Byamukam & Agbolosoo *IJDM (2024) 7:3, pp 199-212*
DOI: https://doi.org/10.24815/ijdm.v7i3.39754

International Journal of
Disaster Management
E-ISSN: 2527-4341 P-ISSN: 2808-439X

RESEARCH ARTICLE Open Access

Exploring Climate Change, Perceptions, and Adaptive Measures among Dairy Producers in Kiruhura District, Uganda

Obed Byamukama[1,2]*, and John Atsu Agbolosoo3

[1]Natural Resources and Environmental Management Science, Graduate School, Bogor Agricultural University (IPB), Indonesia
[2]Meteorology Unit. Department of Geography, Geo-Informatics and Climate Sciences. Makerere University, Kampala-Uganda.
[3]Department of Agricultural Economics, Faculty of Economics and Management, Bogor Agricultural University (IPB), Indonesia
***Corresponding author:** obedbyamukama1@gmail.com

Received 30 June 2024; *Received in Revised Form* 21 December 2024; *Accepted* 21 December 2024

Abstract

The continuous evidence of climate change highlights the fact that it is a critical worldwide issue with potentially disastrous consequences for agricultural systems and the livelihoods of socioeconomically disadvantaged societies. This research explores dairy producers' perceptions of temperature and precipitation changes, their adaptation strategies, and the influencing factors behind these strategies. Data on dairy producers' perceptions was collected by means of a household survey and analyzed utilizing descriptive statistics and graphical representations. Climate data for the study area (1985–2014) was sourced from the Uganda National Meteorological Authority. It was then analyzed using trend analysis. Results from trend analysis were then used to compare with dairy farmers' responses. Notably, the results show significant agreement between dairy farmers' perceptions and empirical climate data, indicating a clear understanding of climate dynamics. This understanding informs their adaptation practices, which have proven to be diverse and context dependent. These practices include the creation of animal pastures, reforestation, reducing the size of herds through sales, utilizing drought-resistant breeds, and purchasing feed additives for livestock. In addition, the study found that access to credit, household size, education level, and gender are important factors affecting pastoralists' adaptability. These results underscore the importance of recognizing and leveraging farmers' experiential knowledge when developing targeted climate adaptation strategies for specific localities. By bridging the gap between perception and reality, this research provides valuable insights for policymakers for developing tailored climate adaptation strategies and improving resilience within dairy-producing communities in response to climate change.
.

Keywords: adaptation; climate change; dairy producers; perception; Uganda; variability

Introduction

The dairy sector in Uganda is experiencing rapid growth, playing a pivotal role in the country's economic development through job creation, enhancing livelihoods, and reducing rural impoverishment (FAO, 2019). Over the years, Uganda has had an increase in dairy exports and a decrease in dairy imports. "In 2019, exports reached 0.16 million tons, valued at over US$120.74 million, while imports stood at 412 tons, valued at US$1.69 million" (FAO, 2022). Uganda now ranks third in East Africa for milk production, with 2.04 million tons produced, following Tanzania and Kenya (UBOS, 2020; FAO, 2022). The southwestern region, where Kiruhura District is located, is the main contributor to national production.

Despite its crucial contribution, the Ugandan dairy sector faces significant challenges from climate change. Studies in Ugandan regions with high livestock density confirm that climate shocks—such as changes in precipitation, temperature, droughts, and floods—are negatively affecting the sector. For instance, Kirui et al. (2015) identified a correlation between increasing dry spells and rising incidences of livestock diseases, feed shortages, and reduced milk production in Wakiso District. Similarly, dairy farmers in Uganda's cattle corridor report experiencing these climatic changes firsthand, as reported by Nimusiima et al. (2013). The vulnerability of the sector is further compounded by heavy reliance on rain-fed forage and the persistent poverty of smallholder farmers, which limits their capacity to adapt (Kirui et al., 2015). Despite livestock serving as a buffer against food insecurity and economic vulnerability, Bagamba and Kuyvenhoven (2022) project that between 70 and 97% of Uganda's smallholder farmers will be severely impacted by climate change.

The Ugandan government has demonstrated a commitment to addressing these climate challenges through the development of policies like the National Climate Change Policy (NCCP) in 2015, which aligns with Uganda's Vision 2040 and emphasizes the need for both mitigation and adaptation. Programs such as the Uganda Climate Change Action Plan and the Climate-Smart Agriculture Program (2015-2025) reflect national efforts to support climate-resilient agriculture and reduce vulnerability to climate change in the agricultural sector (MAAIF and MWE, 2016). While the government's initiatives provide essential support, challenges remain. Limited financial resources, infrastructural deficits, and socioeconomic factors such as widespread poverty and restricted access to technology hinder the implementation of effective adaptation measures.

In addition, there is a limited understanding of how rural, small-scale dairy producers recognize and address these climate-related effects. While most research on climate-related impacts on African farming focuses on large geographical contexts, adaptation strategies need to be site-specific and consider the differing perspectives and coping mechanisms of various agricultural communities. Models often fail to capture local perceptions accurately, underscoring the importance of documenting how climate changes affect the lives of local people. This research aims to address these knowledge gaps. Its uniqueness lies in the fact that it offers a site-specific analysis of climate change impacts on dairy farming in a single district in Uganda, providing a focused perspective that contrasts with previous studies, which often combined data from multiple districts, sometimes with differing climatological zones and socioeconomic characteristics. The approach acknowledges that broad regional analyses can mask local variability in climate conditions and farming practices, resulting in generalized adaptation strategies that may not reflect the realities faced by farmers in specific locales. This research is structured based on three main questions: (1) What views do dairy producers have about climate change in comparison to historical climate trends in the region? (2) What adaptation strategies do local dairy farmers use? and (3) What factors influence their adaptation decisions?

Literature Review

Climate Change and Variability

"Climate change is the change in the state of climate identified using statistical tests by changes in the mean and/or the variability of its properties persisting for an extended period, typically decades or longer. While climate variability refers to the variations in the mean state and other statistics such as the standard deviation or occurrence of extreme events of climate on all temporal and spatial scales beyond that of individual weather events" (IPCC, 2022; Sloat et al., 2018). Numerous studies worldwide indicate that climate variability and changes are increasingly prevalent and disproportionately impact impoverished populations, who have limited ability to adapt and weak support systems (FAO, 2008; Wang, 2019). Several studies have documented noticeable changes in temperature and precipitation patterns across Uganda, affecting various sectors (Sentongo et al., 2018; Jury, 2018; Nuwagira et al., 2022). Even so, these studies are general and do not provide local site-specific information. To inform the process of adaptation with certainty and accuracy, examining the patterns of rainfall and temperature features at Kiruhura is one of this study's goals.

