The Effect of Climate Change on Beef Cattle Production in Eswatini

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Abstract- The demand for beef in Africa is expected to increase by 15% in 2030 due to high population growth, though threatened by increasing negative impact of climate change on beef cattle production. Literature suggests that climate change has resulted in declining number of cattle attributable to deaths caused by lack of palatable pastures during extreme drought events, and diseases exacerbated by adverse weather patterns. However, Eswatini's accessed literature related to the relationship between beef cattle production and climate change selected variables is limited. Hence this study was conducted to examine the short- and long-term effects of climate change related variables on beef cattle production in Eswatini for the period 1982 to 2020. The unit root test was carried out and the Autoregressive Distributed Lag Model were applied to analyze the data. Beef cattle production was expressed as a function of annual average temperature, annual average rainfall, annual carbon emissions and area of land used for beef cattle production. The results showed that temperature, rainfall, land and carbon emissions have a negative and significant effect on beef cattle production in the long run while temperature, rainfall and carbon emissions have a positive and significant influence on beef cattle production in the short run. The results further suggest that 92% disequilibrium of beef cattle production in the previous year is adjusted in the current year, which justifies the long-run relationship among the variables. It is therefore recommended that Eswatini government develops and enforces policies that encourage environmental sustainability through reducing carbon emissions. It is also recommended that Eswatini Environmental Authority advocates for government endorsement and enforcement of initiatives that support environmental sustainability such as the development of climate resilient beef cattle breeds and farmers 'adaptation strategies that build the resilience of the beef cattle sub-sector.

Index Terms- Beef cattle production, Temperature, Rainfall, Carbon emissions, Eswatini.

I. Introduction

Beef cattle comprise the largest component of Eswatini's livestock sector and are the main investment asset. Small holder farmers who own 85% of the national beef cattle herd are reluctant to sell their cattle unless it's a do or die situation. This stems from the fact that Swazis view beef cattle as a source of wealth and a very important part of their traditional ceremonies such as paying dowry and other religious rituals. Beef cattle are also used as draught animals and for provision of manure which is environmentally friendly and affordable (Ministry of Agriculture, 2004).

Although most of beef cattle production occurs on Swazi Nation Land (SNL) and at a subsistence level, the country manages to produce good quality beef for exports predominantly to the European Union countries. The lower grade of beef produced is retained and supplied within the country to meet the local demand (Mhlanga-Ndlovu & Mhlanga, 2019). This economic activity of beef production contributes a fraction of the 8.6% of agriculture contribution to Eswatini's Gross Domestic Product (Central Statistical Office, 2022). Between years 2017 and 2021, Eswatini recorded increased beef cattle production from 496,094 to 548,999 heads of cattle, a recuperation from the rampant drought in 2015/2016 that saw a decline in the national beef cattle herd from about 779,751 to 496,094 between 2011 and 2017 (DVLS, 2021).

The noticeable decline in the number of beef cattle produced in the country was mostly attributed to increased mortality rates caused by prolonged drought that led to reduced vegetation cover and water scarcity, and poor rangelands due to overgrazing. In 2015, a total of 47 000 cattle died in Eswatini due to lack of pasture and water, which resulted from the drought (Ministry of Agriculture, 2022). The prolonged drought is thought to be one of the negative climate change events that results in long dry periods without or with limited amounts of rain.

The demand for beef in Africa is expected to increase by 15% in 2030 due to high population growth (Food and Agriculture Organization, 2021). This trend is expected to increase the number of livestock reared worldwide, a positive intention which is threatened by climate change (Banik et al., 2015). In agreement, Steinfeld et al., (2006) stated that the estimated global demand for meat is expected to double between 1999 and 2050. The global numbers of meat-producing animals will have to increase to meet this demand. Livestock farmers have a huge role to play in meeting this demand since their production systems output can improve substantially with appropriate interventions (Rust & Rust, 2012).

