than the preceding month by the amount of storage and finance charges or carrying charges.

According to SAFEX APD (2002:74), "the futures prices will not always reflect the full carrying charges as sellers are always quick to capitalize on any carrying charge that is greater than the actual cost of storage or transport. Future prices may sometimes reflect negative carrying charges when there is a strong demand for Maize and short supply." Mofokeng, (2012) also state that “the future price of the last month of the Maize marketing season (March) may differ sharply from the first two months of the next marketing season (May and July). The March contract reflects old crop Maize which may be in short supply, while May and July reflect the new crop as the harvesting period starts during these months, which might depress the price of Maize (SAFEX APD 2002:74).”

2.9. MAIZE PLANTING IN THE NORTH WEST PROVINCE

White Maize and yellow Maize are used in a lot of products used by South-African consumers daily and is the country’s most important field crop and the staple food of the population according to the DAFF (2015). The price movement can have a significant impact on the whole economy, from, the low-income class to the high-income class.

Farming activities are heavily dependent on rainfall each year in South Africa. During the 2015/2016 season, the Free State province planted the biggest number of Maize hectares, around 40% of total Maize sowings, and the North-West province the second biggest sower of Maize at around 25%, according to the DAFF (2015). What is important to note, is that Maize consist of two variants, namely White Maize, and yellow Maize. White Maize is predominately used for human consumption by means of milling the White Maize into Maize meal and selling it to the consumer, while yellow Maize is used mainly for animal feed, which include pigs, chicken, and cattle. The North West province plant around 30% of the total White Maize plantings in the country, which is around 5% more than the proportion total Maize planting in the North-West province in relation to South-African Maize plantings according to DAFF (2015).

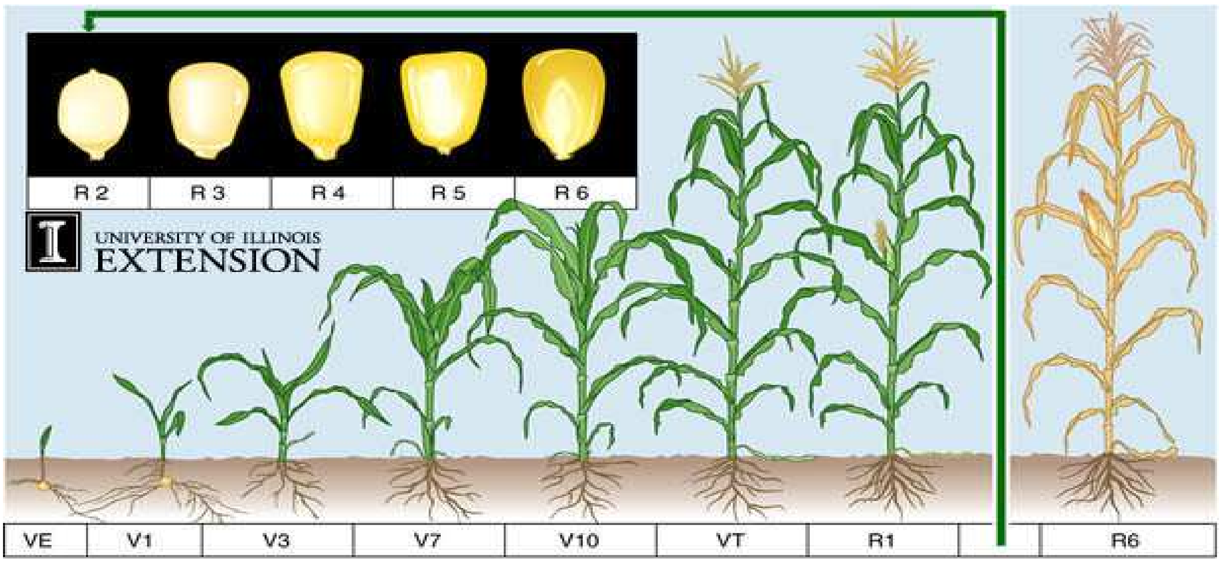
According to the Du Plessis (2003), Maize needs around 350 to 450 mm of water per season which is mainly acquired from the soil moisture. Rainfall of more than 450 mm can be beneficial and will increase yield. Between 10 and 16 kg of grain is produced for every millimetre of water consumed. At maturity, each plant will have consumed around 250 litres of water. The assimilation of nitrogen, phosphorus and potassium reaches a peak during flowering. At maturity level, the Maize plant takes up 8.7 gram of nitrogen, 5.1 gram of phosphorus and 4 gram of potassium. Each ton of grain produced removes around 15 to 18 kg of nitrogen, 2.5 to

3 kg of phosphorus and 3 to 4 kg of potassium from the soil. Frost is a threat every year. The norm is 120 – 140 frost-free days from planting is needed to prevent frost-damage. The growth and development consist of 10 stages.

During germination, the growth point and the entire stem are about 25 to 40 mm below the soil surface. Under warm, moist conditions seedlings emerge after about 6-10 days, but under cool or dry conditions this may take two weeks or longer. The optimum temperature range for germination is between 20 and 30 degrees Celsius. (Odell's World, 2010)

The first more or less 60 days until the tassel stage is known as the vegetative stage, whilst from the silking stage, the reproductive stage starts (Odell's World, 2010). Figure 17 below show the different stages from plant to harvest time. A description of each stage is also attached.

Figure 17: The growth stages of a Maize plant



Source: Odell's World (July, 2010)

Vegetative stage:

VE: Emergence

V1: First leaf of collar is visible

V2: Second leaf of collar is visible

V3: Third leaf of collar is visible

V (n) nth leaf of the collar is visible

VT: Tasseling is almost completely visible

Reproductive stage:

R1: Silking visible outside the husks. Fallen Pollen grains are captures by the silk and grow down the silk

R2: Blister (kernels are White and resemble a blister in shape) (Drought during this period can reduce potential by 6% per day)

R3: Milk (kernels are yellow on the outside with a milky inner fluid)

R4: Dough (milky inner fluid thickens to a pasty consistency)

R5: Dent (almost all the kernels are denting)

R6: Physiological maturity

Growth stage lasts from the planting of the seed up to when seeding is just visible from the soil surface. Growth stage 10 is reached when the plant is biologically mature. A few of the most important steps will be discussed below, not all of the steps (Odell's World, 2010). Table 8 below breaks down the different stages of a Maize plant since seeding up to physiological maturity.

The three phases marked in red is the most crucial part of a Maize plant's development. The 60^{th} to the 80^{th} day period after emergence is the time when the most water is consumed (Odell's World, 2010). A total of more or less 120 mm of water is needed during this phase for optimal yield. Every mm of water less than this amount will result in yield losses. During the blistering stage, 6% yield losses per day can be experienced during drought situations (Odell's World, 2010).

Table 8: Maize stages and water needs

Phase	Name	Days after emergence	Day stage ends	days	Water need per day (mm)	Total water usage per stage (mm)	Total days
Seeding							
Emergence	VE	5	10	7	3	21	
Leaf stage	V1-V12	15	60	45	3	135	156
Tasseling (VT)	VT	60	67	7	7	49	
Silking (R1)	R 1	63	68	6	7	42	
Blister	R 2	73	78	5	7	35	126
Milk	R 3	83	88	5	6	30	
Dough	R 4	89	94	5	5	25	
Dent	R 5	99	104	5	5	25	
Maturity	R 6	104	135	31	3	93	173
Total				**116**		**455**	**455**

Source: Odell's World (July, 2010)

Table 9 below has been adapted from above data in table 8. The typical planting date scenarios in the North West province for Maize has been summarized using the data from Odell's World. Modern day cultivars differ between Seed Companies. Farmers can plant Maize and Sunflower seed that is either fast growers or normal growers, depending on the time of the season they plant. Below data is just indicative and used in broad spectrum, but every farmer and area will have different characteristics.

Table 9: Typical planting dates in the North West province

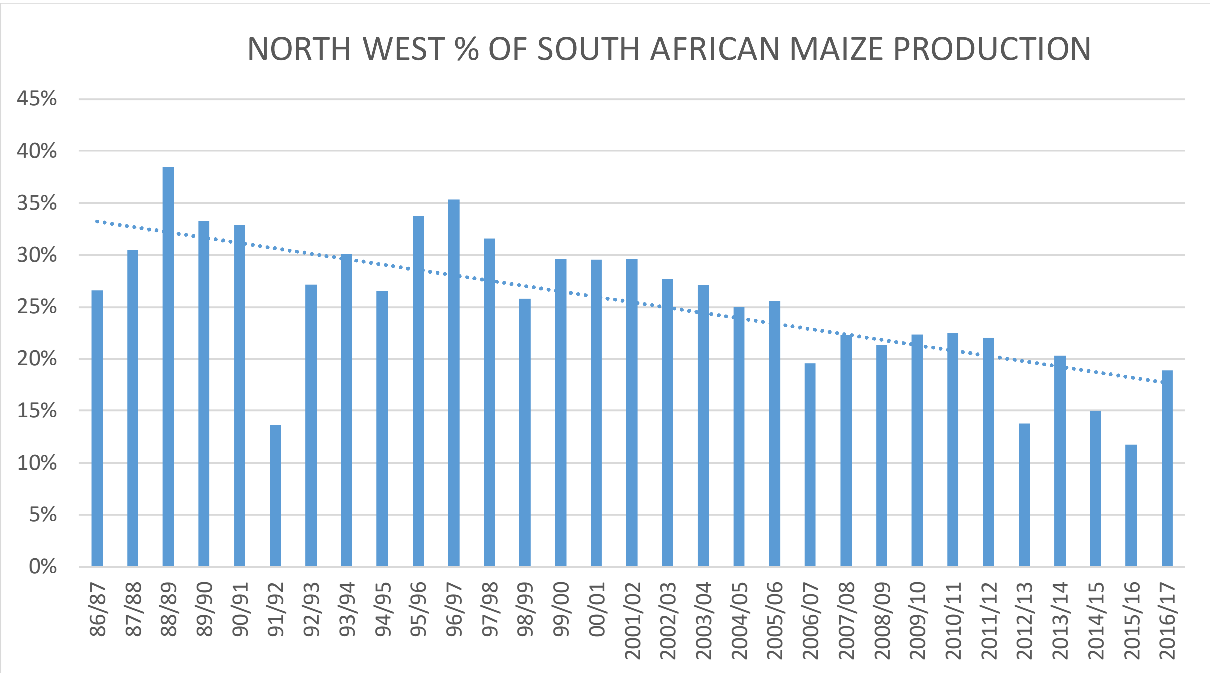
Maize plant date	21-Nov	28-Nov	05-Dec	12-Dec	19-Dec	26-Dec	02-Jan
Emergence days	10	7	7	7	7	7	7
Date emerged	1-Dec	5-Dec	12-Dec	19-Dec	26-Dec	2-Jan	9-Jan
Tassel stage start	60	60	60	60	60	60	60
Date	30-Jan	03-Feb	10-Feb	17-Feb	24-Feb	03-Mar	10-Mar
Critical part duration	18	18	18	18	18	18	18
Critical part end	17-Feb	21-Feb	28-Feb	07-Mar	14-Mar	21-Mar	28-Mar
Maturing	56	56	56	56	56	56	56
Physiologically ripe	14-Apr	18-Apr	25-Apr	02-May	09-May	16-May	23-May

Source: Odell's World (July, 2010) and own compilation

When the average planting date is calculated from the table above, the date will be 12 December, with emergence on 19 December. The critical part for Maize pollination will start on 17 February, and last for 18 days to the 7th of March. During the pollination stage, the Maize will need the most water for average to above average yields. The big question for farmers will be the following, whether to use the moisture in the ground during pre-season rainfall to aid their plantings and plant before the average, or "normal" window, or if pre-season rainfall was absent, to still plant in the dry ground and hope for rainfall, or the third option, to wait for rainfall before planting, but the ideal planting window will be missed which could have an impact on yield when harvesting.

Figure 18 below show the declining trend of Maize production in the North West province versus the South African Maize production. The average was around 29% during the 1990's, and declined to 25% during the 2000's, and only 17% for the 2010's. Overall since the 1990's, the North West province has produced around 25% of the Maize in South Africa, but since 2000, only 22%.

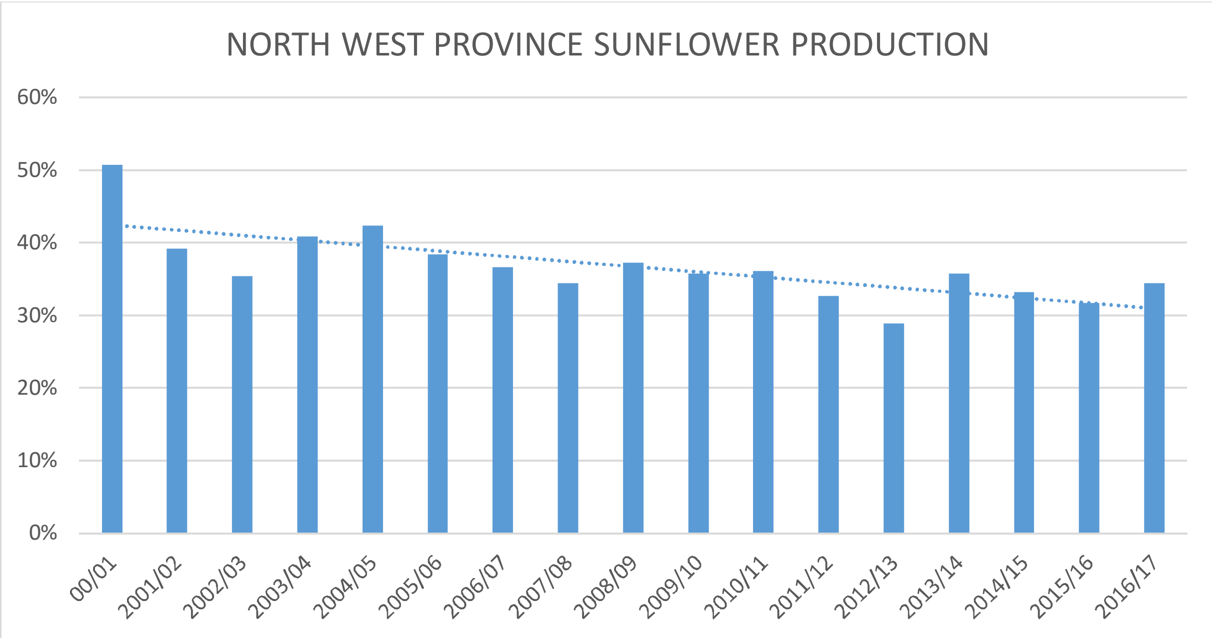
Figure 18: The North West province and percentage of the South African Maize production



Source: DAFF (2017)

Figure 19 below show the average Sunflower tonnages that have been produced by the North West province since 2000. On average the province has produced around 37% of the South African Sunflower, while this figure has dropped to around 33% during the past 6 seasons. What is interesting to note is the declining trend for both Maize and Sunflower production totals in the North West province.

Figure 19: The North West province and percentage of the South African Sunflower production



Source: DAFF (2017)

CHAPTER 3:

This chapter consist of an empirical study where data was collected on a quantitative basis through research. It includes a research design, population sampling, data collection, and data analysis. The data analysis consisted out of five steps. They are:

Step 1: Collecting the rainfall statistics and calculating the average rainfall per month for the North West province.
Step 2: Can the NIŇO 3 and IOD SST's individually or together predict rainfall for the North West province?
Step 3: Doing the correlation between the NIŇO 3 and IOD SST's and rainfall for the North West.
Step 4: Calculating the correlation between the monthly rainfall in the North West province and the prices of White Maize and Sunflower.
Step 5: Getting the results and analysing them.

3. RESEARCH METHODOLGY

3.1. RESEARCH DESIGN AND METHODS/ RESEARCH METHODOLOGY

3.1.1. DESCRIPTION OF OVERALL RESEARCH DESIGN

Collecting rainfall data for the North West province in monthly totals

Collecting price data for White Maize and Sunflower and dividing them into monthly totals / movements

Collecting SST data for the Niño 3 region in the Pacific Ocean, and the IOD data for the Indian Ocean.

Correlating the data from above and analysing the outcomes

The nature of the study will be quantitative of nature. The variables include monthly rainfall totals in the North West province, price movement of White Maize and Sunflower, and the weekly and monthly Niño 3 SST and IOD indexes. The analyses will require different techniques. The idea behind this thesis is to find the relationship between the NIŇO 3 SST and IOD, monthly rainfall in the North West province and price movement.

The nature of the study will be longitudinal, because changes can be mapped, the mechanisms can contextualize and the processes through which changes are created can be analysed vertically and horizontally to establish inter-connections over time. Longitudinal studies can provide insights into the time-order of the variables so that causal inferences can be made. Data will be tested numerously and not only once to determine relationships between the different variables.

3.2. POPULATION/SAMPLING

Who?

Summergrain Markets in South Africa
The NIŇO 3 SST in the Pacific Ocean,
The IOD in the Indian Ocean.

Located where?

Rainfall in the North West province.

When?

Since 1971

How?

Impact of rainfall in the North West province and other fundamental factors on the South African grain markets

3.3. DATA COLLECTION

The price data was collected via the Thompson Reuters Research Portal as well as the South African Grain Services, the weather data was collected from the National Oceanic and Atmospheric Administration (NOAA) in the United States of America, The Australian Weather Bureau, The Japanese Weather Bureau, whilst rainfall data was supplied by the South African Weather Services (SAWS).

3.4. DATA ANALYSIS

The data analysis for this dissertation was done by the NWU Statistical Consultation Service Department in Potchefstroom.

