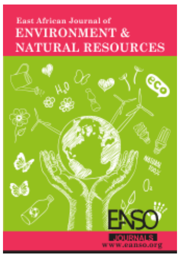

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Original Article

Influence of Seasonal Climate Variability on Newcastle Disease Spread on Free Range Chicken Production in Kitutu Chache, Kenya

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Free Range Indigenous Chicken, Poultry, Newcastle Disease, Rainfall Variability, Temperature Variability.

ABSTRACT

Newcastle Disease is a frequent disease that occurs every year in Kitutu Chache South Constituency. However, the disease is directly or indirectly linked to changes in climate patterns during the outbreak and spread periods. Therefore, the study sought to examine the influence of climate variability on Free Range Indigenous Chicken (FRIC) death occurrence due to the spread of Newcastle Disease. The study adopted a descriptive research design with a sampling size of 500 farmers. The research used purposive selection to administer a questionnaire to poultry farmers in Kitutu Chache. From 1990 to 2019, climate data were obtained from the Kisii Meteorological Services office. The data were analysed using descriptive statistics in STATA-14, and multiple linear regression models were used to examine the relationship between climate variability and NCD. To determine trends in climatic variability, the climate trend data were analysed in R-Studio using the Mann-Kendall trend test with Sense slope estimators. The results showed that there was a significant increase in minimum and maximum temperatures at ($p < 0.05$); and a decreasing trend in the mean amount of rainfall, though it was not significant ($p > 0.05$). Moreover, climate factors were found to strongly influence the spread of Newcastle Disease ($p < 0.001$) hence FRIC death occurrence; rainfall was found to positively influence the spread of Newcastle Disease, while minimum temperatures were found to be negatively correlated. Therefore, the study concluded that climate factors were influencing the spread of the Newcastle Disease Virus. Finally, the study recommended that the county and the national governments of Kenya harmonise climate issues when drafting policies to curb the spread of Newcastle Disease among FRIC.

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INTRODUCTION

Poultry plays a key role in the lives of poor rural communities in developing countries (Attia *et al.,* 2022). This is especially in Sub-Saharan Africa (SSA), where they provide income, capital assets, and fertilisers (FAO, 2018). In Kenya, both hybrid and indigenous poultry are reared, where indigenous poultry production presents a significant portion of the economy and a source of income for small-scale farmers (Annapragada *et al.,* 2019). Most farmers in rural areas rear chickens because the capital used is slightly lower, affordable, and available because of the cheap household labour. Despite their importance, Free Range Indigenous Chicken (FRIC) is faced with many challenges, such as climatic variations. Different communities domesticate free-range indigenous chicken for commercial and subsistence purposes. However, accrued climate variability has a great effect by influencing the sensitivity of temperature and rainfall changes. The climate strongly determines how the vectors are distributed, transmitted, and evolved and can also be able to influence those factors that can be related to or associated with the emergence of the poultry diseases and how the birds can be able to respond to the diseases (Kangai *et al.,* 2021; Tilakasiri *et al.,* 2015).

Climate variables on the earth's surface have been changing over time, triggering fluctuations in the daily weather patterns (Innocent, 2017). Climate change also generates life-threatening scenarios, for instance, heat waves, cold waves, droughts, frosts, floods, and cyclones (Ngare *et al.,* 2020; Trimmel *et al.,* 2018). The IPCC (2014) reported that extreme circumstances showed certainty, unlimited susceptibility, and tough experience of various biomes (Rabach *et al.,* 2020). Chickens cannot endure high temperatures, erratic rainfall, and high humidity irrespective of their different stages of life. During moist conditions, there is no moisture absorption in the breathing system of chickens and birds; therefore, they tend to breathe quickly (Dimitrov *et al.,* 2016). Likewise, when the ambient temperature is high and moisture carries the day, birds do not respire adequately by panting to eradicate heat from the body. Normally, sweating is not the process of heat elimination in birds as perceived in humans (Richard *et al.,* 2017). Chende (2012) researched indigenous chickens in some parts of Ethiopia. The research study established that rainy days were upsetting breeder hens. The study also found that enhanced rainfall and moisture were escalating the disease occurrences in poultry and livestock, leading to minimal production.

