EFFECTS OF RAINFALL VARIABILITY ON MAIZE PRODUCTION IN ESWATINI

ABSTRACT

Crop production is increasingly under threat as rainfall becomes more erratic and unreliable due to climate change. The rainy season in Eswatini is mainly between October and March, but a variation in the amount of rainfall, onset and cessation of rainfall season, and dry spells has been lately threatening rain-fed maize production. This study was meant to assess the degree of rainfall variability and its impacts on rain-fed maize production in Eswatini. Rainfall data for the years 1991-2021 from six weather stations representing the various agro-ecological zones in Eswatini was obtained from the Department of Meteorological Services. The degree of rainfall variability was then determined using the coefficient of variability (CV). Also determined was the relationship between rainfall and the maize production. This was done to determine how maize production responds to rainfall variability. Maize production data was obtained from the FAO online platform, FAOSTAT. Results from the study indicated that in Eswatini there is moderate to high rainfall variability. The Middleveld and Highveld had a year-to-year variability of 25% and 23%, respectively which is classified as moderate while the Lowveld had high variability of 34%. The seasonal rainfall was found to have a statistically significant relationship with nationwide maize production (in metric tonnes). The Pearson correlation coefficient (r) between seasonal rainfall and yield was found to be 0.68, which was tested and found to be significant ($P<.05$), indicating a significant positive correlation.

Key words: Rainfall Variability, Maize Production, Staple crop, Food Security

1.0 INTRODUCTION

Climate is, with particular reference to rainfall, known to be changing worldwide and there has been growing concern as to the direction and effects of these changes on agriculture. Climate change has caused a shift in the seasonal variation of various weather parameters, and especially manifested as a shift in the normal timing and length of wet and dry season and increase in the seasonal fluctuation of rainfall [1]. The possibility for rapid and irreversible changes in the climate system exists, although there is a large degree of uncertainty about the mechanisms involved, also about the likelihood or time-scales of such transitions [2][3][4]. Rainfall variability, which is the degree to which rainfall amounts vary across an area or time [5], and also related to climate change, has been a major concern in crop production [6].

The El Niño Southern Oscillation (ENSO), land surface changes and accumulation of greenhouse gases in the atmosphere are some probable causes of climate variability and change [7]. Greenhouse gases are accumulating in the earth's atmosphere as a result of human activities, causing surface air temperatures and ocean temperatures to rise [8], which then contributes to climate change and variability. ENSO leads to variability of agro-climatic variables affecting vegetation and contributes to the seasonal crop yield variability [9].

ENSO explains changes in the tropical Pacific Ocean surface temperatures represented by the terms El Niño and La Niña. Such variations affect tropical weather patterns but can have a global effect [10]. El Niño and La Niña is the warming and cooling , respectively, of the sea surface temperatures in the equatorial pacific region which influences atmospheric circulation and consequently rainfall and temperatures in specific areas of the world [11]. At the Southern hemisphere, El Niño gives rise to below normal rainfall while La Niña gives rise to normal to above normal rainfall conditions [12]. This creates a high variability of rainfall patterns which results to uncertainties to which agriculture is exposed.

Agriculture in Africa is more vulnerable to climate variability and change when compared to developed countries where crop insurance, irrigation and crop protection are used as adaptation strategies [13]. Climate change is projected to negatively impact maize yield in Southern Africa reducing its average yield by 18 % [14]. A reduction in maize yield is set to aggravate food insecurity in the region. One study showed that climate anomalies substantially affect crop yield variability in Eastern and Southern Africa as results showed a decrease by 20% and an increase of 11% of maize production in Southern Africa due to El Niño and La Niña respectively [15].

Agriculture is said to be the mainstay to the livelihood of the people of Eswatini. This is because the people derive their food and income from agricultural activities, either as small-scale subsistence farmers or as employees of medium and large-scale farms and estates [16]. Subsistence agriculture is predominantly rain-fed in rural areas of Eswatini which renders crop production more vulnerable to climate variability and change. Evidence reveals that the country has experienced shifts in the planting season, as well as frequent and unfavorable incidences of food insecurity that were largely attributed to droughts and extended dry spells [17]. Significant rainfall deficits or cessation at critical stages of crop growth have frequently led to a serious shortfall in crop production, especially maize, the staple crop in Eswatini [18].