Climate Change Effects on Dairy Industry

Climate change can have negative consequences for the dairy sector. According to EFSA (2020), dairy cattle are prone to heat stress and have trouble enduring high temperatures. Heat stress negatively affects dairy animals' ability to reproduce; it usually causes a decrease in milk yield, increases mortality, and decreases fertility rate (EFSA, 2020; Magiri, et al., 2021). Climate change is anticipated to increase temperature, which will intensify heat stress (Jacobs et al., 2019; Hempel et al., 2019).

Seasonal variations in weather play a major role in pasture productivity, with the quantity and timing of rainfall determining how variable pasture growth is both seasonally and yearly (Timlin et al., 2021; Le et al., 2023). Additionally, the water cycle is impacted by rises in temperature and variations in precipitation patterns, resulting in water scarcity to cater for the drinking needs of the cows (Rojas-Downing et al., 2017). Furthermore, available evidence suggests a connection between the prevalence of cattle diseases and climate variability and change. The unusual outbreak of avian influenza, bluetongue across Europe, and Rift Valley fever in areas across Africa because of catastrophic floods are three instances of epidemics linked to the changing climate (Nohrstedt al., 2024; Munyera et al., 2020).

Adaptation to Climate Change

Adaptation to climate change involves adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities. (IPCC, 2007). Improving adaptations to consequences is the most effective action plan for combating the effects due to climate change, especially for the most vulnerable and developing countries (Elum et al., 2017; Bosire et al., 2019; AFDB, 2020). Risk management is an essential part of people's ability to adapt to climate change. It may be seen as a result of the interaction between equity, well-developed institutions, technology, resources, infrastructure, and human capital (NASA, 2020). Most research studies highlight adaptation strategies that are broad and not particular to a farming community. Furthermore, adaptation differs from location to location. Therefore, it is important to comprehend how dairy producers in Kiruhura District are adjusting to climate change consequences. This is required to minimize livestock losses and enhance systems for producing cattle. This study explored reducing herds by selling, buying livestock feed supplements, using drought-resistant livestock breeds, planting trees or afforestation and planting pastures for animals as adaptive strategies.

Dairy Farmers’ Perceptions of Changes in Climate

Comprehending perceptions of climate change within rural agricultural communities is critical to managing vulnerability and promoting adaptation. “Perception is the process by which individuals receive information or stimuli from the environment and transform it into psychological awareness to learn about the environment and respond accordingly” (Ricart et al., 2023). Farmers’ local knowledge of climate change enables them to arrange a local reaction to expected effects (Abid et al., 2015; Adimassu & Kessler, 2016). Therefore, understanding climate change perceptions and its effects within pastoral societies is crucial in providing guidance to planners and decision-makers so they can make the right decisions and enhance pastoralists' capacity to adjust to changing climate conditions (Debela et al., 2015). Most studies focus on scientific modeling and proof of climate change, consequences on sectors, with little attention devoted to critically analyzing local people’s comprehension of climate change. As highlighted by the IPCC (2014) report, there is a need to incorporate rural residents’ understanding of climate change and other weather-related stressors. Thus, this research aims to contribute to the body of current literature by examining how dairy producers in rural Kiruhura District perceive changing climate conditions.

Methods

Study Area

The research was conducted in Kiruhura District, located in the southwestern region of Uganda, approximately 254 kilometers from the capital city, Kampala (UBOS, 2017). Kiruhura is part of Uganda’s cattle corridor, bordered by the districts of Kyenjonjo and Sembabule to the northeast, Isingiro and Rakai to the south, Mbarara to the west, Ibanda and Kamwenge to the northwest, and Lyantonde to the east. The district experiences two distinct rainy seasons, occurring from mid-August to October and from March to May, with an average annual rainfall of approximately 900 millimeters. Situated at an elevation of 1,800 meters above sea level, Kiruhura is characterized by extended dry spells, with temperatures ranging from 17°C to 30°C. Livestock farming is the primary economic activity in Kiruhura, with 342,315 cattle reported in the district (UBOS, 2021). This predominantly rural area relies heavily on livestock as a major source of income for its farmers. The geographic coordinates of Kiruhura District are 00°12′S and 31°00′E. According to UBOS (2017), the district has a total population of 151,685 people.

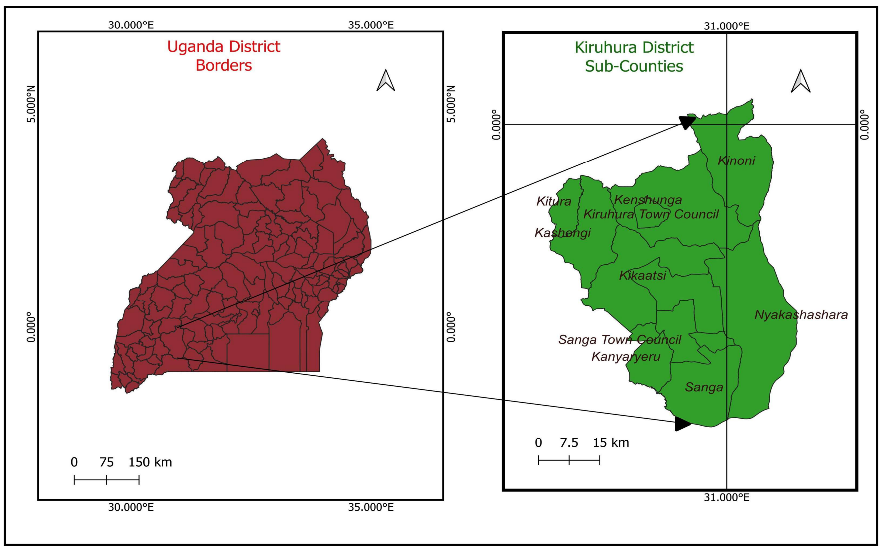

Figure 1. Kiruhuru District location

Data Type and Sources

Meteorological Data

Rainfall and temperature data for the years 1985–2014 at the Mbarara meteorological station was sourced from Uganda National Meteorological Authority (UNMA). Datasets at Mbarara weather station were used because it is in the same climatic zone as the research area and contained complete data without missing values. It was analyzed using trend analysis, which is described as the general movement of a time series over time. In this case, the long-term variations in rainfall and temperature variables over time were the dependent variables.