Despite the high demand for livestock products, the impact of climate change on livestock has been reported in several research publications (Tubi & Feitelson, 2016). Several studies carried out in other countries indicate that there is a decline in the number of cattle, which is attributed to death caused by lack of green pasture during extreme drought events, disease and starvation (Roever et al., 2015). With all evidence indicating that climate change results in the reduction of beef cattle due to drought and livestock deaths, no research has been done to evaluate the impact of climate change on the levels of beef cattle production in Eswatini. Therefore, this study aimed at establishing the short-run and long-run relationship between beef cattle production and climate change in Eswatini.

II. Literature Review

The effect of climate change is real and is adversely affecting livestock population in many ways. Climate change leads to an increase in weather-related disasters and extreme weather patterns such as storms, heat waves, desertification, drought and a rise in insect infestations (Khanal, Shrestha & Singh, 2010). Climate change has negative effects on both male and female reproductive system. The conception rate of cows may drop by 20-27% in summer as heat stressed cows often have poor expression of oestrus due to reduced estradiol secretion from the dominant follicle developed in a low luteinizing hormone environment. Reproductive inefficiency due to heat stress involves changes in ovarian function and embryonic development by reducing the competence of oocyte to be fertilized and the resulting embryo (Naqvi et al., 2011). Heat stress compromises oocyte growth in cows by altering progesterone secretin, the secretin of luteinizing hormone, follicle-stimulating hormone and ovarian dynamics during the oestrus cycle. Heat stress has also been associated with impairment of embryo development and increase in embryonic mortality in cattle. Heat stress during pregnancy slows growth of the foetus and can increase foetal loss. Secretion of the hormones and enzymes regulating reproductive tract function may also be altered by heat stress (Naqvi & Sejian, 2011).

Global warming may reduce body size, carcass weight and fat thickness in ruminants (Mitloehner et al, 2001). In addition, high ambient temperature increases tissue catabolism and decreases anabolic activity. Decreased anabolic activity reduces feed intake and increased tissue catabolism causes fat depots which affect growth performance adversely. Heat stress also has an effect on the uterine environment which reduces the total embryo cell number and placentae size, hence small sized calves are born.

Erratic rainfall patterns which come in the form of floods or drought pose a potential threat to the health and wellbeing of animals. Drought and delay in the onset of rain lead to poor regeneration of grass, water shortage and heat stress on livestock. This also leads to increased mortality of livestock, vulnerability to diseases and physical deterioration due to long distance travel for water and pastures. (Khanal et al., 2010). In agreement, Ayanlade & Ojebisi (2020) reported that irregular rainfall patterns in form of floods or drought may lead to death of animals, which results to a decline in beef cattle production.

According to Rowlinson (2008), cold stress leads to increased concentration of plasma corticosteroids and circulating non-esterified fatty acid concentration. Thermal stress may also lead to increased testicular temperature in bulls which could change the quality of semen and alter the biochemical composition leading to infertility problems. There will also be a change in testicular volume, hormonal profiles, sexual behaviour and semen quality which will adversely affect the reproductive performance of bulls (Balic et al., 2012).

A study about the long and short-term impacts of climate change on livestock production was carried out by Warsame (2020). The study used spanning data from 1985 to 2016 and found that rainfall and temperature patterns have a significant positive and negative impact on livestock production both in the long run and short run, respectively. The observed carbon dioxide emissions had no significant impact on livestock production in the long run but enhanced livestock production in the short run. The study showed that carbon dioxide emissions granger cause livestock production and an un-bidirectional causation was observed from rural population to temperature and livestock production.

The impact of climate change on livestock production at the Mpolonjeni area in Swaziland was conducted by Manyatsi et al., (2014). The results suggested that livestock production is highly sensitive to climate change and there was a non-linear relationship between climate change and livestock productivity. The estimated marginal impacts suggested very modest gains from rising temperatures and losses from increased precipitation.

A study by Asamadusarkodie & Owusu (2017) investigated the relationship between carbon dioxide emissions and agriculture in Ghana. Results showed that carbon dioxide emissions affect the total livestock per hectare of the agricultural area.

Based on the literature that was reviewed, the study revealed an empirical gap in that there were insufficient studies that examined the effect of climate change on beef cattle production in Eswatini.