Poultry plays a key role in the lives of poor rural communities in developing countries. This is especially so in Sub-Saharan Africa (SSA), where they provide income, capital assets, and manures (Seo & Mendelsohn, 2007). Both hybrid and indigenous poultry are raised in Kenya, where indigenous poultry makes for a considerable percentage of the economy and provides revenue

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to small-scale farmers (Kingori et al., 2010). Because of the availability of cheap home labour, most farmers in rural areas rear chickens because the capital required is modest and accessible. Free Range Indigenous Chicken (FRIC) plays an important role in the process of improving the nutritional status and also boosts the income of most rural households (Henning *et al.,* 2013). The chicken provides proteins in the form of meat and eggs to the world's population as they are majorly reared as food supplements (Enahoro *et al.*, 2019; Kingori *et al.,* 2010). It is an investment that many farmers keep as the simplest one since it is so helpful mostly when households are in financial crisis, such as getting medicine, clothing, and school fees at times when they are needed. More benefits that are related to chicken rearing are the control of pests, provision of farm manure, traditional ceremony contributions, cleanliness, and hygiene as FRIC feed on leftover foods (Chende, 2012). The Newcastle disease (ND) is influenced either directly or indirectly by the changes in weather patterns and climate in general. For example, the spread and change of weather patterns have a proportional effect on the spread of diseases like Newcastle (Saelao *et al.,* 2021).

Newcastle Disease outbreaks are commonly associated with alternating heavy rains, persistent drought, and rising temperatures (Brown & Bevins, 2017). Despite the fact that people are aware that the disease is related to ecological changes, research on the other hand has found that there are some environmental drivers that facilitate the dynamics of the emergence of the disease (Odey *et al.*, 2018). There have been many research studies about the cause of Newcastle Disease and its effects on free-range chickens around the world, such as Brown & Bevins (2017); Dimitrov et al., (2016); Ferreira *et al.*, 2019; Lv *et al.*, 2019; Richard *et al.*, 2017; Sultan *et al.*, 2020). However, there is still scant literature about the nexus of climate variability and Newcastle Disease. Both Nyaiyo and Tilakasiri (2014) worked in the Ilorin area of Nigeria; both studies related to climate variability and Newcastle Disease but did not exhaustively study the influence of climate variability on the spread of Newcastle Disease virus. Therefore, it was necessary for this study to broaden the nexus between seasonal climate variability and the spread of Newcastle Disease among free-range chickens at Kitutu Chache in Kisii County, Kenya.

METHODOLOGY

Study Area

The study was conducted in Kitutu Chache South, Kisii County, Kenya. The Kisii county lies between latitude 0º 40' 38.4" South and longitude of 34º 34' 46º 61 "East, which exhibits a highland equatorial climate that results in long and short rainfall patterns with an average annual rainfall of 1500 mm. The long rains take place between the months of March and May, while the short rains are received between the months of October and December every year. The months of January and February are relatively dry, while the coldest months are June, July, and August. The maximum temperatures range from 21 °C to 30 °C, while the minimum temperatures range from 15 °C to 20 °C (Ummenhofer *et al.*, 2009). The outlined conditions suit the growing of crops like bananas, beans, coffee, maise, pyrethrum, and tea, as well as dairy farming. The studied area consisted of the following wards: Bogisero, Bogeka, Nyakoe, Kitutu Central, and Nyatieko.

