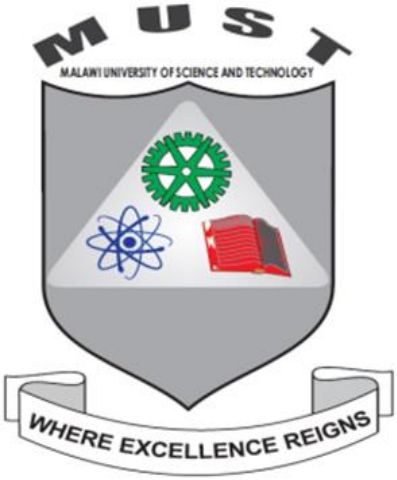



# THE IMPACTS OF THE RAINFALL VARIABILITY ON MAIZE YIELDS IN MANGOCHI DISTRICT

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Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the Bachelor of Science degree in Meteorology and Climate Science.

JULY, 2021

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# ABSTRACT

Climate variability and change are already affecting Malawi, which has experienced a greater incidence of dry spells and intense rainfall events over the last two decades. The changes have led to an increase in the frequency of floods and droughts, with severe economic and social consequences. With projected increases in temperatures, more erratic precipitation patterns, and increasing frequency and intensity of extreme weather events in Malawi become more strained (Malawi adaptation fact sheet, 2012). Rainfall is the main weather element for rain-fed agriculture. Supplemental irrigation, crop diversification and natural conservation methods are promising adaptation strategies to improve Malawi's food security and socioeconomic stability. This study has observed the impacts of rainfall variability on maize yields in Mangochi. The study has been conducted at Traditional Authority (T/A) Namkumba at Monkey bay. The main objective of this study is to provide better understanding on the yields of maize as a result of rainfall variability in Mangochi district. The specific objectives are: (1) to observe the impacts of rainfall variability on maize yields in Mangochi, (2) to analyze the causes of rainfall variability in Mangochi district, (3) to find the ways how the impacts of rainfall variability on maize can be minimized and (4) to observe the trends of rainfall. The rainfall data was collected from the department of climate change and meteorological services (DCCMS) and estimated crop yields for maize was collected from district agricultural development office in Mangochi district. The data collected has been analyzed by tables, plotting graphs and charts. The data has also been analyzed by calculating the average and standard deviation of the rainfall amount and maize production. The finding of this study is that with the trends of rainfall the maize yields have some fluctuations in response to varying rainfall of the area (Monkey Bay in Mangochi).

ACKNOWLEDGEMENTS

The author would like to thank the Department of Meteorology and Climate change, Government of Malawi for providing rainfall data for Monkey Bay weather station. The author would also like to thank the Mbwadzulu Extension Planning Area (EPA) for providing maize production data for Koche, Nkope and Mbwadzulu ADC. Supports by the School of Climate and Earth Sciences, my supervisor Mr. Malazi Mkandawire, Mr. Issa Omar (father), Mrs. Esnart Issa (mother), Mr. Anold Issa, Mr. David Anthony and Mrs. Monique Anthony are gratefully acknowledged. This project wouldn't have been possible without support of the following people: Mcdonald Kalikokha, Patrick chiwalo, Francis Bizeck and saulosi Saidi.

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ACRONYMS/ABBREVIATION

| | |
|---|---|
| $\mu$ | Mean |
| $\sigma$ | Standard deviation |
| ADC | Agricultural Development Corporation |
| DCCMS | Department of Climate Change and Meteorological Services |
| DRC | Democratic Republic of Congo |
| EPA | Extension Planning Area |
| FAO | Food Agriculture Organization |
| IPCC | Inter-governmental panel on Climate Change |
| IFAD | International Fund for Agricultural Development |
| NSO | National Statistical Office |
| OPV | Open Pollinated Varieties |
| USAID | United States Agency for International Development |
| $R_{xy}$ | Correlation |
| R | Correlation coefficient |
| T/A | Traditional Authority |

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# CHAPTER 1: INTRODUCTION

In agriculture, a knowledge of both climate and weather is an important basis for the adoption of any farming system, and many farmers all over the world have discovered over long periods of time, patterns of farming suited to their climatic areas (Brady, 2000).

Malawi's agriculture sector is vulnerable to climate change due to its high reliance on rain-fed crops. Production is already constrained by limited landholdings (average of 1.2 hectares per household), declining soil fertility and limited use and uptake of improved inputs and sustainable land practices (USAID, 2017).

Climate change can disrupt food availability hence reduce access to food, and affect food quality (https://www.epa.gov). Climate change refers to the change in weather conditions in an area, country or in the whole world. One of the consequences of the climate change is the alteration of rainfall patterns. Due to global warming precipitation amount, type and timing are changing or are expected to change because of increased evaporation, especially in the tropics (Ritter, 2006). Rainfall characteristics have shown considerable variations from region to region with some areas experiencing decline and in others increase in precipitation due to increased extreme weather patterns. Decrease in precipitation has been experienced in the Sahel, Mediterranean, southern African and parts of southern Asia where much of the rains fall as intense storms particularly in the dry areas (Ritter, 2006). The degree to which rainfall amounts vary across an area or through time is an important characteristic of the climate of an area. There are two types (or components) of the rain variability, namely, areal and temporal.

Maize is the plant of the tropical regions. Maize because of its many different types, is grown over a wide range of climatic conditions (Brady, 2000). According to Brady (2000) some varieties of maize grow very short, others up to 6 metres in height, some varieties require 60 to 70 days to mature the grain after germination, others require up to 10 months. A summer rainfall of 15 cm per month is the lowest limit for maize production without irrigation, but yield responses to irrigation are obtained with much

higher summer rainfall, the response depending upon rainfall distribution and soil moisture reserves (Waddington, 2018). In general, maize requires moderate amount of rainfall for it to grow properly. It does not need heavy rains since heavy rains can destroy maize hence little amount of yields. There seems to be no upper limit of rainfall under which maize does not grow but excessive rainfall will decrease yields (Chabala, Kuntashula, Kaluba, & Miyanda, 2015).

## 1.1. Background

At present, approximately most of the countries in Africa practice maize production. Most of the maize is produced in countries like Malawi, Mozambique, Zambia, Tanzania, Zimbabwe, Democratic Republic of Congo (DRC), Nigeria, Uganda, Angola, Rwanda, Sudan, Togo, Chad, South Africa, Egypt, Kenya, Cameroon, Benin, Ghana and Ethiopia (FAO, 2009). The maize crop is vital for both food security and income generation. The vision for maize in Africa is that if the maize food system is improved, it will enhance rural industrial development and raise incomes for producers, processors and traders. Maize will contribute more to the food security status of its producing and consuming households, and will become an even more important cash crop that can promote rural development (FAO & IFAD, 2005). Maize is a staple food crop for almost 70% of the population in Malawi and is the most important food crop (Chipeta & Bokosi, 2013).

Almost all the countries which practice maize production rely on climate sources like rainfall, temperature and sunshine. There are factors that produce the climate in any given place-**the climatic controls**, namely, intensity of sunshine and its variability with latitude, distribution of land and water, ocean currents, prevailing winds, positions of high-and low-pressure areas, mountain barriers and altitude (Ahrens & Henson, 2006).

## 1.2. Problem statement

Mangochi district is one of the districts in Malawi which face hunger problem most of the times. Here in Malawi people rely on rain-fed agriculture to get food. Maize crop is widely cultivated because it is staple food for more than 70% of Malawian population (Gaveta, 2017). Cultivation of maize in Mangochi district is a challenge as most parts in the area (Mangochi) do not receive enough rainfall for the growth of maize crop and

some areas experience floods. This results in food insecurity. This problem can be minimized if there is a change on relying one crop such as maize as main source of food in the area.

## 1.3. Research questions

- What are causes of the rainfall variability in Mangochi district?
- What are the trends of the annual rainfall?
- What are the impacts of rainfall variability on maize production?
- How the impacts of rainfall variability on maize yields can be minimised?

## 1.4. Research objectives

### 1.4.1. Main objective

The main objective of this study is to provide better understanding on the yields of maize as a result of rainfall variability in Mangochi district.

### 1.4.2. Specific objectives

- To analyze the causes of rainfall variability in Mangochi district.
- To analyze the trends of the annual rainfall
- To observe the impacts of rainfall variability on maize production.
- To find the ways how the impacts of rainfall variability on maize can be minimized.

## 1.5 Significance of study

Since climate is a component of agricultural production, many studies have focused on how climate variability affects agriculture in terms of crop production. These studies indicate that changes in climatic variables have a major impact on crop production (Akpalu, Hassan, & Ringler, 2008). In countries with a staple food crop relate the climatic variations to output so as to put in place measures that will assure food security. In Malawi, studies at district level are so limited to determine which crop is suitable for that particular area. Every crop has its own climatic requirements that have to be met by the area so that the crop has to produce better yields. Most people are limited in cultivating maize crop regardless of its climatic requirements since its only crop from which they can get their main food. Providing better understanding on the yields as

function of some climate variables such as rainfall variability in a particular area (Mangochi) will help people to know that rainfall variability is a major cause of the decline in maize production. The people will plan and make decisions to minimize the impacts of rainfall variability on maize production. As a result there will be food security.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Climate variability and crop production

In Southern Africa, agricultural production is projected to suffer negative impacts for several important crops (Malawi climate change case study, 2014). This affects food security and exacerbate poverty and malnutrition. Maize is dominant crop produced in Malawi, occupying more than 70% of available agricultural land. Over the last two decades, maize productivity has been erratic due to weather variability, declining soil fertility, limited use and uptake of technologies and market failures. The most serious events have been dry spells, seasonal droughts, intense rainfall, riverine floods and flash floods (Malawi climate change case study, 2014). Malawian farmers experience localized dry spells which can impact on food production. Flooding has also severely disrupted food production in several districts of the country. In 2012/13 rainy season, 12 districts experienced floods which flooded smallholder farmers across the country.

