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VULNERABILITY OF INDIGENOUS CHICKEN SCAVENGING PRODUCTION SYSTEM TO CLIMATE VARIABILITY

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DELCARATION

I Zainah Nampijja declare that this thesis is an original report of my research, written by myself and has not been submitted or will not be submitted for an award of any degree in any other academic institution. All collaborative contributions have been clearly indicated and fully acknowledged, and all sources have been properly cited.

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DEDICATION

To my dear husband and our wonderful children, whose love, patience, and understanding have been my greatest source of strength, and to our devoted house help, whose unwavering support made this journey possible.

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ACRONYMS

CV	Climate Variability
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
IACUC	Institutional Animal Care and Use Committee
IC	Indigenous Chickens
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
MMK	Modified Mann-Kendall
RCP	Representative Concentration Pathway
SFR	Scavengeable Feed Resource
SFRH	Scavengeable Feed Resource Harvest
SPS	Scavenging Production System
SRAI	Seasonal Rainfall Anomaly Index
STI	Standardized Temperature Index
UBOS	Uganda Bureau of Statistics
UNMA	Uganda National Meteorological Authority

ABSTRACT

Indigenous chickens (ICs) reared under scavenging production system are central to food security and poverty alleviation among rural households in Uganda. However, climatic variability threatens their productivity by altering the availability and quality of scavengeable feed resources and compromising chicken welfare. Farmers' limited ability to modify the open scavenging environment further heightens chickens' vulnerability to environmental fluctuations. This study assessed farmers' knowledge and perceptions of climate variability, its effects on indigenous chickens, coping strategies employed, and factors influencing adoption of these strategies. It further evaluated seasonal variation in Scavengeable Feed Resources (SFR) and examined the effects of elevated ambient temperature on the physiology and thermoregulatory behavior of ICs. Data were collected in Soroti District through a cross-sectional survey of 271 indigenous chicken farmers, 10 key informant interviews, four focus group discussions, and analysis of local climate records (2003–2022). In addition, 120 ICs aged 4–5 months were obtained across four seasons for crop content characterization and chemical analysis. Two indigenous chicken ecotypes one from the cooler Kabale (KAB) and the other from the hotter Soroti (SOR) regions were assessed for thermal responses. These pullets were sequentially exposed to ambient temperatures of 30, 33, 36, and 39 °C in a controlled heat chamber, with thermoregulatory behaviors recorded and rectal temperature measured. Quantitative data were analyzed using descriptive statistics, chi-square tests, ordered probit regression, the Modified Mann–Kendall test, and linear mixed-effects models, while qualitative data were analyzed thematically. Most farmers perceived decreases in annual rainfall (63.8%) and rainy-season duration (>50%), alongside increases in dry (91.1%) and rainy-season (71.2%) temperatures and drought frequency (79.3%). Meteorological data showed a significant rise in monthly minimum temperatures but no significant trends in rainfall or average and maximum temperatures. Farmer perceptions of rising temperatures aligned with observed minimum temperature trends, while perceived rainfall declines did not. Perceived impacts of high temperature on ICs included reduced egg production (56%), hatchability (63.4%), increased disease incidence (58.6%), and higher mortality (45.1%). Coping strategies mainly involved provision of drinking water, shade, and feed supplementation, with adoption significantly influenced by gender, age, flock size, weather information access, training in poultry management and resource access. Seasonal variation significantly ($P<0.05$) affected feed availability and quality. Insects dominated ($P=0.032$) crop contents, with higher proportions during wet seasons which was followed by food waste, while dry seasons had more cereals and legumes. Nutrient levels in crop contents were generally below age-specific requirements for protein, calcium, and metabolizable energy during the first dry season and both wet seasons. Whereas crude fiber consistently exceeded recommended levels. Thermoregulatory responses differed by ecotype, with KAB chickens exhibiting earlier and longer heat-dissipating behaviors and greater increases in body temperature than SOR chickens. Overall, climatic variability imposes both nutritional and thermal stress on indigenous chickens, increasing their vulnerability under the scavenging production system. The findings highlight the need for integrated adaptation strategies, including climate literacy, localized weather information, season-specific low-fiber feed supplementation, provision of cool, clean drinking water under shaded areas, and practical training in climate-resilient poultry management to enhance the resilience of IC scavenging production system.