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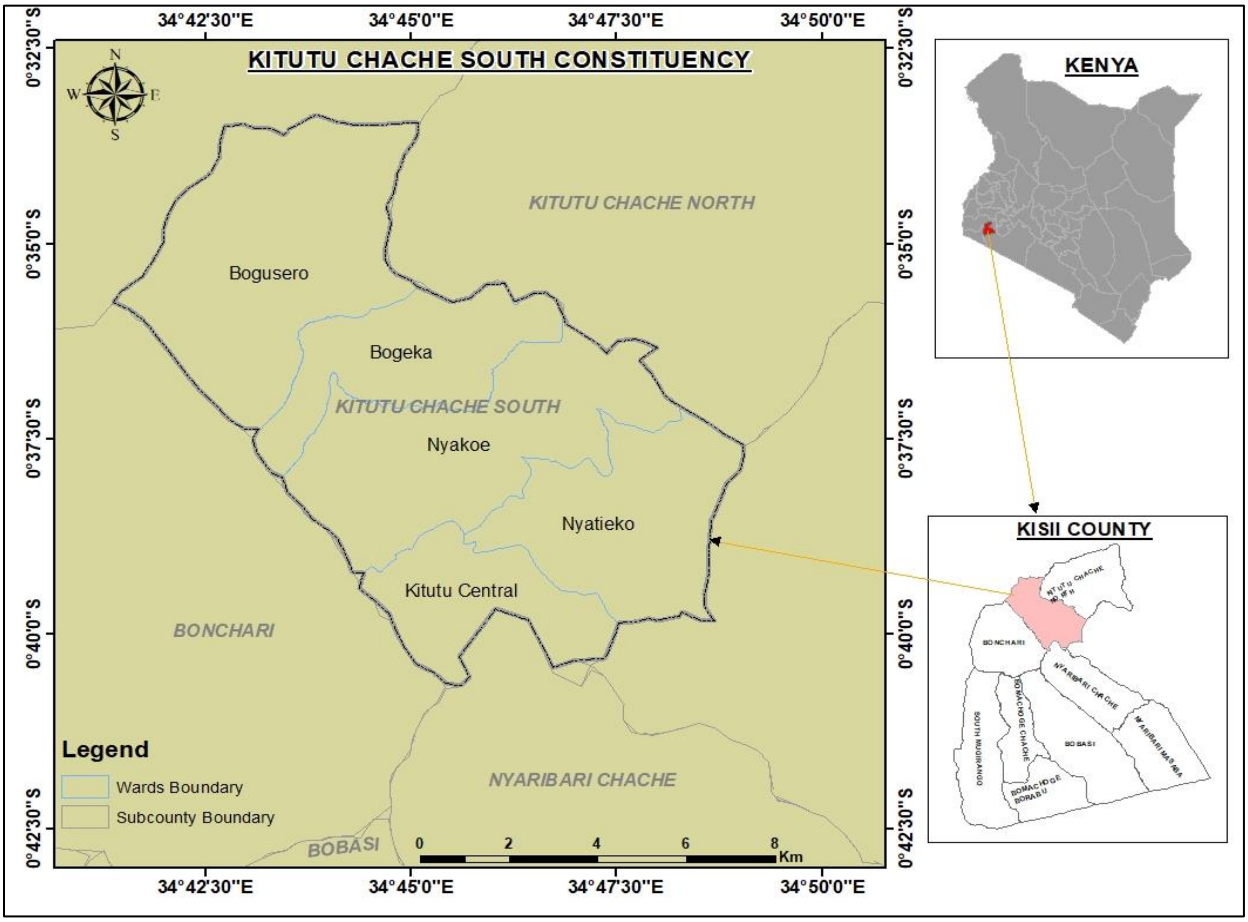
Figure 1: Map of the study area -Kitutu Chache South Constituency



Source: Generated from ArcGIS

Sampling Procedures and Data Collection

The study adopted an exploratory survey research design that determined the seasonal occurrence of Newcastle Disease in relation to the elements of weather patterns. The study included cross-sectional data collected through both primary and secondary methods, but it used the Cossia (2011) recommended formula for calculating sample size for environmental surveys. The study adopted systematic and random sampling to collect primary data from poultry farmers' households within the Kitutu Chache. The survey questionnaires were distributed among 500 farmers' households to collect the seasonal incidences of chicken deaths due to Newcastle Disease. Secondary data regarding climate variables (temperature and rainfall) on a monthly basis was obtained from the Kisii Meteorological Service (KMS) for a period from 1990–2019 (30 yrs).

Data Analysis

Statistical variables (Rainfall, Minimum & Maximum temperature) data were analysed by a non-parametric test in the modified Mann-Kendall trend test (mkttest) with Sen.'s slope estimator (Mann, 1945) in R-version 4.0.2 to determine the seasonal climate trends of Kitutu Chache South. Moreover, descriptive statistics were also used to analyse the seasonal death occurrence and trends of FRIC, which were then presented in tables and graphs drafted in Excel 2016.

Multiple linear regression models (Eq. 1) below were used to test and show the influence of climate variables (temperature and rainfall) on free-range Indigenous chicken (FRIC) incidences of deaths due to the spread of Newcastle disease. The analysis was computed in STATA-14, thereby presented in table format.

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$$\gamma_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon_0 \quad \text{(Eq. 1)}$$

Where γ_t- Seasonal incidences of death at time t; β_0 – Intercepts of the variables; $\beta_{1,2}$ – Coefficients of predictors; $X_{1,2}$ – Predictors variables (rainfall and temperature); ε_0 – Random effects/Error terms

The model used assumed maximum temperature due to the high correlation with minimum temperature (0.808; $p < 0.01$). However, studies have shown that minimum air temperature influences favourable conditions for virus and vector parasitic survival and multiplication (Ferreira et al., 2019), so the study chose to use minimum temperature. The choice of a linear regression model fitted to evaluate the adjusted effect of climate variables on chicken death incidence due to Newcastle Disease. The intercept standardised the comparison rate of death incidences and climate variables.

RESULTS AND DISCUSSION

Kitutu Chache South Climate Variability (1990-2019)

Seasonal Rainfall Trend

There were no significant rainfall trends in all the seasons of the year ($p > 0.05$) (*Table 1*). However, SON (September, October, November) and MAM (March, April, May) showed an increasing amount of rainfall, though it was not significant, while JJA (June, July, August) and DJF (December, January, February) showed a reducing amount of rainfall, though it was not significant. Therefore, these results imply that the dry seasons (JJA and DJF) of the year are becoming drier and drier, as illustrated in *Figure 2*.