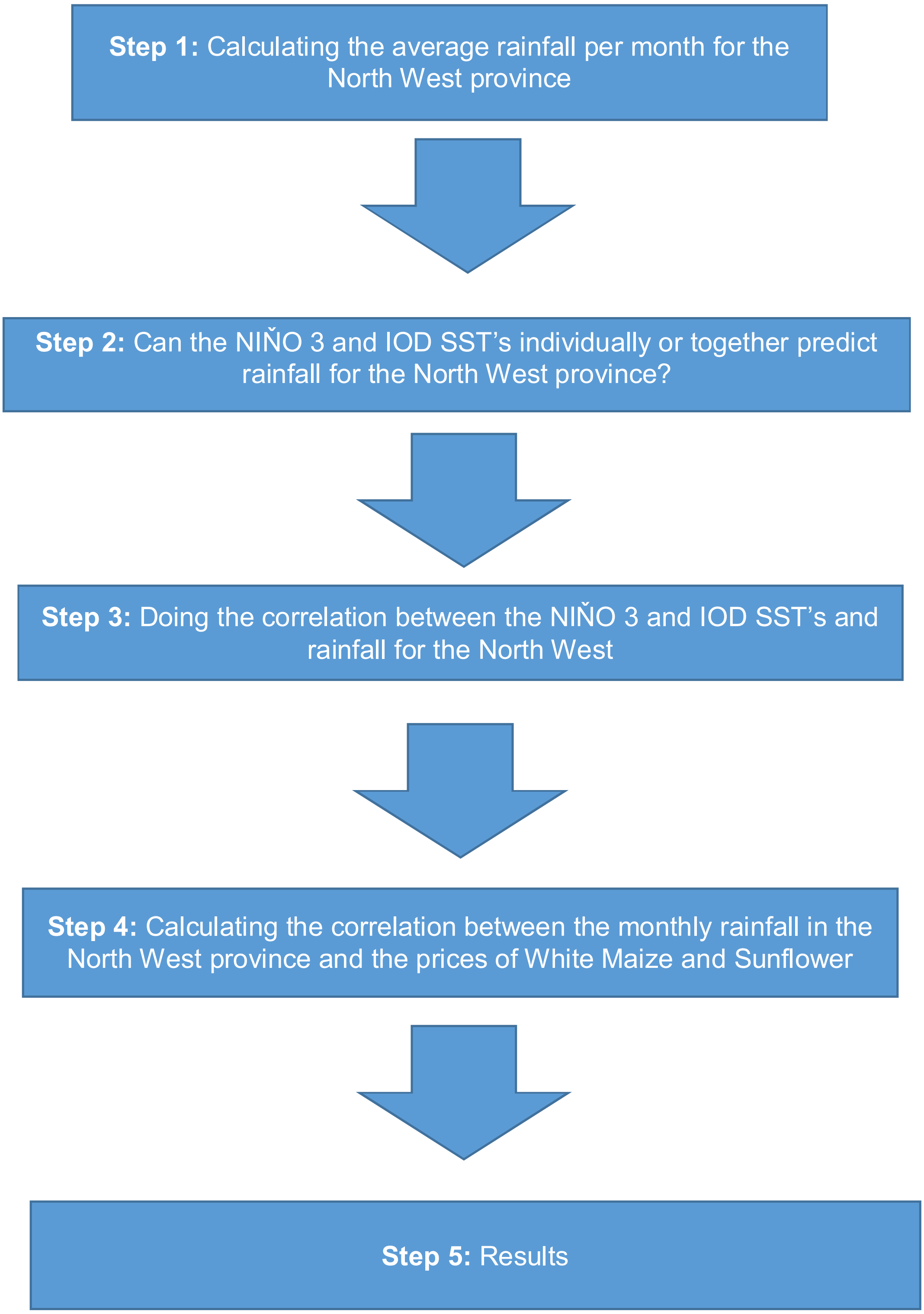
The plan is to advise farmers during October and November on more or less what to do, should they plant, when the most likely time to plant is, what the price tendencies is in years that closely correlate with this year and what should the marketing plan be for the season ahead. As stated earlier, the Niño 3.0 SST is very important for determining the weather patterns in South Africa. But the other potentially very important figure is the sea surface temperature along the KwaZulu-Natal coast and the IOD index.

There will be two main data analyses done for this dissertation. The first analysis will be correlating data for the Niño 3 region, IOD and rainfall in the North West province and the second analysis will be correlating the monthly rainfall in the North West province to the price movement for White Maize and Sunflower.

Nigrini (2016) states that no two years are the same, meaning that one El Niño or La Niña is not a mirror effect of the next one. But what is important to note is that there are a few cues as to what more or less can be expected with what has happened previously. The sea surface temperatures in the Niño region is very important, as well as the sea water temperature around the South African coast. The aim will be to correlate the Niño 3 SST's for the current year and the weekly SST's versus previous years and selecting the three most closely related years. Drawing up correlations between the current year or seasons Niño 3 SST's before the season starts off during September and October, can help and assist more or less when rainfall can be expected, when to plant or not to plant and what will be the potential impact on prices going forward.

The aim is not to be a weather forecaster, nor a price predictor. What this dissertation is trying to do is to evaluate the current year's SST's in the Niño 3.0 region with previous years, comparing monthly and weekly rainfall tendencies for that year and see what prices on the Safex market did for that season. It is important to inform a producer of summer grains in the North West province beforehand what conditions currently are, what is expected for the season ahead and during what times of the season he must take into account prices and hedge or not on Safex?

Figure 20: Flow chart of the data analysis that was done for this dissertation.



3.4.1. THE NIŇO 3 SST, IOD SST AND THE NORTH WEST PROVINCE RAINFALL

The data in Appendix A was compiled using the Thompson Reuters Research Portal, the NOAA website, and the rainfall data was supplied by the South African Weather Services (SAWS). All this data was compiled into a table and placed in monthly order since 1996 until December 2016. For example, January 1996 had a Niño 3 temperature of -0.67 ˚C, a IOD reading of 0.25 ˚C and the monthly rainfall total in the North West province was 123.22 millimetres.

STEP 1:

3.4.1.1. The average rainfall per month

The first analysis that was done, was the average rainfall per month for the North West province. Rainfall is the dependent variable, and the regression calculation was done.

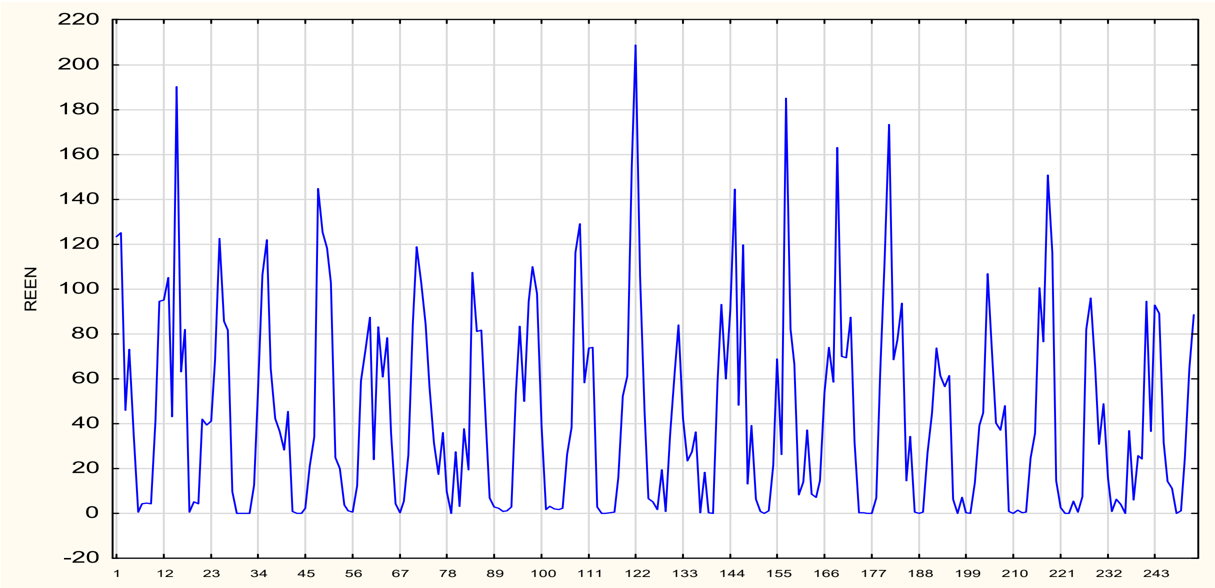
Table 10: Average rainfall per month in the North West province

	Summary Statistics; DV: REEN (Meng_reenNino)
Statistic	Value
Multiple R	0.0965325867
Multiple R²	0.0093185403
Adjusted R²	0.00535581446
F(1,250)	2.35154807
p	0.126423165
Std.Err. of Estimate	43.9924196

	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .09653259 R²= .00931854 Adjusted R²= .00535581 F(1,250)=2.3515 p<.12642 Std.Error of estimate: 43.992					
N=252	b*	Std.Err. of b*	b	Std.Err. of b	t(250)	p-value
Intercept			51.27037	5.559061	9.22285	0.000000
tyd	-0.096533	0.062950	-0.05842	0.038095	-1.53348	0.126423

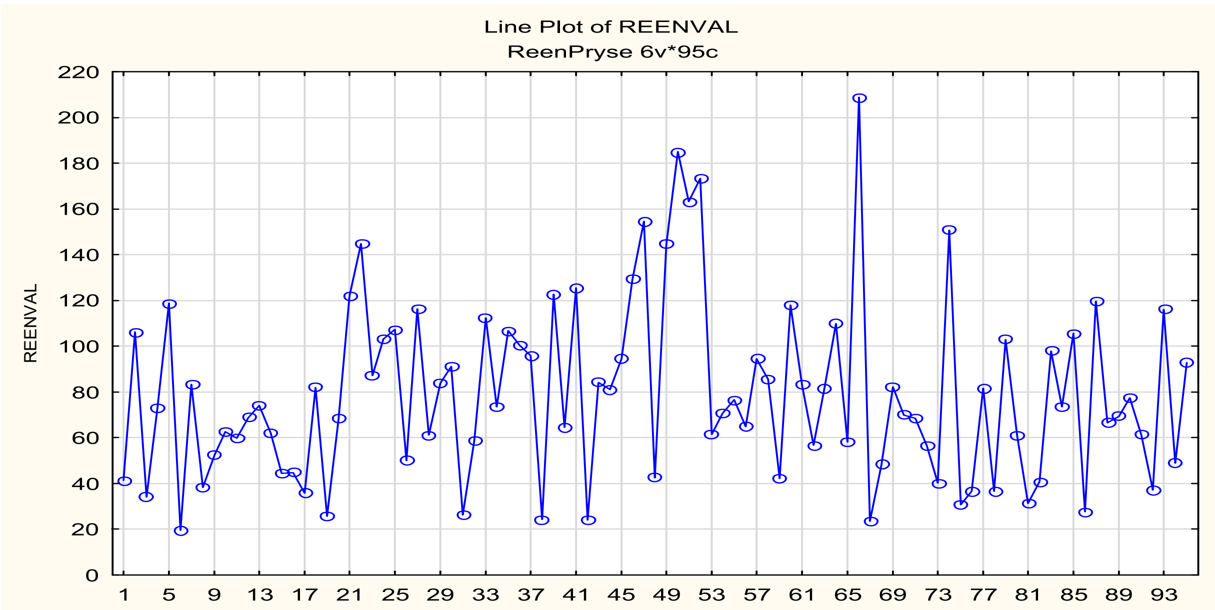
b=51.27, if seasonal differences are ignored, which means on average the North West province's average rainfall over time is 51.27 mm/month as can be seen below in figure 21.

Figure 21: The monthly rainfall (January to December) in the North West province since 1996



The following analysis, show a graph that was drawn up which shows the rainfall in the North West province for the November to March timeframe since 1998. Figure 22 below show that there is a slight upward trend in the rainfall for the North West province in the November to March timeframe since 1998.

Figure 22: Monthly rainfall from November to March from 1998 to 2016



STEP 2:

3.4.1.2. Can the NIŇO 3 and IOD SST's predict rainfall for the North West province?

The second analysis that was done, was to take the same data as in Appendix A, and do a regression analysis on the dependent variables to see whether the NIŇO 3 and IOD SST's can predict rainfall for the North West province.

A hypothesis test is used to validate or invalidate a claim about a population. The elements of a population that is most often used is the population mean, the population proportion and the difference in the two population means or proportions. When a hypothesis test is done, a p-value help you determine the significance of your results. It can be used to test the validity of a claim that is made about a population. This is called the null hypothesis. A small p-value (typically $p < 0.05$) indicate strong evidence against the null hypothesis, so you can reject the null hypothesis. A large p-value ($p > 0.05$) indicate weak evidence against the null hypothesis, so you fail to reject the null hypothesis.

The first hypothesis test was done to determine if both the NIŇO3 and IOD SST's can determine rainfall in the North West province. The p-value of 0.162 is bigger than the norm of 0.05, so the null hypothesis cannot be rejected.

The standard error of estimate / standard error of the regression represents the average distance that the observed values fall from the regression line. Small values indicate that the observations are closer to the fitted line. In Below analysis in table 11, the residuals have a Standard error of estimate of 43.96, which is very high and means that together the IOD and NIŇO3 cannot predict rainfall in the North West province ($p=0.162$).

Table 11: The NIŇO 3 and IOD SST Regression

Statistic	Summary Statistics; DV: REEN (Meng_reenNino) Value
Multiple R	0.120518062
Multiple R²	0.0145246032
Adjusted R²	0.00660913821
F(2,249)	1.83496525
p	0.161770895
Std.Err. of Estimate	43.964694

N=252	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .12051806 R²= .01452460 Adjusted R²= .00660914 F(2,249)=1.8350 p<.16177 Std.Error of estimate: 43.965 b*	Std.Err. of b*	b	Std.Err. of b	t(249)	p-value
Intercept			42.12859	10.45427	4.02980	0.000074
NINO 3	-0.125745	0.069648	-5.47945	3.03497	-1.80544	0.072214
IOD	0.013656	0.069648	3.27695	16.71320	0.19607	0.844716

The second hypothesis test was done to determine if the IOD SST's can determine rainfall in the North West province. The p-value of 0.524 is bigger than the norm of 0.05, so the null hypothesis cannot be rejected. The standard error of estimate / standard error of the regression represents the average distance that the observed values fall from the regression line. Small values indicate that the observations are closer to the fitted line. In Below analysis, the residual has a Standard error of estimate of 44.16, which is very high and means that the IOD cannot predict rainfall in the North West province (p=0.524).

Table 12: The IOD SST Regression

Statistic	Summary Statistics; DV: REEN (Meng_reenNir Value
Multiple R	0.0402981539
Multiple R²	0.00162394121
Adjusted R²	-0.00236956303
F(1,250)	0.406645671
p	0.524260581
Std.Err. of Estimate	44.1629331

N=252	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .04029815 R²= .00162394 Adjusted R²= ----- F(1,250)=.40665 p<.52426 Std.Error of estimate: 44.163					
	b*	Std.Err. of b*	b	Std.Err. of b	t(250)	p-value
Intercept			49.74518	9.60840	5.177260	0.000000
IOD	-0.040298	0.063194	-9.67027	15.16458	-0.637688	0.524261

The third hypothesis test was done to determine if the NIŇO 3 SST's can determine rainfall in the North West province. The p-value of 0.057 is just bigger than the norm of 0.05, so the null hypothesis cannot be rejected.

The standard error of estimate / standard error of the regression represents the average distance that the observed values fall from the regression line. Small values indicate that the observations are closer to the fitted line. In below analysis in table 13, the residual has a Standard error of estimate of 43.88, which is very high and means that the NIŇO3 cannot predict rainfall in the North West province (p=0.057).

Table 13: The NIŇO 3 SST Regression

Statistic	Summary Statistics; DV: REEN (Meng_reenNinc Value
Multiple R	0.119885176
Multiple R²	0.0143724554
Adjusted R²	0.0104299452
F(1,250)	3.64550876
p	0.057365384
Std.Err. of Estimate	43.8800635

N=252	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .11988518 R²= .01437246 Adjusted R²= .01042995 F(1,250)=3.6455 p<.05737 Std.Error of estimate: 43.880					
	b*	Std.Err. of b*	b	Std.Err. of b	t(250)	p-value
Intercept			44.10498	2.766684	15.94146	0.000000
NINO 3	-0.119885	0.062789	-5.22412	2.736114	-1.90932	0.057365

Above analysis in table 13 show that no significant statistical correlation was identified between NIŇO3 and the prediction of rainfall in the North West province (p>0.05).

STEP 3:

3.4.1.3. Correlation between the NIŇO 3 and IOD SST's and rainfall for the North West province in different timeframes

Spearman's rank order correlation is a nonparametric measure of rank correlation (statistical dependence between the ranking of two variables). It assesses how well the relationship between two variables can be described using a monotonic function. In below analysis in table 14, the year was divided into two semesters, namely semester one which runs from January to June, and semester two, which run from July to December to try and find a correlation between the IOD and NIŇO3 SST's and rainfall in the North West province.

During the first semester which run from January to June, the correlations are not very strong between rainfall and the IOD SST's at only -0.020 and rainfall and the NIŇO3 SST's at -0.124, but reasonably strong at 0.574 between the NIŇO3 and IOD SST's. This means that the two variables increase concurrently, meaning that if the NIŇO3 SST increase, the IOD SST increase as well.

During the second semester which run from July to December, the correlation between the NIŇO 3 and IOD SST's become weaker at 0.358, and even weaker between rainfall in the North West province and the IOD SST's at –0.056 and rainfall in the North West province and the NIŇO3 SST's at -0.079.

Table 14: Spearman's Rank order correlation between IOD, Niño 3 and Rainfall in the North West province

	Semester=1 Spearman Rank Order Correlations (Meng_reenNino) MD pairwise deleted Marked correlations are significant at p <.05000		
Variable	NINO 3	IOD	REEN
NINO 3	1.000000	0.573650	-0.123832
IOD	0.573650	1.000000	-0.020279
REEN	-0.123832	-0.020279	1.000000

Variable	Semester=2 Spearman Rank Order Correlations (Meng_reenNino) MD pairwise deleted Marked correlations are significant at p <.05000 NINO 3	IOD	REEN
NINO 3	1.000000	0.357506	-0.079724
IOD	0.357506	1.000000	-0.055618
REEN	-0.079724	-0.055618	1.000000

The second part of the analysis is to try and determine what part of variance in the summer rainfall semester is caused by the IOD SST's and NIŇO 3 SST's.

Table 15: How much variance in the summer rainfall semester is caused by the IOD SST's ?

Statistic	Summary Statistics; DV: REEN (Meng_reenNino) Include condition: Somer=1 Value
Multiple R	0.224927021
Multiple R^2	0.050592165
Adjusted R^2	0.0351546392
F(2,123)	3.27721979
p	0.041053284
Std.Err. of Estimate	43.8916095

N=126	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .22492702 R²= .05059216 Adjusted R²= .03515464 F(2,123)=3.2772 p<.04105 Std.Error of estimate: 43.892 Include condition: Somer=1 b*	Std.Err. of b*	b	Std.Err. of b	t(123)	p-value
Intercept			87.9087	14.93135	5.88753	0.000000
NINO 3	-0.072223	0.103147	-2.6478	3.78150	-0.70020	0.485127
IOD	-0.178512	0.103147	-40.6349	23.47937	-1.73066	0.086020

Statistic	Summary Statistics; DV: REEN (Meng_reenNino) Include condition: Somer=1 Value
Multiple R	0.165749699
Multiple R^2	0.0274729626
Adjusted R^2	0.0196300027
F(1,124)	3.50288191
p	0.0636183619
Std.Err. of Estimate	44.2433146

Above analysis show that the IOD SST accounts for around 5% of the variance in the summer rainfall pattern which run from September to March each year. P<0.5 at 0.04, which means that there is a statistically significant correlation.

To summarize above analysis, the NIŇO3 and IOD account for around 5% of the variance in the summer rainfall pattern which run from September to March each year since 1996. It reveals a statistical significance, but as a whole, it is very little.

