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# Effect of Climate Change on Maize (*Zea mays*) Production and Food Security in Swaziland

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**Abstract:** Climate variability has been and continues to be, the principal source of fluctuations in global food production in countries of the developing world and is of serious concern in the Kingdom of Swaziland. The mean annual rainfall is considerably low in most parts of the country and temporal variability is quite high. In some places, as much as 60% of the annual total rainfall is recorded in just two months of the year. There is however, no definite trend discernible in the long-term mean rainfall. Rainfall variability is a threat to food production in Swaziland especially maize production which is the staple food. The objective of this study was to investigate the effects of climate variability and change on maize production and household food security in Swaziland. To achieve the objective, secondary data on rainfall in two agro-ecological zones and maize production from 1990 to 2009 were analysed using two-way analysis of variance and the data was then subjected to regression analyses to establish trends. Results showed significant differences in average rainfall and growing season rainfall on maize production. The rainfall trends in the Lowveld (severe drought prone area) tended to be declining whilst that of Middleveld (moderate drought prone area) was somewhat stable. Reduced/or erratic rainfall during the years resulted in decreased maize production. However, rainwater harvesting/soil conservation techniques, intercropping, growing of short duration/early maturing maize varieties, crop diversification such as millet and sorghum and migration of farmers to more productive Swazi Nation Land (SNL) for crop production can mitigate further the impacts of climate change and increase household food security in Swaziland.

**Key words:** Climate change · Food security · Maize (*Zea mays*) · Mitigation · Rainfall variability · Swaziland

## INTRODUCTION

Climate change refer to the increase of earth temperature due to the release of gases such as $CO_2$, $CH_4$, CFCs, $N_2O$ and $O_3$ into the earth's atmosphere [1]. Climate change present a challenge for researchers attempting to quantify its local impact due to the global scale of likely impacts and the diversity of agricultural systems. Similarly, the effect of climate change on vegetation can be dramatic, due to variations in the amount of $CO_2$ available for photosynthesis. In addition, climatic factors such as temperature, precipitation, moisture and pressure affect the development of plants, either alone or by interacting with other factors [2]. Considerable research works have been carried out on the effects of weather/climate on agricultural production, [1, 3-7] but few works have been specific on the effects of climate change on maize production. It has been reported by Chi-Chung *et al.* [8] that precipitation and temperature have opposite effects on yield levels and variability of corn (maize). In his study on the influence of climate change on maize production in semi-humid and semi-arid areas of Kenya, Bancy [9] reported that in order to counter the adverse effects of climate change in maize production, it might be necessary to use early maturing cultivars and practice early planting. Earlier, Anderson and Hazell [10] argued that adoption of common high-yielding varieties, uniform planting practices and common timing of field operations have caused yields of many crops to become more strongly influenced by weather patterns, especially in developing countries. Studies have indicated that 1°C increase in global temperature will lead to reduced productivity in some cultivated plants, such as 17% in maize and soybean [11-12].

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**Climate Variability and Food Security:** Various studies by IPCC [1] have pinpointed Africa to be one of the most exposed continents to suffer the devastating effects of climate change and climate variability, with colossal economic impacts because it often lacks adaptive capacity. The African rain-fed agriculture is viewed by many observers to be the most vulnerable sector to climate variability and the potential impacts of climate change on agriculture are highly uncertain. The report by World Meteorological Organization (WMO) [13] revealed that the overall global warming is expected to add in one way or another to the difficulties of food production and scarcity. The report also stated that reduced availability of water resources would pose one of the greatest problems to agriculture and food production, especially in the developing countries. Also Katz and Brown [14] reported that climate variability is likely to increase under global warming both in absolute and relative terms. According to reports of IPCC [1], factors such as endemic poverty, bureaucracy, lack of physical and financial capital, frequent social unrest and ecosystem degradation contribute to Africa's vulnerability to climate variability. Almost 80% of the Swazi population is rural-based with livelihoods predominantly dependent on subsistence crop farming and/or livestock rearing. Over the past years, multiple interrelated factors such as small fragmented landholdings and minimal access to agricultural inputs, reduced employment opportunities, market inefficiencies and high HIV/AIDS prevalence have contributed to chronic food insecurity and gradually weakening livelihoods [15]. In addition, the agricultural system is dominated by a single crop, which is maize, coupled with the extensive dependence on rain-fed agriculture which will further increase households' vulnerability due to erratic rainfall and weather variability. Minimal shocks to agriculture therefore have a profound impact on the ability of rural households, especially the chronically poor, to maintain their food security. Climate change and variability is clearly evident in Swaziland as it manifests itself in various hydrological disasters. Swaziland has experienced severe droughts in the last three decades with the most severe ones occurring in 1983, 1992, 2001, 2007 and 2008. However, in 2007, close to 50% of the population required food aid, as they did not have sufficient food due to failure of their crops during which time the government was less prepared coupled with inadequate formal structure to coordinate emergencies [16].