The Kingdom of Eswatini's Initial Adaptation Communication to the UNFCCC [17], has identified droughts, floods, storms and invasive species as climate hazards to the agricultural sector. Climate change in the form of increasing temperatures has created favorable conditions for the rapid growth and survival of invasive alien plant species. In the 2021 Market Assessment report [19], it was reported that there was a decline of maize production to 86,548 metric tonnes (MT) in 2019/20 from 95,998 MT from the 2018/19 crop season, which was a decline of 10%, partly due to the outbreak of Fall Army worms . During the 2015 – 2016 season, over 630,000 people, which is more than half the population of Eswatini were affected by the El Niño -induced drought [20], which was declared a national emergency by the Government of Eswatini. During that drought, over 80 000 cattle died. Maize production dropped by two thirds from the previous year, contributing to 64 percent rise in the national average price for maize meal compared with the previous year [21].

Statistics on maize production and productivity from 1990 to 2009 show that Eswatini has not been able to meet maize requirements and the observed declines in production and yield coincided with the occurrence of low and/or erratic rainfall [22]. This is a challenge to the country's effort of achieving its Sustainable Development Goal (SDG) 2 of ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture. The Government of Eswatini may therefore need to strengthen the country's resilience on food production under the current threat of climate change. This includes reviewing policies, investing on research and enhancing adaptation strategies.

2.0 METHODOLOGY

2.1 Description of study area

The study was conducted in Eswatini found at latitude 26° 30 S and longitude of 31° 30 E. Eswatini is a landlocked country with a total area of 17 364 km^2, neighbored by Mozambique to its east and by South Africa to its north, west and south. The country is divided into four agro-ecological regions characterized mainly by altitude and climate. From west to east are the Highveld, the Middleveld, Lowveld, and then Lubombo Plateau to the extreme east of the country. Climatic conditions of the Highveld are humid with annual rainfall ranging between 1000 mm and 1500 mm. The climatic conditions are conducive for the growing of a variety of crops and high yields are usually obtained due to adequate rainfall and moderate temperatures. However, the major constraint to increased productivity in this region is excessive leaching of nutrients resulting in inadequate soil fertility. The Middleveld has a sub-tropical rainfall average range of 762 to 1193 mm per annum. This climate is suitable for the production of a variety of agricultural crops including maize. The Lowveld is gently undulating with an average altitude range between 60 and 730 m above mean sea level. The Lowveld has semi-arid to arid climate with annual range of rainfall between 508 mm and 890 mm and is prone to drought. The Lubombo plateau has a climate almost similar to the Middleveld and has an average altitude of 700 m above mean sea level [23].

2.2 Data collection

The study was mainly quantitative whereby the data collected included rainfall data and maize yield data.

2.2.1 Rainfall data

The rainfall data was obtained from a total of six (6) weather stations. Two weather stations (Mbabane and Nhlangano) were selected from the Highveld, two (Malkerns and Matsapha) from the Middleveld and two (Mhlume and Big Bend) from the Lowveld. These stations were selected based on availability of data of acceptable quality. There was not enough rainfall data found for the Lubombo Plateau, although the climate is similar to that of the Middleveld. Also, the Lubombo Plateau occupies less than 10% of the total surface area of the country. Monthly rainfall data from 1991 to 2021 for all the meteorological stations were sourced for these weather stations from the Department of Meteorological Services.

2.2.2 Maize production data

The national maize production for Eswatini was obtained from the FAO online platform, Food and Agriculture Statistics (FAOSTAT). FAO uses questionnaires for data collection related to food and agriculture statistics and the feedback is received from the various countries for publishing in FAOSTAT on a regular basis [24]. The FAO statistics are mainly based on data supplied by national authorities and consequently the quality of the data depends on the input received [25]. The maize production data obtained covered a period of 30 years (1991/92 –

2020/21 maize seasons). The data obtained was nationwide maize production expressed in metric tonnes.