STEP 4 AND STEP 5:

3.4.2. THE MONTHLY RAINFALL IN THE NORTH WEST PROVINCE AND THE CORRELATION WITH WHITE MAIZE AND SUNFLOWER PRICES

Spearman's rank order correlation assesses how well the relationship between two variables can be described using a monotonic function. In below analysis, the price data on Safex since 1998 to 2016 for White Maize, and since 2000 to 2016 for Sunflower, for November through to March, was grouped together with rainfall for the specific month. The reason the months, November through to March was chosen, is because this is when the most rain falls during a Year in the North West province, and it is also the time when the grain pollinates and enters their crucial stadium of development.

The reason Safex prices was correlated against rainfall in the North West province, is because prices play an integral part of the farmer's income and all round profitability of farming. With the correct information on price movement, informed decisions can be made by the farmer which will lead to prosperity. Prices trade daily on Safex, and price movement can be a mixture of weather forecasts, emotion, fundamental news, time and views of traders on the market. White Maize and Sunflower are the two major crops produced in the North West province, and the correlation between rainfall in the North West province and the prices of Sunflower and White Maize can help make informed decisions.

In Table 16 below the following can be seen. The correlation is slightly inverse from November to March each year between rainfall in the North West province and the price of Sunflower at –0.169, and slightly more inversely correlated between rainfall in the North West province and the price of White Maize on Safex at -0.211. The value of -0.211 means there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize decrease.

What is interesting to note is the correlation between the price of White Maize and the price of Sunflower at 0.926, which is a very strong positive correlation. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well.

Table 16: Spearman Rank order correlation between rainfall in the North West province, White Maize prices and Sunflower prices

	Spearman Rank Order Correlations (ReenPryse) MD pairwise deleted Marked correlations are significant at p <.05000			
Variable	Tyd	REENVAL	WITMIELIES	SONNEBLOM
Tyd	1.000000	-0.127912	0.854213	0.909967
REENVAL	-0.127912	1.000000	-0.211380	-0.168829
WITMIELIES	0.854213	-0.211380	1.000000	0.925503
SONNEBLOM	0.909967	-0.168829	0.925503	1.000000

Firstly, White Maize prices will be analysed and correlated. In below analysis in table 17 between the price of White Maize and time, show that time declare 77% of the variance in the price of White Maize when seasonal shifts are ignored. Time plays a major role in the movement of White Maize prices in South Africa.

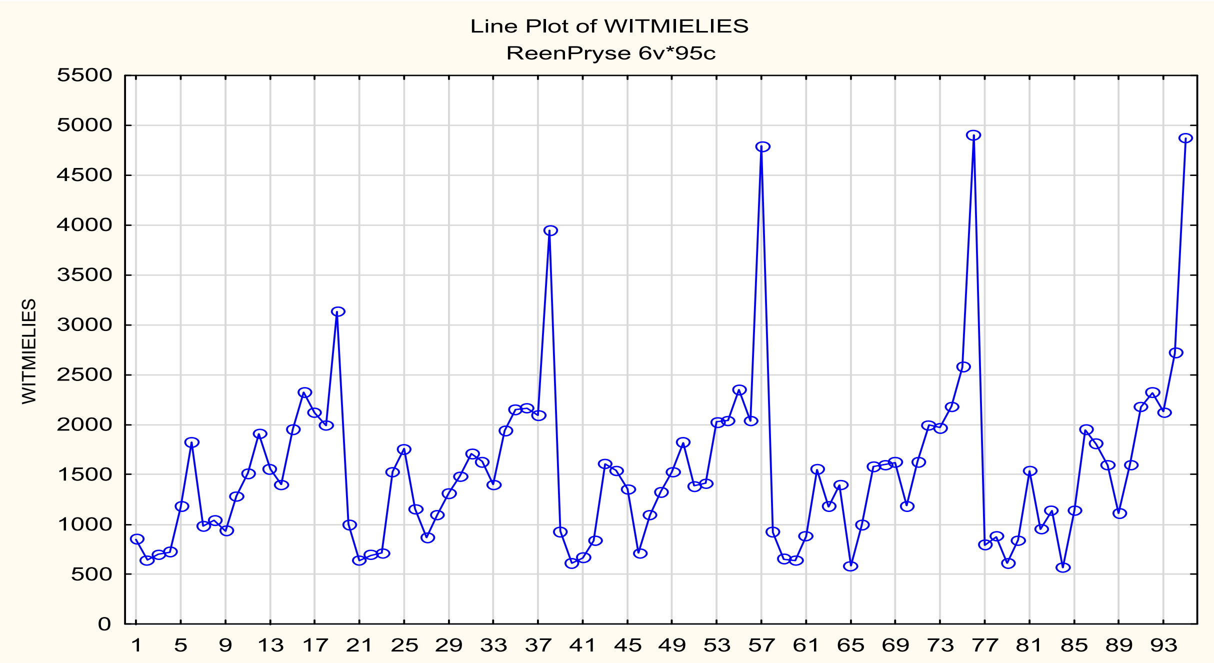
Table 17: The correlation between time and the price of White Maize on Safex

	Summary Statistics; DV: WITMIELIES (ReenPryse)
Statistic	Value
Multiple R	0.770689668
Multiple R²	0.593962565
Adjusted R²	0.589596571
F(1,93)	136.042921
p	6.68192880E-20
Std.Err. of Estimate	549.50723

	Regression Summary for Dependent Variable: WITMIELIES (ReenPryse) R= .77068967 R²= .59396257 Adjusted R²= .58959657 F(1,93)=136.04 p<0.0000 Std.Error of estimate: 549.51					
N=95	b*	Std.Err. of b*	b	Std.Err. of b	t(93)	p-value
Intercept			449.6375	110.6331	4.06422	0.000101
Tyd	0.770690	0.066076	10.0025	0.8576	11.66374	0.000000

Figure 23 below show that the price of White Maize has an upward trend over time, which is good for the producers of White Maize, but not so good for the people buying products which contain White Maize as the prices will also have increased over time.

Figure 23: The line plot of White Maize prices since 1998 through to 2016



Secondly, Sunflower prices trading on Safex will be analysed and correlated. Below analysis in Table 18 show that there is rising trend over time, and that time accounts for 82.8% of the variation in the price of Sunflower trading on Safex.

Table 18: Regression correlation between the prices of Sunflower on Safex and time

	Summary Statistics; DV: SONNEBLOM (ReenPryse)
Statistic	Value
Multiple R	0.909873656
Multiple R²	0.82787007
Adjusted R²	0.825796215
F(1,83)	399.193886
p	1.85821669E-33
Std.Err. of Estimate	637.963605

N=85	Regression Summary for Dependent Variable: SONNEBLOM (ReenPryse) R= .90987366 R²= .82787007 Adjusted R²= .82579622 F(1,83)=399.19 p<0.0000 Std.Error of estimate: 637.96					
	b*	Std.Err. of b*	b	Std.Err. of b	t(83)	p-value
Intercept			405.5704	160.4274	2.52806	0.013364
Tyd	0.909874	0.045540	23.5107	1.1767	19.97984	0.000000

The last analysis that was done was to correlate rainfall in the North West province and the price of Sunflower on Safex and time.

Below analysis in table 19 show that time contributes in a significant way towards the price of Sunflower at a value of 0.905, but rainfall does not contribute in a significant way towards time. (p=0.389).

Table 19: Regression correlation between Rainfall in the North West province and the price of Sunflower trading on Safex

Statistic	Summary Statistics; DV: SONNEBLOM (ReenPryse) Value
Multiple R	0.910731684
Multiple R²	0.8294322
Adjusted R²	0.82527201
F(2,82)	199.373623
p	3.21942776E-32
Std.Err. of Estimate	638.922748

N=85	Regression Summary for Dependent Variable: SONNEBLOM (ReenPryse) R= .91073168 R²= .82943220 Adjusted R²= .82527201 F(2,82)=199.37 p<0.0000 Std.Error of estimate: 638.92					
	b*	Std.Err. of b*	b	Std.Err. of b	t(82)	p-value
Intercept			543.0770	225.8139	2.40498	0.018425
Tyd	0.904829	0.045978	23.3804	1.1881	19.67956	0.000000
REENVAL	-0.039844	0.045978	-1.5306	1.7662	-0.86660	0.388692

Below analysis in table 20 show that there is a statistical significant relationship between time and the price of White Maize of 0.760, but rainfall does not contribute in a significant way towards time (p=0.079)

Table 20: Regression correlation between Rainfall in the North West province and the price of White Maize trading on Safex

Statistic	Summary Statistics; DV: WITMIELIES (ReenPryse) Value
Multiple R	0.779378341
Multiple R^2	0.607430599
Adjusted R^2	0.598896482
F(2,92)	71.1767333
p	2.09004772E-19
Std.Err. of Estimate	543.245523

N=95	Regression Summary for Dependent Variable: WITMIELIES (ReenPryse) R= .77937834 R^2= .60743060 Adjusted R^2= .59889648 F(2,92)=71.177 p<0.0000 Std.Error of estimate: 543.25 b*	Std.Err. of b*	b	Std.Err. of b	t(92)	p-value
Intercept			668.8409	164.8817	4.05649	0.000104
Tyd	0.759614	0.065620	9.8587	0.8516	11.57603	0.000000
REENVAL	-0.116579	0.065620	-2.5688	1.4459	-1.77659	0.078941

3.5. ASSESSING AND DEMONSTRATING THE QUALITY AND RIGOUR OF THE PROPOSED RESEARCH DESIGN

For bivariate analysis, two variables are analysed at a time to uncover whether they are related or not. A variety of techniques are available to be used according to Bryman et al. (2014:321). Pearson correlation coefficient (r) is used to analyse the relationship between two interval variables, Spearman’s rho is used for ordinal variables and the phi coefficient is used for two dichotomous variables according to Bryman et al. (2014:321).

For this dissertation, there is a mixture between a nominal and interval variable, so a Regression analysis and Spearman’s Rank order will be used.

3.6. RESEARCH ETHICS

There are no ethical requirements applicable in this study.

CHAPTER 4:

Chapter 4 consist of the conclusion, summary, as well as a discussion of the results based on all the data gathered for the different chapters.

4. CONCLUSION AND SUMMARY

4.1. CONCLUSION

Rainfall in the North West province is crucial during the second part of January, February and the first half of March timeframe when Maize start to silk. The long-term average for January is 98 mm, February 82 mm and March 75 mm, totalling 255 mm for the three months.

According to De Jager (2016), since records started way back in 1904 by the South African Weather Service, the average annual rainfall in the country has been 608 mm. In 2015 only 403 mm of rain fell, the lowest annual amount of rainfall since 1904 and 205 mm below the long-term average. The three years prior to 2015, an average of 591 mm rain fell. The second lowest amount was recorded in 1945 when 437 mm fell, and the third lowest annual total was set in 1992 when 440 mm fell. The fourth lowest total was recorded in 2003 when 446 mm fell, and the fifth lowest was 1935 when 451 mm of rain fell.

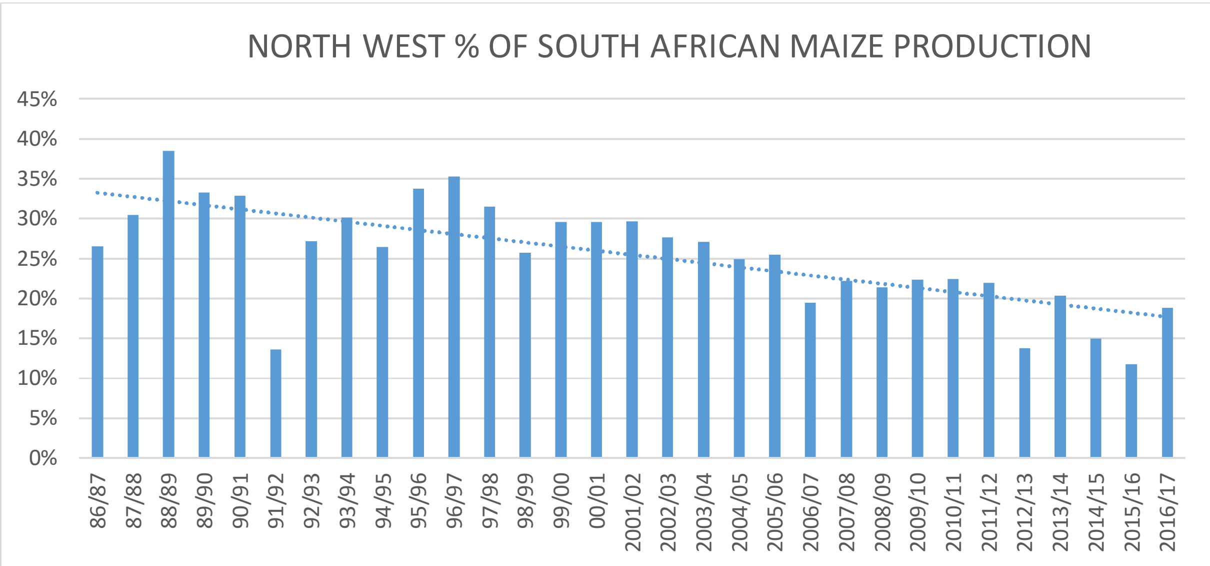
The 45-year average for the North West province is 540 mm, versus the 528 mm 30-year average. South-Africa as a whole has an average of 608 mm according to De Jager (2016), but this is an average of over 100 years. If the 45-year average for the North West province is compared with the South African 100-year average, the province receives less rainfall than the other provinces.

The average Maize yield in South Africa during 1980's was 1.93 ton/ha, during the 1990's 2.24 ton/ha, during the 2000's 3.30 ton/ha and 3.93 ton/ha average from 2010 to 2015.

The average Sunflower yield in South Africa during 1980's was 0.88 ton/ha, during the 1990's 0.99 ton/ha, during the 2000's 1.23 ton/ha and 1.20 ton/ha average from 2010 to 2015.

Overall there is a declining trend of Maize production in the North West province versus the South African Maize production. The average total the North West province produced was around 29% during the 1990's, and declined to 25% during the 2000's, and only 17% for the 2010's. Overall since the 1990's, the North West province has produced on average around 25% of the Maize in South Africa, but since 2000, only 22%. Figure 24 below show the declining trend line for Maize production in the North West province. A specific mention must be made to the last 6 seasons since the 2010/11 season, where production has been below 20%, except for the 2013/14 season.

Figure 24: The North West province % of South African Maize production since 1986/87



Source: DAFF (2017)

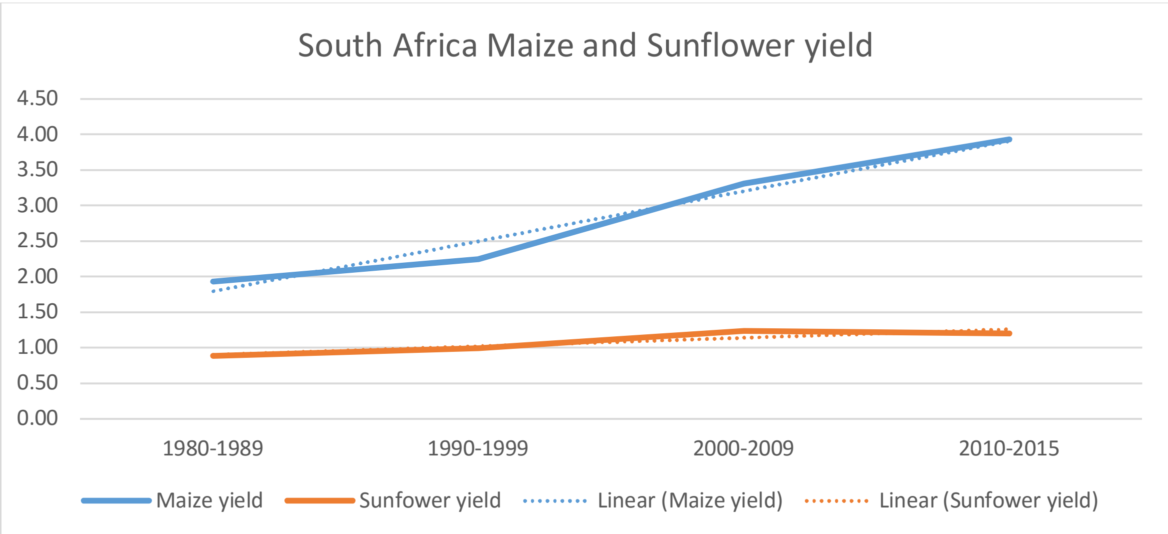
More or less the same as with Maize, there is a declining trend for Sunflower tonnages that have been produced by the North West province since 2000. On average the province has produced around 37% of the South African Sunflower, while this figure has dropped to around 33% during the past 6 seasons, excluding the 2016/17 season.

The average planting date for Maize in the North West province is from 5 to 12 December, with emergence on 19 December. The critical part for Maize pollination will start on 17 February, and last for 18 days to the 7th of March. During the pollination stage, the Maize will need the most water for average to above average yields. The big question for farmers will be the following, whether to use the moisture in the ground during pre-season rainfall to aid the plantings and plant before the average, or “normal” window, or if pre-season rainfall was absent, to still plant in the dry ground and hope for rainfall, or the third option, to wait for rainfall before planting, but the ideal planting window will be missed which could have an impact on yield when harvesting.

Another factor that play a crucial part in the date when farmers will be planting Maize and Sunflower, early season rainfall during July to October to prepare the fields, and the expected rainfall for the season ahead. Usually when a dry winter was experienced with low rainfall, farmers will struggle to prepare their field for planting. Farmers want some sort of moisture in the ground to plant their crops, but sometimes they will plant in the dry ground when rainfall can be expected in the coming weeks.

Below summary in figure 25 show the average yield for Maize and Sunflower in South Africa for the 1980 to 1989 timeframe, 1990 to 1999, 2000 to 2009 and the 2010 to 2015 timeframe. The trend for Maize yield is upwards, and the trend for Sunflower is slightly upwards.

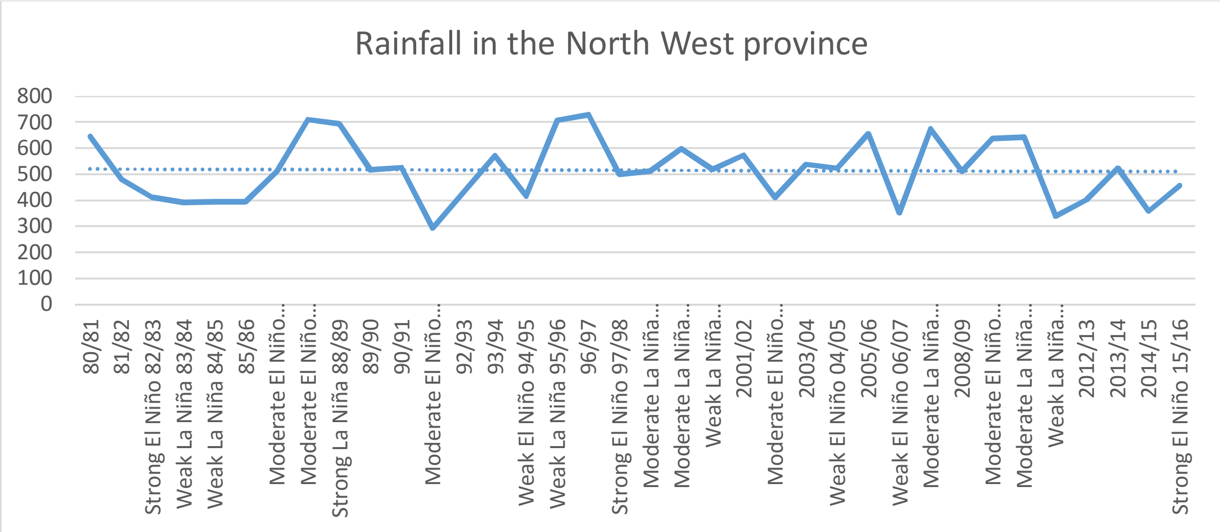
Figure 25: South Africa Maize and Sunflower yield since 1980



Source: DAFF (2017)

The North West province has a sideways shaping trend line with regards to rainfall as can be seen in figure 26 below from 1980 to 2015. The average rainfall is 528 mm per season for this timeframe.