Qualitative Data

This research applied a multi-stage sampling technique, using a mix of sampling methods to choose sample sub-counties and households in the study area for interviews. Kiruhura was selected as it is one of the top milk-producing districts in Uganda, with farms managed by smallholder farmers. The sub-counties of Kenshunga, Sanga, Kashongi, and Nyakashashara were purposefully selected from the ten sub-counties as this is where the majority of cattle keeping is concentrated in Kiruhura, according to Kiruhura District Local Government. These sub-counties consist of 5658, 1454, 5658, and 3373 households, respectively, for 16,143 households (UBOS 2017). A sample size of 390 dairy farmers was determined using equation 1 below, given by Yamane (1967).

$$n = \frac{N}{1+Ne^2} \quad (1)$$

In this case, n represents the necessary sample size, N represents the entire population, and e, also known as sampling error, is the degree of precision. This is the range where the estimated true population value falls, often expressed in percentage points (±5% was considered for this study). Thus,

$$n = \frac{16143}{1+16143*0.05^2}=390$$

Data collection for this study took place between June and September 2021, targeting 390 small-scale dairy producer households. These households were evenly distributed across the four sub-counties, with each sub-county contributing an equal number of participants. A basic random sampling technique was applied within each sub-county to ensure unbiased selection of households for participation. Two local enumerators were recruited and trained by the author to ensure familiarity with the study objectives, ethical considerations, and the structured questionnaire's administration. The training emphasized consistency in administering both closed- and open-ended questions to ensure data reliability and validity. The local recruitment ensured familiarity with the context and enhanced communication with respondents. The questionnaire included both closed-ended and open-ended questions. The study focused on households actively engaged in cattle rearing. Topics covered included socioeconomic characteristics, perceptions of climate change, and adaptation strategies such as stock reduction, purchasing feed supplements, using drought-resistant breeds, tree planting, and pasture management. Data collection involved in-person interviews, with informed consent obtained from all respondents.

Out of 390 questionnaires administered, only 345 were found to have complete information that could be considered for analysis, yielding a response rate of 88.5%. The data was transferred to the Statistical Package for Social Sciences (SPSS) for analysis. To identify the factors influencing herders' decisions on their adaptation tactics, they were surveyed to obtain information on their gender, education level, marriage status, access to credit, and size of their household. These were seen as determining factors in the adaptability of pastoralists. To arrive at meaningful interpretations of the information gathered, the data from this exercise was examined using the logistic regression analysis tool in SPSS. The dependent variables—access to credit, gender, education level, household size, and age—were regressed on a set of independent variables, which were the actual adaptation strategies of pastoralists.

Results and Discussion

Herders' Views of Changes in Climatic Variables

From the interviews conducted, it was found that almost all households (99%) had observed a change in temperature and precipitation patterns in the previous 20 years. 1% were not sure or did not know if the climate had changed in that period. Respondents were requested to state if they believed that temperature and precipitation increased or decreased during this period. Of all participants, 82% stated that temperature had risen, 18% reported that it had decreased, 67% reported that precipitation had increased, 30% reported that precipitation had decreased, and 3% responded that there was no change over the same period. Many described these changes as significant disruptions to their livelihoods. For instance, one respondent, *Mr. Robert K.* from Kashongi sub-county, remarked: *"The heat has become unbearable. It dries up our pastures quickly, and the water sources are gone before we even realize it. Twenty years ago, we never worried like this".* Similarly, another herder, *Ms. Beatrice N.* from Kenshunga, noted: *"The rains used to come on time and last long enough for us to grow and store enough fodder. Now they come late and leave early, and we don't know when to prepare."* These perceptions align with meteorological data showing an increasing trend in both mean annual temperatures and variability in rainfall timing (Figure 4 and 7).

Perception of Temperature Changes in Kiruhura District.

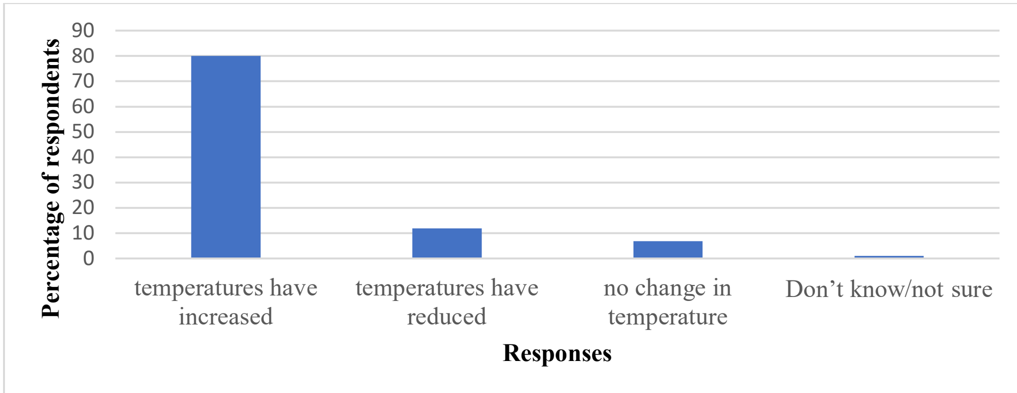

Figure 2. Herders' perceptions of changes in temperature in Kiruhura

The survey's findings show that the majority of the dairy herders have observed long-term temperature changes. Of these, 80% reported an increase in temperature in Kiruhura, while only 12% noticed a decrease and 7% observed no change. Only about 1% were unsure about the changes (Fig. 2). The herders reported that rising temperatures have led to prolonged droughts, causing their pastures to dry out and water sources to become scarce. This has led to a decline in their livestock as they die due to a lack of pasture and water.