**Crop Production in Swaziland:** Agriculture in Swaziland depends on rainfall to a very large extent and the activities in winter season are less affected by climate change than in summer. Since the 1990s, crop production in the country especially of maize has faced the negative impacts of extreme climate events which are believed to be manifestations of long-term climate change. Swaziland has experienced some of its worst droughts and floods in the last two decades whilst significant rainfall deficits/cessation at critical stages of crop growth has frequently led to a serious shortfall in crop production especially maize. According to 2004/2005 crop and food supply assessment of the FAO/ WFP, the production of the country's staple food, maize was on a long term decline, dropping by 70% over a period of five years in most areas. This was due to non-cultivation of the arable lands due to delayed rainfall and the high risk of making loss from agriculture as well as shortage of seeds for alternative crops among others [17]. Swaziland has suffered below average and declining cereal production as a result of erratic rainfall patterns, which are exacerbating the impact of rising unemployment and increased poverty [18]. The purpose of this study is to analyze the impacts of climate change on maize production and yields and to examine the implications of climatic change on household food security in Swaziland.

## METHODOLOGY

**Data Collection:** The Secondary data (meteorological and maize agronomic data) used in this study were collected from Malkerns Research Station, Malkerns and Swaziland Ministry of Agriculture, Manzini Regional office. The meteorological and maize agronomic data included average monthly and annual rainfall as well as the average annual output per hectare of maize in Swaziland. The time series data (1990-2009) covered 20 years.

**Data Analysis:** Analysis of variance (ANOVA) was used to evaluate the differences in rainfall data of two agro-ecological zones (Lowveld and Middleveld) and maize production. The choice of Lowveld (severe) and Middleveld (moderate) agro-ecological zones in this study was based on their drought prone situations and their importance in maize production in Swaziland. The different agro-ecological zones of Swaziland are shown in Fig. 1. The maize production figures and rainfall data set was analysed using correlation analysis.

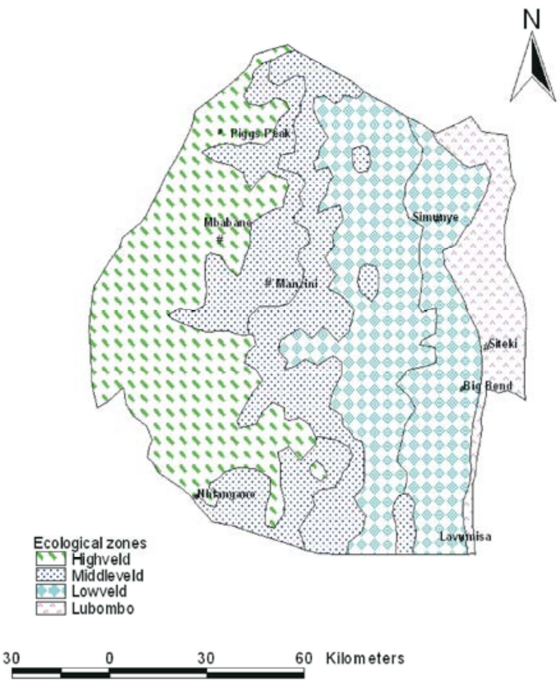


Fig. 1: Agroecological zones of Swaziland

## RESULTS AND DISCUSSION

**Climate Variability and Rainfall Situation:** The rainfall trends in Lowveld (Fig. 2a) and Middleveld (Fig. 2b) showed significant variation in spatial and temporal patterns of both total annual and planting season rainfall which affected crop production in the country including maize crop which is rainfall dependent. Figures 3a and 3b show the mean monthly rainfall distribution from January to December in Lowveld and Middleveld, respectively from 1990 to 2009. Rains for crop production start in October and continue till March in the Lowveld and Middleveld with over 80% of annual rainfall in the country occurring during this period. Heavy rainfall occurring in December and January are often not able to support high yield of maize crop as a result of late planting which is usually carried out during the second and third week of November and first week of December. According to the National Meteorological Service of Swaziland, there was not enough moisture during the 2006/2007 cropping season (Table 1) to sustain the maize crop in the Lowveld,