Table 1: Kitutu Chache Seasonal Rainfall variability

Seasons	tau	z-value	p-value
MAM	0.044	0.321	0.748
JJA	-0.062	-0.464	0.643
SON	0.140	1.070	0.284
DJF	-0.229	-1.726	0.084

The same results of a slight increase in rainfall during MAM and SON were found by Bari *et al.* (2016) in the Northern Region of Bangladesh. However, Gebrechorkos *et al.* (2020) study conversely supported this study, where it was reported that the seasons of MAM and OND showed a significant variability decrease in the number of rainfall trends. This study found that there was a negative correlation for dry periods in both short and long dry seasons (JJA and DJF) (tau = -0.062 and tau = -0.229; p >0.05), respectively which were also the same as the results of Amadi *et al.*, (2018) which was done in Baringo County, Kenya. Moreover, the years 2014 and 2003 showed high rainfall, while 2001 and 2016 were the driest years during the seasons of JJA, as shown (*Figure 2*).

There was high rainfall between 1997 and 2006 during the dry month of December to January (Figure 2). However, in 1997 rains were associated with El-Niño as it is indicated in other studies such as Sunday et al. (2014).

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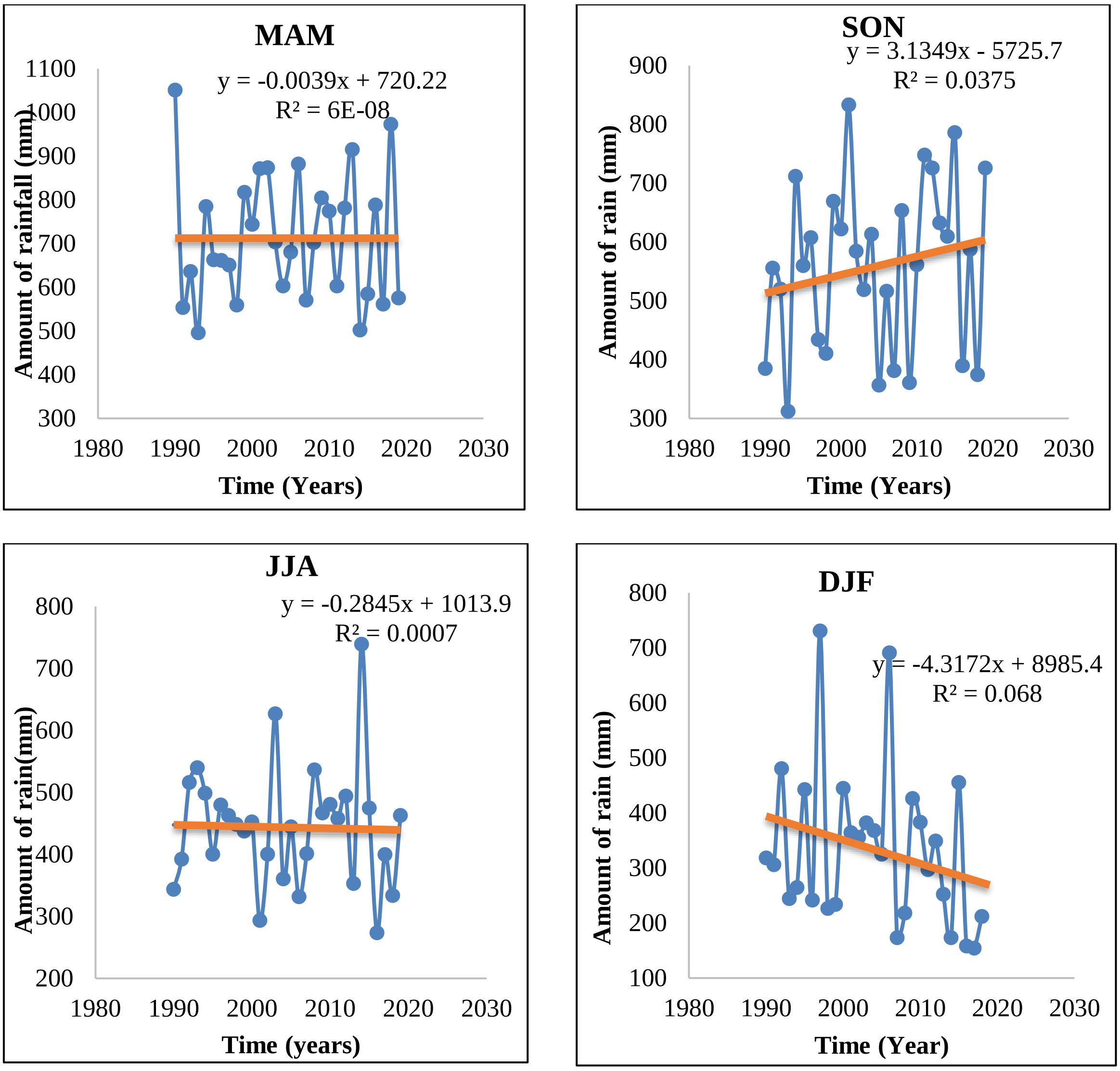
Figure 2: Seasonal amount of rainfall trends in Kitutu Chache South