The survey's findings show that the majority of the dairy herders have observed long-term temperature changes. Of these, 80% reported an increase in temperature in Kiruhura, while only 12% noticed a decrease and 7% observed no change. Only about 1% were unsure about the changes (Fig. 2). The herders reported that rising temperatures have led to prolonged droughts, causing their pastures to dry out and water sources to become scarce. This has led to a decline in their livestock as they die due to a lack of pasture and water.

Perception of precipitation Changes in Kiruhura.

In the past two decades, 95% of respondents have noticed shifts in rainfall trends. These changes were observed in the timing and amount of precipitation. Three-quarters of them reported a reduction in precipitation or a shorter rainy season, while 84% reported a rise in rainfall. 45% of them experienced an early onset of rain, while 92% observed a delay. Only 8% of respondents noted no changes in rainfall trends in the last 20 years (Fig. 3).

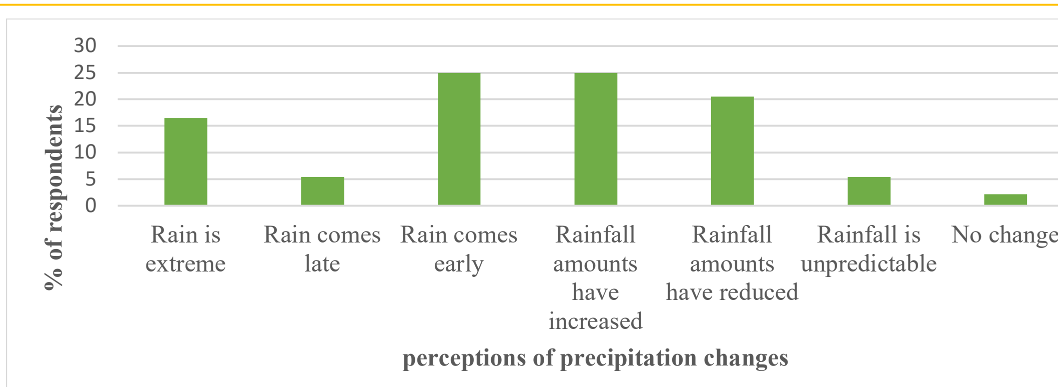

Figure 3. Pastoralists' perceptions of rainfall changes in Kiruhura district

Actual Climate Change in Kiruhura

Analysis of Temperature Trends

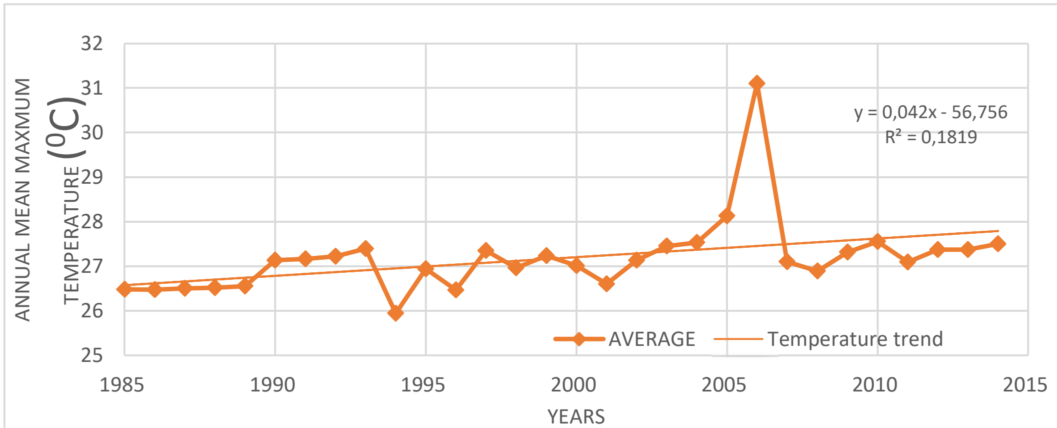

Figure 4. Annual mean maximum temperatures for Kiruhura District (1985–2014)

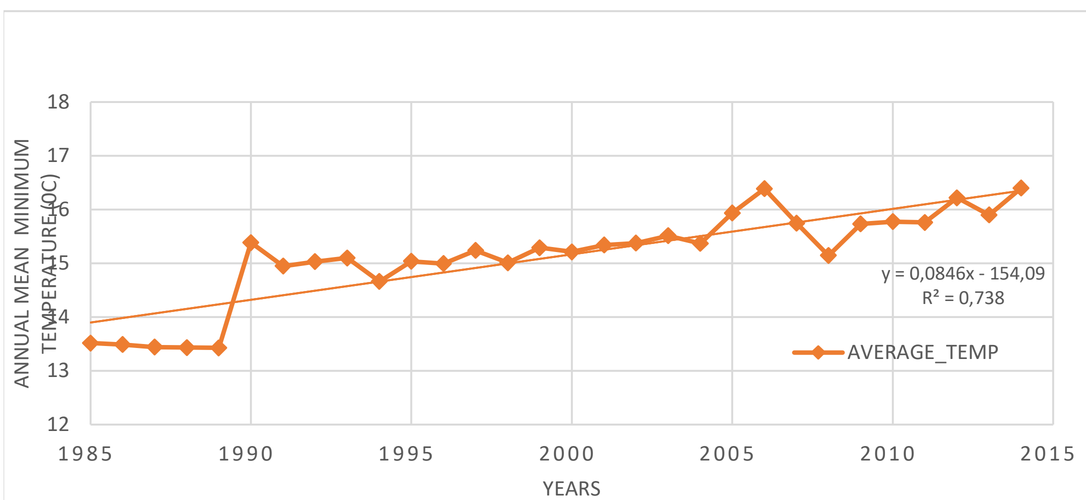

Figure 5. Annual mean minimum temperatures for Kiruhura District (1985–2014)