2.3 Data analysis

2.3.1 Extent of Rainfall variability

To determine the degree of rainfall variability, the coefficient of variability (CV) was used. Equation 1 shows how CV can be computed:

(1)

Where CV is the coefficient of variation; σ is standard deviation and μ is the mean precipitation. CV is used to classify the degree of variability of rainfall events as; low variability when CV < 20%, moderate when 20% < CV < 30% and high variability when CV > 30% [26].

As part of the rainfall analysis, the dependable rainfall was also determined. Equation 2 was used to calculate dependable rainfall.

(2)

Where P_{dep} is the dependable rainfall, μ is the mean rainfall and σ is the standard deviation. Dependable rainfall can be defined as rainfall expected to occur with a certain probability (27), or rainfall that is expected in a certain number of years out of a total number of years (28). Estimation of the dependable rainfall is required to design appropriately for sustainable agricultural practices particularly in line with the changing climate witnessed globally. So for purposes of planning and design of agricultural projects, it is recommended to use dependable rainfall instead of average rainfall.

2.3.2 Correlation between seasonal rainfall and maize yield

In Eswatini, most rainfall is received in the form of convectional showers in summer i.e. between October and March [29], and that is when most of the maize production takes place. Rain-fed maize is grown in all agro-ecological zones of Eswatini, but mostly in the Highveld and Middleveld, when considering the area under maize production [30]. The Pearson correlation coefficient was used to determine the relationship between seasonal rainfall received and maize production in the country (Equation 3).

(3)

Where r is the correlation coefficient, x_i and y_i are the variables being correlated and $\bar{x}$ and $\bar{y}$ are the mean values of variables being correlated, annual mean rainfall and yield respectively.

Seasonal rainfall data for the Highveld and Middleveld agro-ecological regions was correlated with nationwide maize production. These two regions are the major producers of rain-fed maize in Eswatini [31]. The seasonal rainfall (mm) as an arithmetic mean of the four stations in the

Highveld and Middleveld was used as the independent variable and the nationwide maize production (MT) as the dependent variable.
The range of r is from -1 to 1. If the r value is close to -1 then the relationship is considered anti-correlated, or is negatively correlated. If the value is close to 1 then the relationship is considered positively correlated. As the r value deviates from either of these values and approaches zero, the points are considered to become less correlated and eventually are uncorrelated [32].
The significance of the relationship was determined using a two-tailed student's t-test as given in Equation 4. If the calculated t value was greater than the tabulated value at n-2 degrees of freedom, then the value was considered significant. The level of significance used in the study was 0.05.

(4)

Where t is the value required for the test of significance of the correlation coefficient, n is the sample size and r is the computed correlation coefficient being tested for significance.

The coefficient of determination (r^2) was also determined and it examines how difference in one variable can be explained by the difference in the other variable. The value of r^2 indicates how well a predictor variable account for the variation in the response variable [33]. The values range between 0 and 1, with values closer to 1 indicating a strong goodness of fit/linear relationship between correlated variables [32].

3.0 RESULTS AND DISCUSSION

3.1 Extent of Rainfall Variability

Annual rainfall means, standard deviation and coefficient of variation (CV) were calculated and are as presented in Table 1.

Table 1: Annual rainfall statistics for selected weather stations in Eswatini for the years 1991 to 2021.

	HIGHVELD		MIDDLEVELD		LOWVELD	
	Mbabane	**Nhlangano**	**Malkerns**	**Matsapha**	**Big Bend**	**Mhlume**
Annual mean(mm)	1433	783	959	813	561	665
Std. dev. (mm)	299	190	229	206	178	236
CV (%)	20.8	24.3	23.8	25.3	31.8	35.5

The rainfall variability in the Highveld and Middleveld were found to be moderate as the CV fell in the range 20 < CV<30, and was high (CV >30) in the Lowveld of Eswatini as presented in Table 1. This is consistent with findings of a study which concluded that there was high variability in rainfall characteristics such as the onset and total rainfall in Eswatini making it hard to predict the amount of rainfall to be available for crop production in a given season [34]. High rainfall variation makes it difficult to identify trends with a high degree of certainty [35].