Seasonal Temperature Trends

There were significant changes in minimum temperature trends during the study period of 1990–2019 within all seasons the years ($p = 0.001$), as shown in Table 2. On the other hand, there were no significant trends in maximum temperatures in all seasons of the year during the study period from 1990–2019. JJA and MAM, on the other hand, showed a slight positive increase in maximum temperature, while SON and DJF showed a negative decrease in maximum temperature (*Table 2*). Results were similar to those of the study by Amadi et al. (2018), which showed a high increase in seasonal temperature trends during the DJF, with JJA being the coolest (*Figure 3*). Generally, Kitutu Chache South reported an increasing temperature trend, as shown in *Figure 4*.

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Table 2: Kitutu Chache Seasonal Temperature variability

Maximum Temperatures				**Minimum Temperatures**		
Seasons	tau	**z-value**	**p-value**	**tau**	**z-value**	**p-value**
MAM	0.189	1.448	0.148	0.278*	2.143	0.032
JJA	0.239	1.838	0.066	0.494*	3.819	0.0001
SON	-0.053	-0.393	0.695	0.455*	3.519	0.0004
DJF	-0.053	-0.053	0.115	0.303*	2.288	0.0002

*Note: * means p < 0.05 showing a significant change in the trend*

Figure 3: Seasonal maximum temperature in Kitutu Chache South

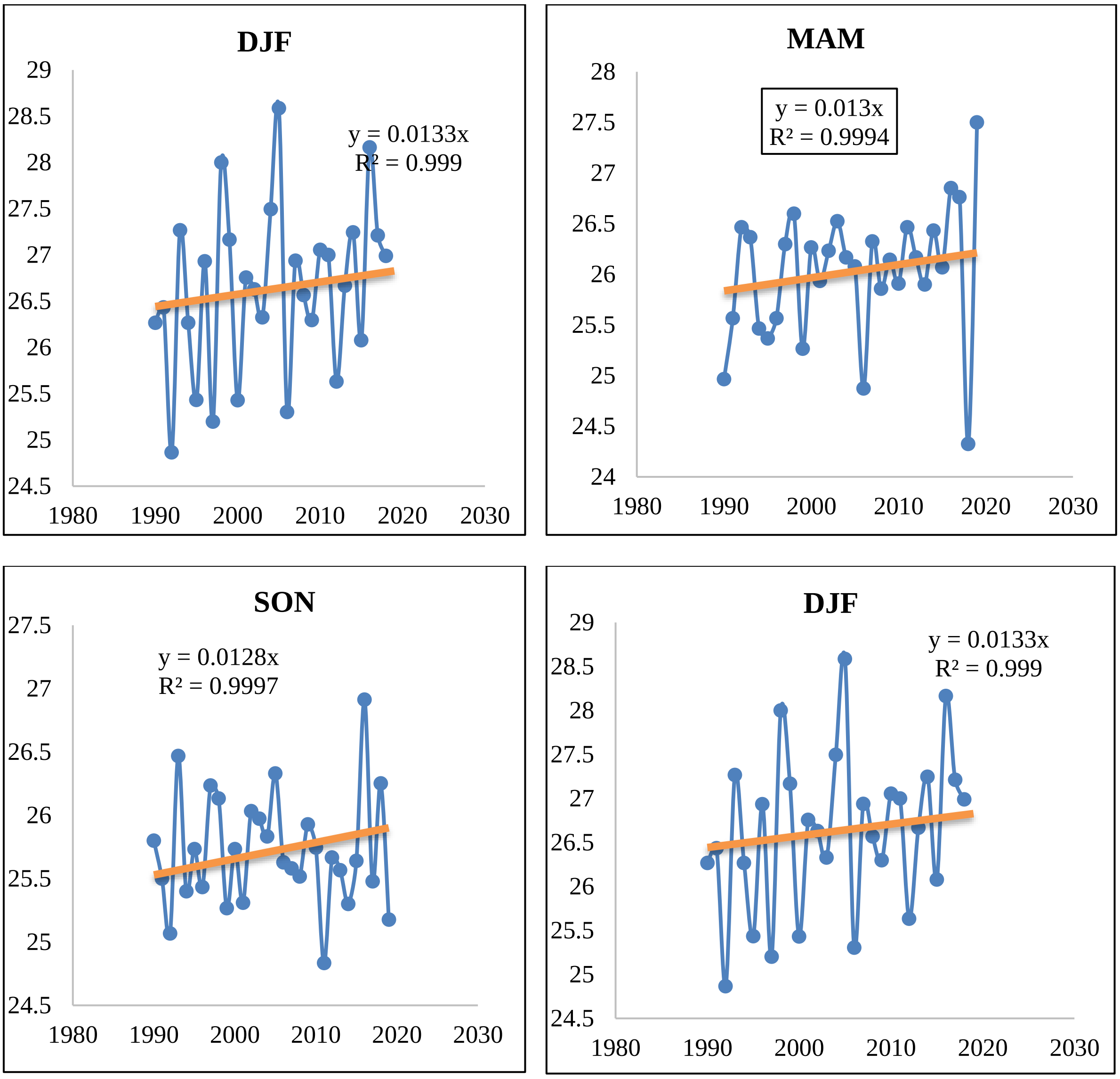

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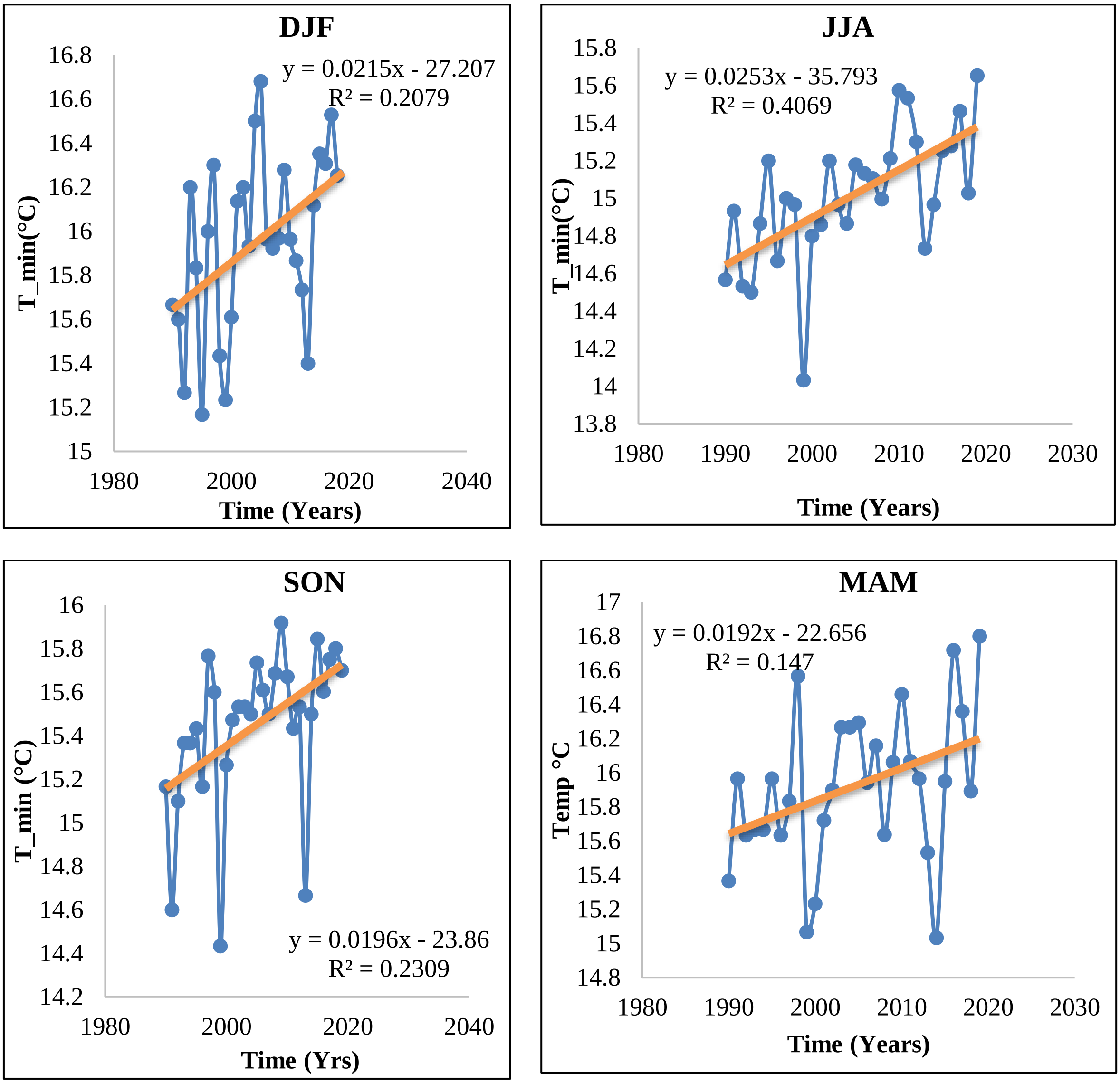
Figure 4: Seasonal minimum temperature trends in Kitutu Chache South