Setsoto Municipality in the Free State Province, South Africa faces the impacts of climate variability on maize production. Droughts and extreme events are becoming more frequent (Bello, Scholes & Newete, 2020).

People focus on the characteristics of the earth's major climates as we experience them today. But it is important to know that these climate characteristics have changed many times over the course of the earth's history (Strahler, 2013). Based on the variety of field data, scientists agree that our planet (Earth) has experienced a series of climate changes over the course of its geological history, alternating between colder periods of glaciation and milder interglacial periods. As climate changes, humans, other animals and plants will all have to face new challenges and develop new strategies to adapt. Climate variations, such as a persistent drought or a delay in the annual monsoon rains, can adversely affect the lives of millions. Even small changes can have an adverse effect when averaged over many years, as when grasslands once used for grazing gradually become uninhabited deserts (Ahrens & Henson, 2015).

Global climate change affects all economic sectors, but the agricultural sector is perhaps the most sensitive and vulnerable. World agriculture, in both developing and developed

countries, remains very dependent on climate resources (Strahler, 2013). Climate change and climate variability are projected to contribute to increased drought episodes, food insecurity and deepening poverty. Most of the African countries are facing challenges of climate variability largely due to their low income, greater reliance on climate sensitive sectors such as agriculture, and weak capacity to adapt to the changing climate (Gill, 2004). There are limited studies that have documented adverse socio-economic impacts of extreme weather events specifically in Malawi. The effects have been felt on almost all sectors such as health, agriculture, livestock, environment, hydropower generation and tourism (Tol *et al.,* 2018). In agriculture, impacts of climate variability are observed in such a way that crop yields are affected by variations in climatic factors such as air temperature and precipitation, and the frequency and severity of extreme events like droughts, floods, hurricanes, windstorms, and hail. Malawi is adversely affected by climatic variability and change because of its dependency on rain-fed agriculture.

Malawi is ranked as one of the world's twelve most vulnerable countries to the effects of climate change (World Bank, 2010) and subsistence farmers suffer in a number of different ways, namely, increased exposure to extreme climate events such as droughts, dry spells and floods. Given that agricultural production remains the main source of income for most rural communities, the increased risk of production failure associated with increased frequency of extreme events causes a major threat to food security and poverty reduction.

## 2.2. Rainfall variability and crop production

A study by Xuebin Zhang and Francis Zwiers, of environment Canada in Toronto revealed that rainfall in Mexico and northern Africa decreased by nearly 70 mm per year in recent years compared to the 1925 rainfall as quoted in Boswell (2007). Wright and Jones (2003) note that rainfall in southwest Australia has declined by 15 to 20% from the late 1960s. On the other hand, significant increase in rainfall of 2.4% per decade was witnessed over the tropical lands during the 20th Century (IPCC, 2001). Similarly, rainfall has increased by up to 50% in parts of northern Europe (Ritter, 2006). Compared to the 1925 rainfall, Canada, Russia and Europe's annual rainfall has increased by 45 mm and in

Peru and Madagascar, rainfall has increased by 60 mm annually (Boswell, 2007). It is also observed that the wet and dry seasons have changed with an increase in wet season rainfall in the southern region and a decreased dry season rainfall in the northern region of Indonesia (Case et al. 2008).

Global rainfall pattern change affects crop production (Strahler, 2013). Agriculture in the world mostly depends on rainfall. Since the amount and distribution of rainfall greatly impact crop production, food security and economic growth of countries in southern Malawi, it has been described as the most limiting factor for crop production in most parts of Malawi (Perera et al. 2002). In view of the importance of rainfall, a knowledge of its patterns, duration and amounts is essential for crop production planning and management (Ndamani & Watanabe, 2013).

The past studies have observed that rainfall is the most important climate element which influences the growth characteristics of crops (Befekadu and Berhanu 2000). Water serves as a carrier of nutrients and energy exchanger in crop development. Inadequacy of water supply hampers efficient crop growth, resulting in low productivity (Ndamani & Watanabe, 2013). When the area receives little or no rainfall then the yields of crops that are grown are very low. Rainfall is important in crop production. Bewket (2009) seen the relationship between rainfall variability and crop production using time series data and correlation analysis. The analysis was on aggregate level where annual rainfall and production records were taken for comparison. It has been observed that crops particularly cereals they are highly influenced with the rainfall variability. The impact of rainfall variability on crop production has been assessed differently by various authors in the sub-humid areas (Kyei-Mensah, Kyerematen, & Adu-Acheampong, 2019).

Different studies conducted to investigate the impact of rainfall variability on maize crop production in Tanzania have reported mixed relationship between rainfall variability and crop production. Lema *et al.* (2014) reported the existence of positive relationship between rainfall variability and maize crop production and negative relationship between rainfall variability and maize crop production. Mndeme (2016) and Majule

(2015) reported that climatic variables, especially change of rainfall patterns lead to the reduction of crop production in Tanzania at Mbeya region. The effect of rainfall variability may cause maize yields change between 2.4% and 3.5% in 2021-2042 in Tanzania.

Ghana also suffers the impacts of rainfall variability on maize yields. It has been reported that maize yield in Ghana is expected to reduce by about 20% by 2050 due to climate change and rainfall variability (Kyei-Mensah, Kyerematen, & Adu-Acheampong, 2019).

Although the relationship between low yield and droughts has been documented in various annual reports, statistical analysis of crop yields and rainfall at regional and district levels has not been conducted (Ndamani & Watanabe, 2013). This research will analyze rainfall data and yields of maize in Mangochi district where events of food insecurity are found. The research will try to find the correlation of annual average rainfall of the area and estimated yields of the maize crop.

# CHAPTER 3: METHODOLOGY

## 3.1. Study area

Study area of this research was Mangochi. Mangochi is at an elevation of 1,541 feet (470m), near the Southern end of Lake Malawi between the main lakeshore road and the Shire River and 5 miles (8 km) south of its entrance into the Lake Malombe. The town is roughly 120 miles (190km) northeast of Blantyre. The district has the human population of 1,148,611 according to the National Statistical Office (NSO) (2018). There are 603, 111 females representing 52.5% of the whole population and there are 545,500 males representing 47.5% of the whole population. The study targeted the area of Traditional Authority (T/A) Namkumba at Monkey bay. This area has the human population of 159,654 (National Statistical Office (NSO), 2018). 78,019 are males and 81,635 are females. The figure below shows map of Mangochi district.

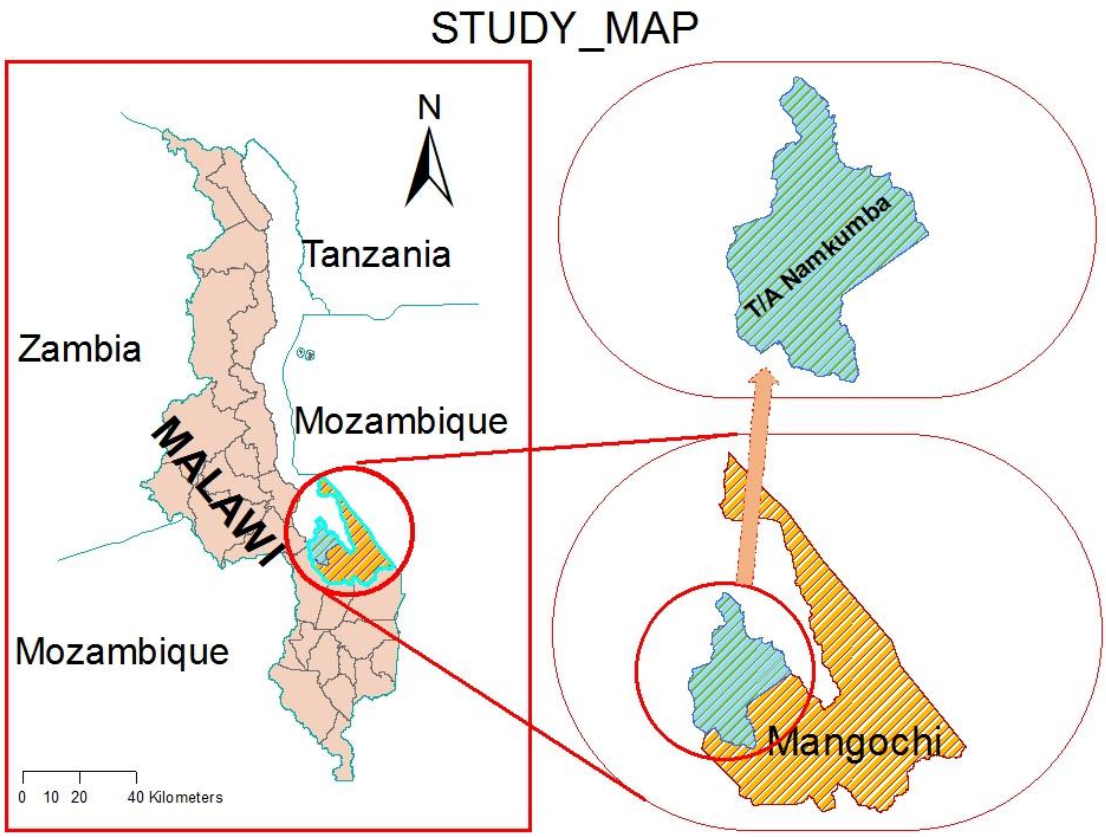



**Figure 1**: Map of Namkumba at Monkey Bay in Mangochi

## 3.2. Research design

The type of research that was used is observation and it used secondary data. This is where the impact of the rainfall variability on maize production was observed. The rainfall variability was observed by analyzing the rainfall data of 21 years (from 2000 to 2020) that was collected from the department of climate change and meteorological services. The rainfall data was put in 20 seasons (2000/2001 to 2019/2020) to match with the maize production which was also put in seasons. The data of estimated maize yields for each season (from 2000/2001 to 2019/2020) was collected from the Mbwadzulu Extension Planning Area (EPA) at Monkey Bay in Mangochi district and it was analyzed.