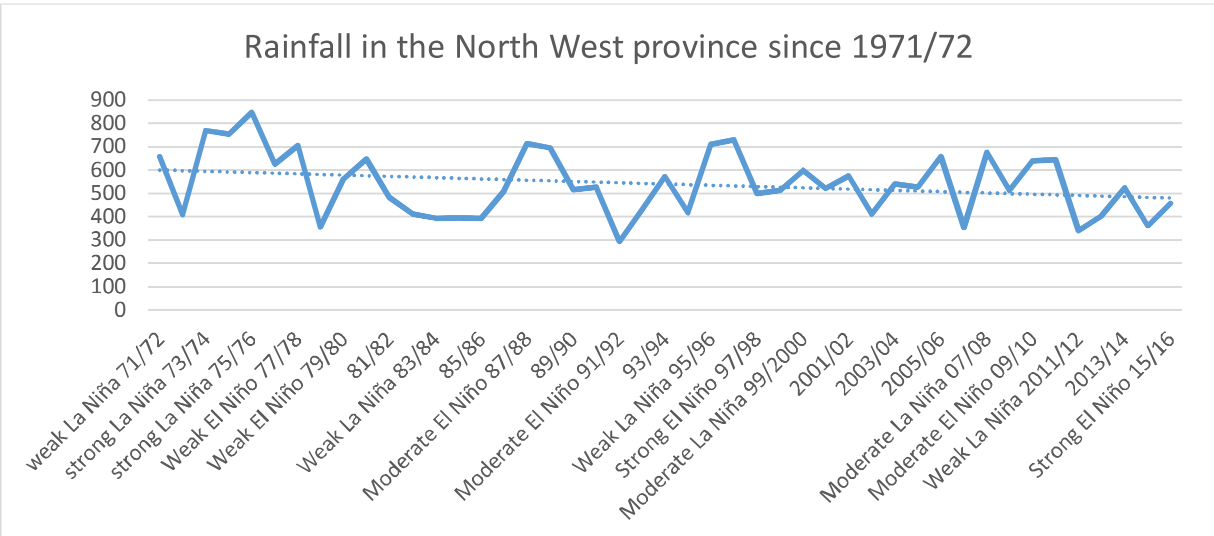
Figure 26: Rainfall in the North West province since the 1980/81 season



Source: SAWS (2017)

When the figure is drawn from 1971 to 2015, the trend is downward sloping as can be seen in figure 27 below. When looking at the early 1980's, the very low rainfall can be seen clearly, which was followed up by a few good seasons of rainfall. The average rainfall is 540 mm for this timeframe.

Figure 27: Rainfall in the North West province since the 1971/72 season



Source: SAWS (2017)

The sea temperatures of the NIŇO3 and the NIŇO3.4 regions in the Pacific Ocean play a crucial role in determining the summer grain production in South Africa. Reuters state that ENSO is short for El Niño-Southern Oscillation, a reference to the state of the Southern Oscillation and sea-surface temperatures, or SST's. ENSO is a climate phenomenon generally defined by sea surface temperatures in the central and eastern Pacific Ocean between Australia and South-America. The most common SST used to determine and monitor ENSO status (El Niño, La Niña or neutral conditions), is the NIŇO3.4 region in the Eastern Pacific Ocean.

According to Reuters, El Niño can be described a warming of the ocean current along the coast of Peru and Ecuador in South America that is generally associated with dramatic changes in the weather patterns of the region. It occurs every 3 to 7 years according to Reuters and changes in weather patterns worldwide is associated with it. El Niño and La Niña are a naturally occurring phenomena that result from interactions between the ocean surface and the atmosphere over the Pacific. Changes in the ocean surface temperatures affect tropical patterns and atmospheric winds over the Pacific Ocean which in turn impact the ocean temperatures and currents.

La Niña, the opposite of El Niño, refers to the periodic cooling of ocean surface temperatures in the central and eastern-central equatorial Pacific that occurs every 3 to 5 years or so according to the National Weather Service (2016). La Niña represents the cooling phase of the ENSO cycle, and is sometimes referred to as a Pacific cold episode. To count as a La Niña event, the 3-month average sea surface temperatures departure exceeds -0.5˚C in the east-central equatorial Pacific Ocean to the west of South America according to the National Weather Service (2016).

On average, during an El Niño season, 39 mm less than the long-term average can be expected in the North West province. During the strong El Niño episode, it is where the most deviation can be expected. Since 1971, three events have occurred with the previous event occurring in 1997/98 before the record strong 2015/16 event. In zero out of the 3 events, above normal rainfall was experienced.

On average, during a La Niña event, 67 mm more rain can be expected in the North West province with the episode producing the most deviation, being a strong La Niña event. The last Strong La Niña event occurred during the 1988/89 season and since 1971 there has been 3 events. During a weak La Niña, there have been 4 instances where below average rainfall has been experienced, while 3 have events have produced above average rainfall. Only in one instance, has below average rainfall been experienced during a moderate La Niña, while 3 events have produced above average rainfall.

The Indian Ocean Dipole, or IOD, is the sustained changes in the difference between sea surface temperatures of the Tropical Western and Eastern Indian Ocean, according to The Australian Weather Bureau (2017). The Indian Ocean is the Ocean basin bounded to the north by the Asia continent, to the south by the Southern Ocean, to the west by Africa and to the east by Australia according to Randriamahefasoa, (2013). The Indian Ocean is the smallest ocean compared to the Atlantic, Pacific and Southern Oceans. It is also the warmest ocean on earth according to Randriamahefasoa, (2013).

The IOD has three phases, neutral, positive, and negative. Events start around May or June, and peak between August and October.

A negative IOD typically results in above-average winter–spring rainfall over parts of southern Australia as the warmer waters off northwest Australia provide more available moisture to weather systems crossing the country according to the Australian Weather Bureau, 2017. Olivier (2016) state that the tendency of cooling over the South-Western Indian Ocean south of Madagascar, may create favourable conditions for rainfall activities over South Africa, partly corresponding with the IOD’s impact on Australia for above normal rainfall.

The sea temperatures along the Western Cape coastline and the KwaZulu-Natal coastline is crucial for rainfall in South Africa. Weather forecasting is a very difficult process, but each season gives clues as to what can be expected. Research has come through tremendously regarding technology on predictions, but more work is still needed.

According to Nigrini (2016), two of the most important factors for summer rainfall in South Africa is the seawater temperature in the NIŇO3 region, as well as the sea water temperature along the KwaZulu-Natal coast. It is true that the warm Mozambique stream is flowing along the coast from north to south, but when the water gets too warm caused by trade winds blowing in warmer than normal water from the western and southern coast of South-Africa, it can lead to the forming of tropical cyclones. What happens when tropical cyclones form in the Indian Ocean off the KwaZulu-Natal coast, is a low-pressure system emerge, and “pulls” most of the moisture that is over South Africa to over the ocean, and causes rain to fall over the sea, and not over land (Nigrini, 2016).

During summer months, moisture is transported from the Inter tropical convection zone along the equator in Africa. The trade winds allow this moisture to flow southwards towards the Southern Africa regions. When a high-pressure system forms on the east coast of South Africa, cooler air is flowing towards the central parts of South Africa, and with the moisture coming from the Inter tropical convection zone, a rise of moistures occurs creating favourable rainfall conditions for the summer rainfall regions. It is true that high moisture from the inter tropical convection zone can be present over South Africa, but without a good and solid burst of cold air from the north-eastern parts of South Africa, only heat storms and thunderstorms will occur, and be sporadic, not widespread rainfall that is needed to aid crops. (Nigrini, 2016)

An Indian Ocean high pressure system forming over KwaZulu-Natal coast, is one of the most important elements needed for rain across the interior parts of South Africa where summer grains are planted. When a high-pressure system forms over KwaZulu-Natal during the South African summer months, it creates the North-Eastern wind to blow in/channel moisture from the tropics over the interior of South Africa.

When the North-Eastern wind blows, it keeps the warmer water on South African east coast in a narrow band, and forces it to flow in a southern direction, creating an upwelling of cooler water either side of it (Nigrini, 2016). The cooler the water, the better the chances are of a surface high developing, and that increases the chances for rain over the interior. When a high-pressure system on the eastern part of the country is in place, and a low-pressure system (upper-air low) forms over the central and western parts of the country, conditions for widespread rainfall increases. As stated previously, in a high-pressure system, air is flowing anti-clockwise, and this process is what pushes colder air from the ocean to the interior parts of South-Africa. If this high-pressure system is not in place, the amount of cold air pushed over the interior diminishes and lowers the chances of rainfall (Nigrini, 2016).

Cycles play a very important role in the rainfall history of South Africa as illustrated by Alexander (2006).

Cycles have been previously tried and researched by Dyer & Tyson (1977). Dyer and Tyson reported that a quasi-18- or quasi 20-year oscillation predominated in the summer rainfall region covering the north-eastern part of South Africa, i.e. the Limpopo province. Basically, it is a 9-year wet spell and 10-year dry spell that Dyer and Tyson predicted. Dyer and Tyson predicted a wet spell for the 1972-1981 period, and then 1981-1990 they predicted a dry spell.

They then predicted a wet spell for the 1991-2000 period. The rainfall in the North West correspond well with their 1972-1981 period, when above-normal rain fell for this period. Below normal rainfall fell during the 1981-1990 period, which also correspond with Dyer and Tyson (1977). Near normal rainfall fell during the 1991-2000 period which also correspond well with Dyer and Tyson.

Table 21: The Dyer & Tyson table with regards to seasonal rainfall in South Africa

Year	Duration	Wet spell	Dry spell
1905-1915	10	-	10
1916-1924	8	8	-
1925-1932	7	-	7
1933-1943	10	10	-
1944-1952	8	-	8
1953-1961	8	8	-
1962-1970	8	-	8
1971-1980	9	9	-
1981-1990	9	-	9
1991-2000	9	9	-

Source: Alexander (1995): 354

Alexander (1978) identified the presence of a 20-year (later 21-years) periodicity in the annual river flow. River-flow in South Africa was below-normal during certain periods, and periods of high river flow and floods was also experienced and confirms Alexander's studies. Alexander, 2006, state that subsequent years confirmed the periodicity, which reached the 95% level of statistical significance in a number of rivers across South Africa. Alexander (2006) state that there is also very strong evidence of a periodic pattern of prolonged droughts suddenly being broken by one or more years of abnormally high runoff. Alexander (1995b) identified the reversal years as follow, 1912, 1933, 1954, 1974 and 1995.

In a study by Alexander (2006), the linkage between the sunspot cycle and the annual flow of the Vaal-river is very apparent. The sunspot cycle is around a 11-year cycle, but in his study, Alexander talks about a double sunspot cycle, more or less 21 to 22 years, and this correlate well with Alexander (1995b) study showing the 21-year cycle and the flow of the Vaal-river in Alexander (2006) studies. Alexander (2006) state that major flood events occur during the first half of a sunspot cycle, as this is where the sunspot density is at its greatest, and is associated with global atmospheric and oceanic turbulence at this time.

This in turn generates the processes that produce heavy, widespread rainfall over South Africa that generate river flow. During the second half of the cycle, the sunspot density decreases (Alexander, 2006). This is a sub-period with reduced turbulence in the pole-ward energy distribution process, and consequent absence of high rainfall events that generate river flow.

Drought occur during these events. After a few years of intensive research, Alexander (2006) state that for interpretation purposes, a 2 to 4-year timeframe should be used if the concern is agricultural droughts, not isolated years. For hydrological droughts, Alexander (2006) state that a range of 3 to 7 years should be used.

During August 1995, Alexander published his much-anticipated paper, Floods, Droughts and Climate change in South Africa. During this paper, he stated the following: "The acid test that will demonstrate whether or not the 20-year periodicity is at hand. If the drought is broken by widespread rainfall during the next two years, it will surely be conclusive." As Alexander (2006) states, widespread rainfall and floods occurred later in 1995, with hundreds of lives lost, but the drought was broken. The reliability of this prediction from Alexander was spot-on. The nine years following the massive rains during 1995, was in accordance with the climate prediction model according to Alexander (2006), which lends strong support to the validity of the model. Alexander (2006) state that the periodicity and the association of wet and dry sequences, is extremely important for all those who maintain that global warming will result in increased variability in the hydrological process, specifically floods, droughts and water supplies. Alexander (2006) state that despite a diligent examination of a very large and comprehensive hydrological database, no evidence could be found to support the claims that climate change will result in an increase in the frequency and magnitude of floods and droughts, or pose a threat to water supplies. "The study shows the presence of a statistically significant 21-year periodicity in rainfall, river flow and flood peak maxima" Alexander, 2006.

"The periodicity is predictable and is characterised by severe droughts being broken by sudden widespread floods. The periodicity is associated with alternating sequences of wet and dry periods that have been reported since Biblical times. The model designed by Alexander demonstrates that previously assumed climate-related groupings of years with unusually high or low characteristics are not the result of climate change, but are natural sequences" Alexander, 2005. Alexander also noted that an important characteristic is that the most extreme conditions occur at the beginning of periods (floods) and at the end of periods (droughts) with sudden reversals from droughts to floods at the end of periods.

From Alexander's (2006) analyses, his prediction model started the period when floods broke the previous drought. The first six years of the sequence, 1995-2000, he stated that widespread floods can be expected. The average rainfall in the North West province for this period was 609 mm, well above the long-term median of 520 mm. The following five years, 2001 to 2005, Alexander notes that droughts are increasingly likely. During this period, the average rainfall in the North West province was 514 mm versus the long-term median of 520 mm. During the 2002/03 season, only 411 mm of rainfall was received, and Maize yield dropped to 2.04 ton/ha, well below the average of 2.46 ton/ha for the period.

Alexander (2006) noted that the 2005/06 season some relief in terms of rainfall can be expected, and during this season, the North West province received above normal rainfall of 657 mm. “The following seven years will be critical for South Africa’s water supply situation, with frequent years of well-below average flows and steadily decreasing high inflows to compensate for them Alexander, (2006). Alexander stated way back in 2005 that water restrictions will be almost inevitable from 2008 in South Africa, which mostly became a reality in 2016 across major parts of South Africa. On the 7th of November 2016, the Vaal Dam in Gauteng was at only 26.08% full according to the Africa News agency (2016). The Vaal Dam supplies water to the most parts of Gauteng. Also on the 7th of November 2016, water was released from the Sterkfontein dam in the Free State to supply water to the Vaal Dam (TMG Digital, 2016).

The important and exciting part is that Alexander (2006) states that the next reversal is due within a year or two of 2016. What he means is that the current dry conditions that South Africa have experienced since the start of 2015 will be broken by floods within a year or two from 2016.

Table 22 below was compiled by Alexander (1995) which combine the independent observations of by Tyson, Bredenkamp and Alexander, each using different processes and different analytical methodologies. The reading must start from the right hand column of the table, because this shows the reversals that occurred according to studies done by Alexander (1995).

A note must also be made that the analysis is only up to 1990 that was tabled below. In Bredenkamp’s study, the average duration for the dry sequences are 6.25 years, with the smallest duration being 3 years and the longest being 12 years. The wet years on average duration is 6.60 years, with the shortest duration being 5 years and the longest duration being 9 years. In Tyson’s study, the average duration for the dry sequences are 8.25 years, with the smallest duration being 7 years and the longest being 10 years. The wet years on average duration last 8.75 years, with the shortest duration being 8 years and the longest duration being 10 years. The average between these two studies indicate that the wet year’s sequence last 7.70 years, and the dry years last 7.25 years.

Table 22: The combination of the independent observations by Tyson, Bredenkamp and Alexander

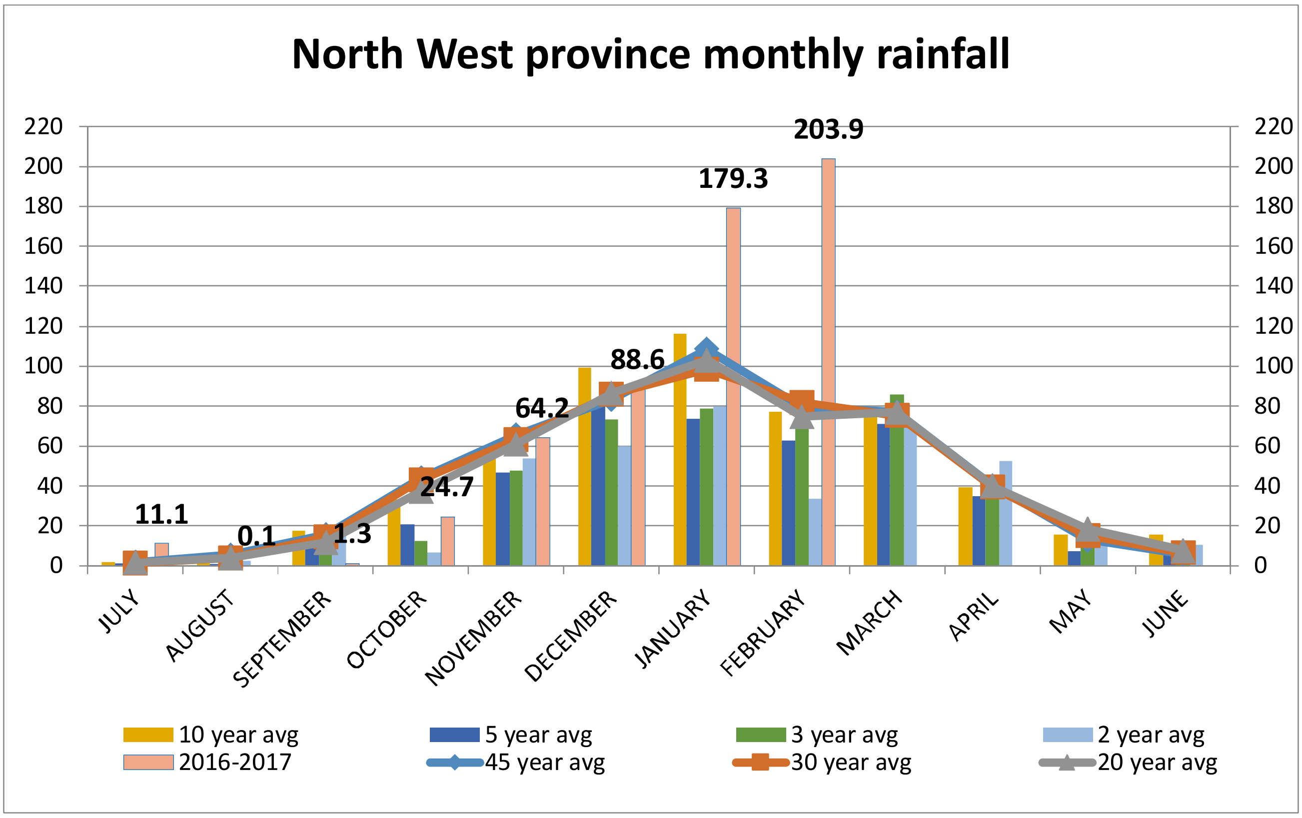
Years	Wet/dry	Periodic sequence number	Length of sequence		Reversals (Alexander)
			Wet	Dry	
Bredenkamp: Mzimgazi + St Lucia + Uitenhage + Wondergat					
1919-24	Wet	08 to 13	5		
25-29	Dry	14 to 18		4	1933
30-39	Wet	19 to 07	9		
41-53	Dry	09 to 21		12	1954
55-62	Wet	02 to 09	7		
65-71	Dry	12 to 18		6	1974
72-78	Wet	19 to 05	6		
80-83	Dry	07 to 10		3	
84-90	Wet	11 to 19	6		1995
Tyson: South African rainfall					
1905-15	Dry	15 to 04		10	1912
16-24	Wet	05 to 13	8		
25-32	Dry	14 to 21		7	1933
33-43	Wet	01 to 11	10		
44-52	Dry	12 to 20		8	1954
53-61	Wet	21 to 08	8		
62-70	Dry	09 to 17		8	1974
71-80	Wet	18 to 07	9		

Source: Alexander (1995): 414

4.2. SUMMARY

In Figure 28 below is a summary of the rainfall in the North West province since around 1971. Notice the two and three-year average rainfall for the province. It is for the 2013/2014, 2014/2015 and 2015/2016 season. The current season, 2016/2017 until 28 February 2017, was illustrated apart from the rest, just to illustrate how low rainfall was previously, and how good a season was experienced with regard to rainfall. December and January are the months when the most rainfall can be expected on average, while June, July and August is the months where the lowest rainfall can be expected.