Seasonal Trend of Newcastle Disease Occurrence and FRIC mortality

From the descriptive statistics, the study found that the months of March, April, and May (MAM) mark the highest emergence of Newcastle Disease by 49.5% (*Figure 5*). The months of December, January, and February (DJF) recorded 25.4% of FRIC deaths, June, July, and August (JJA) recorded 14.8%, and September, October, and November (SON) recorded the lowest death occurrence by 10.3% (Figure 5). These results deduce that the Newcastle Disease spreads so quickly, causing high mortality of free-range Indigenous chickens (FRIC) during the MAM season due to high rainfall, which is conducive to virus survival (Ferreira et al., 2019). Likely, the results also implied that dry seasons would reduce the number of death cases, but post-dry season periods would report more deaths (Wondmeneh et al., 2016). The results from this study were also supported by Nyaiyo (2014) from Kenya and Tilakasiri et al. (2015) from Nigeria. They reported that in the months of March and April, there were more death occurrences in chickens due to adverse weather conditions such as high rainfall than in other seasons of the year.

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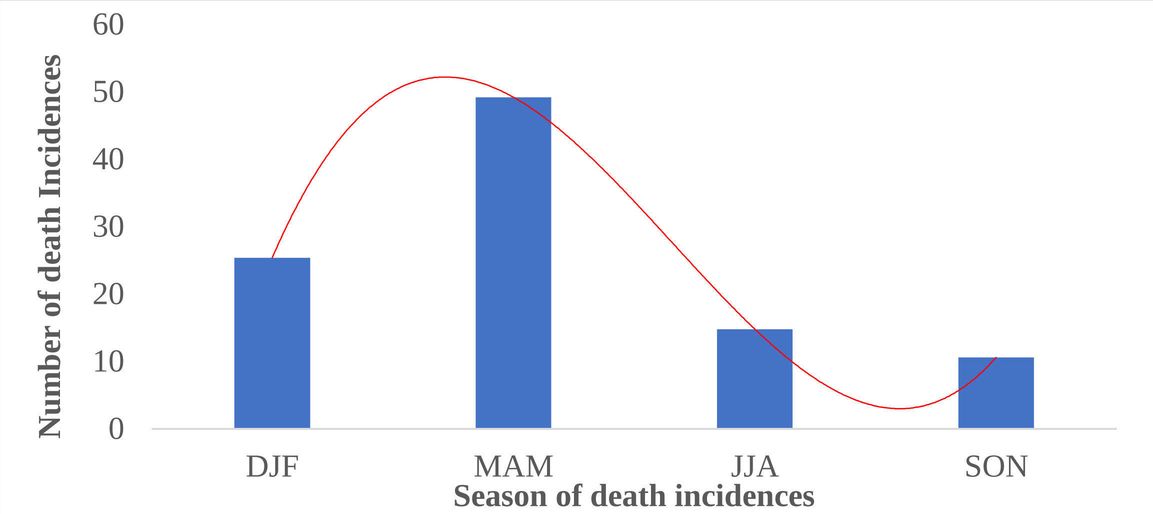
Figure 5: Trends of seasonal Newcastle Disease occurrence and poultry mortality



Effects of Climate Variability on Newcastle Disease Occurrence and FRIC Mortality

Regression analysis was used to measure the effects of climate variables on the seasonal deaths of FRIC due to the spread of Newcastle Disease in Kitutu Chache South. During the analysis, the maximum temperature was omitted from the regression model because of its high correlation with minimum temperature, as shown in equation 1, since that would cause collinearity in the results. As shown in *Table 3* below, there was a positive and highly significant increase in chicken deaths due to rainfall variability ($p = 0.001$), while there was a negative and highly significant decrease in chicken deaths occurrence during minimum temperature ($p = 0.001$).