CHAPTER ONE

INTRODUCTION

1.1 Background

Poultry is the major source of white meat in Uganda, and its demand is expected to rise fourfold by 2050 (FAO, 2019). The Ugandan poultry sector is dominated by chickens, with a population of 57.8 million birds, representing a 54.5 % increase from the 37.4 million recorded in 2008 (UBOS, 2024). These chickens account for 94% of all domesticated birds with their population growing at an average rate of 3% annually (UBOS, 2020a). This contributes over 65 metric tons of meat per year (Sumuni, 2020) which constitutes 15 % of all the meats consumed in the country (FAO, 2019). Most of the chickens in the country are produced under the free range or backyard or Scavenging Production System (SPS) (Yussif et al., 2023). The SPS is characterized by low input which works in favor of many smallholder farmers in developing countries (Nampijja et al., 2025; Singh et al., 2023), and the scavenging indigenous chicken breeds that can thrive under marginal conditions (Admasu et al., 2019).

Scavenging indigenous chicken s (IC) constitute more than 70% of the country's chicken flock (UBOS, 2020b; UBOS, 2024) and contribute over half of the total chicken meat consumed in the country (FAO, 2019). Scavenging indigenous chicken s are not only a source of affordable animal protein in the form of meat and eggs, but also serve social, economic, and cultural functions, especially among the resource-constrained populations, including women and youth (Tamasgen et al., 2025). These chickens are produced at a small scale of an average of 42 birds per household, although the flock size widely varies from one to 276 birds (Nampijja et al., 2025). Scavenging indigenous chicken s depend heavily on the environment, obtaining over 90% of their feed through scavenging (Anyona et al., 2023). Despite their importance, ICs in developing countries receive very minimal health care (Tamasgen et al., 2025), with most farmers using local herbs for their treatment and rarely implementing proper biosecurity measures (Lubandi et al., 2019). Under the predominant free-range production system, ICs are hardly housed, and some farmers use temporary structures to shelter the birds only at night (Yussif et al., 2023). Such heavy reliance on the environment makes ICs highly vulnerable to the impacts of climate variability.

Uganda, like any other Sub-Saharan African country is experiencing temperatures and rainfall variations (Mukasa et al., 2020). For instance, the average temperatures have risen 30 °C in some parts of the country (Egeru et al., 2019), and there is an anticipated future increase coupled with a decline in the volume of rainfall (Egeru et al., 2019). According to available meteorological data, mean countrywide annual temperatures in Uganda have risen by 1.3 ºC per decade since 1960 (FAO, 2016). Also mean annual temperatures in most parts of the country range above 23 °C, an indication that the optimum temperature ranges for egg production (19 – 22 °C) and growth (18 – 22 °C) of chickens have been surpassed (Charles & Walker, 2002; Asseng et al., 2021). Future climate projections indicate that temperatures will increase by 2.5 to 4.4 °C in the near future (2021-2050) and by 4.5 to 6.0 °C in the mid-century (2051-2080) in most agro-ecological zones in Uganda (FAO, 2018; Nimusiima et al., 2014). The resultant heat stress may have a significant negative impact on the performance and in worst case scenarios, survival of ICs under the scavenging production system.

Heat stress is a major environmental challenge that adversely affects poultry productivity and welfare (Bekele, 2021). Chickens thrive within a narrow thermal comfort zone of approximately 15–23 °C (Asseng et al., 2021; Bhawa et al., 2023), and when ambient temperatures exceed this range, their ability to regulate body heat becomes compromised (Bhawa et al., 2023). This leads to hyperthermia and physiological stress, which manifest in reduced feed intake, poor feed conversion, reduced growth rate and egg production (Asseng et al., 2021; Brugaletta et al., 2022). The economic implications of thermal stress in chickens are extensive, as the condition not only affects performance metrics but also degrades meat and egg quality through oxidative damage and acid–base imbalances (Wasti et al., 2020). In extreme cases, it can result in mortality, making it a critical issue for poultry producers globally.