## 3.3. Data collection

The data that was used in this study is secondary data. The research required rainfall data for 21 years starting from 2000 up to 2020 and maize production data for 20 seasons starting from season of 2000/2001 to season of 2019/2020. This period has been considered in the study because in these seasons there have been weather events such as heavy rains and droughts in the area which affected the crop yields. Rainfall data was collected from the department of climate change and meteorological services (DCCMS) and estimated crop yields for maize was collected from the Mbwadzulu Extension Planning Area (EPA) at Monkey Bay in Mangochi district.

## 3.4. Data analysis

Microsoft excel was used to analyze the data. The data collected was analyzed by using tables, plotting graphs and pie charts. The graphs that were plotted are: the yearly rainfall trends against year, maize yield trends against year and maize yield trends against rainfall amount. Correlation of rainfall amount and maize yield per hectare was analyzed. The standard deviation, averages, trends and ranges were also analyzed.

Rainfall season in Southern region of Malawi starts from October to April according to Department of Climate Change and Meteorological Services (DCCMS), so the rainfall data for Monkey bay from October to April was analyzed.

### 3.4.1. Correlation of rainfall amount and maize yield

Rainfall data has been statistically analyzed to obtain annual average rainfall for each year. To observe the relation of rainfall variability and crop yields, the correlation concept had been employed. Correlation concept is used to display the association of two quantitative variables (Woodbury, 2002). The formula below is for linear correlation.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

**Equation 1**: Correlation of maize yields and rainfall

In correlation analysis, annual average rainfall was regarded as independent variable (x) whereas crop production was regarded as the dependent variables (y). This helped in observing the effect of rainfall variability on crop yields. To measure the strength of the correlation, the **correlation coefficient, r** was calculated. According to Woodbury (2002), the correlation coefficient is always a value between –1 and 1. If the correlation coefficient is positive, then the correlation for the two variables is positive as well. If the correlation coefficient is negative, then the correlation for the two variables is negative as well. If r=1, there is positive perfect correlation, which means that all of the points on the scatterplot lie on a straight line with positive slope. If r=-1, there is perfect negative correlation, which means that all of the points on the scatterplot lie on a straight line with negative slope. The closer the value of *r* is to 1 or –1, the stronger the correlation is. The closer the value of *r* is to 0, the weaker the correlation is. If *r* = 0, then there is no correlation.

A graph that is very helpful in determining whether there is a correlation between two variables is the **scatterplot.** If each ordered pair (x, y) of the sample data on the Cartesian plane is plotted, putting a dot on each point, then we would have a scatterplot (Woodbury, 2002).

### 3.4.2. Annual Average Rainfall and Annual Average Maize Production

The annual average rainfall and maize production for each year was calculated using the following formula:

$$\text{Mean } (\mu) = \frac{\sum x}{n}$$

(Woodbury, 2002)

**Equation 2**: average of the maize production and rainfall amounts

Where x =amount of rainfall and maize production and n =number of years of rains and number of years maize produced

### 3.4.3. Standard Deviation

The standard deviation was calculated to check the gap of the rainfall amounts that was there. The gap is between the highest rainfall amount and lowest rainfall amount. The standard deviation to check on the gap between the highest yield and the lowest maize yield was also calculated.

Standard deviation = √variance

Standard deviation $\sigma = \sqrt{\frac{\Sigma(x - \mu)^2}{N}}$

(Woodbury, 2002)

**Equation 3**: Variance of maize production and rainfall amount

Where $\mu$ is the mean, x is the amount of rainfall and maize yields and N is the number of years of rains and number of years maize produced

### 3.4.4. Range of maize yields and rainfall

The range of maize yields and rainfall was calculated. To find the range, the lowest value was subtracted from the highest value.

Range = Highest – Lowest (Woodbury, 2002)

**Equation 4**: Range of maize yields and rainfall amount

### 3.4.5. Trends of rainfall and maize production

How the maize yields and rainfall amount are changing in 20 years (2 decades) was analyzed using graphs. Maize yield trends have some fluctuations due to varying rainfall of the area.

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1. Rainfall analysis

### 4.1.1. Seasonal rainfall amount variations and trends

Rainfall amount was analyzed from the growing season of 2000/2001 to the growing season of 2019/2020. The trend of the rainfall was analyzed. Figure 2 shows the rainfall and rainfall amount trend at Monkey Bay in Mangochi in twenty seasons (season starts from October to April in Southern region of Malawi according to Department of Climate Change and Meteorology Services) from the season of 2000/2001 to the season of 2019/2020.

Figure 2 shows that there are some variations in the rainfall amount in these twenty (20) seasons (2000/2001 to 2019/2020). In season of 2000/2001, there was highest amount of rainfall (1349.6 mm) than the rest of the seasons. In the season of 2015/2016 there was lower rainfall (347.1 mm) than the rest. This can be concluded that in 2015/2016 season, there was some kind of drought since rainfall amount for the season was very low as compared to other 19 seasons. From the season of 2002/2003 to season of 2003/2004, the rainfall amount decreases drastically. From the season of 2003/2004 to season of 2014/2015, the rainfall pattern variations are minimal while from season of 2014/2015 to 2015/2016, the rainfall amount drops drastically. From the season of 2015/2016 to season of 2017/2018, there was much rainfall pattern variations (rainfall amount increases rapidly). Finally, starting from the season of 2017/2018 to season of 2019/2020, the rainfall was a bit constant (there were no significant changes). Rainfall pattern variations were caused by climate change and variations in the area of T/A Namkumba at Monkey Bay in Mangochi. There are many factors that contribute to the climate change and climate variations in the area. The factors include deforestation, increasingly intensive agriculture, and high population growth (www.wwf.org.nz). Deforestation is the main factor contributing to rainfall pattern variations in the area. Most of the people in the area cut down of trees for firewood and charcoal burning. The people sell the firewood and charcoal for a living since most of the people are poor. Most of the people do not find an alternative to firewood and charcoal burning. To avoid further rainfall variations, the people in the area should practice afforestation and

re-afforestation. Figure 2 shows that the trend of rainfall amount for the first 20 seasons (2000/2001 to 2019/2020) is decreasing. The trend is like that because of the climate change and climate variability in the area.

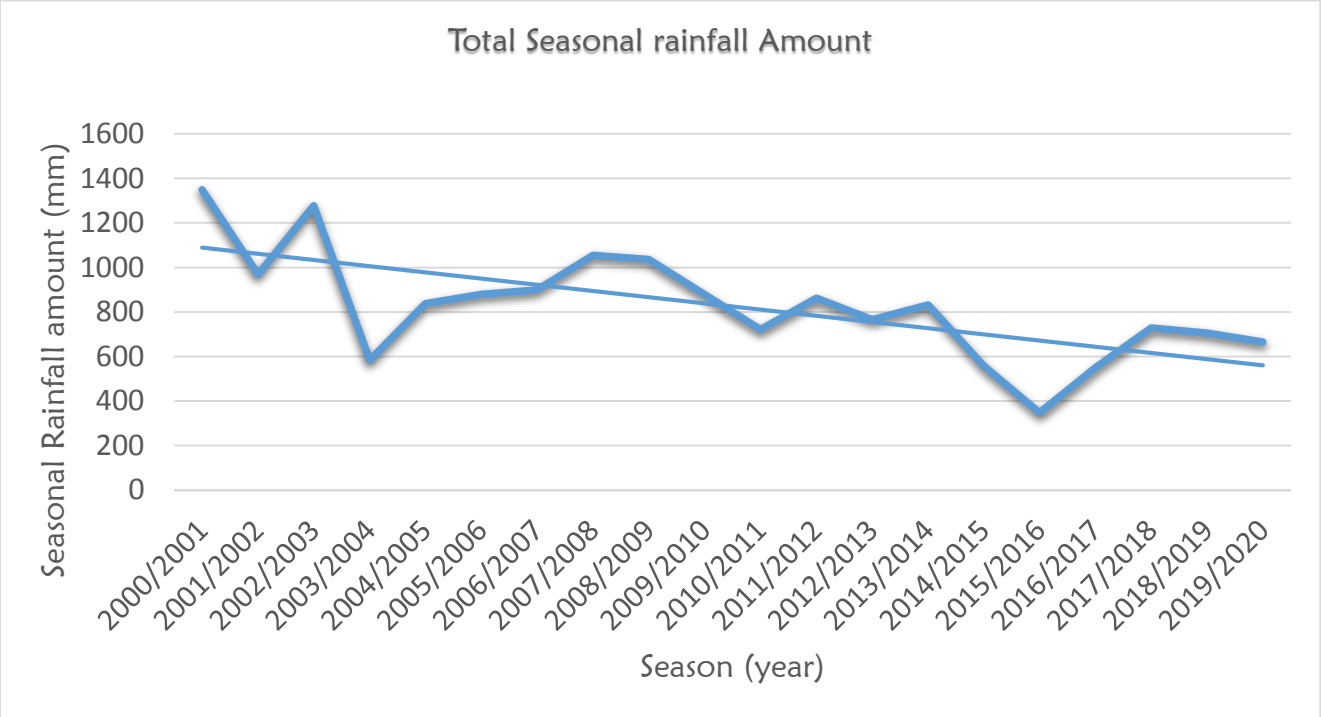



**Figure 2**: Rainfall amount and its trend for 20 seasons (2000/2001 to 2019/2020) at Monkey Bay in Mangochi

Table 1 shows 20 rainfall seasons (2000/2001-2019/2020), rainfall for 7 months for 20 seasons, total seasonal rainfall amount, monthly rainfall mean, monthly standard deviation, monthly rainfall amount range, seasonal rainfall mean, seasonal rainfall range and seasonal rainfall standard deviation. The seasons start from October to April according to the department of climate change and meteorological services. The observed data for the period 2000/2001 to 2019/2020 indicate that Monkey Bay had higher levels of precipitation in the summer months (November – March) with an average of over 253.3 mm in January. In April, average rainfall dropped drastically, to less than 25 mm. The seasonal rainfall varies greatly from season to season (standard deviation is 241.4467763), for example 2000/2001 saw 1349.6 mm of rainfall while the

next season (2001/2002) only received 969.0 mm. The monthly rainfall, for example January, varies greatly from season to season (standard deviation is 123.0689), for example 2007/2008 saw 478.4 mm of rainfall while the next season (2008/2009) only received 116.0 mm, a drop of almost a third. The observed data also indicates that Monkey bay had lower levels of rainfall in October and April. October had 27.4 mm rainfall amount as its highest in the season of 2000/2001 while April had 88.2 mm rainfall as its highest in the season of 2003/2004. The data also indicates that Monkey bay had higher total seasonal rainfall amount in the season of 2000/2001 which is 1349.6 mm and had lowest rainfall amount in the season of 2015/2016 which is 347.1 mm.