As the growing of maize in Eswatini under rain-fed agriculture is in the rainy season between October and March, analysis was carried out for the rainy season to determine the rainfall parameters that could have an impact on maize production. Table 2 shows the results obtained from such analysis.

Table 2: Seasonal rainfall for selected weather stations in Eswatini for the seasons 1991-92 to 2020-21.

	HIGHVELD		MIDDLEVELD		LOWVELD	
	Mbabane	**Nhlangano**	**Malkerns**	**Matsapha**	**Big Bend**	**Mhlume**
Seasonal mean rainfall (mm)	1162	623	793	673	451	534
% of annual rainfall	81.1	79.6	82.7	82.8	80.4	80.3
Std. dev.(mm)	264	136	220	166	136	212
P_{dep} (mm)	941	509	608	533	338	356

The results showed the seasonal rainfall to be ranging between 450 mm in the Lowveld to up to 1162 mm in the Highveld. When calculated as a proportion of annual rainfall, the rainfall recorded in the maize cropping season was found to be approximately 80%. The seasonal dependable rainfall ranged between 338 mm in the Lowveld to up to 941 mm in the Highveld. The Lowveld had dependable rainfall which is lower than the water requirement of maize of 450 to 600 mm [36]. This means that one cannot depend on rainfall to supply the maize crop water requirement in the Lowveld. Therefore, low maize yield, and also the chances of crop failure are expected in the Lowveld since the moisture content can hardly sustain the growth and development of the crop. The Highveld and Middleveld have average dependable rainfall of 725 mm and 571 mm respectively, which means that in most years, there is enough water to meet maize crop water requirements. However, in the Highveld, there may be higher chances of waterlogging and leaching of nutrients due to excessive rains and that could negatively affect the yield.

3.2 Relationship between rainfall and maize production

The relationship between rainfall and maize production is graphically illustrated in Figure 1 to show how maize production responds to variability in rainfall.

Figure 1: Relationship between seasonal rainfall and nationwide maize production in Eswatini

Figure 1 shows that in most cases when the rainfall was high the production also responded positively and vice-versa, which then suggested that maize production responded to the variability in rainfall. Figure 2 emphasizes that relationship in the form of a scatter plot.

Figure 2: A scatter plot showing the relationship between rainfall and maize production

Figures 1 and 2 show that that an increase in seasonal rainfall generally corresponds to an increase in maize production and also a decline in rainfall observed corresponds to a decline in maize production. However, Figure 2 also shows that the highest rainfall observed does not necessarily result in the highest production. This could be because the total seasonal rainfall does not explain the distribution of the rainfall over the growing season. Also there may be deleterious effects of excessive rainfall which may result in reduction of yield.

During the 2014-2015 season which was an El Nino-induced drought season, the country received the lowest rainfall ever recorded (2014/15) which resulted to a nationwide maize production of 33,460 MT, which was a severe decline in national maize yield, the lowest in the past 30 years. A similar pattern, though less severe, was observed during the 2002/03 drought season which also resulted in a low maize production of 67,273 MT, which was one of the lowest yields in the past 30 years. The same was observed in the 2007 drought condition where below average rainfall was also received which coincided with a decline in maize yield in the same period. The opposite is true when looking at the 2013/14 farming season where abundant seasonal rainfall, above 1 000 mm, was received across the country, resulting to a bumper harvest (101,041MT). The same was observed in 1999/00 where above 1300 mm seasonal rainfall was received with 112 779 MT harvest.

The 30-year rainfall data was also divided into dry, medium and wet terciles as shown in Figure 3. When plotted against the average maize production, the results show that there was a notable difference in average maize production for the different terciles. The medium tercile had 18,996 MT (28%) more than the dry tercile, and the wet tercile had 6,867 MT (8%) more than the medium tercile.