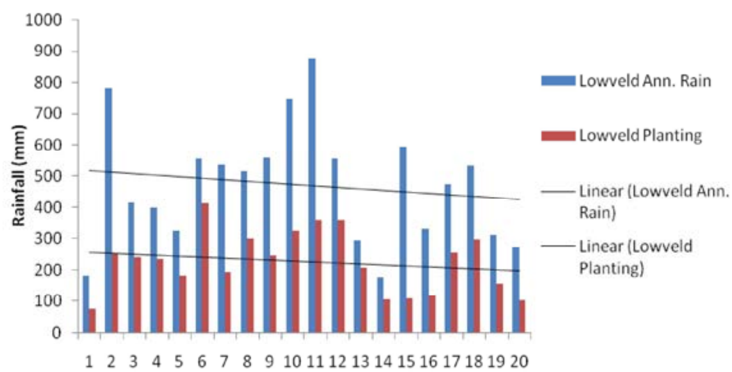


Fig. 2a: Rainfall trend in Lowveld (1990-2009)

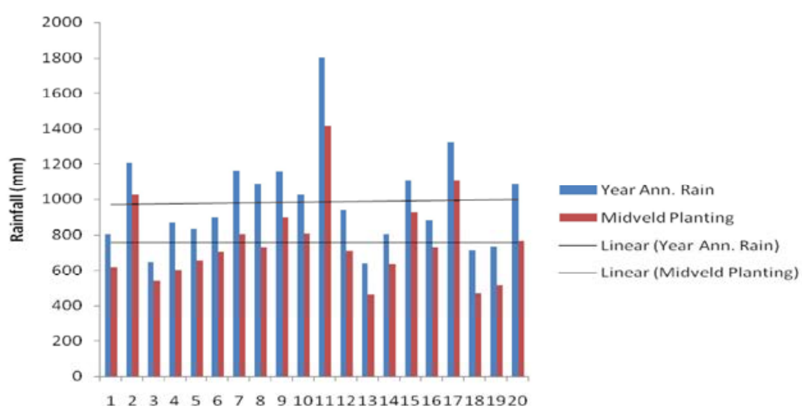


Fig. 2b: Rainfall trend in Middleveld (1990-2009)

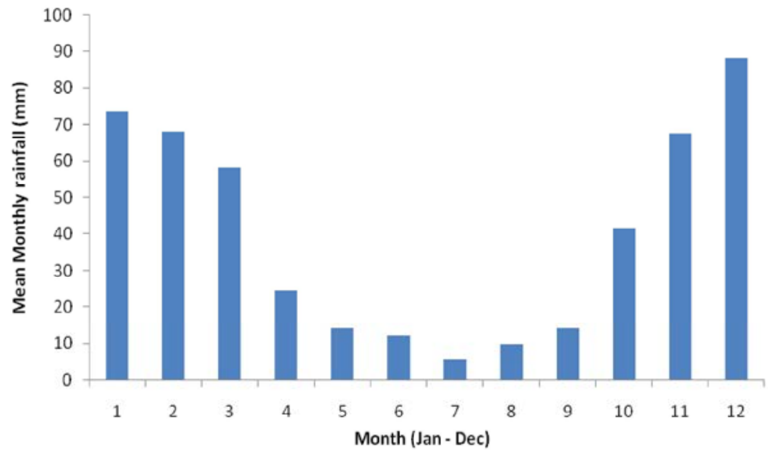


Fig. 3a: Mean monthly rainfall distribution in Lowveld (1990-2009)

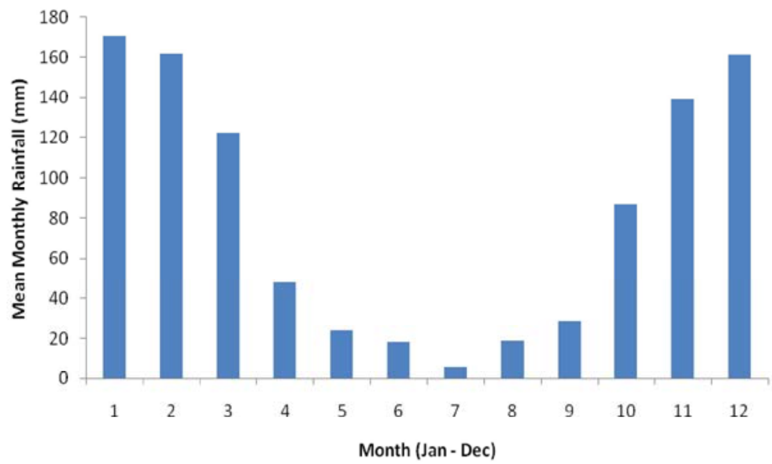


Fig. 3b: Mean monthly rainfall distribution in Middleveld (1990-2009)