Table 1: Observed monthly average rainfall (mm) at Monkey Bay from 2000/2001 to 2019/2020

| Season | October | November | December | January | February | March | April | Total seasonal rainfall amount (mm) |
|---|---|---|---|---|---|---|---|---|
| 2000/2001 | 27.4 | 94.3 | 207.3 | 328.4 | 340.3 | 332.9 | 19.0 | 1349.6 |
| 2001/2002 | 3.3 | 7.9 | 326.8 | 278.9 | 273.7 | 63.8 | 14.6 | 969.0 |
| 2002/2003 | 2.5 | 40.9 | 390.2 | 407.5 | 249.5 | 180.9 | 5.2 | 1276.7 |
| 2003/2004 | 0.0 | 2.0 | 97.0 | 168.6 | 160.0 | 67.6 | 88.2 | 583.4 |
| 2004/2005 | 15.2 | 66.2 | 378.2 | 227.4 | 133.3 | 0.3 | 16.9 | 837.5 |
| 2005/2006 | 0.0 | 5.3 | 126.6 | 157.0 | 167.6 | 394.0 | 28.4 | 878.9 |
| 2006/2007 | 0.2 | 45.0 | 179.9 | 360.4 | 229.8 | 84.3 | 0.2 | 899.8 |
| 2007/2008 | 1.6 | 7.4 | 312.9 | 478.4 | 214.1 | 40.6 | 0.0 | 1055.0 |
| 2008/2009 | 0.0 | 63.2 | 255.0 | 116.0 | 302.0 | 241.6 | 57.5 | 1035.3 |
| 2009/2010 | 0.0 | 12.2 | 108.8 | 205.5 | 475.7 | 71.4 | 4.5 | 878.1 |
| 2010/2011 | 0.0 | 21.5 | 89.6 | 94.0 | 231.1 | 275.5 | 9.4 | 721.1 |
| 2011/2012 | 0.0 | 244.6 | 86.6 | 293.3 | 109.8 | 110.0 | 18.1 | 862.4 |
| 2012/2013 | 8.3 | 5.0 | 79.4 | 508.7 | 127.2 | 34.3 | 2.9 | 765.8 |
| 2013/2014 | 0.0 | 49.7 | 104.5 | 297.9 | 267.1 | 96.7 | 15.6 | 831.5 |
| 2014/2015 | 16.7 | 0.1 | 115.8 | 201.7 | 131.4 | 26.7 | 64.5 | 556.9 |
| 2015/2016 | 0.5 | 8.0 | 71.0 | 93.4 | 68.8 | 99.8 | 5.6 | 347.1 |
| 2016/2017 | 5.3 | 3.5 | 55.0 | 184.4 | 192.7 | 109.7 | 0.0 | 550.6 |
| 2017/2018 | 2.5 | 33.6 | 52.7 | 91.9 | 325.6 | 183.4 | 39.0 | 728.7 |
| 2018/2019 | 0.0 | 25.1 | 192.5 | 255.2 | 112.4 | 84.9 | 34.7 | 704.8 |
| 2019/2020 | 18.4 | 35.6 | 163.5 | 316.8 | 112.4 | 18.1 | 0.0 | 664.8 |
| Average | 5.1 | 38.6 | 169.7 | 253.3 | 211.2 | 125.8 | 21.2 | 824.9 |
| Range | 27.4 | 244.5 | 337.5 | 416.8 | 406.9 | 393.7 | 88.2 | 1002.5 |
| Standard deviation | 7.95809 | 54.975789 | 108.26423 | 123.0689 | 100.4325 | 108.9215 | 24.47562 | 241.4467763 |

## 4.2. Maize production analysis

### 4.2.1. Seasonal maize production variations

Maize yields of different varieties in kilograms per hectare were analyzed from the growing season of 2000/2001 to the growing season of 2019/2020. The trend of the maize was analyzed. Figure 3, figure 4 and figure 5 below show the local maize yield, hybrid and OPV maize yield per hectare at Monkey Bay in Mangochi respectively in twenty seasons (from the season of 2000/2001 to the season of 2019/2020).

Maize yield per hectare are different as seasons vary. Some seasons receive high amount of rainfall while others receive little amount of rainfall.

Figure 3 shows that local maize yields per hectare vary in 20 seasons (2000/2001 to 2019/2020). In season of 2000/2001, maize yield per hectare is a bit lower (526 kilograms). In 2001/2002 season, maize yields increase (reaches 700 kilograms). In 2002/2003, maize yield decreases (587 kilograms) and it starts increasing in the season of 2003/2004 and it reaches its peak (910 kilograms) in the season of 2005/2006. In 2006/2007 season, maize yield decreases (798 kilograms) and it increases in the season of 2007/2008 (865 kilograms). Maize yield starts decreasing drastically from the season of 2008/2009 to the season of 2019/2020. Maize decreases in the last 12 seasons (2009/2010 to 2019/2020) (ranging from 117 kilograms to 670 kilograms) because there is little amount of rains and some floods in those seasons (ranging from 347.1 mm to 878.1 mm).

Figure 4 shows that hybrid maize yields per hectare vary in 20 seasons (2000/2001 to 2019/2020). In season of 2000/2001, maize yield per hectare is a bit lower (1200 kilograms). In 2001/2002 season, maize yields increase (reaches 2355 kilograms). In 2002/2003, maize yield decreases (1120 kilograms) and it starts increasing in the season of 2003/2004 and it reaches its peak (2675 kilograms) in the season of 2008/2009. In 2009/2010, maize yield decreases (1855 kilograms) and it increases a bit in the season of 2011/2012 (1876 kilograms). Maize yield starts decreasing drastically from the season of 2012/2013 (1533 kilograms) and increases in the season of 2013/2014 (1780 kilograms). Maize yield also decreases in the 5 seasons (2014/2015 to 2018/2019) because there is

little amount of rains and some floods in those seasons. There is much small amount of yield (253 kilograms) in the season of 2015/2016 than any other season because there was little amount of rains (347.1 mm) in this season. And maize yield increases (reaches 1586 kilograms) in the season of 2019/2020.

Figure 5 shows that OPV maize yields per hectare vary in 20 seasons (2000/2001 to 2019/2020). In season of 2000/2001, maize yield per hectare is a bit lower (800 kilograms). In 2001/2002 season, maize yields increase (reaches 1941 kilograms). In 2002/2003, maize yield decreases (1009 kilograms) and it starts increasing in the season of 2004/2005 and it reaches its peak (2707 kilograms) in the season of 2005/2006. In 2006/2007 season, maize yield decreases (1210 kilograms) and it increases in the season of 2008/2009 (1719 kilograms). Maize yield starts decreasing drastically from the season of 2009/2010 to the season of 2019/2020. Maize decreases in the last 11 seasons (2009/2010 to 2019/2020) (ranging from 160 kilograms to 1350 kilograms) because there is little amount of rains and some floods in those seasons (ranging from 347.1 mm to 878.1 mm). There were many dry spells in the last 11 seasons hence little amount of rains.