Figure 3: Average maize production for the dry, medium and wet terciles

Table 3 shows the relationship between seasonal rainfall observed and maize produced. From the table, 6 of the 10 in the dry tercile resulted in low production, with 3 years resulting in medium production and only one dry season resulted in high production. Only 2 years from the medium tercile resulted in low production, and 4 years resulted in medium production and 4 years resulted in high production. Only 2 out 10 in the wet tercile resulted in low production, 3 years resulted in medium production and 5 resulted in high production. It should be noted that there was minimal difference in the production between the medium and wet terciles. The medium and wet terciles in this data have rainfall above 757 mm corresponding to maize production of at least 76,052 tonnes.

Table 3: Terciles categorized according to rainfall related to terciles categorized according to maize production

	Rainfall category

Production category	*Dry tercile (523 – 748 mm)*	*Med. Tercile (757 – 848 mm)*	*Wet tercile (850 – 1312 mm)*
Low tercile **(33,460 – 75,068 tonnes)**	6/10	2/10	2/10
Medium tercile **(76,052 – 84,519 tonnes)**	3/10	4/10	3/10
High tercile **(86,548 – 135,627 tonnes)**	1/10	4/10	5/10

A statistical analysis was then carried out on the relationship between seasonal rainfall and maize production in Eswatini. A coefficient of correlation (r) and the coefficient of determination (r^2) were determined. A significance test was also conducted on the coefficient of correlation. The results for the statistical analysis are shown in Table 3.

Table 4: Statistical relationship between national maize yield and seasonal rainfall

Statistics	
Correlation coefficient (r)	0.68
Coefficient of determination (r^2)	0.47
Table t	2.05
Calculated t	4.90
P-value	.000*

The correlation coefficient value, r presented in Table 4 indicates that there is a strong positive correlation (r = 0.68) between maize yield and seasonal rainfall for the 30 crop seasons (1991/92 to 2020/21). A change in seasonal rainfall amount received results to a change in maize yield in a similar fashion. This indicates that rainfall can be used to predict maize yield.
From Table 4, the coefficient of determination (r^2) was found to be 0.47. This indicates that seasonal rainfall (the predictor variable) is able to account for approximately 47% of the variations in the annual maize yield over the period. Indirectly, about 53% of the variations in the maize yield produced annually cannot be explained by the seasonal rainfall. Other climatic and non-climatic factors such as temperature, rainfall onset and cessation, length of dry spells, maize cultivar, pests and diseases management could also be responsible for the variations in the annual maize production.

The critical value table for t at 28 degrees of freedom (two-tailed test) was found to be 2.048. Since the calculated t (Table 4) is greater than 2.048 at 28 degrees of freedom, resulting to a *P*-value of .000, the null hypothesis (H_0) that "there is no significant relationship between seasonal rainfall variability and national maize yield was rejected. Several researchers [37][29][38] [39] concur that food production (especially rain-fed) is significantly affected by the amount of rainfall received.

4.0 CONCLUSIONS

Based on the results, it was concluded that Eswatini experiences moderate to high rainfall variability with CV of 25 % in the Middleveld, 23% in the Highveld and 34% in the Lowveld. This indicates the inconsistency and unpredictability of rainfall in the area under study. Dependable seasonal rainfall was found to average 347 mm in the Lowveld, 571 mm in the Middleveld, and 725 mm in the Highveld. Therefore, it was concluded that for the Lowveld, at any given year, there is high likelihood that there may be inadequate rainfall to meet water requirements of the maize crop.

The study also indicated a statistically significant relationship between seasonal rainfall and maize yield. The correlation coefficient of seasonal rainfall and yield was 0.68, which indicated a strong positive linear relationship between seasonal rainfall amounts received and yield. The correlation was found to be significant at significance level .05. A decrease in seasonal rainfall received resulted in decrease in maize yield. This meant that rainfall has had an impact on maize production in the country. The coefficient of determination was found to be 0.47, which means that 47% of yield variation could be explained by the variation in rainfall.