III. Methods

A. Study Area and Data Sources

The present study considered national secondary data that covered all regions of Eswatini. Data on number of beef cattle produced in Eswatini from 1982 to 2020 were obtained from FAOSTAT. Annual time-series data on precipitation, average temperatures and greenhouse gas emissions was sourced from World Bank databases.

B. Data Analysis

The ARDL econometrical model employed in this study was based on the Cobb-Douglas production function which models the relationship between factors of production and output. For purposes of this study, the model was specified as follows:

$$Beef = \alpha + \beta_1 Temp + \beta_2 Rain + \beta_3 Carb + \beta_4 Land + \mu_{1t} \quad (1)$$

Where:

Beef: Beef cattle produced (Number)
Temp: Annual Average Temperature (^{O}C)
Rain: Annual Average Rainfall (mm^3)
Carb: Annual Carbon Emissions (tons)
Land: Area of land used for beef production (Ha)
α: is the constant
βi: is the parameter estimate for independent variables
μ_{1t}: is the error term

Natural logarithms were used to transform the variables so to normalize data and allow easy interpretation of coefficients. Hence, the model was specified as:

$$lnBeef = \alpha + \beta_1 lnTemp + \beta_2 lnRain + \beta_3 lnCarb + \beta_4 lnLand + \mu_{1t} \quad (2)$$

Where:

*ln*Beef: is the log of beef cattle produced in Eswatini
*ln*Temp: is the log for temperature (^{O}C)
*ln*Rain; is the log for rainfall (mm^3**)**
*ln*Carb: is the log for carbon emissions (tons)
*ln*Land: is the log for area of land used for beef production (Ha)

The Augmented Dickey-Fuller (ADF) test was applied to test for stationarity and determine the order of integration. The null hypothesis states that time series data is non-stationary. In general, a *p-value* of 0.05 or less means that the null hypothesis can be rejected. The ADF test was estimated with the following regression model:

$$\Delta Y_t = \beta_1 + \sum_{i=1}^{k} \alpha_i Y_{t-1} + e_t \quad (3)$$

Where:

Y_t: is the data series tested for stationarity.
β_1: is the constant term.
α_i: is the estimated variable.
e_t: is the white noise.

The specified model was estimated using the ARDL model pioneered by (Pesaran, Shin and Smith, 2001) to examine the impact of climate change on beef cattle production in Eswatini. To estimate the ARDL model was re-expressed as an ARDL form to incorporate short-run multipliers in the model along with the long-run multipliers. Thus, it was written as follows:

$$\Delta lnBeef_t = \alpha_0 + \sum_{i=1}^{n} bi\Delta lnBeef_{t-1} + \sum_{i=1}^{n} ci\Delta Llnemp_{t-1} + \sum_{i=1}^{n} di\Delta lnRain_{t-1} + \sum_{i=1}^{n} fi\Delta lnCarb_{t-1} + \sum_{i=1}^{n} gi\Delta lnLand_{t-1} + \delta_1 lnBeef_{t-1} + \delta_2\, lnTemp_{t-1} + \delta_3 lnRain_{t-1} + \delta_4 lnCarb\,_{t-1} + \delta_5 lnLand_{t-1} + \emptyset ECT_{t-1} \quad (4)$$

Where:

*ln*Beef, *ln*Temp, *ln*Rain, *ln*Carb, *ln*Land are denoted as previously
Δ: first difference operator
A: intercept
n: lag length
ECT_{t-1}: error correction term
bi, ci, di, fi, and gi are short run coefficients of the model
δ1, δ2, δ3, δ4, δ5 are long run coefficients of the model

To test the long run and short run relationship between climate change variables and beef production in Eswatini, the study employed the F-statistic to test the null hypothesis of no relationship between climate change variables and beef production in Eswatini against the alternative hypothesis which stated that there is a significant relationship between climate change variables and beef production in Eswatini.

H_0: $\delta_1=\delta_2=\delta_3=\delta_4=\delta_5= 0$
H_1: $\delta_1\neq\delta_2\neq\delta 3_{\neq}\delta_4\neq\delta_5\neq 0$

The ADF test results revealed that some variables were stationary at levels, as some were stationary after first differencing. Hence, the ARDL model was the best model to be employed for this study.