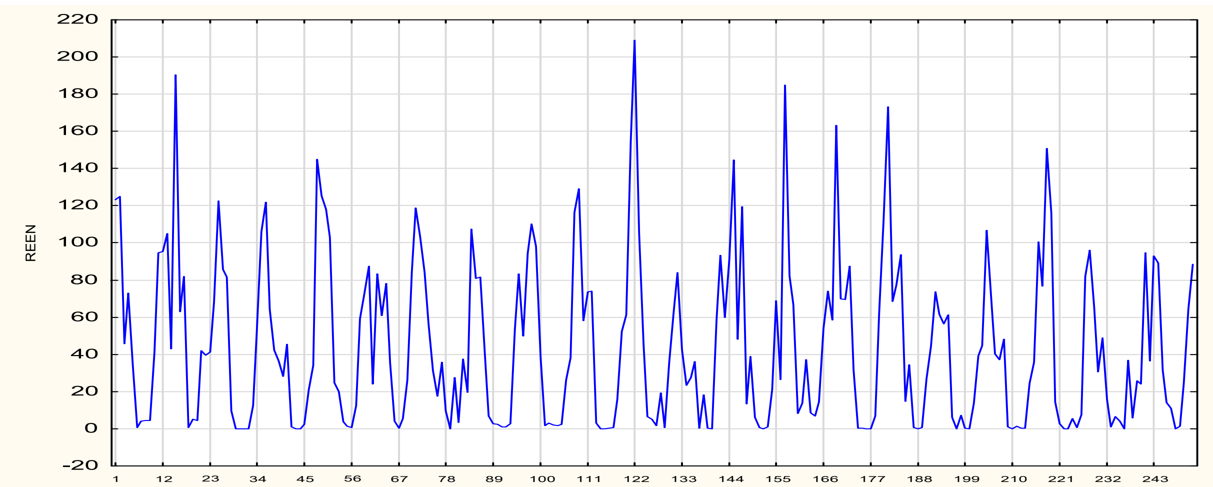
Figure 28: The North West province monthly rainfall history



Source: SAWS (2017) and own compilation

If seasonal differences are ignored, on average the North West province's average rainfall over time is 51.27 mm/month as can be seen below in figure 29.

Figure 29: The rainfall in the North West province since 1996



Source: SAWS (2017)

Below analysis in table 23 show that no significant statistical correlation was identified between NIŇO3 and the prediction of rainfall in the North West province (p>0.05).

Table 23: The NIŇO 3 SST Regression

Statistic	Summary Statistics; DV: REEN (Meng_reenNinc Value
Multiple R	0.119885176
Multiple R²	0.0143724554
Adjusted R²	0.0104299452
F(1,250)	3.64550876
p	0.057365384
Std.Err. of Estimate	43.8800635

N=252	Regression Summary for Dependent Variable: REEN (Meng_reenNino) R= .11988518 R²= .01437246 Adjusted R²= .01042995 F(1,250)=3.6455 p<.05737 Std.Error of estimate: 43.880 b*	Std.Err. of b*	b	Std.Err. of b	t(250)	p-value
Intercept			44.10498	2.766684	15.94146	0.000000
NINO 3	-0.119885	0.062789	-5.22412	2.736114	-1.90932	0.057365

In below analysis in table 24, the year was divided into two semesters, namely semester one which runs from January to June, and semester two, which run from July to December to try and find a correlation between the IOD and NIŇO3 SST's and rainfall in the North West province.

During the first semester which run from January to June, the correlations are not very strong between rainfall and the IOD SST's at only -0.020 and rainfall and the NIŇO3 SST's at -0.124, but reasonably strong at 0.574 between the NIŇO3 and IOD SST's. This means that the two variables increase concurrently, meaning that if the NIŇO3 SST increase, the IOD SST increase as well.

During the second semester which run from July to December, the correlation between the NIŇO3 and IOD SST's become weaker at 0.358, and even weaker between rainfall in the North West province and the IOD SST's at –0.056 and rainfall in the North West province and the NIŇO3 SST's at -0.079.

In Table 24 below the following can be seen. The correlation is slightly inverse from November to March each year between rainfall in the North West province and the price of Sunflower at –0.169, and slightly more inversely correlated between rainfall in the North West province and the price of White Maize on Safex at -0.211. The value of -0.211 means there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize decrease.

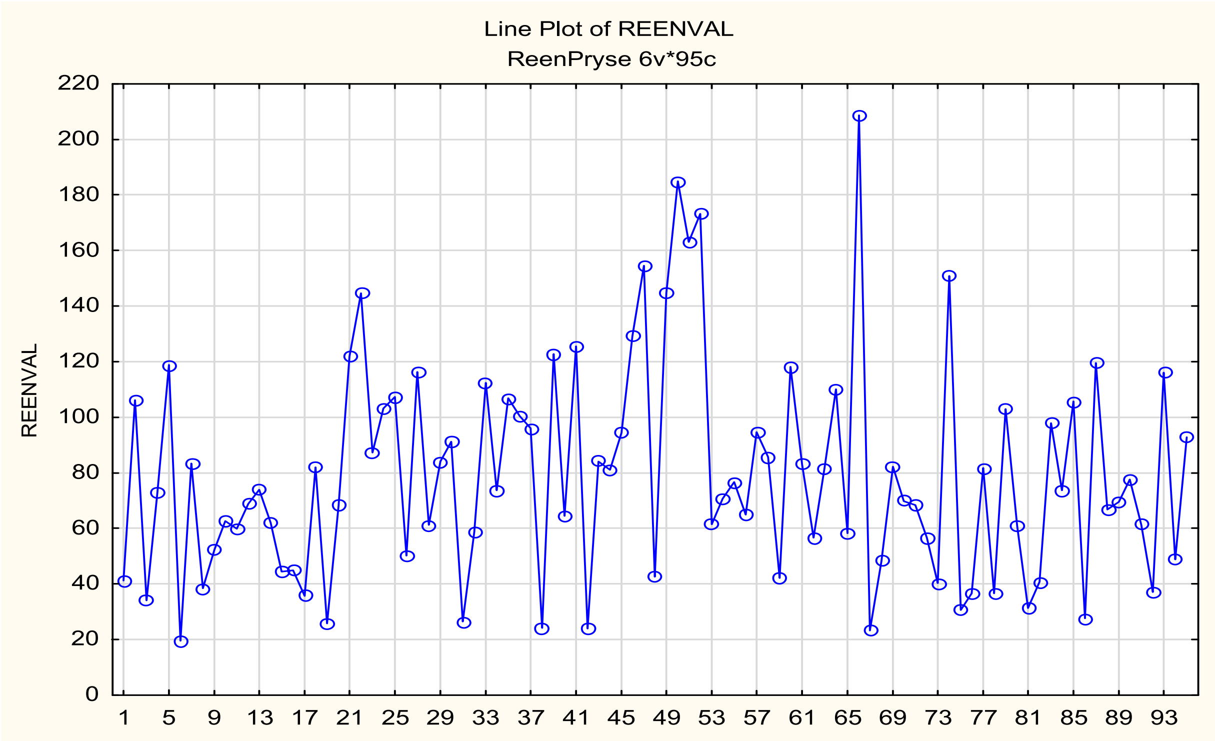
What is interesting to note is the correlation between the price of White Maize and the price of Sunflower at 0.926, which is a very strong positive correlation. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well.

Table 24: Spearman Rank order correlation between rainfall in the North West province, White Maize prices and Sunflower prices

	Spearman Rank Order Correlations (ReenPryse) MD pairwise deleted Marked correlations are significant at p <.05000			
Variable	Tyd	REENVAL	WITMIELIES	SONNEBLOM
Tyd	1.00000(	-0.12791:	0.85421:	0.90996
REENVAL	-0.12791:	1.00000(	-0.21138(	-0.16882!
WITMIELIES	0.85421:	-0.21138(	1.00000(	0.92550:
SONNEBLOM	0.90996	-0.16882!	0.92550:	1.00000(

Below in figure 30, there is a slight upward trend in rainfall specifically in the November to March timeframe since 1998.

Figure 30: Monthly rainfall from November to March from 1998 to 2016



In below analysis in table 25, it shows that time contributes in a significant way towards the price of Sunflower at a value of 0.905, but rainfall does not contribute in a significant way towards time. (p=0.389).

Table 25: Regression correlation between Rainfall in the North West province and the price of Sunflower trading on Safex

	Summary Statistics; DV: SONNEBLOM (ReenPryse)
Statistic	Value
Multiple R	0.910731684
Multiple R²	0.8294322
Adjusted R²	0.82527201
F(2,82)	199.373623
p	3.21942776E-32
Std.Err. of Estimate	638.922748

N=85	Regression Summary for Dependent Variable: SONNEBLOM (ReenPryse) R= .91073168 R²= .82943220 Adjusted R²= .82527201 F(2,82)=199.37 p<0.0000 Std.Error of estimate: 638.92					
	b*	Std.Err. of b*	b	Std.Err. of b	t(82)	p-value
Intercept			543.0770	225.8139	2.40498	0.018425
Tyd	0.904829	0.045978	23.3804	1.1881	19.67956	0.000000
REENVAL	-0.039844	0.045978	-1.5306	1.7662	-0.86660	0.388692

In the below analysis in table 26, the results show that there a statistical significant relationship between time and the price of White Maize of 0.760, but rainfall does not contribute in a significant way towards time (p=0.079).

Table 26: Regression correlation between Rainfall in the North West province and the price of White Maize trading on Safex

Statistic	Summary Statistics; DV: WITMIELIES (ReenPryse) Value
Multiple R	0.779378341
Multiple R²	0.607430599
Adjusted R²	0.598896482
F(2,92)	71.1767333
p	2.09004772E-19
Std.Err. of Estimate	543.245523

N=95	Regression Summary for Dependent Variable: WITMIELIES (ReenPryse) R= .77937834 R²= .60743060 Adjusted R²= .59889648 F(2,92)=71.177 p<0.0000 Std.Error of estimate: 543.25					
	b*	Std.Err. of b*	b	Std.Err. of b	t(92)	p-value
Intercept			668.8409	164.8817	4.05649	0.000104
Tyd	0.759614	0.065620	9.8587	0.8516	11.57603	0.000000
REENVAL	-0.116579	0.065620	-2.5688	1.4459	-1.77659	0.078941

To conclude, analysis show that there is no significant statistical correlation that could be identified between NIŇO3 and the prediction of rainfall in the North West province (p>0.05).

What analysis did show was that there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize decrease. The correlation between the price of White Maize and the price of Sunflower is at 0.926, which is a very strong positive correlation. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well.

4.3. DISCUSSION OF RESULTS

The analysis is concluded by discussing the findings. The main focus was on the impact of rainfall in the North West province on the summer grain markets in South Africa.

The reason summer grain markets were chosen, is because Maize is used as a staple food in South Africa, and crucial for millions of South Africans in their daily diets. The North West province is one of the major provinces in South Africa that produce Maize, creating jobs for many in the Agricultural sector, and providing food to the citizens of the country.

The North West province consist of around 90% dryland farming, which is directly dependant on rainfall for Maize and Sunflower to pollinate. During the analysis stage, it was discovered that Maize plants use around 455 mm of water from seeding to mature stage and produce an average harvest. The average planting date for Maize in the North West province is from 5 to 12 December, with emergence on 19 December. The critical part for Maize pollination will start on 17 February, and last for 18 days to the 7th of March. During the pollination stage, the Maize will need the most water for average to above average yields. The summer season from December to February each year is where the most of the rainfall fall on average in the North West province, but it is also the hottest time of the year. Maize and Sunflower plants going into the pollination stage, will take heavy strain if rainfall is absent, or lower during summer time and hamper an average harvest.

Since 1990, the North West province have produced on average around 25% of the Maize in South Africa, predominantly White Maize which is a source of staple food for most South Africans. There has been a declining trend since 2000 through to 2015/2016 to around 22% of Maize production, and below 20% during the past six seasons, excluding data from the 2016/17 season. Sunflower production since 2000 show that on average the province has produced around 37% of the South African Sunflower, while this figure has dropped to around

33% during the past 6 seasons, excluding data from the 2016/17 season.

The reason why this is important, is because of a lower contribution towards the total production in South Africa, it can be concluded that the role of production in the North West province will become more and more important as the population grows and more mouths need to be fed. The impact of rainfall in the North West province on price movements trading on Safex will become more important and play a large portion of decisions and planning on marketing for farmers and producers of White Maize and Sunflower.

The 45-year average rainfall for the North West province is 540 mm, versus the 528 mm 30-year average. South-Africa as a whole has an average rainfall figure of 608 mm according to De Jager (2016), but this is an average of over 100 years. If the 45-year average for the North West province is compared with the South African 100-year average, the province receives less rainfall than the other provinces.

The sea temperatures of the NIŇO3 and the NIŇO3.4 regions in the Pacific Ocean play a crucial role in determining the weather for the summer grain production in South Africa. The most common SST used to determine and monitor ENSO status (El Niño, La Niña or neutral conditions), is the NIŇO3.4 region. El Niño can be described as a warming of the Pacific Ocean current along the coast of South America, while La Niña, the opposite of El Niño, refers to the periodic cooling of ocean surface temperatures along the coast of South America that occurs every 3 to 5 years.

On average, during an El Niño season, 39 mm less than the long-term average can be expected in the North West province, while on average, during a La Niña event, 67 mm more rain can be expected in the North West province with the episode producing the most deviation, being a strong La Niña event.

The other factor influencing weather in South-Africa, is the Indian Ocean Dipole, or the IOD, which is the sustained changes in the difference between sea surface temperatures of the tropical western and eastern Indian Ocean. The Indian Ocean is situated off the KwaZulu-Natal coast, and it can aid or hamper rainfall systems over South Africa. Warmer water along the Kwa Zulu-Natal coast can cause tropical depressions to form and it can influence rainfall negatively over the interior of South Africa, while cooler water along the KwaZulu-Natal coast can help with high pressures forming which is very crucial in causing widespread rainfall for the interior of South Africa.

To summarize, together or individually the IOD SST and NIŇO3 SST cannot predict rainfall in the North West province. The fact that these two SST's cannot predict rainfall, does not mean they do not influence the weather in South Africa, and around the world. Research has shown that there is a connection between these two SST's and weather around the world, albeit not on rainfall in the North West region.

Regarding commodity prices, there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize and Sunflower trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize and Sunflower decrease. What is interesting to note is the very strong positive correlation between the price of White Maize and the price of Sunflower. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well.

CHAPTER 5:

Chapter 5 consist of six conclusions and six recommendations for the results based on all the data gathered for this dissertation. The chapter starts off with an introduction. This is followed by the six conclusion and six recommendations, areas for further study are outlined and finally ends off with a summary for the dissertation and the major highlights.

5. CONCLUSION AND SUMMARY OF THE STUDY

5.1. INTRODUCTION

Sporadic rainfall in South Africa is the main reason for these cycles not to have been determined yet. Annual patterns have been identified however, where it has been established that little or no rainfall is recorded in the winter and most rain occur in the summer and mid-summer, with drought generally being prevalent during December, January, or February.

These patterns are repeated year after year, but the intensity differs. New developments in the field of weather research in recent years can aid considerably in more accurate seasonal predictions. The interaction between the ocean and the atmosphere have a major impact on the weather and climate. It takes several months before one big event will happen. The Ocean and atmosphere are closely related. They are both components of the climate and together form a system called the climate system.

Drought has been noted as having severe impacts on the agricultural sector of South Africa. The vulnerable populations of the country are the ones that are impacted the most by this occurrence. Maize is the staple food of most individuals in the Southern African region and as a result the reliance on rain-fed agriculture is tremendous. Rainfall variability in the region also has serious consequences for agriculture and for food security. The onset of a drought is generally the trigger required to cause large-scale food shortages in the Southern African region.

The performance of Maize is highly sensitive to the intra-seasonal distribution of rainfall, particularly at the time of flowering, which generally occurs around February. Any extended halt in rainfall can cause a considerable reduction in grain formation and a resultant Maize yield that is substantially smaller. The onset date of the rainy season is also crucial to subsistence farmers as they need to decide when to plant their Maize. Frequent dry spells may occur if planting is too early and intense rains washing seeds away could occur if planting is too late. The variability in seasonal rainfall characteristics such as onset, cessation and dry spell frequency are harmful to the agricultural sector and especially to the staple food of most South Africans.