REFERENCES

- Odjugo PA (2010). General Overview of Climate Change Impacts in Nigeria. J. Hum Ecol., 29 (1), Pp. 47-55.
- Osang JE, Obi EO, Ewona IO, Udoimuk AB, Nnwankukwu NC (2013). Review of gas flaring activities in Niger Delta Area of Nigeria. *International Journal of Scientific & Engineering Research*, 4 (9), Pp. 2229-5518
- Obi EO, Osang JE, Ewona IO, Udoimuk AB, Kamgba FA (2013). Environmental Health Effect and Air Pollution from Cigarette Smokers in Cross River State, Nigeria. *Journal of Applied Physics (IOSR-JAP)*, 4 (6), Pp. 61-68.
- Ushie PO, Ojar JU, Egor AO, Ohakwere-Eze MC, Osang JE, Alozie SI (2014). Investigation of the efficiency of olive oil as dielectric material and its economic value on the environment using its dielectric properties. International Journal of Advance Research, 2 (2)
- Pendergrass AG, Knutti R, Lehner F, Deser C, Sanderson BM (2017). Precipitation variability increases in a warmer climate. *Scientific Reports*. https://www.nature.com/scientificreports.
- Onwuadiochi IC, Onyeanusi CC, Mage JO (2021). Assessment of Rainfall Variability for Sustainable Agriculture in Owerri, Imo State, Nigeria. *Journal Clean WAS*, *5(2): 39-46*. http://doi.org/10.26480/jcleanwas.02.2021.39.46
- Dunning CM, Black EC, Allan RP (2016). The onset and cessation of seasonal rainfall over Africa. *J. Geophys. Res. Atmos*., 121, 11,405–11,424, doi:10.1002/2016JD025439
- National Research Council. (2001). *climate Change Science*: An analysis of same key www.nmc.co.sz. National Academies Press. HTTPs://doi.org/10.1722/10139
- Ray DK, Gerber JS, Graham K, MacDonald GK, West, PC (2015). Climate variation explains third of global crop yield variability. *Nature communication* 6:5988.
- Hanley DE, Bourassa MA, O'Brien JJ, Smith SR, Spade ER (2003). A quantitative evaluation of ENSO indices. *J. Clim*. 16, 1249–1258. https://doi/10.1175/ 1520-0442(2003)162.0.CO;2.
- Cai W, Santoso A, Wang G (2015) ENSO and greenhouse warming. *Nature Clim Change* **5**, 849–859 (2015). https://doi.org/10.1038/nclimate2743.