Table 1: Swaziland: Total water requirement (TWR) for maize compared to seasonal rainfall (mm) from 2003/ 04-2006 /07

| Agro-ecological zone | TWR for Maize | Rain 2003-2004 | 2003-2004 minus TWR | Rain 2004-2005 | 2004-2005 minus TWR | Rain 2005-2006 | 2005-2006 minus TWR | Rain 2006-2007 | 2006-2007 minus TWR |
|---|---|---|---|---|---|---|---|---|---|
| Highveld | 462 | 774 | 312 | 870 | 408 | 930 | 469 | 482 | 20 |
| Middleveld | 493 | 639 | 146 | 669 | 176 | 859 | 366 | 456 | -37 |
| Lowveld | 536 | 530 | -6 | 543 | 7 | 539 | 3 | 287 | -249 |
| Lubombo Plateau | 632 | 489 | 143 | 595 | 106 | 589 | 100 | 414 | -74 |

Source: Crop and Food Supply Assessment Mission (CFSAM)

Middleveld and the Lubombo plateau. Almost all regions had rainfall amounts that were well below the previous years' averages, as shown in Table 1. The poor spread of rainfall throughout the growing season will have a damaging impact on the maize crop yields especially in the Lowveld. The results yielded a model that can be used to forecast trend in crop yield in relation to variability in rainfall. Also, correlation analysis revealed that the planting season rainfall variability was relatively high in Middleveld ($r = 0.513$) compared to Lowveld ($r = 0.225$). Similarly, in the Lowveld, there was negative correlation between the total annual rainfall ($r = -0.031$) and planting season rainfall ($r = -0.176$) on maize production areas, indicating significant reduction in maize cultivatable area which may in turn affect the household food security.

**Effects of Climate Variability and Change on Maize Growth and Productivity:** Climate variability affects maize yield and the various crop processes and activities in maize production. There has been a significant fluctuation in maize yield and production trends in Swaziland (Fig. 4).

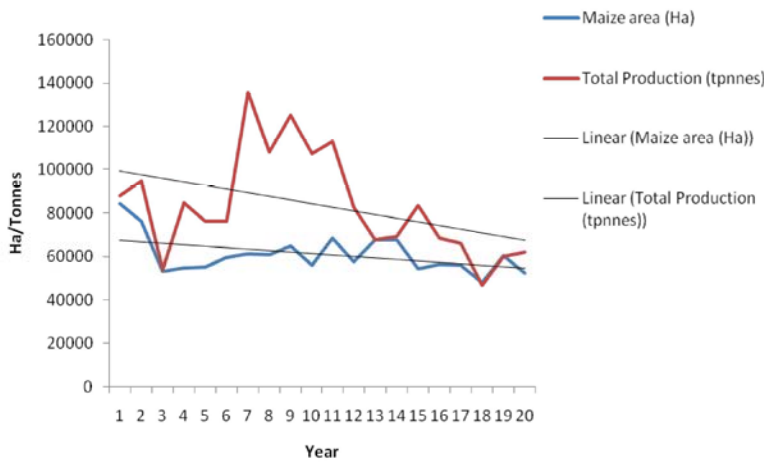


Fig. 4: Trend in maize production in Swaziland (1990-2009)

Table 2: Maize production (Ha) and yield (Tonnes) in Swaziland from 1990 to 2009

| Year | No. of hectares | Production (tonnes) | Yield/hectare |
|---|---|---|---|
| 1990 | 84371 | 87956 | 0.96 |
| 1991 | 76400 | 94757 | 1.07 |
| 1992 | 53330 | 53890 | 0.94 |
| 1993 | 54757 | 84519 | 1.5 |
| 1994 | 55274 | 76195 | 1.39 |
| 1995 | 59726 | 76052 | 1.27 |
| 1996 | 61467 | 135627 | 2.21 |
| 1997 | 60905 | 108207 | 1.78 |
| 1998 | 65149 | 125205 | 1.92 |
| 1999 | 55969 | 107340 | 1.92 |
| 2000 | 68533 | 112779 | 1.65 |
| 2001 | 57851 | 82536 | 1.43 |
| 2002 | 67893 | 67639 | 0.97 |
| 2003 | 67683 | 69273 | 1.02 |
| 2004 | 54470 | 83337 | 1.53 |
| 2005 | 56425 | 68565 | 1.22 |
| 2006 | 56265 | 65837 | 1.17 |
| 2007 | 47990 | 46598 | 0.92 |
| 2008 | 60355 | 60012 | 0.99 |
| 2009 | 52445 | 62000 | 1.18 |

Source: Swaziland Ministry of Agriculture.