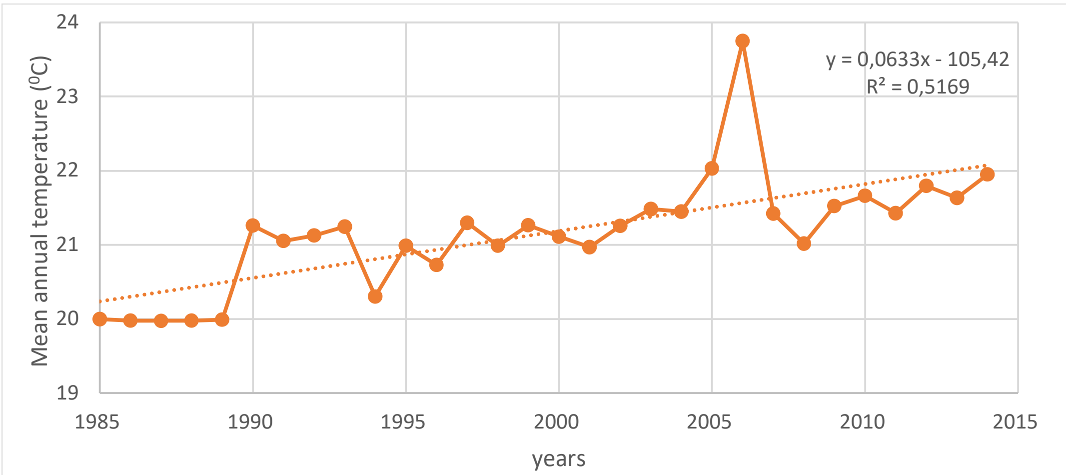

Figure 6. Annual mean temperatures for Kiruhura District (1985–2014)

An examination of temperature data for Kiruhura for the years 1985—2014 shows that temperatures in this region are on an increasing trend. The trend line equation for mean annual temperature, y=0.0633x−105.42, indicates that the mean annual temperature has been increasing at an average rate of 0.0633 °C per year. The R-squared value of 0.5169 suggests that approximately 51.69% of the variability in mean annual temperature can be explained by the year, indicating a moderate fit of the trend line to the data (Fig. 6).

This upward trend is particularly noticeable for yearly average minimum and yearly average temperatures, as shown in figs. 5 and 6. Both the yearly average maximum temperatures and the yearly average minimum temperatures increased during this period, as shown in figs. 4 and 5. However, annual minimum temperatures have increased faster than maximum temperatures. On average, annual mean temperatures have increased since 1985, which is consistent with the perception of pastoralists in the district.

The observed rise in temperatures and variability in rainfall over the study period is consistent with previous studies in similar contexts. For instance, Nimusiima et al. (2013) reported comparable increases in temperature and rainfall variability in Uganda's cattle corridor. This suggests that smallholder farmers are acutely aware of climatic shifts, which shape their agricultural practices. Such awareness is crucial for effective adaptation planning, as highlighted in IPCC (2022), which emphasizes integrating local perceptions into broader climate adaptation frameworks. Notably, 99% of respondents observed significant climatic changes, with 80% reporting rising temperatures and 95% citing shifts in rainfall patterns. These findings mirror those of Bhattacharya et al. (2018) in India and Paolo et al. (2021) in Guinea, where farmers' perceptions of climate variability were similarly consistent with historical climate records. This consistency not only validates the reliability of local observations but also underscores the importance of farmer engagement in climate resilience initiatives.

Analysis of Rainfall Trends

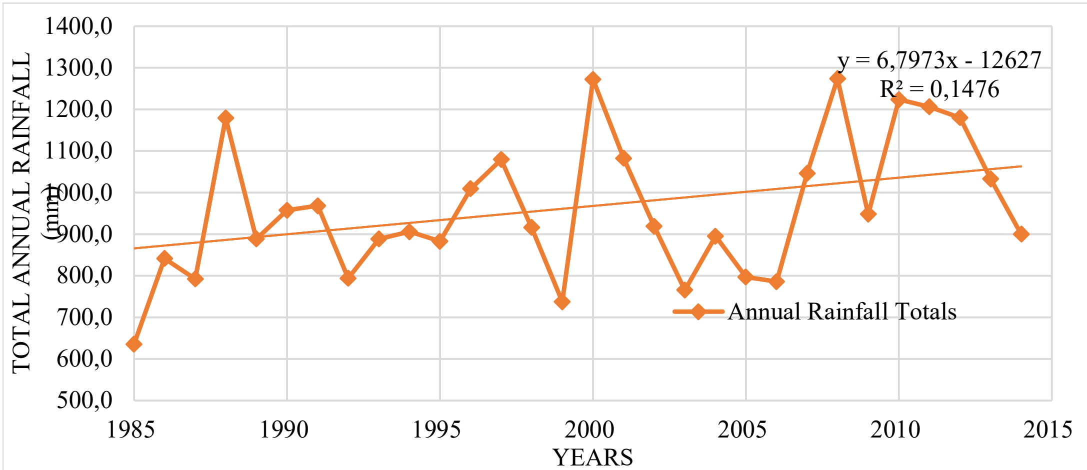

Figure 7. Annual mean rainfall for Kiruhura District (1985–2014)

From Fig. 7 above, the linear trend analysis of total annual rainfall from 1985 to 2014 reveals a slight upward trend, with an average annual increase of 6.7973 mm. The equation of the trend line is y=6.7973x-12627, whereby y is the total annual rainfall (in mm), x is the year, and 6.7973 is the slope of the trend line, indicating that on average, the total annual rainfall has increased by approximately 6.7973 mm per year. However, the low R-squared value of 0.1476 indicates that this trend explains only 14.76% of the variability in rainfall, suggesting that other factors significantly influence the observed rainfall patterns. To further understand the trend, we examined the coefficients of the regression model, and our findings are displayed in Table 1 below.

Table 1. Significance level for total annual rainfall in Kiruhura.

	Coefficients	*Standard Error*	*t-Stat*	*P-value*
Intercept	-12626.53342	5961.094125	-2.11816	0.042557
Years	6.797263563	2.982752318	2.278856	0.02996

Table 1 above shows that the intercept coefficient of -12626.53342 with a p-value of 0.042557 indicates that the intercept is statistically significant at the 5% level. This aligns with the trend line equation's y-intercept.

The coefficient for the 'Years' variable is 6.7973, with a standard error of 2.9828. The t-statistic of 2.278856 and the p-value of 0.02996 indicate that the trend of increasing annual rainfall is statistically significant at the 5% level. This means that there is a statistically significant upward trend in annual rainfall over the study period, even though the overall explained variance (R-squared) is low.