The identification of rainfall cycles over the past 100 years has often been a topic of discussion. Several studies have been conducted by the likes of the Witwatersrand University, University of Pretoria and the University of Cape Town on the rainfall cycles across seasons. Sporadic rainfall in South Africa is the main reason for these cycles not to have been determined yet. Annual patterns have been identified however, where it has been established that little or no rainfall is recorded in the winter and most rain occur in the summer and mid-summer, with drought generally being prevalent during December, January, or February. These patterns are repeated year after year, but the intensity differs. Seasonal rainfall is a very complex concept, and virtually impossible to be predicted with dependable accuracy. However, new developments in this field in recent years can aid considerably in more accurate seasonal predictions. This can aid farmers in deciding when and how much to plant in their specific area.

5.2. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION 1

Individually the NIŇO3 SST cannot predict rainfall in the North West province. The fact that the NIŇO3 SST's cannot predict rainfall in the North West province, does not mean it does not influence the weather in South Africa, and around the world.

Research has shown that there is a connection between weather patterns and sea surface temperatures, but in terms of accurately predicting weather, there are still some research needed to be done. Similarities in terms of El Niño and La Niña patterns and impact on weather patterns do exist, but with regards to predicting the North West province rainfall, the NIŇO3 SST cannot predict rainfall.

RECOMMENDATION 1

Even though the correct procedure and technique was followed, and the desired result was not achieved, it does not mean the NIŇO3 SST does not influence the weather in South Africa, and around the world.

Finding a technique and manner in predicting trade winds in the NIŇO region in the Pacific Ocean can aid this research. The impact of the NIŇO3 region's SST with the rainfall in the KwaZulu-Natal province can also be done, because the province is situated next to the Indian Ocean, and produces Maize, soybeans and sugarcane, and water restrictions have been implemented frequently during the past few years.

The NWU Statistical Department should be contacted to do the research, because there are some technical statistical methods used. To analyse the data personally, will not be recommended.

CONCLUSION 2

Individually the IOD SST cannot predict rainfall in the North West province. The fact that the IOD SST's cannot predict rainfall in the North West province, does not mean it does not influence the weather in South Africa, and around the world.

Research has shown that there is a connection between weather patterns and sea surface temperatures, but in terms of accurately predicting weather, there are still some research needed to be done. Similarities in terms of El Niño and La Niña patterns and impact on weather patterns do exist, but with regards to predicting the North West province rainfall, the IOD SST cannot predict rainfall.

RECOMMENDATION 2

Even though the correct procedure and technique was followed, and the desired result was not achieved, it does not mean the IOD SST does not influence the weather in South Africa, and around the world.

Finding a technique and manner in predicting trade winds in the Indian Ocean can aid this research. The impact of the IOD SST's with the rainfall in the KwaZulu-Natal province can also be done, because the province is situated next to the Indian Ocean, and produces Maize, soybeans and sugarcane, and water restrictions have been implemented frequently during the past few years.

The NWU Statistical Department should be contacted to do the research, because there are some technical statistical methods used. To analyse the data personally, will not be recommended.

CONCLUSION 3

Together the IOD and NIŇO3 SST cannot predict rainfall in the North West province. The fact that the IOD and NIŇO3 SST's together cannot predict rainfall in the North West province, does not mean they do not influence the weather in South Africa, and around the world.

Research has shown that there is a connection between weather patterns and sea surface temperatures, but in terms of accurately predicting weather, there are still some research needed to be done. Similarities in terms of El Niño and La Niña patterns and impact on weather patterns do exist, but with regards to predicting the North West province rainfall, the IOD and NIŇO3 SST together cannot predict rainfall.

RECOMMENDATION 3

Even though the correct procedure and technique was followed, and the desired result was not achieved, it does not mean the IOD and NIŇO3 SST together does not influence the weather in South Africa, and around the world.

Finding a technique and manner in predicting trade winds in the Indian and Pacific Ocean can aid this research. The impact of the IOD and NIŇO3 SST's with the rainfall in the KwaZulu-Natal province can also be done, because the province is situated next to the Indian Ocean, and produces Maize, soybeans and sugarcane, and water restrictions have been implemented frequently during the past few years.

The NWU Statistical Department should be contacted to do the research, because there are some technical statistical methods used. To analyse the data personally, will not be recommended.

CONCLUSION 4

Regarding commodity prices, there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize decrease.

RECOMMENDATION 4

In this case, the desired result was indeed achieved. It shows that rainfall does have an impact on White Maize prices, and when planning is done in terms of marketing for the farmer and producer, rainfall will have an impact on prices, so careful consideration will be needed.

Recommendation one will be because White Maize prices can move very quickly every day, and can have a major impact on the income realized by farmers and producers of Maize, in time rainfall, like daily actual rainfall in the North West province correlated with White Maize prices trading on Safex in one-day or five-day intervals can be very beneficial for the market participants. This can aid informed and quicker decision-making for market participants.

The second recommendation will be to correlate rainfall in the Free State province, with the price of White Maize and Yellow Maize trading on Safex. The Free State is the number one producer of Maize in South Africa, and their impact and correlation on Maize prices can aid informed and quicker decision-making for market participants

CONCLUSION 5

Regarding commodity prices, there is a statistical significant negative relationship between rainfall in the North West province and the price of Sunflower trading on Safex. This means that when rainfall in the North West province increase, the price of Sunflower decrease.

RECOMMENDATION 5

In this case, the desired result was indeed achieved. It shows that rainfall does have an impact on Sunflower prices, and when planning is done in terms of marketing for the farmer and producer, rainfall will have an impact on prices, so careful consideration will be needed.

The first recommendation will be to collect in time rainfall, like daily actual rainfall in the North West province and correlate this with Sunflower prices trading on Safex in one-day or five-day Intervals. This can be very beneficial for the market participants and can aid informed and quicker decision-making for market participants.

The second recommendation will be to correlate rainfall in the Free State province, with the price of Sunflower trading on Safex. The Free State is the number one producer of Sunflower in South Africa, and their impact and correlation on Sunflower prices can aid informed and quicker decision-making for market participants

CONCLUSION 6

The last conclusion is the very strong positive correlation between the price of White Maize and the price of Sunflower trading on Safex. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well, and vice versa.

RECOMMENDATION 6

In this case, the desired result was indeed achieved. It shows that White Maize prices trading on Safex correlate with Sunflower prices, and when planning is done in terms of marketing for the farmer and producer, there is a very close relationship between the two commodities. The price of White Maize will be an indicator of what will happen to the price of Sunflower.

The first recommendation will be to collect in time rainfall, like daily actual rainfall in the North West province and correlate this with White Maize and Sunflower prices trading on Safex in one-day or five-day Intervals. This can be very beneficial for the market participants and aid informed and quicker decision-making for market participants. Conducting trading in the aforementioned fashion can be very beneficial for the market participants allowing for informed and quicker decision-making.

5.3. AREAS FOR FURTHER STUDY

A study that can potentially be done with the current variables, will be one that look at the impact of the NIŇO3 SST and IOD SST on the rainfall in KwaZulu-Natal and Free State province. The KwaZulu-Natal province produce Maize, soybeans and sugarcane, while the Free State is the biggest producer of Maize and Sunflower in South Africa.

5.4. SUMMARY

The plan is to advise farmers during October and November on more or less what to do regarding planting of summer grains and should they plant, when the most likely time to plant is, what the price tendencies is in years that closely correlate with this year and what should the marketing plan be for the season ahead. As stated earlier, the NIŇO3.0 SST in the Pacific Ocean is very important in influencing weather patterns in South Africa. The other potentially very important influencer is the sea surface temperature along the KwaZulu-Natal coast and the IOD index.

There were two main data analyses done for this dissertation. The first analysis was correlating data for the NIŇO3 region, IOD and rainfall in the North West province and the second analysis was correlating the monthly rainfall in the North West province to the price movement for White Maize and Sunflower.

Nigrini states that no two years are the same, meaning that one El Niño or La Niña is not a mirror effect of the next one. But what is important to note is that there are a few cues as to what more or less can be expected with what has happened previously. The sea surface temperatures in the Niño region is very important, as well as the sea water temperature around the South African coast.

The aim is not to be a weather forecaster, nor a price predictor. What this dissertation is trying to do is to evaluate current year SST's in the NIŇO3.0 region with previous years, comparing monthly and weekly rainfall tendencies for that year and see what prices on the Safex market did for that season. It is important to inform a producer of summer grains in the North West province beforehand what conditions currently are, what is expected for the season ahead and what times of the season he must take into account prices and hedge or not on Safex?

To summarize this study, a brief summary of each chapter will be outlined below.

Chapter 1 consist of an introduction and the problem statement that was put out, and the core research question was stated: What is the relationship between rainfall in the North West province and the South African summer grain markets?

The introduction starts off with the background on agriculture in South Africa, and moving towards factors that could have an adverse or positive impact on the grain production in South Africa. One of these factors are actual and expected rainfall data and strategies towards managing price risk. Rainfall, for one, plays a critical part in determining the price of grain, because farmers are dependent on rain to productively manage their fields and land for planting. The average rainfall for the North West province is discussed in normal, dry and wet years and analysed. The production figures of Maize and Sunflower of the North West province and South Africa are discussed, and the chapter finishes off with a discussion and explanation of the pricing mechanism on Safex.

Chapter 2 consist of the literature study needed to explain the different terms, and give background on them. The chapter also provides insight on the relevant keywords, NIŇO3, Rainfall, North West province, Grain prices, South Africa and how they are interconnected.

The different divisions in chapter 2 are: Background on drought, Background on rainfall, Weather forecasting and interpretation, Sea surface temperatures, The Indian Ocean Dipole, El Niño and La Niña, The rainfall impact on South Africa and the North West province, Grain price background, Maize planting in the North West province.

Chapter 3 consist of the research methodology, the description of the overall research design, the data collection method, and the data analysis that was done.

The steps in the data analysis were the following:

Step 1 - Calculating the average rainfall per month for the North West province.

Step 2 - Can the NIŇO3 and IOD SST's individually or together predict rainfall for the North West province?

Step 3 - Doing the correlation between the NIŇO3 and IOD SST's and rainfall for the North West.

Step 4 - Calculating the correlation between the monthly rainfall in the North West province and the prices of White Maize and Sunflower.

Step 5 - Evaluating the results.

Chapter 4 consist of the conclusion, the summary and the discussion of the results.

Overall there is a declining trend of Maize production in the North West province versus the South African Maize production. The average total the North West province produced was around 29% during the 1990's, and declined to 25% during the 2000's, and only 17% for the 2010's. Overall since the 1990's the North West province has produced on average around 25% of the Maize in South Africa, but since 2000, only 22%. During the last 6 seasons since the 2010/11 season, production has been below 20% of the total South African Maize production, except for the 2013/14 season.

There is a declining trend as well for Sunflower tonnages that have been produced by the North West province since 2000. On average the province has produced around 37% of the South African Sunflower, while this figure has dropped to around 33% during the past 6 seasons, excluding the 2016/17 season.

With regards to weather and the impact it has on the rainfall in the North West province, the following can be seen as the most important conclusions.

During summer months, moisture is transported from the Inter tropical convection zone along the equator in Africa. The trade winds allow this moisture to flow southwards towards the Southern Africa regions. When a high-pressure system forms on the east coast of South Africa, cooler air is flowing towards the central parts of South Africa, and with the moisture coming from the Inter tropical convection zone, a rise of moistures occurs creating favourable rainfall conditions for the summer rainfall regions.

It is true that high moisture from the inter tropical convection zone can be present over South Africa, but without a good and solid burst of cold air from the north-eastern parts of South Africa, only heat storms and thunderstorms will occur, and be sporadic, not widespread rainfall that is needed to aid crops. When the north-eastern wind blows, it keeps the warmer water on South African east coast in a narrow band, and forces it to flow in a southern direction, creating an upwelling of cooler water either side of it. The cooler the water, the better the chances are of a surface high developing, and that increases the chances for rain over the interior. When a high-pressure system on the eastern part of the country is in place, and a low-pressure system (upper-air low) forms over the central and western parts of the country, conditions for widespread rainfall increases. As stated previously, in a high-pressure system, air is flowing anti-clockwise, and this process is what pushes colder air from the ocean to the interior parts of South-Africa. If this high-pressure system is not in place, the amount of cold air pushed over the interior diminishes and lowers the chances of rainfall.

The most important conclusions from the statistical evaluation, show that the North West province has a downward shaping trend line with regards to rainfall from 1971 to 2015. The average rainfall is 540 mm per season for this timeframe. Rainfall in the North West province is crucial during the second part of January, February and the first half of March timeframe when Maize start to silk. The long-term average for January is 98 mm, February 82 mm and March 75 mm, totalling 255 mm for the three months (or 47% of the yearly rainfall).

With regards to El Niño and La Niña and their impact on rainfall in the North West province, the following conclusions have been drawn: On average, during an El Niño season, 39 mm less than the long-term average rainfall of 540 mm can be expected in the North West province. During the strong El Niño episode, the most deviation can be expected. Since 1971, three events have occurred with the previous event occurring in 1997/98 before the record strong 2015/16 event. In zero out of the 3 events above normal rainfall was experienced.

On average, during a La Niña event, 67 mm more rain than the long-term average rainfall can be expected in the North West province, with the episode producing the most deviation, being a strong La Niña event. The last Strong La Niña event occurred during the 1988/89 season and since 1971 there has been 3 events. During a weak La Niña, there have been 4 instances where below average rainfall has been experienced, while 3 events have produced above average rainfall. Only in one instance, below average rainfall has been experienced during a moderate La Niña, while 3 events have produced above average rainfall.

The statistical analysis show that the correlation is slightly inverse from November to March each year between rainfall in the North West province and the price of Sunflower, and slightly more inversely correlated between rainfall in the North West province and the price of White Maize trading on Safex. The results show that there is a statistical significant negative relationship between rainfall in the North West province and the price of White Maize trading on Safex. This means that when rainfall in the North West province increase, the price of White Maize decrease. What is also significant is the very strong positive correlation between the price of White Maize and the price of Sunflower trading on Safex. This correlation means that when the price of White Maize increase, the price of Sunflower increase as well, and vice versa.

To summarize, together or individually the IOD SST and NIŇO3 SST cannot predict rainfall in the North West province. The fact that these two SST's cannot predict rainfall, does not mean they do not influence the weather in South Africa and around the world. Research has shown that there is a connection between these two SST's and weather around the world, albeit not on rainfall in the North West region.

6. REFERENCE LIST

Africa news agency. 2016. Reserve water released into Vaal Dam. https://www.enca.com/south-africa/reserve-water-supply-released-to-counter-crisis-in-gauteng Date of access: 19 January 2017.

Alexander, W.J.R. June 2006. Climate change and its consequences – an African perspective. (pp. 94-107). www.sinotechcc.co.za/courses/climate Date of access: 17 June 2017.

Alexander, W.J.R. June 1995. Floods, droughts and climate change. *South African Journal of Science*, 91:403-408. https://journals.co.za/content/sajsci/91/8/AJA00382353_6774 Date of access: 17 June 2017.

Australian Weather Bureau. 2013. Indian ocean influences on Australian climate. www.bom.gov.au/climate/iod Date of access: 19 January 2017.

Bown, A.N., Ortmann, G.F. & Darroch, M.A.G. 1999. Use of Maize marketing alternatives and price risk management tools by commercial Maize farmers in South Africa. *Agricultural economics research, policy and practice in Southern Africa*, 38(3):275-301.

Burns, J.M. 1979. Leadership. New York, NY: Harper and Harper.

Bryman, A., Bell, E., Hirschsohn, P., Dos Santos, A., Du Toit, J., Masenge, A., Van Aardt, I., & Wagner, C. 2014. Research methodology: Business and management contexts. Cape Town: Oxford University.

Chicago Board of Trade (CBOT). 1998. An introduction to futures and options. Student manual. Chicago, IL: CBOT.

Chance, D.M. 2003. Analysing of derivatives for the CFA program. Charlottesville, VA: AIMR.

Chuey, T.A. & Nelson, D.O. 2017. Formation of precipitation and clouds. http://www.waterencyclopedia.com/Po-Re/Precipitation-and-Clouds-Formation-of.html. Date of access: 26 September 2016.

Clay, E., Bohn, L., Blanco de Armas, E., Kabambe, S. & Tchale, H. 2003. Malawi and Southern Africa: Climatic variability and economic performance, disaster management Facility, the World Bank Working Paper Series No. 7, Washington D.C.

De Jager, E. 2016. SA rainfall in 2015 the lowest on record - SAWS. http://www.politicsweb.co.za/documents/sa-rainfall-in-2015-the-lowest-on-record--saws. Date of access: 26 September 2016.

Du Plessis, J. 2003. Maize production. Pretoria. http://www.arc.agric.za/arc-gci/Fact%20Sheets%20Library/Maize%20Production.pdf Date of access: 16 January 2017.

Dyer, T.G.J. & Tyson P.D. 1977. Estimating above and below normal rainfall periods over South Africa, 1972–2000. *Journal of Applied Meteorology,* 16:145-147.

Edwards, F.R. & Ma, C.W. 1992. Futures and options. Series in Finance. London: Oxford: McGraw-Hill.

Encyclopedia of the Atmospheric Environment (Ecoca). 2016. Rainfall patterns. http://www.ecoca.ro/meteo/tutorial/climate/older /rainfall_patterns.html Date of access: 26 Sep. 2016.

Garner, R. 2015. NASA Studying 2015 El Niño event as never before. http://www.nasa.gov/feature/goddard/nasa-studying-2015-el-Niño-event-as-never before. Date of access: 22 Feb. 2016

Geyser, J.M. 2013. Short and long of futures markets: SAFEX, Grain Hedging, Speculation. Krugersdorp: Kejafa Knowledge Works.

Giddy, I. 2015. The corporate hedging process. New York, NY: New York University.

Greyling, J. 2015. A Look at the contribution of the agricultural sector to the South African economy. http://www.grainsa.co.za/a-look-at-the-contribution-of-the-agricultural-sector-to-the-south-african-economy. Date of access: 20 Sep. 2016.

Groenewald, J., Geldenhuys, F., Jooste, A., Balyamujura, H., & Doyer, T. 2003. The marketing of agricultural products in the new millennium. Johannesburg: First National Bank Agricultural division.

Groenewald, J.A., Gudeta, A.Z., Fraser, G., Jari, B., Jooste, A., Jordaan, A., Kambewa, E.V., Klopper, J., Magingxa, L., Obi, A., Pote, P.P.T.,Stroebel, L., van Tilburg, A. & van Schalkwyk, H.D. 2003. Agricultural Marketing in the New Millennium. Johannesburg: First National Bank.

Guru, M. 2015. El Niño does not always cause drought. http://gurumavin.com/el-Niño-doesnt-always-cause-drought. Date of access: 6 Oct. 2016

Halpert, M. 2014. United States El Niño Impacts. https://www.climate.gov/news-features/blogs/enso/united-states-el-Niño-impacts-0. Date of access: 6 Oct. 2016.

Investopedia. 2015a. What is a long hedge? www.investopedia.com/terms/l/longhedge.asp. Date of access: 6 Oct. 2016.