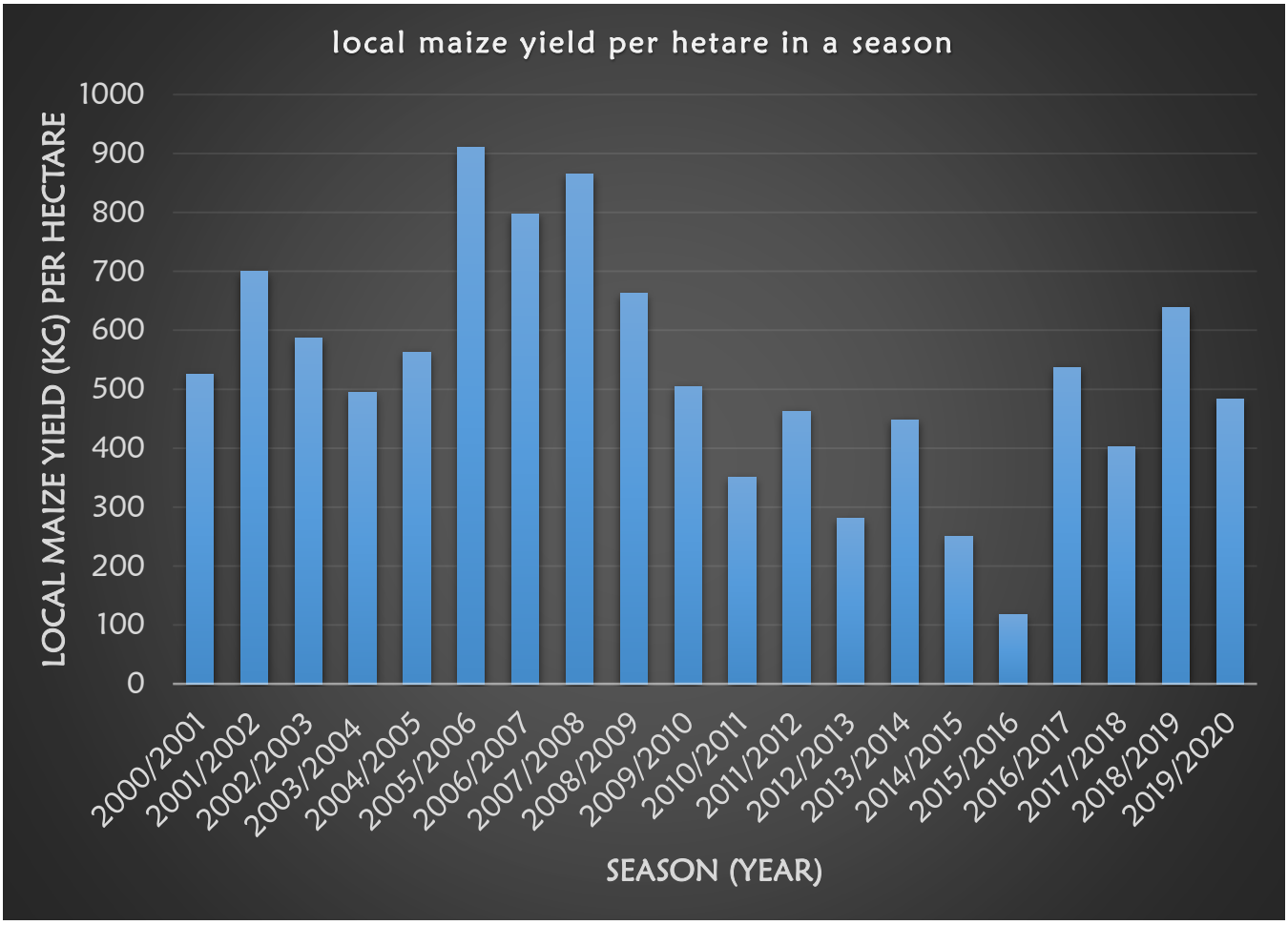



**Figure 3**: Local maize yield per hectare for 20 seasons (2000/2001 to 2019/2020) for Monkey bay in Mangochi

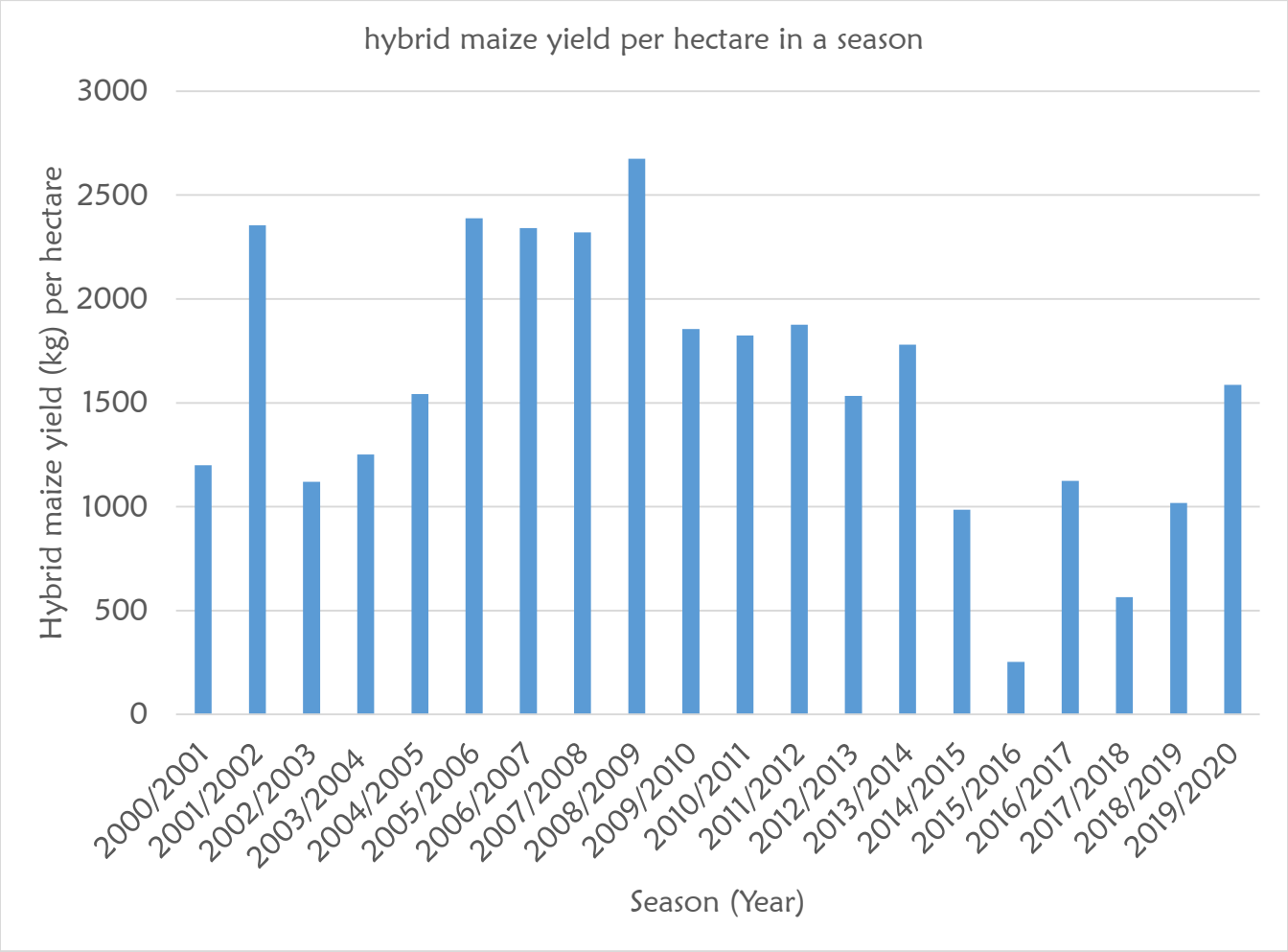



**Figure 4**: Hybrid maize yield per hectare for 20 seasons (2000/2001 to 2019/2020) for Monkey bay in Mangochi

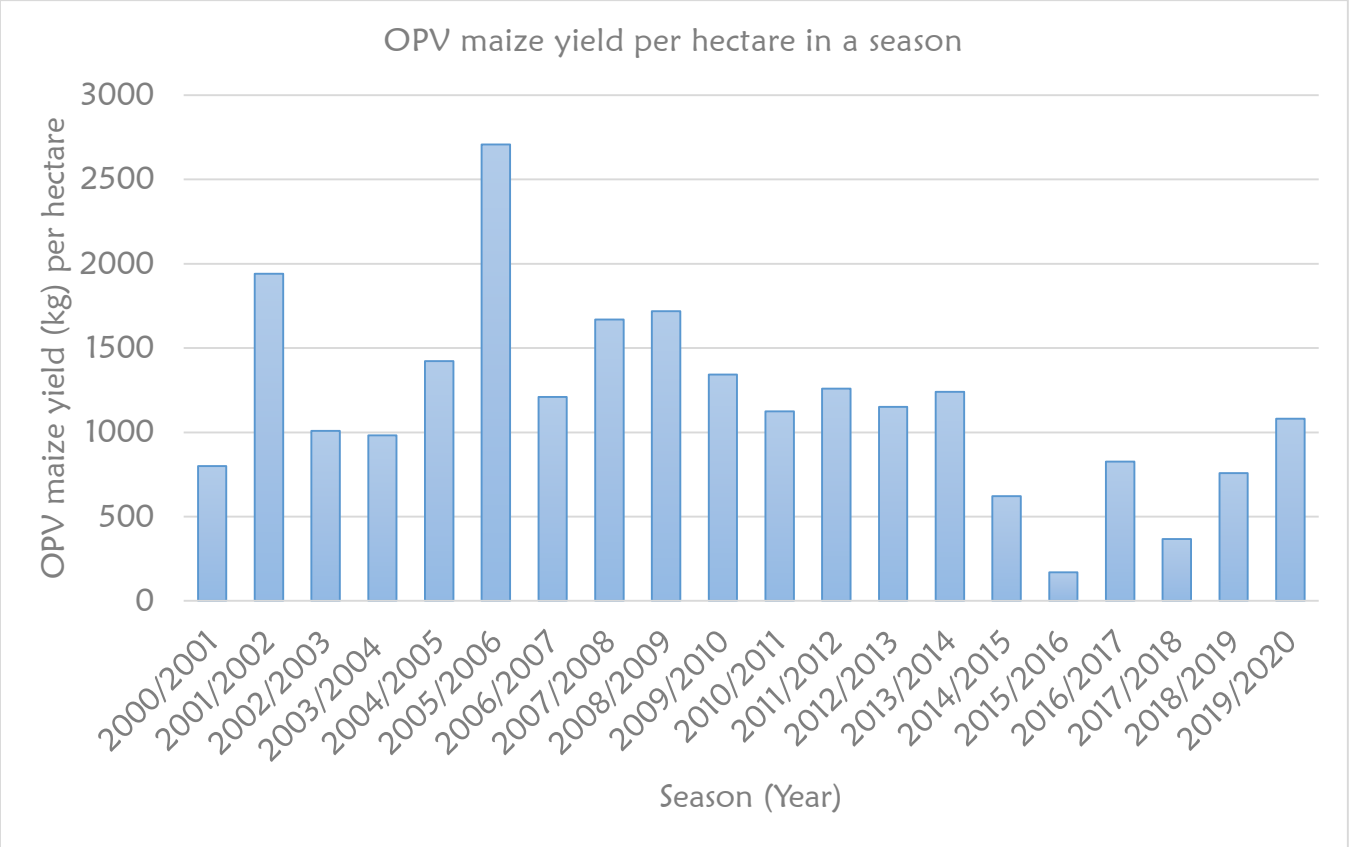



Figure 5: OPV maize yield per hectare for 20 seasons (2000/2001 to 2019/2020) for Monkey bay in Mangochi