To cope with the effects of heat stress, chickens instinctively adopt behavioural and physiological strategies to reduce internal heat load (Bekele, 2021). These include panting to increase evaporative cooling, elevating wings to enhance air circulation, and minimizing physical activity (Bekele, 2021; Brugaletta et al., 2022). Although these strategies aid thermoregulation, they are also associated with negative impacts (Mota-Rojas et al., 2021). Panting, for instance, accelerates water loss and induces respiratory alkalosis, which disrupts calcium metabolism and impairs eggshell formation (Mota-Rojas et al., 2021). Similarly, energy diverted toward thermoregulation detracts from growth and reproductive functions

(Kim et al., 2024). The cumulative impact of these stress responses results in significantly reduced productivity. This highlights the urgent need for targeted management strategies through which performance can be sustained during periods of heat stress.

In addition, the current and anticipated changes in climate are expected to have a significant impact on poultry feed resource availability and quality (Mwaura & Okoboi, 2014). The major feed resource for scavenging ICs are grains and their by-products, pulses and insects (Admasu et al., 2019), whose availability is influenced by climatic parameters (Kishimoto-Yamada & Itioka, 2015). For instance, Mwaura & Okoboi, (2014) found that crop yield is directly correlated with rainfall and temperature. Moreover, there is a consistent reduction in land for agriculture among the farming households (UBOS, 2018) due to several factors like population increase, urbanization among others. This therefore reduces the availability of scavenging land for the scavenging indigenous chicken s. The challenges on chicken welfare and feed resource availability not only increase the vulnerability of ICs to climate variations, but also threaten their sustainable productivity under the conventional free range production system common among the resource constrained farmers.

Many farmers, especially the resource constrained, are increasingly observing variations in climate (Selormey et al., 2019). However, perceptions of climate variability often differ across regions and farming systems (Nyangoko et al., 2022). Understanding how scavenging chicken farmers perceive climate variability, the specific risks they associate with it, and the indigenous coping strategies they employ is therefore essential for designing context-appropriate interventions. For instance, their perceptions are important in shaping adaptation strategies in response to impacts of climate variability like feed shortages, disease outbreak, water scarcity and thermal stress. These human perceptions play a vital role in guiding both individual and collective adaptation decisions. Despite their relevance, IC farmers' perceptions remain under-documented and are rarely incorporated in climate studies.

Despite the threats on chicken production, the demand for chicken and their products is rapidly rising. A report by FAO, (2018) indicated that the population of Uganda will rise to 100 million people by 2050 with the urban occupants increasing two folds. In addition, the GDP per capita is expected to rise by 186% to reach USD 2000 by 2050 (FAO, 2018). The increase in human population, urbanization and incomes will automatically increase the demand for animal source foods including chicken and chicken products. Projections indicate that by 2050 the consumption of chicken will increase by 213% while that of eggs will increase by 230% (FAO, 2019). However, some studies show a higher predicted percentage increase in both demand and consumption of the products. For example, recent predictions indicate that the population of chickens will rise by 272% to reach 175m birds by the year 2050 (FAO, 2017). To contribute to meeting the projected demand for chickens and their products, objectives of the fourth National Development Plan (2025/2026-2029/2030) and targets of Sustainable Development Goals (SDGs 1, 2 and 13), it is crucial to understand how vulnerable the IC scavenging production system is to climate variability. Such knowledge can inform the formulation of appropriate coping strategies, thereby enhancing the resilience of scavenging indigenous chicken.