- Holleman C, Rembold F, Crespo O, Conti V (2020). *The impact of climate variability and extremes on agriculture and food security – An analysis of the evidence and case studies. Background paper for The State of Food Security and Nutrition in the World 2018.* FAO Agricultural Development Economics Technical Study No. 4. Rome, FAO. https://doi.org/10.4060/cb2415en.
- Woetzel J, Pinner SD, Samandari H, Frankfurt MK, McCullough BR, Melzer DT, Boettiger S (2020). Climate risk and response: Physical hazards and socioeconomic impacts: How will African farmers adjust to changing patterns of precipitation? *McKinsey Global Institute*: Climate risk and response: Agriculture in Africa-2.
- Zargar A, Sadiq R, Naser B, Khan KI (2011). A review of drought indices. *Environ. Rev.* 19, 333–349. doi: 10.1139/a11-0
- Sazib N, Mladenova1 IE, Bolten JD (2020) Assessing the Impact of ENSO on Agriculture Over Africa Using Earth Observation Data. Front. Sustain. *Food Syst*. 4:509914. https://doi: 10.3389/fsufs.2020.509914.
- CCARDESA (2018). Eswatini. http://www.ccardesa.org [Accessed 23/04/2022]
- Government of Eswatini (2021). Eswatini Initial Adaptation Communication to the United Nations Framework Agreement on Climate Change. Tfwala, S.S., Mabaso, S.D., and Groenewald, M. (Editors). Ministry of Tourism and Environmental Affairs, Mbabane, Eswatini. http://www.gov.sz/index.php/ministries-departments/ministry-of-tourims-environments-a-communication. [Accessed 30/11/2022]
- Mhlanga-Ndlovu BS, Nhamo G (2016). Farmer perceptions of climate change impacts on Swaziland's sugar industry. African Journal of Science, Technology, Innovation and Development, 8(5-6), 429–438. doi:10.1080/20421338.2016.1219503
- Government of Eswatini (2021). Eswatini Market Assessment report. Eswatini Ministry of Agriculture, Mbabane, Eswatini. [Accessed 10/02/2022]
- FAO (2016). Early action and response for agriculture, food security and nutrition. http://www.fao.org/3/a-i5128e.pdfd [Accessed 17/04/2022]
- National Disaster Management Agency (2017). The socio-economic impacts of the 2015-16 El Nino-induced drought in Swaziland. Prepared by Swaziland Economic Policy Analysis and Research Centre (SEPARC). Mbabane. Swaziland.
- Oseni TO, Masarirambi MT (2011). Effect of Climate Change on Maize (Zea mays) Production and Food Security in Swaziland. American-Eurasian J. Agric. & Environ. Sci., 11 (3): 385-391.
- Tfwala CM, Mengistu AG, Seyama E, Mosia MS, van Rensburg LD, Mvubu B, Mbingo M, Dlamini P (2020). Nationwide temporal variability of droughts in the Kingdom of Eswatini: 1981–2018. *Heliyion 6*. https://doi.org/10.106/j.heliyon.2020.e05707
- FAOSTAT (2022). database: https://www.fao.org. [Accessed 25/04/2022]
- FAO (2011). Eastern Africa Climate-Smart Agriculture Scoping Study; FAO: Rome, Italy. https://www.fao.org/docreo/018/i3325e/i3325e.pdf. [Accessed 31/12/2022]
- Abadi H (2010) Coefficient of Variation. *Encyclopedia of Research Design*, In Neil Salkind (Ed).
- Ucar Y, Kociecka J, Liberacki D, Rolbiecki R (2023) Analysis of Crop Water Requirements for Apple Using Dependable Rainfall. *Atmosphere* 14: 99.
- Haque M (2005) Estimating monthly and yearly dependable rainfall for different climatic zones of the world. *Songklanakarin J. Sci. Technol.* 27:3, pp. 667-673
- Manyatsi AM, Mavuso SM, Vilane BRT (2015). Climate Change Impacts, Adaptation and Coping strategies at Malindza, Rural semi-Arid area in Swaziland. *American Journal of Agriculture and forestry.*Vol.3, No. 3, pp 86-92.

- Dlamini DV, Dlamini SG, Akelrele D, Jele Q (2019). The Influence of Price and Non-Price Factors on Acreage Response of Maize in Eswatini. *Journal of Agriculture and Crops*, 5, Issue. 3,38-42. https://arpgweb.com/journal/journal/14.
- National Maize Corporation, (2016). Annual reports 2014/2015. http://www.nmc.co.sz. [Accessed 30/10/2022].
- Mukaka MM (2012). A guide to appropriate use of Correlation Coefficient in medical research. *Malawi Medical journal* ,24(3):69-71.
- Sapra RL (2014) Using R2 with caution. Current Medicine Research and Practice. Vol. 4(3): 130-134.
- Mamba SF, Salam A, Peter G (2015) Farmers perception of climate Change a case study in Swaziland. J. Food Secur. 3 (2), 47–67. https://doi.org/10.12391/jfs-3-2-3.
- Ferijal T, Batelaan O, Shanafield M (2022). Determination of rainy season onset and cessation based on flexible driest period. *Theor Appl Climatol* 148, 91-104. https://doi.org/10.1007/s00704-021-03917-1.
- du Plessis J (2003). Maize production. department: agriculture Republic of South Africa.https:// www.nda.agric.za/publications
- Dlamini DD, Masuku MB (2011). Land tenure and land productivity: a case study of maize production in Swaziland. *Asian Journal of Agricultural science 3(4): 301-307.*
- Mohammed M, Dlamini T (2018). Predictors of food insecurity in ESwatini. *African Review of Economics*. Vol 10 (2).
- Baffour-Ata F, Tabi JS, Sangber-Dery A, Etu-Mantey EE, Asamoah DK (2023) Effect of rainfall and temperature variability on maize yield in the Asante Akim North District, Ghana, Current Research in Environmental Sustainability, Volume 5. https://doi.org/10.1016/j.crsust.2023.100222.