Table 3: Regression coefficient showing the effects of climate factors on seasonal death occurrence of FRIC due to outbreak of Newcastle Disease

Variables	Coefficient	Std. Err	t
Rainfall	0.003***	(0.0001)	22.62
Minimum temp.	-2.357***	(0.0620)	-38.00
Intercept	37.56***	(0.958)	39.21

****means $p < 0.001$ at significance level*

These results implied that increasing rainfall would significantly increase the number of FRIC death occurrences due to the spread of Newcastle Disease. Therefore, it means that high rainfall provides a conducive and favourable environment for pathogens and viruses to multiply (Dortmans, 2011; Seal *et al.*, 2000). Similarly, increasing the minimum temperature would reduce the number of FRIC deaths occurring due to the outbreak of Newcastle Disease. It was reported in other studies that a drop in temperature conditions would increase the death occurrence of chickens due to the Newcastle Disease outbreak (Tilakasiri *et al.*, 2015). Therefore, these results were in agreement that increasing temperatures would be favourable to the survival of viruses up to an optimum level, and then viruses die at maximum levels (Dimitrov *et al.*, 2016). It was also reported that high rainfall limits free-range Indigenous chicken behaviours within their environment. The cold environment has affected the breathing systems of chickens, as reported by Annapragada et al. (2019). Henning et al. (2013) came to the conclusion that the spread of the Newcastle Disease virus to FRIC was affected by changes in

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temperature and rainfall from season to season in most rural households.

Implications of Climate Variability on Chicken Production

Poultry farmers reported that the extreme alternating wet and dry seasons would affect egg and meat production amongst the chicken breeds. However, 60.6% of the farmers reported that extreme fluctuations in wet and dry weather conditions would increase eggs and meat production, while only 39.4% reported that alternating wet and dry conditions would decrease eggs and meat production in chicken (see *Table 4*).

Table 4: Alternating dry and wet seasons

Response	Frequency	Percent (%)
Increase	303	60.6
Decrease	197	39.4
Total	500	100.0

Nath et al.'s (2016) study from Northeast India reported that Newcastle Disease affects the molecular characteristics of chickens and therefore the production of meat and eggs would be affected during chicken breeding. 22% of the respondents agreed that severe and prolonged dry spells increased the spread of Newcastle Disease, therefore causing a reduction in chicken productivity, while 78% of the respondents agreed that prolonged dry spells would reduce chicken productivity (*Table 5*).

Table 5: Severe and prolonged dry spell

Responses	Frequency	Percent (%)
Increase	110	22.0
Decrease	390	78.0
Total	500	100.0

The results in *Table 5* sensibly showed that farmers' perceptions of dry spells do not increasingly affect the spread of Newcastle Disease. Most of the studies reported that the spread of Newcastle Disease during the dry season was not as much as in the wet seasons. Therefore, most of the effects of Newcastle Disease are felt during the wet seasons (Salinas-Ramos et al., 2019). Further, 82.8% of the respondents reported that high temperatures and high amounts of rainfall could reduce the production of chicken among farmers' households of Kitutu Chache. However, 17.2% of the respondents (*Table 6*) suggested that high temperatures and rainfall could increase the production of eggs and meat in chickens.

Table 6: High temperatures and rainfall

Response	Frequency	Percent (%)
Increase	86	17.2
Decrease	414	82.8
Total	500	100.0

The results in *Table 6* were in agreement with many studies around the world that found an increase in temperature reduced the quality and number of eggs hatched by chickens (Kingori et

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al., 2010; Nath et al., 2016). Conclusively, the occurrence of Newcastle Disease every year and its effects have resulted in huge losses due to FRIC deaths, reduction in egg production, fluctuation in prices of chicken in the market; and increase in production costs through the purchase of drugs and vaccination.

CONCLUSION

The research employed a quantitative study to collect data and analyse it. A significant increase in minimum temperatures was observed, and maximum temperatures did not show trends; the results showed that Kitutu Chache south is warming. This study confirmed the substantial influence of climate variables on the spread of Newcastle Disease. Further, this study confirms that rainfall and minimum temperature variations are favourable to the survival of Newcastle Disease Virus up to optimum levels. Therefore, future climate change is anticipated to alter the FRIC productivity among poultry farmers. Harmonically, these climatic factors should be considered when planning for Newcastle Disease control.

Recommendation

Kenya's Ministry of Agriculture and Livestock should come up with participatory approaches that collaborate with poultry farmers in poultry policy making so that farmers will engage in new adaptive measures to climate change issues. This will help farmers develop an applied farmer-centred intervention with a positive mindset to adapt to the effects of climate variability on poultry production.

Competing Interest

The authors declare no conflicts of interest

Data Availability

The data used to support the findings of this study are available upon request

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