1.2 **Problem statement**

The Scavenging Production System (SPS) under which scavenging indigenous chickens (ICs) are dominantly produced in Uganda (Yussif et al., 2023), is highly vulnerable to climate variability and change. This is due to the direct exposure of chickens to unregulated environmental conditions. The changes in climate have significant impacts on the availability and nutritional quality of scavengeable feed resources, which are significant in the low input SPS (Admasu et al., 2019). Variations in feed resource quality has direct implications on feed intake, growth and egg production (Nampijja et al., 2023). Unfortunately, studies on vulnerability to climate variability and change have been limited to commercial chicken lines while neglecting scavenging indigenous chickens (Kim et al., 2021; Teyssier et al., 2022). Furthermore, farmers' knowledge and perceptions influence adoption of climate adaptation strategies. These vary greatly and are under-explored in the context of the scavenging production system (Hyland et al., 2016). Temperature, one of the most important climatic variables affecting performance in chickens (Madkour et al., 2022; Xu et al., 2018), has shown a consistent increasing trend (Egeru et al., 2019). Climate projections indicate a further rise of more than 4 °C by 2050 across Uganda's Agro-Ecological Zones (AEZ) with high densities of scavenging indigenous chickens (Nimusiima et al., 2014). Chickens are homeotherms that regulate their core body temperature within a narrow range of 41.0 and 42.0 °C (Wasti et al., 2020). This limitation of chickens' thermoregulatory system makes them most prone to climate variability, especially the increasing environmental temperatures (Nampijja et al., 2024). Heat stress in chickens sets in at 30 °C and this comes with many effects including a 50% reduction in weight gain and 57% reduction in egg production (Lara & Rostagno, 2013; Santos et al., 2015). Despite the importance of ICs to Uganda's food systems, and the imminent effects of climate variability, there is limited empirical data on the impacts of the variations specific to the Scavenging Production System (SPS). Additionally, farmers' perceptions, indigenous knowledge, and adaptive responses under the SPS remain poorly documented. This knowledge gap limits deployment of locally relevant adaptation strategies for sustainable production of chickens under the scavenging production system. This study therefore seeks to fill the knowledge gaps by assessing the vulnerability of IC production to climate variability through assessing knowledge, perceptions and coping strategies of farmers to CV, determining the effect of climate variability on availability and quality of scavengeable feed resources and determining the effect of elevated temperatures on behavioral responses of scavenging ICs.

1.3 Justification of the study

Indigenous chickens contribute significantly to food and nutrition security of many households in the country through provision of high-quality eggs and chicken (UBOS, 2008, 2020b). Chicken products account for the bulk of the animal protein sources consumed not only globally but also in most Ugandan rural households (Mottet et al., 2017). The contribution of chicken to diets of people of all age groups is rapidly growing given their biological performance and social acceptability. Globally, chickens have been presented as the most suitable replacement to ruminants due to the fact that they are not direct methane emitters. However, some of the dominant indigenous chicken producing communities are found in Agro-ecological Zone (AEZ) that are most vulnerable to climate variability and change (FAO, 2016).

Among climate variables, temperature affects the performance of chickens the most. This means that optimal performance of chickens is attained within a given temperature range that is between 15– 20 °C (Asseng et al., 2021; Wasti et al., 2020). However, the mean annual temperatures in most parts of the country is above 23 °C (Nimusiima et al., 2014), and projections indicate a rise by up to 4.4 °C by 2050 and 6.0 °C by 2080 (Egeru et al., 2019).

Despite the fact that indigenous chickens have been chosen and credited for their hardiness, resilience, and adaptation to environmental stressors (Singh et al., 2023; Ssewannyana et al., 2008), it is not known whether the adaptive capacity of these chickens would still be outstanding under the current and anticipated changes in climate. In addition, to the sector being so vulnerable, there are no measures taken to cushion it against the effects of climate variability. Consequently, the scavenging chicken sub-sector is poorly prepared for the variations in climate and adaptation.

1.4 **Significance of the study**

This study will contribute significantly to knowledge in the field of climate adaptation, nutrition, chicken production and rural development. Results of the assessment of farmers' knowledge, perceptions and coping strategies will provide valuable insights into how small-scale chicken farmers understand and respond to climate variations. Furthermore, the findings will bridge a gap between local knowledge and scientific approaches to climate adaptation. By determining how climate variability affects the availability and quality of scavengeable feed resources, the study will enhance understanding of the nutritional challenges faced by scavenging indigenous chickens under changing environmental conditions. This information will be used in the development of alternative or supplemental feeding strategies, particularly during periods of climatic stress. In addition, by determining the behavioral responses of indigenous chickens to elevated temperature, the study will generate baseline data on physiological and behavioral thresholds of indigenous breeds. The same study will also provide information on temperature thresholds for the indigenous chickens. At a broader level, the study will support national and regional efforts to build climate-resilient agricultural systems by informing climate-smart policies and interventions. It will also guide extension services, and projects promoting sustainable IC production, ultimately improving rural livelihoods, enhancing food and nutrition security, and preserving indigenous poultry genetic resources. Furthermore, the information will be used by several categories of people (1) animal nutritionist in making decisions about seasonal supplementary rations for scavenging chickens, (2) agricultural or extension officers in guiding farmers on appropriate adaptation strategies, (3) farmers to improve their management practices of local chickens especially during periods of high temperatures (4) Policy makers while formulating policies related to climate change adaptation, (5) the study is the first of its king in the country and will provide preliminary information for further studies.