IV. Results and discussion

Temperature, rainfall and carbon emission were found to be stationary at levels. However, beef production and land were not stationary, and at first differencing they became stationary as shown in Table 1 and Table 2, respectively.

Table 1: ADF test results before first differencing.

Variable	T-statistic	1% critical value	5% critical value	10% critical values	p-value
LGBeef	-2.447	-3.662	-2.964	-2.614	0.1290
LGTemp	-3.3651	-3.662	-2.964	-2.614	0.0049
LGRain	-5.199	-3.662	-2.964	-2.164	0.0000
LGCarb	-2.610	-3.662	-2.964	-2.164	0.0409
LGLand	-1.412	-3.662	-2.964	-2.164	0.5765

Source: Author's computations from data (1982-2020)

Table 2: ADF test results after first differencing

Variable	T-statistic	1% critical value	5% critical value	10% critical value	p-value
LGBeef	-5.755	-3.668	-2.966	-2.616	0.0000
LGLand	-4.674	-3.668	-2.966	-2.616	0.0001

Source: Author's computations from data (1982-2020).

Table 3: Multicollinearity test.

Variable	VIF	1/VIF
LGLand	2.12	0.471
LGCarb	1.98	0.505
LGTemp	1.26	0.793
LGRain	1.12	0.890

Source: Author's computations from data (1982-2020).

The Breusch-Godfrey test was used to test for autocorrelation. The null hypothesis stated that there is no serial correlation.
Given the *p-value* of 0.37 presented in Table 4, the study concluded that the variables did not have a problem of autocorrelation.

Table 4: Breusch-Godfrey test for autocorrelation

lags(p)	chi2	Df	Prob > chi2
4	4.240	4	0.3746

H0: no serial correlation

Given that some variables were not stationary before first differencing, one of the best models to employ in this situation is the Autoregressive Distributive Lag (ARDL). The ARDL test was used to test cointegration among the variables. The ARDL procedure started with determining the optimal lag. In this case, the optimal lags were obtained by applying the Aikake Information Criteria (AIC) indicating p=4 as shown in Table 5.

Table 5: Optimal lag strength selection

Lag	LL	LR	Df	P	AIC	SBIC
0	241.446				-13.511	-13.289
1	310.86	138.83	25	0.000	-16.049	14.716*
2	346.252	70.784	25	0.000	-16.643	14.1988
3	365.946	39.389	25	0.034	-6.3397	-2.7847
4	403.656	75.521*	25	0.000	-7.066*	[illegible]

Author's computation from data

Table 6 shows the long run relationship between the series. The researcher can reject the null hypothesis at 1% level of significance. The calculated F-Statistic of 6.98 surpassed the upper bounds critical values of 5.06 at 1% and the null hypothesis of no cointegration was rejected. It was therefore accepted that beef cattle production, temperature, rain are cointegrated in the long run in the examined period. From these tests, it was concluded that the model was well estimated and could adequately be used to determine the relationship between the selected variables in the model.

Table 6: Pesaran, Shin and Smith (2001) Cointegration Test.

Critical values	***Fm(Beef prod, Temp, Rainfall, Carbon, Land) k= 4***	F-statistics 6.98
	Lower Bound 1(0)	Upper Bound1(1)
1%	3.74	5.06
2.5%	3.25	4.49
5%	2.86	4.01
10%	2.45	3.52

Source: Authors' computations

The obtained value of Adjusted R-squared of 0.64 demonstrates overall goodness of fit of the model. The error coefficient is negative and statistically significant at 1%, which confirms the long run relationship between variables presented in Table 7. Its value of -0.92 indicates a rapid adjustment process. A 92% disequilibrium of beef cattle production in the previous year is adjusted in the current year.