The graph shows dramatic variations in both maize yield and cultivatable areas both with significant downward trend. The occurrence of extreme climate variability such as may be characterized by a prolonged dry period or heavy rainfall spell coinciding with the critical stages of crop growth and development may lead to significantly reduced crop yields and extensive crop losses. Maize production in Swaziland has been on steady decline due to erratic rainfall variability and the area planted to maize has also been reduced to adapt to the anticipated drought period. The risk associated with climate variability of maize production in general depends mainly on the growth stage of the maize crop when the weather aberration occurs. Statistics on maize production and productivity from 1990 to 2009 (Table 2), shows that Swaziland has not been able to meet its maize requirements as the observed declines in production and yield coincide with the occurrence of low/or erratic rainfall. However, it is important to state that other factors such as poor accessibility to inputs partly due to increased prices may have also contributed to decline of maize yields.

**Food Insecurity and Climatic Variability:** Almost 80% of the Swazi population is rural-based with livelihoods predominantly dependent on subsistence farming and/or livestock rearing. Over the past years, multiple interrelated factors such as small fragmented land holdings and minimal access to agricultural inputs, reduced employment opportunities, market inefficiencies and high HIV/AIDS prevalence have contributed to chronic food insecurity and gradually weakening livelihoods.

The agricultural system which is dominated by a single crop, maize, which is largely dependent on rain-fed agriculture has declined over the years due to rainfall variability and drought, subsequently increasing households' vulnerability to erratic weather and food insecurity. Minimal shocks to maize production due to weather vagaries therefore have a profound impact on the ability of rural households, especially the chronically and resource poor, to maintain their food security. As the impact of the drought worsens, Swaziland is experiencing increasing reports of sexual exploitation and abuse, in particular rape. Conflicts over scarce resources increase during droughts putting women and girls at higher risks of experiencing sexual violence. Sexual intercourse in most cases is used as a commodity for food exchange, which can lead to physical injury, transmission of HIV/AIDS and other sexually-transmitted infections (STIs) and unwanted pregnancy [15].

Extreme climate variability conditions due to the global warming phenomenon have greatly affected the spatial and temporal distribution of rainfall in most parts of the world including Swaziland. In as much as climate variability and change are inevitable, maize production systems should be able to adapt to weather fluctuations and climatic aberrations to minimize their negative effects. Coping with or managing climate variability and change in maize production systems requires a combination of adaptation and mitigation measures that involve the choice of maize crop variety, adaptation of cultural management practices and understanding of climate science by agricultural experts and the community [19]. Crop management and mitigation measures for climate variability should include a range of possible strategies such as (1) adjusting the cropping calendar to synchronize crop planting and the growing period with soil moisture availability based on seasonal climate/ rainfall forecast, (2) changing the maize variety to plant (i.e., planting a drought-tolerant or early-maturing variety or the use of genetically modified (GM) maize, where acceptable), (3) diversification from traditional maize crops to other types of crops such as millet, sorghum, acha (fonio) which can withstand drought and higher temperatures, (4) optimizing water-use efficiency by improving irrigation facilities, bringing more agricultural land under irrigation for maize production and introducing water-saving techniques as used in sugarcane production, (5) allocation of adequate funding to the National Meteorological Department to procure latest equipment and build capacity in climate data collection, storage, analysis and forecasting. Similarly, risks associated with reduced maize production and yield losses caused by climate variability can be partly alleviated by providing appropriate crop insurance coverage to maize farmers. In order to address the maize shortage and food insecurity experienced as a result of the drought, the government should seek emergency food assistance from WFP and unequivocally switch to drought-tolerant maize varieties and appropriate management practices in the short term [20].

## CONCLUSION

This study attempted to investigate the impact of climate change on rain dependent maize production and household food security in Swaziland. The vulnerability of maize production systems to climate change and variability in Swaziland depends on its time of occurrence relative to the growth stage of the crop. Maize production on the Swazi Nation Land (SNL) depends solely on natural precipitation and rainfall variability affects its production. The results indicate that reduction in both mean annual and planting season precipitation have negative impacts on maize production and which may pose a serious threat to household food security since maize is the staple food of most Swazi people. Thus, effective and efficient adaptation and mitigation measures should be promoted to prepare stakeholders in maize production systems to enhance their resilience and flexibility when facing inevitable climatic change and variability.

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