1.5 **Aim of the study**

To generate evidence to inform strategies for increasing the resilience of indigenous chicken scavenging production system to climate variability.

1.6 **Specific objectives**

1. To assess farmers' perceptions of climate variability (CV) and their coping strategies.
2. To determine the effect of CV on availability and quality of scavenged feed resources (SFR)
3. To determine the effect of extreme temperatures on thermoregulatory behaviors and body temperature of IC

1.7 **Research Questions and study hypotheses**

1.7.1 Research questions

1. Are farmers aware of climate variability, how do they perceive it?
2. How do farmers perceive the impacts of climate variability on indigenous chickens?
3. How do farmers rearing indigenous chickens cope with climate variability?
4. What factors influence the adoption of coping strategies among IC farmers?

1.7.2 Hypotheses

H1: Availability of Scavenged Feed Resource (SFR) varies with season

H2: Quality of Scavenged Feed Resource (SFR) varies with season

H3: The effect of elevated ambient temperature on time budget allocation to thermoregulatory behaviours differs among indigenous chicken ecotypes.

H4: The effect of elevated ambient temperature on body temperature differs among indigenous chicken ecotypes.

1.8 Conceptual framework

The conceptual framework (Figure 1) illustrates how climate variability influences the vulnerability of the indigenous chicken (IC) scavenging production system through interconnected pathways of exposure, system sensitivity, and adaptive capacity. Climate variability, expressed through fluctuations in temperature and rainfall, represents the primary exposure affecting the system. These climatic drivers directly influence system sensitivity by altering the quantity and quality of scavengeable feed resources and by exposing chickens to varying degrees of thermal stress, ranging from thermoneutral conditions to lethal temperatures.

System sensitivity is reflected in two main components: the availability and nutritional quality of scavenged feed resources, and exposure to extreme ambient temperatures. Changes in feed availability affect feed intake and nutrient supply, while elevated temperatures impose physiological stress on birds. These stressors manifest through behavioral and physiological responses such as panting, wing elevation, altered drinking, feeding and sitting behavior, and changes in body temperature, which collectively indicate the birds' capacity to cope with thermal challenges.

Adaptive capacity moderates the effects of exposure and sensitivity and is shaped by farmers' knowledge, perceptions, and coping strategies. Management decisions informed by farmer awareness influence both the feed environment and the birds' responses to climatic stressors, thereby affecting overall system performance. The interaction between adaptive capacity and chicken behavioral and physiological responses determines the extent to which the system can buffer climatic shocks.

The outcome of these interacting components is reflected in the resilience of the indigenous chicken scavenging production system. Increased resilience is achieved when adaptive capacity effectively mitigates sensitivity to climate variability, enabling the system to sustain productivity and functionality under changing climatic conditions.