Impacts of Climate Change

From the survey findings, 95% of respondents said drought was the most adverse impact of climate change in the past two decades. Drought directly impacts livestock production as it causes pastures to dry out and leads to massive evapotranspiration, resulting in water loss for both crops and livestock. These results align with broader literature on climate change's effects on livestock systems (Rojas-Downing et al., 2017). For example, Jacobs et al. (2019) identified heat stress and water scarcity as critical challenges to dairy production in Europe under future climate scenarios, findings that resonate strongly with the experiences of Kiruhura's dairy farmers.

Additionally, 82% of respondents cited pests and disease as the basic impact of climate change, while 35% reported flooding, 50% reported disease and animal death, 55% reported a lack of pasture, and 63% reported a decline in milk prices and quantity to be the primary effects of climate change.

Strategies by Dairy Producers to Adjust to Climate Change.

Of all the dairy producers surveyed, 80% admitted that they had to alter their mode of life due to the impacts of climate change and variability. Only 9% said they had not made any adjustments, while 11% were unsure whether they had done so or not.

In response to changes in seasonal rainfall and temperatures, pastoralists in Kiruhura have taken five major adaptation measures. These measures include the creation of animal pastures (99%), reforestation (87%), reducing the size of herds through sales (68%), utilizing drought-resistant breeds (92%), and purchasing feed additives for livestock (53%).

Dairy Farmers' Determinants of Adaptation Strategies

Logistic regression analysis was utilized to investigate the determinants of pastoralists' actual strategies in reaction to climate change. This research focused on independent variables including education level, age, marital status of the household head, gender, and household size. The dependent variable is the probability of adopting specific adaptation strategies. The logistic regression model utilized in this study can be represented as:

$$In\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X1 + \beta_2 X2 + \cdots + \beta_{\mathrm{n}} Xn + \varepsilon \qquad (2)$$

In this case;

p represents the likelihood of adopting a specific adaptation strategy.

$\beta 0$ stands for intercept term.

$\beta 1$, $\beta 2 \cdots \beta$n, represent coefficients linked with the independent variables $X 1 \cdots$Xn (education level, gender, household size, age and marital status), with n=5.

ϵ represents the error term.

Summary of Analysis

Logistic regression analysis revealed that a pastoralist's gender, education level, and household size are the primary variables influencing the choice of strategies to be adopted. These variables were statistically significant at the 5% significance level for all adaptation strategies, as shown in Table 2. The rest of the independent variables run in model (age and marital status of the household head) had no statistical significance at the 5% significance level. This suggests that while age and marital status may play roles in other aspects of pastoralist livelihoods, they do not significantly influence the choice of adaptation technique in this context.

The age of farmers plays a significant role in their ability to assess and implement effective climate change adaptation strategies. In the context of climate change adaptation, older farmers possess more experience and are better equipped to evaluate the most suitable approach to adopt (Ndiwa et al., 2024). However, the age of respondents negatively influences their willingness to implement new pasture planting and drought-resistant breeds, as older farmers may be less inclined to embrace new technologies (Kogo et al., 2022). This could be due to their slower adoption of novel techniques and breeding strategies (Baffour-Ata et al., 2023).

The findings underscore the importance of education in fostering awareness and understanding of climate change among pastoralists. Educated individuals are better equipped to comprehend and implement adaptive measures, thus highlighting the pivotal role of education in enhancing resilience to environmental challenges. These results are consistent with those of Daberkow and McBride (2003), who argue that higher levels of education increase the likelihood of adopting new technologies and enable people to take in, decipher, and comprehend information needed to make creative decisions. Garekae et al. (2017) observed that education reduces household forestry dependence in the Chove enclave in Botswana.

Gender may influence the decision to introduce changes. Men and women may have different approaches to farming, which can affect the way they adapt to new situations.

The size of the household also plays a role in the adjustment. Families with many members may need to devote some of their labor to non-agricultural activities to generate income and support their large families. This may lead them to consider different adaptation strategies. By elucidating the determinants of adaptation strategies among pastoralists, this study contributes valuable insights to the discourse on climate change adaptation in rural contexts (Hirpha et al., 2020). Worku et al. (2017) found that household members were involved in household tree planting in the Beressa Watershed of Ethiopia.

Table 2. Results from the logistic regression

Variable	Afforestation		Reducing herd by selling		Using drought-resistant breeds		Planting pasture		Buying livestock feed supplements	
	B	SE	B	SE	B	SE	B	SE	B	SE
Education	-0.19***	0.36	-1.60***	2.04	0.36***	1.62	0.74	0.56	1.32*	1.36
Gender	3.53**	1.25	-2.23	1.92	-0.19**	1.85	0.13**	1.25	-1.23	1.47
Age	0.38	0.40	2.75	0.35	1.35	0.00	-0.57**	0.45	0.35	3.29
Credit access	-0.36	0.34	0.35	2.82	1.36	1.36	-1.58	0.53	0.12	1.85
Household size	-1.62***	0.55	-1.46***	1.52	1.12**	1.28	-3.12**	0.54	-1.23***	1.30

Field survey (2019): Note: *, **, and *** are significant at 10%, 5%, and 1% significance level. The table includes coefficients (B), standard errors (SE), and significance levels (SIG).

Conclusions and recommendations

The analysis of climate data from 1985 to 2014 in Kiruhura reveals a consistent upward trend in maximum and minimum temperatures, accompanied by increased precipitation. These findings correspond closely with the firsthand observations of dairy producers in the region, who have noted a rise in temperatures and precipitation levels. This alignment between observed climate trends and dairy producers' perceptions underscores their profound understanding of climate dynamics, supported by empirical evidence. The recognition that dairy producers' perceptions mirror actual climate trends underscores the significance of including indigenous knowledge in climate change studies and adaptation strategies. It suggests that farmers possess valuable insights that complement scientific data and can enhance the effectiveness of adaptation strategies.

While a slight upward trend in rainfall was observed, the low R-squared value suggests other significant factors are influencing rainfall patterns. This highlights the complexity of rainfall data in the region and the need for further research incorporating additional variables to better understand these influencing factors. The government, in collaboration with other stakeholders like the Dairy Development Authority of Uganda, should prioritize livestock technology development through breeding drought-resistant livestock, the introduction of enhanced pasture species, and improved feed additives. Additionally, dairy producers should be facilitated with affordable credit tailored to improving livestock systems for improved yields. This will empower livestock producers in Kiruhura District to enrich their adaptability to climate change, fostering sustainable livelihoods and food security while significantly reducing climate risk.