Investopedia. 2015b. What is a short hedge? www.investopedia.com/terms/s/shorthedge.asp. Date of access: 6 Oct. 2016.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC). 2016. Low-latitude Prediction Research. http://www.jamstec.go.jp/frcgc/research/d1/iod/e/seasonal/outlook.html Date of access: 20 February 2016.

Johannesburg Stock Exchange (JSE). 2016. Agricultural Derivatives. https://www.jse.co.za/trade/derivative-market/commodity-derivatives/agricultural-derivatives Date of Access: 3 January 2017.

JSE (Johannesburg Stock Exchange). 2016. Agricultural Derivatives. https://www.jse.co.za/content/JSEContractSpecificationItems/GrainContractSpecEnglish.pdf Date of Access: 3 January 2017.

Kaskus. 2016. El Niño and Economic impacts. http://www.kaskus.co.id/thread/57b6b7ecc1cb17ca198b456b/penyebab-krisis-ekonomi-dunia-menuju-babel-modern. Date of access: 27 September 2016.

Lamb, R. 2008. How Weather works. http://science.howstuffworks.com/nature/climate-weather/atmospheric/weather6.htm. Date of access: 7 October 2016.

Krugel, L.J. 2003. White Maize futures contracts in South Africa. Potchefstroom: Potchefstroom University for Christian Higher Education. (Dissertation - MCom).

Mofokeng, M.J. 2012. Factors affecting the hedging decision of farmers: The case of Maize farmers in Gauteng Province. Stellenbosch University. (Thesis).

NAMC. 2008. Agricultural futures markets as a price forming mechanism for grains and oilseeds. Pretoria: NAMC.

National Weather Service. 2016. Climate Prediction Center. Frequently asked questions about El Niño and La Niña. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml#NIÑO Date of access: 27 Sep. 2016.

National Weather Service. 2016. Climate Prediction Center. Weekly SST data. http://www.cpc.ncep.noaa.gov/data/indices/wksst8110.for. Date of access: 3 Oct. 2016.

National Weather Service. 2016. Climate Prediction Center. Writing about La Niña, the U.S. and the Jet Stream and this happens. https://www.climate.gov/news-features/blogs/enso/writing-about-la-ni%C3%B1a-us-and-jet-stream-and-happens-clickbait-headline Date of access: 22 Dec. 2016.

NDA. 2007. Abstract of agricultural statistics. Pretoria: Department of Agriculture.

NDA. 2009. Agricultural strategic plan for the department of Agriculture, forestry and fisheries. 2009/10.Pretoria: National Department of Agriculture.

Nelson, C.R., Siegel, A.F., 1987. Parsimonious modelling of yield curves. The Journal of Business 60 (4), 473-489.

Nigrini, S. 2017. Weather Forecasting for South Africa. www.netfor.co.za. Date of access: 6 April 2017.

Odell's World (July 2010). Corn Growth Stages. odells.typepad.com/blog/corn-growth-stages.html. Date of access: 16 December 2016.

Olivier, C. 2016. Seasonal climate watch. http://www.ingwelala.co.za/files/news_downloads/scw%2020%20Oct%202016.pdf Date of access: 16 January 2017.

Randriamahefasoa, T.M.S. 2013. Circulation of the Indian ocean and its climate variability with their impacts on Northern Madagascar rainfall. https://open.uct.ac.za/handle/11427/417/browse?value=Randriamahefasoa%2CTsinampoizina+Marie+Sophie&type=author. Date of access: 19 August 2017.

Reason, C.J.C., Hachigonta, S. and Phaladi, R. F., 2005: Inter-annual variability in rainy season characteristics over the Limpopo Region of Southern Africa. *International Journal of Climatology,* 25:1835-1853.

Safex APD. 2002. JSE – a division: Exam Material. Sandton: Safex.

South-Africa. Department of Agriculture, Forestry and Fisheries (DAFF). 2015. Pretoria http://www.nda.agric.za/doaDev/sideMenu/Marketing/Quartely%20Bulletins%20Uploaded/QUARTERLY%20MAIZE%20MARKET%20ANALYSIS%20BULLETIN%201%20OF%202015.pdf Date of access: 27 September 2016.

South-Africa. Department of Agriculture, Forestry and Fisheries (DAFF). 2017. Crop estimates Committee final production estimate 28 September 2017. Pretoria. http://www.daff.gov.za/daffweb3/home/crop-estimates. Date of access: 29 September 2017.

South-Africa. Department of Agriculture, Forestry and Fisheries (DAFF). Fact Sheet. Pretoria http://www.nda.agric.za/docs/FactSheet/Maize.htm. Date of access: 22 February 2016

SAGIS. 2017. Historic Summary: Hectares & Production. http://www.sagis.org.za/historical hectares&production.html. Date of access: 29 September 2017.

Skwirk online education. (2016?). Year 9, Geography, Geography skills, Maps 2, Synoptic charts. http://www.skwirk.com/p-c_s-16_u-188_t-631_c-2345/synoptic-charts/nsw/synoptic- charts/geography-skills/maps-2. Date of access: 16 December 2016.

South-African Weather Services (SAWS). 2016. How do I interpret a synoptic chart? http://www.weathersa.co.za/learning/educational-questions/68-how-do-i-interpret-maps-charts-and-diagrams Date of access: 16 December 2016.

South-African Weather Services (SAWS). 2017. Email 22 March 2017. Musa.Mkhwanazi@weathersa.co.za.

South-African Weather Services (SAWS). 2016. Observation – synoptic charts. http://www.weathersa.co.za/observations/synoptic-charts. Date of access: 16 December 2016.

Standard bank, Agricultural Department. 2010?. The Management of rainfall risk. Johannesburg: SB.

Tadross, M.A., Hewitson, B.C. & Usman, M.T. 2005: The Inter-annual variability of the onset of the Maize growing season over South Africa and Zimbabwe. *Journal of Climate*, 18:3356-3372.

Thomson Reuters Research Portal. 2017. Glossary or relevant terms. Date of access: 7 June 2017. [Computer application/software]

Times Live. 2016. DA calls for drought to be categorized a national disaster. http://www.timeslive.co.za/politics/2016/01/26/DA-calls-for-drought-to-be-categorised-a-national-disaster Date of access: 20 February 2016.

TMG Digital. 2016. Vaal Dam level continue to rise. http://www.timeslive.co.za/local/2016/12/28/Vaal-Dam-level-continues-to-rise. Date of access: 19 January 2017.

Ucar education. 1998. Ucar Communications/news releases. http://www.ucar.edu/communications/newsreleases/1998/regions.gif Date of access: 27 September 2016.

Van Zyl, J. 1986. 'n Statistiese ontleding van die vraag na mielies in Suid-Afrika. *Agricultural economics research, policy and practice in Southern Africa*, 25(3):49-55.

Wilhite, D.A., 2000: Drought as a Natural Hazard: Concepts and Definitions. *In*: D.A. Wilhite (ed.). Drought (Volume 1) A Global Assessment. London: Routledge. Pp 3-18.

APPENDICES

APPENDIX A: Data collection instrument (-s)

The North West province rainfall by month since 1970

North-West Provincial Rainfall by Month 1970 to 2017

Northwest	1980/ 81	1981/ 82	1982/ 83	1983/ 84	1984/ 85	1985/ 86	1986/ 87	1987/ 88	1988/ 89	1989/ 90	1990/ 91	1991/ 92	1992/ 93	1993/ 94	1994/ 95	1995/ 96	1996/ 97	1997/ 98
Province																		
July	0.0	0.1	13.3	13.7	6.5	0.4	0.2	1.2	0.8	0.0	1.9	0.3	0.2	0.1	0.3	0.0	4.3	5.2
August	1.7	28.6	0.2	2.3	9.1	2.1	17.7	6.2	0.9	1.8	0.6	0.0	8.2	1.2	0.1	2.9	4.5	4.4
September	47.5	5.9	2.1	4.1	4.5	5.0	18.0	82.7	35.9	0.0	7.3	32.9	1.6	6.7	1.0	10.2	4.3	41.9
October	11.0	30.1	88.6	41.8	62.6	66.9	77.2	31.1	98.9	19.0	25.4	55.1	28.1	131.7	15.6	61.5	41.8	39.5
November	148.6	59.5	42.1	64.8	46.6	25.5	106.5	63.7	48.0	102.3	16.5	34.3	113.7	59.8	41.8	88.9	94.6	41.2
December	67.2	90.8	57.0	93.9	38.9	77.4	83.5	84.7	87.4	84.0	73.3	65.6	80.9	94.4	50.7	142.4	95.2	68.3
January	164.0	87.9	66.9	32.8	89.6	81.8	71.3	62.0	105.4	58.9	175.9	31.8	50.3	115.0	94.4	123.2	105.0	122.7
February	104.5	33.8	45.9	19.8	65.7	50.4	62.5	177.0	173.4	85.2	83.9	30.7	74.4	110.4	39.7	125.0	43.1	85.5
March	80.2	65.3	32.1	83.5	58.9	52.5	62.8	131.7	42.6	79.0	117.7	22.9	49.9	39.7	125.7	45.9	190.2	81.7
April	15.0	77.6	15.0	10.3	2.8	20.6	11.0	64.0	66.1	80.4	0.9	18.3	23.9	12.4	29.1	73.0	63.1	9.7
May	2.3	0.4	24.6	12.0	7.6	0.6	0.1	3.9	19.4	4.3	0.6	0.0	2.5	0.2	17.5	34.8	82.1	0.0
June	3.9	1.6	22.6	13.8	2.4	10.2	0.0	3.3	15.8	0.6	23.1	1.0	0.0	0.2	0.0	0.7	0.7	0.0
otal for seaso	**645.9**	**481.6**	**410.4**	**392.8**	**395.2**	**393.4**	**510.8**	**711.5**	**694.6**	**515.5**	**527.1**	**292.8**	**433.7**	**571.9**	**415.8**	**708.6**	**729.0**	**500.1**

Northwest	1998/ 99	1999/ 2000	2000/ 01	2001/ 02	2002/ 03	2003/ 04	2004/ 05	2005/ 06	2006/ 07	2007/ 08	2008/ 09	2009/ 10	2010/ 11	2011/ 12	2012/ 13	2013/ 14	2014/ 15	2015/ 16	2016/ 17
Province																			
July	0.1	0.2	1.2	0.4	0.1	1.0	2.1	0.0	1.7	0.3	0.8	8.7	0.2	0.6	0.4	1.6	0.0	4.2	11.1
August	0.1	0.0	0.6	5.5	27.5	1.1	1.7	0.4	19.3	0.0	0.1	7.1	0.0	0.2	0.1	0.3	5.5	0.1	0.1
September	12.5	2.5	12.4	26.0	3.3	2.8	2.3	0.7	0.8	58.6	1.2	14.6	0.1	0.6	13.9	0.5	0.7	37.0	1.3
October	53.8	21.0	59.1	84.4	37.7	53.6	26.2	16.0	35.5	93.1	21.5	53.9	7.0	26.8	39.2	24.6	7.5	6.0	24.7
November	106.2	34.1	73.0	118.7	19.6	83.4	38.4	52.2	62.6	59.9	68.8	74.0	62.0	44.5	44.8	35.7	81.9	25.8	64.2
December	121.8	144.7	87.3	103.2	107.4	50.1	116.3	61.2	83.9	91.1	26.4	58.6	112.4	73.6	106.8	100.4	96.0	24.2	88.6
January	64.5	125.4	24.0	84.1	81.0	94.5	129.2	154.6	42.6	144.5	185.0	163.1	173.3	61.5	70.7	76.7	64.9	94.6	179.3
February	42.2	118.1	83.2	56.6	81.5	110.0	58.1	208.7	23.3	48.2	82.3	69.9	68.4	56.6	40.2	150.8	30.7	36.5	203.9
March	36.5	102.9	60.9	31.3	40.7	97.9	73.6	105.6	27.5	119.6	66.7	69.4	77.5	61.3	37.1	116.1	48.8	92.8	
April	28.2	24.8	78.1	17.5	6.8	39.7	73.9	45.4	36.2	13.3	8.4	87.4	93.6	6.2	48.1	14.6	15.8	89.1	
May	45.3	20.0	35.8	35.9	2.8	1.9	3.0	6.5	0.4	39.0	13.9	32.0	14.7	0.2	0.9	2.7	1.0	31.5	
June	0.9	3.8	4.2	9.8	2.3	3.1	0.0	5.1	18.3	6.2	37.3	0.3	34.4	7.2	0.0	0.1	6.4	14.3	
otal for seaso	**512.1**	**597.5**	**519.9**	**573.6**	**410.7**	**539.0**	**524.9**	**656.5**	**352.3**	**673.9**	**512.3**	**638.9**	**643.7**	**339.2**	**402.2**	**524.1**	**359.3**	**456.1**	**573.2**

The NIŇO3 SST, IOD SST and Rainfall in the North West province

YEAR	MONTH	NIŇO3	IOD	RAINFALL
measure		**˚C**	**˚C**	**mm**
1996	January	-0.67	0.25	123.22
1996	February	-0.65	0.48	125.03
1996	March	-0.43	0.32	45.92
1996	April	-0.78	0.36	73.03
1996	May	-0.75	0.27	34.79

1996	June	-0.54	0.26	0.68
1996	July	-0.27	0.35	4.28
1996	August	-0.39	0.48	4.48
1996	September	-0.48	0.25	4.34
1996	October	-0.55	0.18	41.79
1996	November	-0.60	0.40	94.60
1996	December	-0.94	0.40	95.22
1997	January	-0.93	0.31	105.05
1997	February	-0.62	0.37	43.14
1997	March	-0.16	0.53	190.22
1997	April	0.09	0.36	63.09
1997	May	0.98	0.36	82.09
1997	June	1.71	0.54	0.68
1997	July	2.39	0.35	5.18
1997	August	2.85	0.41	4.37
1997	September	2.99	0.53	41.86
1997	October	3.25	0.62	39.51
1997	November	3.57	0.64	41.23
1997	December	3.62	0.58	68.27
1998	January	3.31	0.59	122.66
1998	February	2.56	0.89	85.54
1998	March	2.00	0.63	81.71
1998	April	1.59	0.63	9.73
1998	May	1.09	0.69	0.01
1998	June	-0.43	0.78	0.00
1998	July	-0.38	0.68	0.10
1998	August	-0.36	0.65	0.06
1998	September	-0.66	0.41	12.48
1998	October	-0.86	0.44	53.82
1998	November	-0.87	0.49	106.15
1998	December	-1.28	0.55	121.82
1999	January	-1.22	0.47	64.53
1999	February	-0.80	0.65	42.22
1999	March	-0.47	0.34	36.50
1999	April	-0.84	0.33	28.25
1999	May	-0.64	0.31	45.29
1999	June	-0.84	0.36	0.88
1999	July	-0.77	0.38	0.16
1999	August	-0.97	0.31	0.01
1999	September	-1.13	0.40	2.46
1999	October	-1.17	0.39	21.05
1999	November	-1.52	0.38	34.12
1999	December	-1.60	0.43	144.73
2000	January	-1.75	0.23	125.41
2000	February	-1.06	0.56	118.12

2000	March	-0.53	0.57	102.94
2000	April	-0.04	0.57	24.76
2000	May	-0.28	0.36	20.00
2000	June	-0.59	0.41	3.79
2000	July	-0.49	0.39	1.23
2000	August	-0.52	0.42	0.62
2000	September	-0.50	0.39	12.39
2000	October	-0.51	0.28	59.09
2000	November	-0.81	0.32	72.98
2000	December	-0.71	0.29	87.28
2001	January	-0.64	0.41	24.03
2001	February	-0.31	0.44	83.16
2001	March	0.09	0.56	60.94
2001	April	0.02	0.51	78.15
2001	May	-0.19	0.57	35.81
2001	June	-0.08	0.54	4.20
2001	July	-0.19	0.60	0.38
2001	August	-0.27	0.48	5.49
2001	September	-0.58	0.54	26.02
2001	October	-0.47	0.50	84.39
2001	November	-0.63	0.69	118.74
2001	December	-0.54	0.55	103.17
2002	January	-0.54	0.75	84.13
2002	February	-0.16	0.75	56.65
2002	March	0.08	0.90	31.33
2002	April	0.06	0.57	17.51
2002	May	0.16	0.63	35.94
2002	June	0.63	0.54	9.84
2002	July	0.41	0.61	0.12
2002	August	0.48	0.53	27.46
2002	September	0.69	0.62	3.30
2002	October	0.93	0.55	37.69
2002	November	1.39	0.58	19.56
2002	December	1.34	0.44	107.38
2003	January	0.75	0.73	80.96
2003	February	0.33	0.55	81.55
2003	March	0.14	0.57	40.73
2003	April	-0.35	0.54	6.81
2003	May	-0.94	0.61	2.78
2003	June	-0.60	0.48	2.33
2003	July	0.13	0.54	1.00
2003	August	0.05	0.66	1.10
2003	September	0.12	0.64	2.75
2003	October	0.41	0.74	53.61
2003	November	0.42	0.53	83.37

2003	December	0.42	0.74	50.09
2004	January	0.29	0.58	94.48
2004	February	0.09	0.72	109.99
2004	March	0.02	0.64	97.92
2004	April	-0.13	0.62	39.73
2004	May	-0.36	0.40	1.87
2004	June	-0.16	0.44	3.08
2004	July	-0.21	0.24	2.06
2004	August	0.06	0.44	1.75
2004	September	0.32	0.51	2.32
2004	October	0.40	0.64	26.19
2004	November	0.48	0.71	38.36
2004	December	0.63	0.48	116.35
2005	January	0.26	0.70	129.21
2005	February	-0.17	0.55	58.15
2005	March	-0.13	0.71	73.56
2005	April	0.27	0.68	73.94
2005	May	0.40	0.63	3.00
2005	June	0.38	0.66	0.01
2005	July	0.31	0.65	0.00
2005	August	0.20	0.61	0.39
2005	September	-0.28	0.75	0.73
2005	October	-0.23	0.76	16.01
2005	November	-0.70	0.73	52.20
2005	December	-0.86	0.66	61.21
2006	January	-0.63	0.56	154.62
2006	February	-0.29	0.69	208.75
2006	March	-0.60	0.62	105.60
2006	April	-0.25	0.49	45.39
2006	May	-0.04	0.46	6.48
2006	June	0.01	0.64	5.14
2006	July	0.18	0.53	1.75
2006	August	0.46	0.70	19.32
2006	September	0.89	0.62	0.82
2006	October	1.04	0.66	35.54
2006	November	1.09	0.70	62.60
2006	December	1.22	0.74	83.94
2007	January	0.87	0.95	42.58
2007	February	0.08	0.70	23.35
2007	March	-0.35	0.70	27.54
2007	April	-0.37	0.75	36.17
2007	May	-0.73	0.66	0.42
2007	June	-0.60	0.58	18.28
2007	July	-0.83	0.61	0.29
2007	August	-1.13	0.58	0.01