Table 2 shows 20 growing seasons (2000/2001 to 2019/2020), total seasonal rainfall amount (from November to April), seasonal rainfall standard deviation, seasonal rainfall amount range, seasonal rainfall mean, local maize yield, hybrid maize and OPV maize yield per hectare for 20 growing seasons; local maize yield range, hybrid maize yield range, OPV maize yield range, local maize yield standard deviation, hybrid maize yield standard deviation, OPV maize yield standard deviation, local maize yield mean, hybrid maize yield mean and OPV maize yield mean per hectare for 20 seasons. The seasons start from October to April according to the department of climate change and meteorological services. The observed data for the period 2000/2001 to 2019/2020 indicates that Monkey Bay had higher levels of precipitation in the season of 2000/2001 (1349.6 mm). The observed data for the period 2000/2001 to 2019/2020 indicates that

Monkey Bay had lower levels of precipitation in the season of 2015/2016 (347.1 mm) and this is the season where there is lowest yield per hectare for the three maize varieties (local maize yield per hectare in this season is 117 kg, hybrid maize yield is 253 kg and OPV maize yield is 169 kg). The highest local maize yield per hectare is 910 kilograms in the season of 2005/2006, the highest hybrid maize yield per hectare is 2675 kilograms in the season of 2008/2009 and the highest OPV maize yield per hectare is 2707 kilograms in the season of 2005/2006.

The seasonal rainfall varies greatly from season to season (standard deviation is 241.4467763), for example 2000/2001 saw 1349.6 mm of rainfall while the next season (2001/2002) only received 969.0 mm, a drop of almost a third. The seasonal hybrid maize yield per hectare varies greatly from season to season (standard deviation is 648.0834), for example 2014/2015 saw 986 kilograms of maize yield per hectare while the next season (2015/2016) only had 253 kilograms of maize yield per hectare, a drop of almost a third. The observed data for the period 2000/2001 to 2019/2020 indicates that Monkey Bay had higher yields of hybrid maize with an average of over 1579.6 kilograms seconded by OPV maize which had average yield of 1170.2 kilograms. The data also indicates that monkey bay had lower yields of local maize with an average of 529.05 kilograms per hectare. Hybrid maize yield average is higher than the rest because this is the maize variety which mature in a short period of time, so it suits to the weather and climate of Monkey bay where the rains stop very fast, sometimes the rains end in the late February. While local maize yield average is lower than the rest because it takes long period of time for it to mature and this requires a lot of rains which can fall for a long period, at least reaching the month of March. With this observation, farmers in the area should go for the hybrid maize.

**Table 2:** Observed maize yield (kg) per hectare for three maize varieties at Monkey Bay (Mbwadzulu EPA) from 2000/2001 to 2019/2020

| Season | seasonal rainfall amount (mm) | local maize (kg) | Hybrid (kg) | OPV (kg) |
|---|---|---|---|---|
| 2000/2001 | 1349.6 | 526 | 1200 | 800 |
| 2001/2002 | 969 | 700 | 2355 | 1941 |
| 2002/2003 | 1276.7 | 587 | 1120 | 1009 |
| 2003/2004 | 583.4 | 495 | 1251 | 982 |
| 2004/2005 | 837.5 | 563 | 1542 | 1423 |
| 2005/2006 | 878.9 | 910 | 2388 | 2707 |
| 2006/2007 | 899.8 | 798 | 2341 | 1210 |
| 2007/2008 | 1055 | 865 | 2320 | 1670 |
| 2008/2009 | 1035.3 | 663 | 2675 | 1719 |
| 2009/2010 | 878.1 | 505 | 1855 | 1342 |
| 2010/2011 | 721.1 | 350 | 1825 | 1125 |
| 2011/2012 | 862.4 | 463 | 1876 | 1260 |
| 2012/2013 | 765.8 | 281 | 1533 | 1152 |
| 2013/2014 | 831.5 | 448 | 1780 | 1240 |
| 2014/2015 | 556.9 | 250 | 986 | 621 |
| 2015/2016 | 347.1 | 117 | 253 | 169 |
| 2016/2017 | 550.6 | 537 | 1124 | 826 |
| 2017/2018 | 728.7 | 402 | 564 | 368 |
| 2018/2019 | 704.8 | 638 | 1018 | 759 |
| 2019/2020 | 664.8 | 483 | 1586 | 1081 |
| Average | 824.85 | 529.05 | 1579.6 | 1170.2 |
| Range | 1002.5 | 793 | 2422 | 2538 |
| Standard deviation | 241.4467763 | 200.8027246 | 648.0834 | 564.6937 |

### 4.2.2. Correlation of Rainfall Amount and Maize Yield per Hectare for Three Maize Varieties

Figure 6, figure 7 and figure 8 are scatter plots that show the correlation of the seasonal rainfall amount and maize yield per hectare for three different maize varieties (local maize, hybrid and OPV) at Monkey bay in Mangochi.

Figure 6 below shows the correlation of seasonal rainfall amount and local maize yield per hectare for 20 seasons growing seasons (2000/2001 to 2019/2020) at Monkey bay in Mangochi. On the graph there is presence of linear equation and the coefficient of determination. The coefficient of determination ($R^2$) tells us the proportion of variation in the response variable that can be explained by variation in the independent variable

(Woodbury, 2002). The coefficient of determination ($R^2$) is 0.3053 which depicts that 30.53% of variations in local maize yield per hectare can be explained by variations in seasonal rainfall amount. To measure the strength of the correlation between the seasonal rainfall amount and local maize yield per hectare, the **correlation coefficient r** is calculated. The correlation coefficient (r) is the square root of the coefficient of determination ($R^2$).

Correlation coefficient r = $\sqrt{r^2}=\sqrt{0.3053}=0.552539591$ which is approximately 0.6

**Equation 5**: correlation coefficient of maize yield and rainfall amount (Woodbury, 2002)
Correlation coefficient r of 0.6 shows that there is strong positive correlation (positive linear relationship) between seasonal rainfall amount and local maize yield per hectare. The strong positive correlation depicts that the local maize yield variation is more dependent on seasonal rainfall amount variations. This means that if the seasonal rainfall amount varies much, then the local maize yield per hectare also varies much, and if there is small variations in seasonal rainfall amount, therefore, the variations in local maize yield per hectare will also be small. The more seasonal rainfall amount varies, the more the local maize yield per hectare varies and the little the seasonal rainfall varies, the little the local maize yield per hectare varies. The strong positive correlation shows that when there is an increase in the independent variable (seasonal rainfall amount), there is also an increase in the dependent variable (local maize yield per hectare) as well.

Figure 7 below shows the correlation of seasonal rainfall amount and the hybrid maize yield per hectare for 20 seasons growing seasons (2000/2001 to 2019/2020) at Monkey bay in Mangochi. On the graph there is presence of linear equation and the coefficient of determination. The coefficient of determination ($R^2$) is 0.2129 which depicts that 21.29% of variations in hybrid maize yield per hectare can be explained by variations in the seasonal rainfall amount. To measure the strength of the correlation between the seasonal rainfall amount and the hybrid maize yield per hectare, the **correlation coefficient r** is calculated. The correlation coefficient (r) is the square root of the coefficient of determination ($R^2$).

Correlation coefficient r = $\sqrt{r^2}=\sqrt{0.2129}=0.461410879$ which is approximately 0.5

Correlation coefficient r of 0.5 shows that there is strong positive correlation (positive linear relationship) between seasonal rainfall amount and hybrid maize yield per hectare since it is approaching to r =1. The strong positive correlation depicts that the hybrid maize yield variation is more dependent on seasonal rainfall amount variations. This means that if the seasonal rainfall amount varies much, then the hybrid maize yield per hectare also varies much, and if there is small variations in seasonal rainfall amount, therefore, the variations in the hybrid maize yield per hectare will also be small. The more seasonal rainfall amount varies, the more the hybrid maize yield per hectare varies and the little the seasonal rainfall varies, the little the hybrid maize yield per hectare varies. The strong positive correlation shows that when there is an increase in the independent variable (seasonal rainfall amount), there is also an increase in the dependent variable (hybrid maize yield per hectare) as well and when there is the decrease in the independent variable (seasonal rainfall amount), there is also the decrease in the dependent variable (hybrid maize yield per hectare) as well.

Figure 8 below shows the correlation of seasonal rainfall amount and the OPV (Open Pollinated varieties) maize yield per hectare for 20 seasons growing seasons (2000/2001 to 2019/2020) at Monkey bay in Mangochi. On the graph there is presence of linear equation and the coefficient of determination. The coefficient of determination ($R^2$) is 0.1766 which depicts that 17.66% of variations in OPV maize yield per hectare can be explained by variations in the seasonal rainfall amount. To measure the strength of the correlation between the seasonal rainfall amount and the OPV maize yield per hectare, the **correlation coefficient r** is calculated. The correlation coefficient (r) is the square root of the coefficient of determination ($R^2$).