Table 7: *Dependent variable logbeef and 39 observations were used for estimation (1982-2020). ARDL (1,3,3,2,0) regression.*

	Variable	**Coef.**	**Std. Err.**	**t-value**	**P-Value**
Adjustment	Logbeef	-0.92	0.13	-6.98***	0.000
Long-Run	Logtemp	-2.26	0.51	-4.46***	0.000
	Lograinfal	-0.23	0.07	-3.42**	0.003
	Logcarbon	-0.45	0.06	-7.52***	0.000
	Logland	-3.23	0.59	-5.49***	0.000
Short-run	LogTemp D1	2.62	0.64	4.10***	0.001
	LD	1.82	0.60	3.05***	0.006
	L2D	1.18	0.46	2.57**	0.018
	logRain D1	0.26	0.07	3.59***	0.002
	LD	0.17	0.06	2.72**	0.013
	L2D	0.09	0.05	1.84*	0.079
	logCarb D1	0.33	0.05	6.00***	0.000
	LD	0.23	0.05	4.69***	0.000
	Constant	41.15	6.52	6.31***	0.000

Adjusted R-Squared = 0.64
Number of Observations= 39
Log Likelihood= 127.31
Root MSE= 0.034
Notes: *** = *p<0.01; *** ** = *p<0.05;* * = *p<0.1*

According to the results in Table 7, climate change-related variables show a significant inverse relationship with beef cattle production in the long run at 1% level of significance. A 1% increase in temperature will lead to a 2.26% decrease in beef cattle production. This finding is supported by Rowlinson (2008) who found that increased temperature causes heat stress in animals, leading to reduced growth, sub optimal behaviors and reduced productivity of animals. A 1% increase in rainfall will lead to a decrease in beef cattle production by 0.23%. Under the auspices of climate change, increases in frequency and volume rainfall are associated with adverse conditions such as high rainfall intensity, floods and hailstorms. Such adverse weather conditions impose a negative impact on pastures, depleting pastures through soil erosion. This also brings about high prevalence of livestock disease, which has a negative effect on beef cattle production. The results are in line with the findings by Rojas-Downing et al. (2017) and Nardone et al. (2010), that erratic rainfall patterns which may come in form of floods pose a potential threat to health and well-being of animals by exposing them to diseases, thereby leading to death and morbidity. Additionally, a 1% increase in carbon emission will lead to a 0.45% decline in beef cattle production. These findings are consistent with reasonable expectations that the increase in carbon emissions depletes the ozone layer resulting in increasing temperatures and desertification, which undercuts pasture availably, hence decline in beef production. This is in line with this finding by the Intergovenmental Panel on Climate Change (2007) in that carbon dioxide and other gases are important in the atmosphere, however, an overload of these gases results to negative attributes. As greenhouse gases accumulate, they bring about climate change which is experienced through changes in temperature, rainfall, humidity, solar radiation and airflow, as well as the tendency for extreme events, floods, erosion, drought and heat waves.

In the short runs, the results show that the climate change related variables are positively and significantly related to beef cattle production in Eswatini. A 1% increase in each of the variables, temperature, rainfall and carbon, will induce an increase in beef cattle production by 2.62%, 0.26% and 0.33%, respectively. This is attributable to the interplay between these variables, which promotes the pasture growth to the betterment of beef cattle farming. The results are in line with Manyatsi et al. (2014) and Hatfield et al. (2008).

V. Conclusion and Recommendations

The null hypothesis stated that there is no significant relationship between climate change and beef cattle production in Eswatini. However, the findings of this study indicate that there is a significant relationship between beef cattle production and climate change related variables. The conclusion therefore is that climate change adversely affects beef cattle production in the long run in Eswatini. Hence, the null hypothesis was rejected.

The findings of this research have significant policy implications. The negative long run relationship between beef production and climate change suggests that farming practices and other human activities that discourage carbon emissions could be useful in order to reduce the effect of climate change. The policy implication is that Eswatini Government should consider developing and enforcing policies that encourage sustainability through reducing carbon emissions. Standards focusing on prerequisites for establishments of agricultural entities and any other entity must include environmental sustainability. From this perspective, it is recommended that Eswatini Environmental Authority should advocate for government endorsement and enforcement of initiatives that support environmental sustainability. Based on the findings from this study, the researcher recommends identifying mitigation and adaptation strategies for climate change.

Acknowledgment

Special acknowledgment is accorded to the academic staff of the University of Eswatini, Department of Agricultural Economics and Management for their indelible review of the study.

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