2007	September	-1.33	0.61	58.60
2007	October	-1.56	0.57	93.14
2007	November	-1.81	0.55	59.94
2007	December	-1.55	0.47	91.09
2008	January	-1.50	0.23	144.51
2008	February	-1.32	0.34	48.21
2008	March	-0.58	0.73	119.59
2008	April	-0.32	0.51	13.28
2008	May	0.00	0.47	39.02
2008	June	0.10	0.46	6.22
2008	July	0.50	0.58	0.83
2008	August	0.64	0.43	0.10
2008	September	0.24	0.63	1.15
2008	October	-0.13	0.63	21.50
2008	November	-0.23	0.65	68.84
2008	December	-0.54	0.53	26.35
2009	January	-0.60	0.61	184.95
2009	February	-0.52	0.50	82.27
2009	March	-0.70	0.52	66.67
2009	April	-0.11	0.59	8.42
2009	May	0.32	0.64	13.92
2009	June	0.69	0.64	37.26
2009	July	0.94	0.71	8.66
2009	August	0.95	0.66	7.07
2009	September	0.80	0.69	14.56
2009	October	0.81	0.64	53.86
2009	November	1.26	0.76	74.00
2009	December	1.53	0.65	58.60
2010	January	1.00	0.73	163.12
2010	February	0.75	0.80	69.87
2010	March	0.60	0.92	69.43
2010	April	0.55	0.84	87.42
2010	May	-0.11	0.73	32.03
2010	June	-0.68	0.62	0.29
2010	July	-1.09	0.59	0.21
2010	August	-1.12	0.63	0.01
2010	September	-1.26	0.59	0.15
2010	October	-1.66	0.69	6.98
2010	November	-1.58	0.77	62.01
2010	December	-1.64	0.46	112.45
2011	January	-1.32	0.48	173.28
2011	February	-0.82	0.51	68.45
2011	March	-0.75	0.62	77.50
2011	April	-0.32	0.62	93.57
2011	May	-0.14	0.50	14.72

2011	June	0.10	0.57	34.39
2011	July	-0.01	0.71	0.57
2011	August	-0.42	0.71	0.16
2011	September	-0.63	0.54	0.63
2011	October	-0.95	0.63	26.78
2011	November	-1.09	0.55	44.45
2011	December	-0.94	0.53	73.59
2012	January	-0.73	0.45	61.49
2012	February	-0.18	0.47	56.60
2012	March	-0.21	0.56	61.32
2012	April	0.08	0.68	6.25
2012	May	0.15	0.74	0.16
2012	June	0.66	0.62	7.17
2012	July	0.92	0.54	0.41
2012	August	0.73	0.61	0.10
2012	September	0.43	0.72	13.86
2012	October	0.01	0.75	39.20
2012	November	0.14	0.73	44.83
2012	December	-0.23	0.52	106.84
2013	January	-0.57	0.66	70.66
2013	February	-0.46	0.55	40.20
2013	March	0.07	0.66	37.08
2013	April	-0.15	0.52	48.06
2013	May	-0.69	0.58	0.95
2013	June	-0.64	0.64	0.04
2013	July	-0.66	0.57	1.57
2013	August	-0.55	0.66	0.30
2013	September	-0.13	0.77	0.52
2013	October	-0.21	0.67	24.57
2013	November	-0.17	0.78	35.70
2013	December	-0.04	0.65	100.40
2014	January	-0.37	0.73	76.66
2014	February	-0.81	0.52	150.80
2014	March	-0.24	0.76	116.12
2014	April	0.23	0.78	14.60
2014	May	0.61	0.85	2.72
2014	June	0.89	0.66	0.15
2014	July	0.65	0.56	0.00
2014	August	0.52	0.81	5.53
2014	September	0.45	0.88	0.73
2014	October	0.66	0.82	7.50
2014	November	0.91	0.66	81.90
2014	December	0.80	0.78	96.00
2015	January	0.36	0.81	64.90
2015	February	0.18	0.87	30.74

2015	March	0.15	0.90	48.79
2015	April	0.67	0.74	15.82
2015	May	1.19	0.76	0.97
2015	June	1.66	0.78	6.43
2015	July	2.17	0.71	4.18
2015	August	2.34	0.79	0.10
2015	September	2.63	0.82	37.00
2015	October	2.66	1.07	6.00
2015	November	2.93	1.05	25.80
2015	December	2.85	1.12	24.20
2016	January	2.58	1.18	94.60
2016	February	1.99	1.35	36.50
2016	March	1.57	1.32	92.80
2016	April	0.84	1.09	89.10
2016	May	0.03	0.92	31.50
2016	June	-0.12	0.78	14.30
2016	July	-0.48	0.82	11.10
2016	August	-0.46	0.99	0.10
2016	September	-0.18	0.87	1.30
2016	October	-0.45	0.89	24.70
2016	November	-0.40	0.90	64.20
2016	December	-0.30	0.84	88.60

<u>The Rainfall in the North West province, average price of White Maize and Sunflower in monthly totals since 1998</u>

			AVERAGE PRICE	**AVERAGE PRICE**
MONTH	**YEAR**	**RAINFALL**	**WHITE MAIZE**	**SUNFLOWER**
November	**1998**	41.2	R851.41	
November	**1999**	106.2	R642.22	
November	**2000**	34.1	R699.45	R1 148.18
November	**2001**	73.0	R720.41	R1 226.77
November	**2002**	118.7	R1 177.59	R2 317.23
November	**2003**	19.6	R1 823.86	R2 731.81
November	**2004**	83.4	R984.30	R1 825.00
November	**2005**	38.4	R1 043.32	R1 889.32
November	**2006**	52.2	R935.27	R1 586.45

November	**2007**	62.6	R1 282.73	R2 314.77
November	**2008**	59.9	R1 514.27	R3 723.23
November	**2009**	68.8	R1 906.55	R3 740.85
November	**2010**	74.0	R1 552.10	R3 048.86
November	**2011**	62.0	R1 397.36	R3 851.95
November	**2012**	44.5	R1 950.45	R4 324.18
November	**2013**	44.8	R2 324.86	R4 895.14
November	**2014**	35.7	R2 118.43	R4 779.29
November	**2015**	81.9	R1 993.70	R4 388.50
November	**2016**	25.8	R3 129.05	R5 874.24
December	**1998**	68.3	R1 002.75	
December	**1999**	121.8	R636.50	
December	**2000**	144.7	R691.80	R1 150.00
December	**2001**	87.3	R716.41	R1 237.21
December	**2002**	103.2	R1 526.56	R2 711.50
December	**2003**	107.4	R1 758.53	R2 496.95
December	**2004**	50.1	R1 158.60	R2 046.15
December	**2005**	116.3	R865.90	R1 791.86
December	**2006**	61.2	R1 099.60	R1 691.95
December	**2007**	83.9	R1 315.21	R2 485.79
December	**2008**	91.1	R1 481.50	R3 475.80
December	**2009**	26.4	R1 706.35	R3 336.55
December	**2010**	58.6	R1 630.38	R3 335.14
December	**2011**	112.4	R1 401.19	R4 052.29
December	**2012**	73.6	R1 941.00	R4 204.47
December	**2013**	106.8	R2 153.11	R4 843.06
December	**2014**	100.4	R2 161.37	R4 887.37
December	**2015**	96.0	R2 090.50	R4 582.10
December	**2016**	24.2	R3 949.14	R6 068.10
January	**1998**	122.7	R929.94	

January	**1999**	64.5	R608.95	
January	**2000**	125.4	R663.17	R1 151.90
January	**2001**	24.0	R836.41	R1 408.59
January	**2002**	84.1	R1 608.09	R2 656.23
January	**2003**	81.0	R1 541.77	R2 312.05
January	**2004**	94.5	R1 356.76	R2 351.71
January	**2005**	129.2	R714.00	R1 663.10
January	**2006**	154.6	R1 094.52	R1 600.90
January	**2007**	42.6	R1 327.32	R2 500.73
January	**2008**	144.5	R1 523.50	R4 330.91
January	**2009**	185.0	R1 817.86	R3 420.95
January	**2010**	163.1	R1 385.65	R3 155.75
January	**2011**	173.3	R1 414.57	R4 254.38
January	**2012**	61.5	R2 028.81	R4 384.76
January	**2013**	70.7	R2 044.73	R4 731.64
January	**2014**	76.7	R2 351.36	R5 135.59
January	**2015**	64.9	R2 033.19	R4 665.29
January	**2016**	94.6	R4 792.65	R6 996.65
February	**1998**	85.5	R922.80	
February	**1999**	42.2	R652.96	
February	**2000**	118.1	R634.96	R1 146.71
February	**2001**	83.2	R882.19	R1 560.95
February	**2002**	56.6	R1 549.90	R2 443.00
February	**2003**	81.5	R1 177.30	R2 046.05
February	**2004**	110.0	R1 390.75	R2 327.70
February	**2005**	58.1	R589.25	R1 592.55
February	**2006**	208.7	R998.55	R1 618.25
February	**2007**	23.3	R1 581.45	R2 685.15
February	**2008**	48.2	R1 602.19	R4 967.86
February	**2009**	82.3	R1 621.05	R3 222.90

February	**2010**	69.9	R1 187.90	R3 284.05
February	**2011**	68.4	R1 630.85	R4 457.15
February	**2012**	56.6	R2 000.00	R4 354.05
February	**2013**	40.2	R1 973.75	R5 041.75
February	**2014**	150.8	R2 184.00	R5 176.20
February	**2015**	30.7	R2 575.15	R4 997.20
February	**2016**	36.5	R4 898.90	R6 991.43
March	**1998**	81.7	R794.60	
March	**1999**	36.5	R877.18	
March	**2000**	102.9	R612.27	R1 103.26
March	**2001**	60.9	R844.78	R1 553.10
March	**2002**	31.3	R1 534.79	R2 428.11
March	**2003**	40.7	R954.35	R1 896.35
March	**2004**	97.9	R1 137.86	R2 223.09
March	**2005**	73.6	R568.15	R1 703.05
March	**2006**	105.6	R1 134.71	R1 669.67
March	**2007**	27.5	R1 948.67	R2 794.00
March	**2008**	119.6	R1 806.89	R4 975.26
March	**2009**	66.7	R1 590.68	R3 052.14
March	**2010**	69.4	R1 114.32	R3 348.77
March	**2011**	77.5	R1 602.95	R4 147.32
March	**2012**	61.3	R2 174.52	R4 546.05
March	**2013**	37.1	R2 317.53	R5 245.21
March	**2014**	116.1	R2 129.10	R5 048.05
March	**2015**	48.8	R2 716.73	R4 949.73
March	**2016**	92.8	R4 870.60	R6 898.78

APPENDIX B: Application for Research ethics clearance: 2016

Instructions and recommended path for the completion of your ethics application:

1. **The completed Ethics Application Form must be submitted to the relevant School/ Faculty Representative of the Human Ethics Committee who will then submit it to the Chair of the research ethics committee.**
2. **All applications must be signed by the relevant parties and submitted in Electronic Format.**
3. **Incomplete applications will not be reviewed.**
4. **Proof of Research Proposal Acceptance must be submitted with the application (Please refer to your departmental research committee for relevant documentation).**

Please complete all information below:

SECTION A:				
Title, initials, surname:	**Mr. JM Maritz (JP)**			
Student or staff no.:	26947587			
Department:	NWU Business School			
Telephone:	051-011 1592			
Cell phone:	0827461346			
Fax:				
E-mail:	jp8maritz@gmail.com			
Application:	**First application**	✖	**Resubmission**	☐
Title of research:	**The impact of rainfall in the North West province on summer grain markets**			
Supervisor: **Co-supervisor:**	Prof. Christo Bisschoff			

Purpose of research:		Estimated duration of research:
Honors	☐	**1 year**
Masters (Including mini –dissertations)	✖	
Doctoral	☐	
Non-degree	☐	
Funding (if applicable):	**None**	

SECTION B:

Student Statement on Research Ethics

(to be completed as part of the Proposal Colloquium)

Please answer each question by ticking the appropriate box[1]:

	Yes	No
1. Does the study involve participants who are particularly vulnerable[2] or unable to give informed consent? (e.g. children, people with learning or other mental or physical disabilities, people who are incarcerated, unemployed or otherwise compromised in responding to your questions)	☐	✓

[1] Adapted from Economic and Social Research Council (2005). Research Ethics Framework (REF). www.esrcsocietytoday.ac.uk

[2] ***Vulnerable groups*** raise special issues of informed consent and potential risk. "Vulnerable" participants are not clearly described, but have been noted to include "…children, prisoners, pregnant women, mentally disabled persons, economically or educationally disadvantaged persons" (Common Federal Policy, 1991). Weijer and Emanuel (2000) consider participants to be vulnerable if they are not in a position to provide informed consent, due to their position (such as being in prison), or not possessing adequate intellectual faculty (such as children or the mentally ill)." Children" here are defined as participants younger than 18 years of age.

2. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g. covert observation of people) ☐ ☑
3. Will the study involve discussion of, or questions about, a sensitive topic? (e.g. sexual activity, drug use, crime, harassment, violence) ☐ ☑
4. Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind or any physical, psychological or socio-economic intervention? ☐ ☑
5. Will blood or tissue samples be obtained from participants? ☐ ☑
6. Could the study induce physical, psychological or social stress or anxiety or cause harm or negative consequences beyond the risks[3] encountered in normal life? ☐ ☑
7. Will the study require the personal identification of individuals for follow-up evaluation? (i.e. through names and surnames, identification or staff numbers) ☐ ☑
8. Will financial inducements (other than reasonable expenses and compensation for time) or inducements of any other kind be offered to participants? ☐ ☑
9. Could the image of the NWU, the relevant academic department, your employer, or any other institution however affected by/involved in the project be negatively affected by this research or put in a bad light? ☐ ☑

[3] ***Risk***: These possible risks are described as an "…invasion of privacy, loss of confidentiality, psychological trauma, indirect physical harm, embarrassment, stigma, and group stereotyping" (Oakes, 2002: 449), and also risks posed to. "…a subject's personal standing, privacy, personal values and beliefs, their links to family and the wider community, and their position within occupational settings, as well as the adverse effects of revealing information that relates to illegal, sexual or deviant behaviour" (Economic and Social Research Council (ESRC), 2005: 21). Minimal risk may be defined as where "…the probability and magnitude of harm or discomfort anticipated in the proposed research are not greater, in and of themselves, than those ordinarily encountered in daily life" (Code of Federal Regulations, 2005).

In answering the following 2 questions; consider the classification of the research also as being of *no*, *low*, *medium* or *high* risk, according to NWU guidelines. Attach documentation in which you outline/describe your motivation for this classification.

10. Are you planning on making use of NWU students and/or direct and/or secondary/contracted staff members as research subjects in this research? Also please indicate anticipated *level* of risk: ☐ ☑

No risk X	Low risk	Medium risk	High risk

11. Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? (e.g. students at school, members of self-help groups, residents of a nursing home, the Minister of Education, a tribal chief or village elder). Also please indicate anticipated *level* of risk: ☐ ☑

No risk X	Low risk	Medium risk	High risk

If you answered yes to *any* of the above questions, you will need to describe more fully how you plan to deal with the ethical issues raised by your proposal. *This does not mean that you cannot do the research, only that your proposal will need to be approved by the Faculty Research Ethics Committee. Attach* a full description of the specific issues to this declaration, for discussion by the panel at the Proposal Colloquium. Also, outline/describe your motivation for the classification of the research as being of low, medium or high risk (Please refer to the attached NWU Ethical risk level descriptors).

Please note that it is your responsibility to follow NWU's *Guidelines for Ethical Research* as set out in the *Manual for Postgraduate studies* and any other relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring the confidentiality in the storage and use of data, and anonymity of participants. Any significant change in the question, design or conduct over the course of the research should be notified to the Study Leader and may require a new application for ethics approval.

Candidate

Name and Surname: JM Maritz (JP)

Signature: 

Supervisor

Name and Surname: **Prof. Christo Bisschoff**

Signature:

Chair: Research Proposal Committee:

Name and Surname:

Signature:

APPENDIX C: Ethical clearance letter

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

NWU School of Business & Governance
North-West University

26947587
JM MARITZ
jpdoremaritz@mweb.co.za

Private Bag X6001, Potchefstroom
South Africa 2520
Prof CJ Botha
Tel: (018) 299 1672
Email: christoff.botha@nwu.ac.za

02 August 2017

ETHICAL CLEARANCE

This letter serves to confirm that the research project of **MARITZ, JM** has undergone ethical review. The proposal was presented at a Faculty Research Meeting and accepted. The Faculty Research Meeting assigned the project number **EMSPBS16/06/03-01/55.** This acceptance deems the proposed research as being of minimal risk, granted that all requirements of anonymity, confidentiality and informed consent are met. This letter should form part or your dissertation manuscript submitted for examination purposes.

Yours sincerely

Prof CJ Botha

Manager: Research - NWU Potchefstroom Business School

Original details: Wilma Pretorius(12090298) C:\Documents and Settings\Administrator\My Documents\Bhawe MBA\2017\

APPENDIX D: Solemn Declaration and permission to submit

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Higher Degrees Administration

SOLEMN DECLARATION AND PERMISSION TO SUBMIT

1. Solemn declaration by student

I, JM Maritz 26947587

declare herewith that the thesis/dissertation/mini-dissertation/article entitled (exactly as registered/approved title), The impact of rainfall in the North West province on the summer grain markets

which I herewith submit to the North-West University, Potchefstroom Campus, is in compliance /partial compliance with the requirements set for the degree:

MBA

is my own work, has been language-edited in accordance with the requirements and has not already been submitted to any other university.

* I understand and accept that the copies that are submitted for examination become the property of the University.

LATE SUBMISSION: If a thesis/dissertation/mini-dissertation/article of a student is submitted after the deadline for submission, the period available for examination is limited. No guarantee can therefore be given that (should the examiners' rports be positive) the degree will be conferred at the next applicable graduation ceremony. It may also imply that the student would have to re-register for the following academic year.

Signature of student: JP — Digitally signed by JP Date: 2017.11.03 20:16:19 +02'00'

University number: 26947587

Signed on this 2 day of November of 20 17

2. Permission to submit and solemn declaration by supervisor/promoter

* The undersigned declares that:
  the student is hereby granted permission to submit his/her mini-dissertation/ dissertation or thesis: Yes ✓ No ☐
* that the student's work has been tested by me for plagiarism (for example by Turnitin) and a satisfactory report has been obtained: Yes ✓ No ☐

Signature/Supervisor/Promoter: CA Bisschoff — Digitally signed by CA Bisschoff

Date: 2 Nov 2017

APPENDIX E: LANGUAGE AND TECHNICAL EDITING

RE: Language and technical editing 29 March 2018

To Whom it may concern

I, Johan Botha, former member of the Afrikaans Higher Teaching Federation, teacher and school principle and currently living in Kroonstad, Free state, have read through JM Maritz's dissertation and made the necessary amendments and corrections.

His dissertation title was as follow: The impact of rainfall in the North West province on the summer grain markets.

I am happy to say the language and technical part of the dissertation is at an acceptable standard.

Kind Regards

....
Johan Botha