References

Abid, M., Scheffran, J., Schneider, U. A., & Ashfaq, M. J. E. S. D. (2015). Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics*, 6(1), 225-243.

Adimassu, Z., & Kessler, A. (2016). Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the Central Rift Valley of Ethiopia. *Environmental Systems Research*, 5, 1-16.

AFDB. (2020). Climate Change in Africa. African Development Bank at COP25. Accelerating Climate Action in Africa. *African Development Bank Group*. https://www.afdb.org/en/cop25/climate-change-africa.

Baffour-Ata, F., Awugyi, M., Ofori, N. S., Hayfron, E. N., Amekudzi, C. E., Ghansah, A.& Akorli, R. (2023). Determinants of yam farmers' adaptation practices to climate variability in the Ejura Sekyedumase Municipality, Ghana. *Heliyon*, 9 (3),1-13. https://doi.org/10.1016/j.heliyon.2023.e14090

Bagamba, F., Ruben, R., & Kuyvenhoven, A. (2022). Determinants of smallholder farmer labor allocation decisions in Uganda. *Journal of African Development,* 23(1), 1-34. https://doi:10.5325/jafrideve.23.1.0001.

Bhattacharya, B., Gupta, P., & Sharma, V. K. (2018). Impact of varying climatic conditions on apple, a case study of Shimla district. Himachal Pradesh International Journal of Applied and Pure Science and Agriculture, 4(2), 16–26.

Bosire, C. K., Rao, E. J. O., Muchenje, V., Van Wijk, M., Ogutu, J. O., Mekonnen, M. M., ... & Hammond, J. (2019). Adaptation opportunities for smallholder dairy farmers facing resource scarcity: Integrated livestock, water, and land management. *Agriculture, Ecosystems & Environment*, 284, 106592. https://doi.org/10.1016/j.agee.2019.106592

Ceci, P., Monforte, L., Perelli, C., Cicatiello, C., Branca, G., Franco, S., ... & Scarascia Mugnozza, G. (2021). Smallholder farmers' perception of climate change and drivers of adaptation in agriculture: A case study in Guinea. *Review of Development Economics*, 25(4), 1991-2012. https://doi.org/10.1111/rode.12815

Daberkow, S. G., & McBride, W.D. (2003). Farm and Operator Characteristics Affecting the Awareness and Adoption of Precision Agriculture Technologies in the US. *Precision Agriculture* 4, 163–177. https://doi.org/10.1023/A:1024557205871

Das, P. V. (2022). People's climate knowledge versus scientists' climate knowledge: a study of apple farming communities in Western Himalayas, India. GeoJournal 87, 2227–2238. https://doi.org/10.1007/s10708-021-10371-z

Debela, N., Mohammed, C., Bridle, K., Corkrey, R., & McNeil, D. (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *Springer Plus*, 4, 1–12. https://doi.org/10.1186/s40064-015-1012-9.

ESFA, Maggiore, A., Afonso, A., Barrucci, F., & Sanctis, G. D. (2020). Climate change as a driver of emerging risks for food and feed safety, plant, animal health, and nutritional quality. *EFSA Supporting Publications,* 17(6), 1-146. https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/sp.efsa.2020.EN-1881

Elum, Z. A., Modise, D. M., & Marr, A. (2017). Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management,* 16, 246-257. https://doi.org/10.1016/j.crm.2016.11.001

FAO. (2008). Climate change and disaster risk management. Technical Background Document from the Expert Consultation Held on 28-29, February, Rome, Italy, 1-17. https://www.fao.org/4/ai786e/ai786e.pdf

FAO. (2019). The future of livestock in Uganda. Opportunities and challenges in the face of uncertainty. Rome, Italy 1-2. https://www.fao.org/3/ca5420en/ca5420en.pdf.

FAO. (2022). Food and Agriculture Organization of the United Nations Data. FAOSTAT. http://www.fao.org/faostat/en/#data.

Garekae, H, Thakadu, O. T. & Lepetu, J. (2017). Socio-economic factors influencing household forest dependency in Chobe enclave, Botswana. *Ecological Processes,* 6(4), 1-10.

Government of Uganda (GOU). (2015). Economic Assessment of the Impacts of Climate Change in Uganda, Final Study Report; Ministry of Water and Environment, Climate Change Department: Kampala, Uganda. Available at https://assets.publishing.service.gov.uk/media/57a08980e5274a27b20000e9/Uganda_CC-economics_Final-Report2.pdf

Hempel, S., Menz, C., Pinto, S., Galán, E., Janke, D., Estellés, F., & Amon, T. (2019). Heat stress risk in European dairy cattle husbandry under different climate change scenarios–uncertainties and potential impacts. *Earth System Dynamics,* 10(4), 859-884. https://doi.org/10.5194/esd-10-859-2019

Hirpha, H. H. Mpandeli, S. & Bantider, A. (2020). Determinants of adaptation strategies to climate change among the smallholder farmers in Adama District, Ethiopia. *International Journal of Climate Change and Strategies Management,* 12 (4), 463–476, https://doi.org/10.1108/IJCCSM-01-2019-0002

IPCC. (2007). Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK: 7-22

IPCC. (2022). Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930 https://doi:10.1017/9781009325844.029.

Jacobs, C., Berglund, M., Kurnik, B., Dworak, T., Marras, S., Mereu, V., & Michetti, M. (2019). Climate change adaptation in the agriculture sector in Europe (No. 4/2019). European Environment Agency (EEA).

Jury, M. R. (2018). Uganda rainfall variability and prediction. *Theoretical and Applied Climatology*, 132, 905-919.

Kristjanson, P., Bryan, E., Bernier, Q., Twyman, J., Meinzen-Dick, R., Kieran, C. Ringler, C., Jost, C. & Doss, C. (2017). Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? *International Journal of Agricultural Sustainability,* 15(5), 482-500.

Kirui, W, Muthama JN, Opere AO & Ngaina J. (2015). Influence of climate change on smallholder dairy productivity: A case of Kosirai, Kenya, and Namayumba, Uganda. *Journal of Agricultural Science Research*, 4(6), 109-116.