Correlation coefficient r = $\sqrt{r^2}=\sqrt{0.1766}= 0.42$

Correlation coefficient r of 0.42 shows that there is weak positive correlation (positive linear relationship) between seasonal rainfall amount and OPV maize yield per hectare since it is approaching to r =0. The weak positive correlation depicts that the OPV maize

yield variation is less dependent on seasonal rainfall amount variations. This means that if the seasonal rainfall amount varies much, then the OPV maize yield per hectare does not vary much, and if there is small variations in seasonal rainfall amount, therefore, the variations in the OPV maize yield per hectare will not be much affected. The weak positive correlation shows that when there is an increase in the independent variable (seasonal rainfall amount), there is no significant effect on the dependent variable (OPV maize yield per hectare) and when there is the decrease in the independent variable (seasonal rainfall amount), there is also no significant effect on the dependent variable (OPV maize yield per hectare).

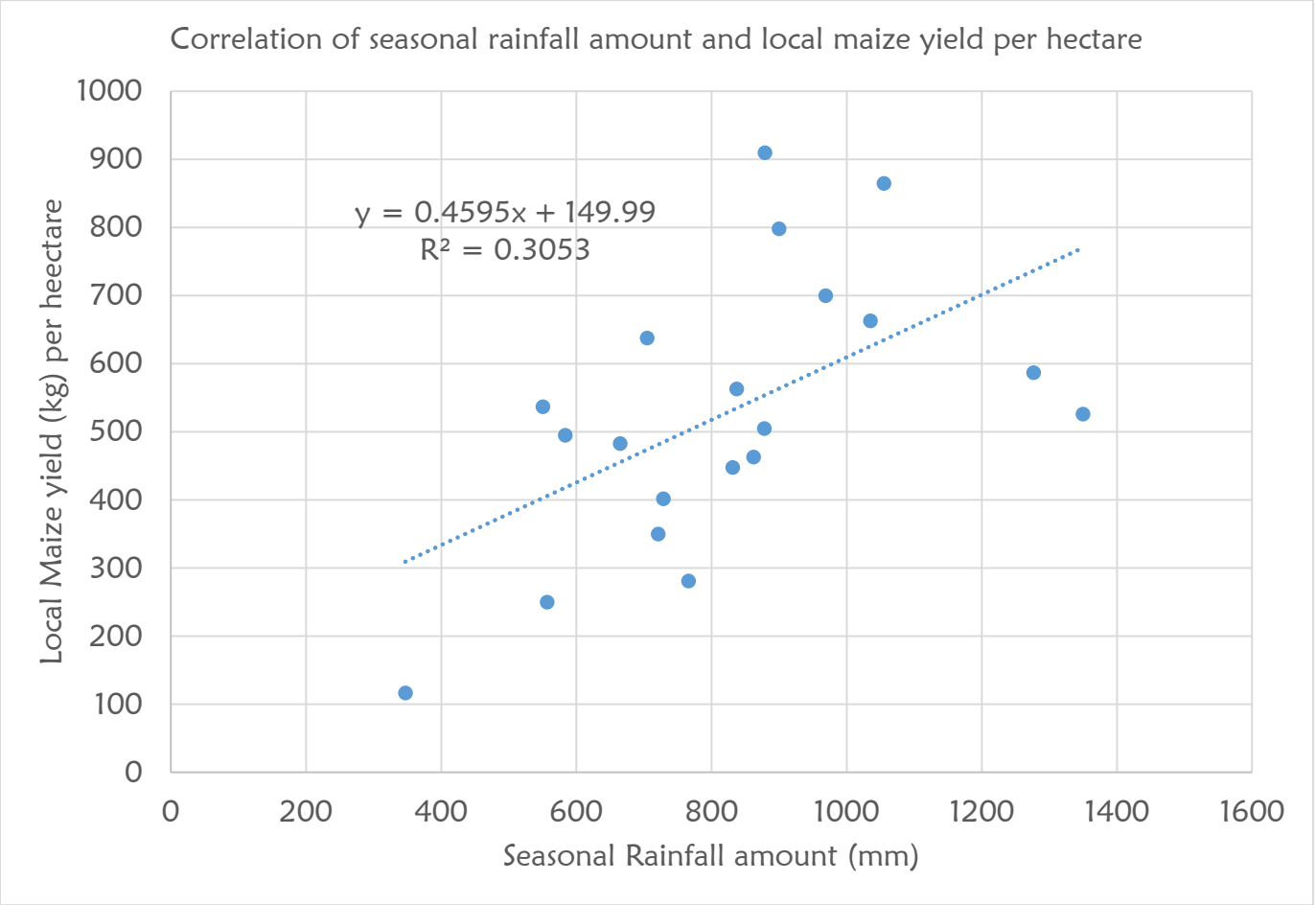



**Figure 6**: Correlation of seasonal rainfall amount and local maize yield per hectare for 20 growing seasons (2000/2001 to 2019/2020)

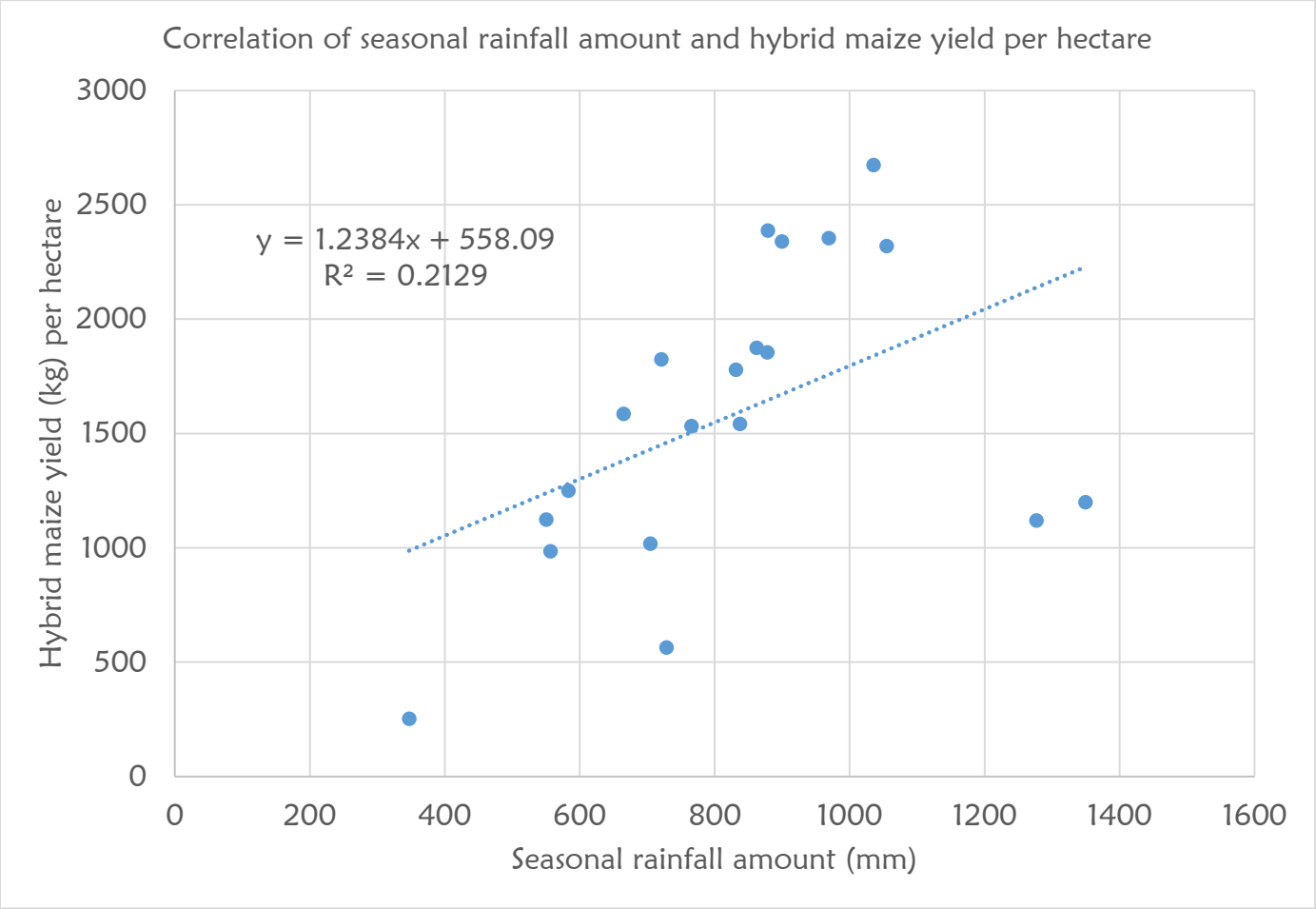



**Figure 7**: Correlation of seasonal rainfall amount and hybrid maize yield per hectare for 20 growing seasons (2000/2001 to 2019/2020)