Kisamba-Mugerwa, W. (2001,). Rangelands management policy in Uganda. International conference on policy and institutional options for the management of rangelands in dry areas, Hammamet, Tunisia, 1-23. https://biodiversitylinks.org/library/resources/rmp/library/content/frame/rangeland-uganda.pdf

Kogo, B. K., Kumar, L., Koech, R., & Hasan, M. K. (2022). Response to climate change in a rain-fed crop production system: insights from maize farmers of Western Kenya. *Mitigation and Adaptation Strategies for Global Change,* 27(50), 1-19. https://doi.org/10.1007/s11027-022-10023-8

Le, P. V. V., Randerson, J. T., Willett, R., Wright, S., Symth, P., Guilloteau, C., Mamalakis, A. & Foufoula- Gergiou, E. (2023). Climate-driven changes in the predictability of seasonal precipitation. *Nature Communications,* 14(3822), 1-10. https://doi.org/10.1038/s41467-023-39463-9

Magiri, R., Muzandu, K., Gitau, G., Choongo, K., & Iji, P. (2021). Impact of Climate Change on Animal Health, Emerging and Re-emerging Diseases in Africa. In: Oguge, N., Ayal, D., Adeleke, L., da Silva, I. (eds) African Handbook of Climate Change Adaptation. *Springer, Nature* 1-18. https://doi.org/10.1007/978-3-030-45106-6_19

Munyera, D. V., Makenzi, P. & Kahi, A. (2020). Aspects of smallholder livestock production affected by the effects of climate change in Njoro Sub-County. *International Journal of Research and Innovation in Social Science,* (7), 262-266.

NASA. (2020). Mitigation and Adaptation: Responding to Climate Change. Government Resources. *Global Climate Change*. https://climate.nasa.gov/solutions/adptation-mitigation

Ndiwa, A. M., Mburu, J., Mulwa, R. & Chumo, C. (2024). Determinants of climate change adaptation strategies and intensity of use; micro level evidence from crop farmers in Kenya. *Frontiers in Sustainable Food Systems,* 8: 1376868. https://doi.org/10.3389/fsufs.2024.1376868

Nhem, S. & Lee, Y. J. (2019). Women's participation and the gender perspective in sustainable forestry in Cambodia: local perceptions and the context of forestry research. *Forest Science and Technology*, 15(3), 93–110. https://doi.org/10.1080/21580103.2019.1595174

Nimusiima, A., Basalirwa, C. P. K., Majaliwa, J. G. M., Otim-Nape, W., Okello-Onen, J., Rubaire-Akiiki, C., & Ogwal-Byenek, S. (2013). Nature and dynamics of climate variability in the Uganda cattle corridor. *African Journal of Environmental Science and Technology*, 7(8), 770-782. https://doi.org/10.5897/AJEST2013.1435

Nohrstedt, D., Mondino,E., Baldassarre, G. D. & Parker, C. F. (2024). Assessing the myth of disaster risk reduction in the wake of catastrophic floods. *Npj Natural Hazards,* 1(5), 1-5. https://doi.org/10.1038/s44304-024-00007-w

Nuwagira, U., & Yasin, I. (2022). Review of the Past, Current, and the Future Trend of the Climate Change and its Impact in Uganda. *East African Journal of Environment and Natural Resources*, 5(1), 115-126.

Paolo C., Lavina M., Chiara P., Clara C., Giacomo B., Silvio F., Fatoumata B. S. D., Emanuele B., & Giuseppe S. M. (2021). Smallholder farmers' perception of climate change and drivers of adaptation in agriculture. A case study in Guinea. *Review of Development Economics,* 25(4),1991-2012.

Ricart, S., Gandolfi, C. & Castelletti, A. (2023). Climate change awareness, perceived impacts, and adaptation from farmers' experience and behavior: a triple-loop review. *Regional Environmental Change,* 23(82), 1-24. https://doi.org/10.1007/s10113-023-02078-3

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). *Climate change and livestock*: Impacts, adaptation, and mitigation. *Climate Risk Management*, 16, 145-163.

Sloat, L. L., Gerber, J. S., Samberg, L. H., Smith, W.K., Harrero, M., Ferreira, L. G., Godde, C. M. & West, P. C. (2018). Increasing importance of precipitation variability on global livestock grazing lands. *Nature Climate Change* 8, 214–218. https://doi.org/10.1038/s41558-018-0081-5

Ssentongo, P., Muwanguzi, A. J., Eden, U., Sauer, T., Bwanga, G., Kateregga, G. ... & Schiff, S. J. (2018). Changes in Ugandan climate rainfall at the village and forest level. *Scientific Reports*, 8(1), 1-10. https://doi.org/10.1038/s41598-018-21427-5

Timlin, M., Tobin, J. T., Brodkorb, A., Murphy, E. G., Dillon, P., Hennessy, D., O'Donovan, M., Pierce, K. M., & O'Callaghan, T. F. (2021). The Impact of Seasonality in Pasture-Based Production Systems on Milk Composition and Functionality. *Foods*,10(607), 1-32. https://doi.org/10.3390/foods10030607

UBOS. (2020). Statistical Abstract, Uganda Bureau of Statistics. https://www.ubos.org/wp-content/uploads/publications/11_2020STATISTICAL__ABSTRACT_2020.pdf

Uganda Bureau of Statistics. (2017). The National Population and Housing Census 2014 – Area Specific Profile Series, Kampala, Uganda. Accessed on 12th March 2024. Available at https://www.ubos.org/wp-content/uploads/publications/03_20182014_National_Census_Main_Report.pdf

Uganda Bureau of Statistics. (2021). The National Livestock Census 2021 Main Report. Accessed on 5th March 2024. Available at https://www.ubos.org/wp-content/uploads/publications/National-Livestock-Census-Report-2021.pdf

Wang, H., Lu, H., Zhao, L., Zhang, H., Lei, F., & Wang, Y. (2019). Asian monsoon rainfall variation during the Pliocene forced by global temperature change. *Nature Communications*, 10 (1), 5272.

Worku, T.Tripathi, S.K. & Khare, D. (2017). Household level tree planting and its implication for environmental conservation in the Beressa Watershed of Ethiopia. *Environmental Systems Research,* 6(10), 1-10.

Yamane, T. (1967). *Statistics: An Introductory Analysis*. 2nd Edition. New York: Harper and Row.