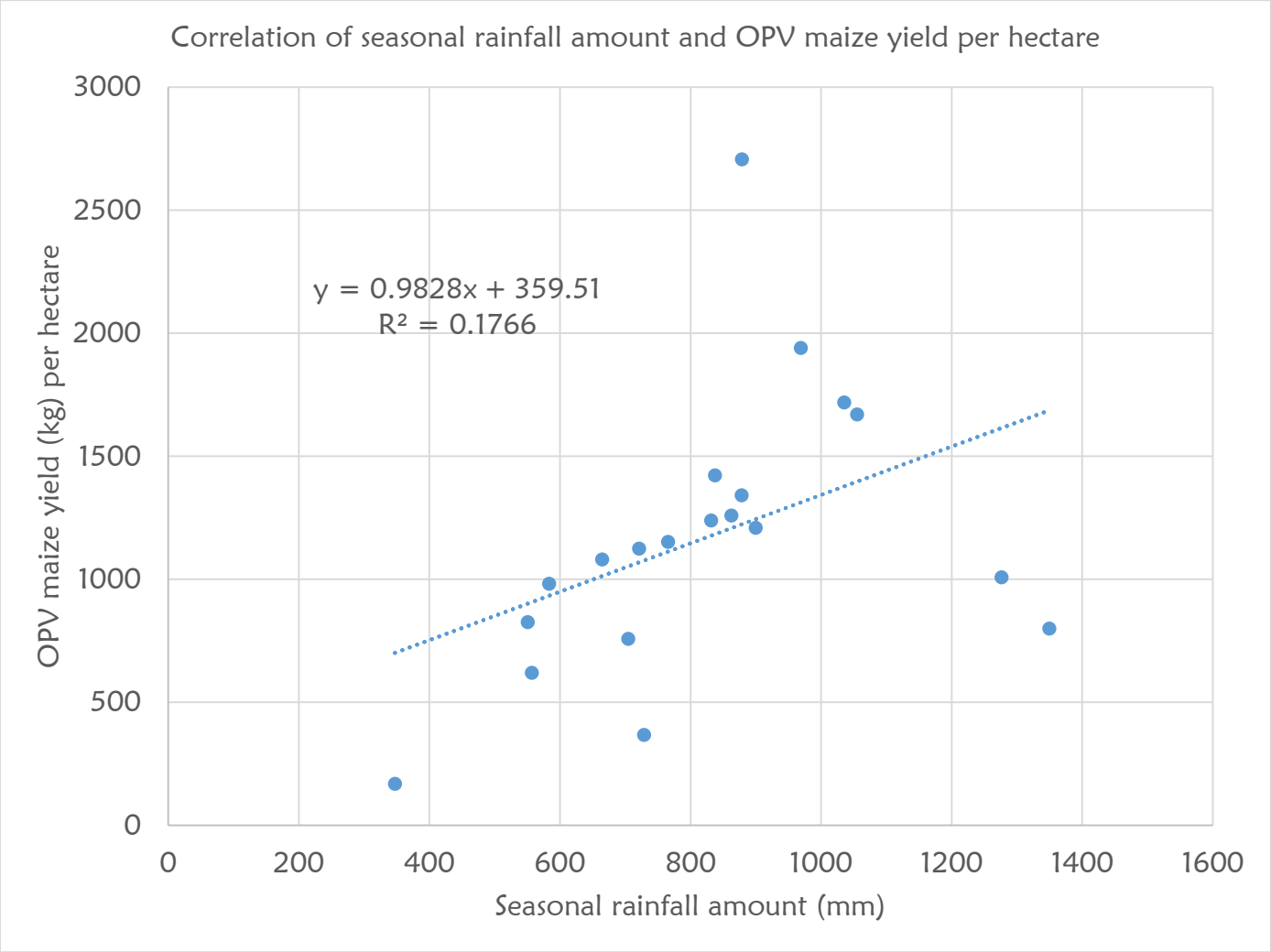



**Figure 8**: Correlation of seasonal rainfall amount and OPV maize yield per hectare for 20 growing seasons (2000/2001 to 2019/2020)

### 4.2.3. Relationship between seasonal rainfall amount and maize yield per hectare

Figure 9 below shows the relationship between seasonal rainfall amount and maize yield per hectare of the three maize varieties (local, hybrid and OPV). The graph shows that the hybrid maize yield per hectare in each season is much higher than the rest of the maize varieties. The local maize yield per hectare in each season is much lower than the rest of the maize varieties. The graph shows that when the rainfall amount decreases, the maize yield per hectare for each variety decreases. The most affected maize variety by the decrease in the rainfall amount is the local maize since it has less adaptive capacity to

dry spells and droughts. The smallholder farmers should opt for the hybrid maize since it withstands the harsh weather conditions such as droughts and dry spells.

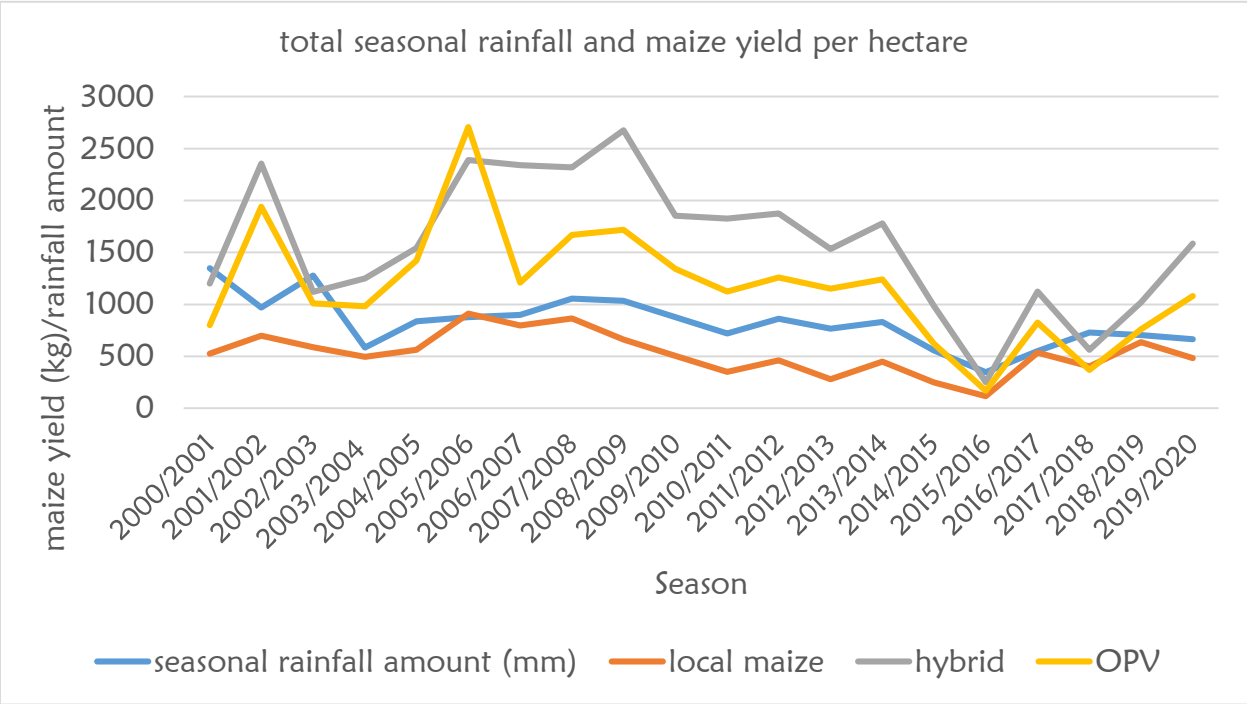



**Figure 9**: Relationship between seasonal rainfall amount and maize yield per hectare

# CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

In the present study we assessed the rainfall patterns and determined the maize production of three varieties at monkey bay in Mangochi district for grid integration of rainfall in order to support the evaluation and planning of future agricultural production. For this purpose, rainfall data for Monkey bay weather station and maize production data for Monkey bay gathered from Mbwadzulu Extension Planning Area (EPA) over a period of 20 growing seasons from 2000/2001 to 2019/2020 was analyzed using Microsoft Excel. The yield of each of the three maize varieties per hectare has been evaluated and analyzed. The rainfall patterns for 20 seasons has been evaluated and analyzed. The rainfall season starts from October to April according to department of Climate Change and Meteorological Services (DCCMS). The most important outcomes of the study can be summarized as follows:

- The maize production is affected mostly by rainfall. If there is little amount of rainfall, the maize yield is very small and if there is much rains the floods will result hence little amount of maize yield. If the amount of rainfall is moderate, the maize yield for each of the three maize varieties increases. Rainfall is an important weather parameter for agriculture according to the findings of the study. Rainfall is important since it makes the crops to grow. Without water, the crops cannot grow hence agriculture can be affected negatively.
- The hybrid maize is the variety which does well even though there is a lot of dry spells or droughts in the area. This shows that the hybrid maize gets matured very fast than the other two maize varieties, local maize and OPV maize. The hybrid maize is also most resistant to harsh weather conditions than the two maize varieties.
- The local variety of maize does not do well as compared to other two varieties, OPV and hybrid varieties of maize. This is because the local variety of maize takes too long for it to mature and is not resistant to the harsh weather conditions. In Mangochi district, the high levels of rains mostly start from December and end in

the late February which is short period of time for the local variety of maize to mature.

- The rainfall pattern shows that at Monkey bay in Mangochi there was many fluctuations or variations of rainfall amount from the season of 2000/2001 to the season of 2019/2020.
- The trend of rainfall amount is decreasing from 2000/2001 to 2019/2020 and this caused the maize yield for each of the three maize varieties also to decrease its trends. This is because, shortage of enough rainfall causes the land being cultivated to be dry that the crops fail to grow freely hence stunted growth of the crops and sometimes the crops start to wilt and dry.
- The study has found out that the rainfall amount is fluctuating for each season due to the changes in temperature. It is believed that an increase in temperature can lead to a more intense water cycle. The rates of evaporation from soils and water, as well as transpiration from plants, could increase. This may result in increase of moisture in the atmosphere. More moisture in the air generally means more rains and more heavy downpours can be expected.

## 5.2. Recommendations

As we have seen that there is rainfall variations at Monkey bay in Mangochi, Malawi. Due to the rainfall pattern variability, the yield of different maize varieties such as OPV, local maize and hybrid maize is affected in many ways, so there is need to have the ways to minimize this situation so that the hunger should be reduced in the area. One of the ways of minimizing the impacts of rainfall variations on maize yield is by planting the maize varieties that can withstand the harsh weather conditions such as droughts or high temperature. The other way is by growing the maize varieties that mature very early before being attacked by the harsh weather conditions. The last way is by practicing the irrigation farming since in this area there are many dry spells and droughts, so irrigation is needed to supplement the yield earned during the rainy season.

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