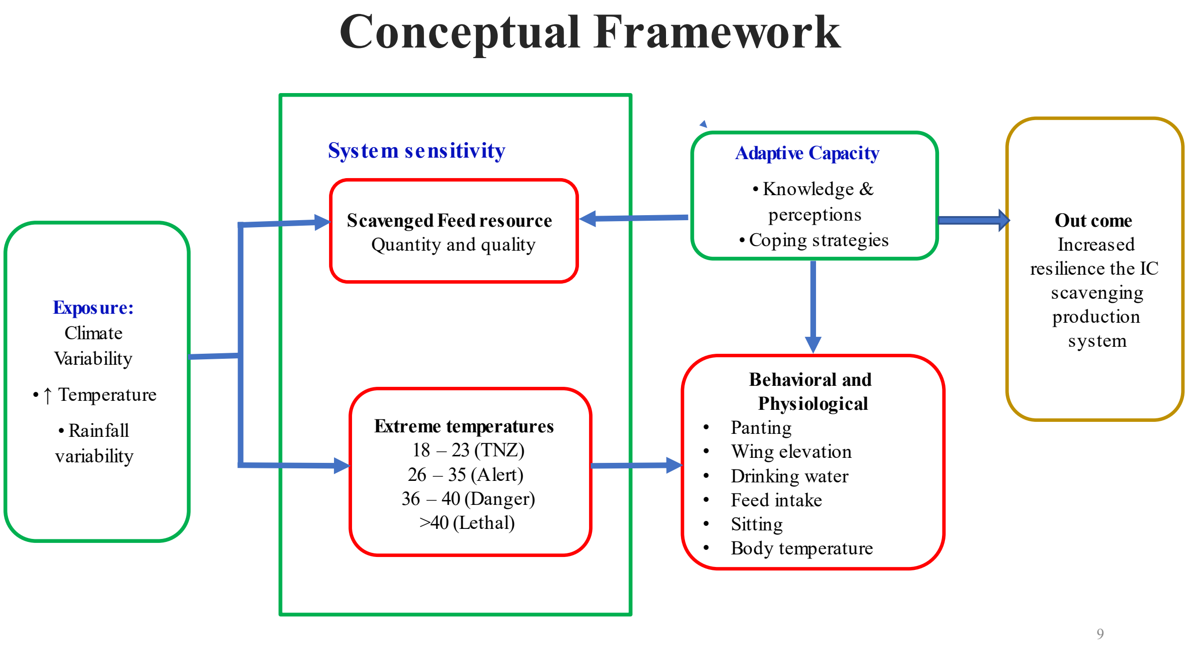


Figure 1: Conceptual framework showing the hypothesized relationships between factors that influence vulnerability of the scavenging chicken production system.

In this study, system vulnerability was assessed using an integrated framework that considered three interlinked components: the environment in which the birds are kept, the human component responsible for management and decision-making regarding coping, and the chickens themselves, which respond physiologically to environmental stressors. Environmental vulnerability was examined through the analysis of 20 years of meteorological data to characterize patterns and variability in climatic conditions. Human vulnerability was assessed by evaluating farmers' knowledge, awareness, perceptions, and the coping interventions they employ in response to climate variability. The chicken component was evaluated through experimental approaches that examined both the availability and accessibility of scavengeable feed resources and the birds' physiological responses to exposure to extreme temperatures. Together, these components provided a holistic assessment of vulnerability across the climate–human–animal interface of the scavenging chicken production system.

1.9 Scope of the Study

This study focused on assessing the impact of climate variability on the scavenging production system of indigenous chickens. The major components investigated included: (i) farmers' perceptions of climate variability and their adaptive responses, (ii) the influence of climatic factors on the availability and nutritional quality of scavengeable feed resources, and (iii) the effects of elevated temperature on behavioral responses of indigenous chickens. As elaborated in subsequent chapters, the study was restricted to one agro-ecological zone representing the hotter lowland (Soroti District - Uganda). However, comparative assessment of the effect of elevated temperature was done with indigenous chickens from both the hotter earlier mentioned and cooler highland (Kabale District) environments. These locations were purposively selected to capture climatic and ecological contrasts that could reveal potential environmental adaptation differences among local chicken populations.

The study was conducted under three interconnected components: (1) a household survey involving 271 respondents to assess farmers' perceptions of climate variability, its impacts on scavenging indigenous chickens and their adaptation practices, (2) field sampling of indigenous chickens to assess scavengeable feed resources across four seasons, two wet and two dry seasons to determine seasonal availability and nutrient composition, and (3) controlled heat-exposure experiments to evaluate thermoregulatory behavior of chickens under varying temperature regimes.

1.10 Structure of the Thesis

This thesis is organized in a chapter-based format and comprises seven chapters. The structure and content of each chapter are summarized below;

Chapter one presents the general introduction, which provides the background to the study, outlines the research problem, objectives, justification, significance, the conceptual framework guiding the research and scope of the study. This chapter establishes the context for understanding the relationship between climate variability and the scavenging production system of indigenous chicken.

Chapter two provides a comprehensive review of literature related to the Ugandan poultry sector, the scavenging production system, climate variability in Uganda, its effects on chicken production, and specifically on ICs. In addition, it explores adaptation strategies to mitigate effects of specifically thermal stress among chickens. The chapter synthesizes existing knowledge, identifies research gaps, and situates the study within the broader scientific discourse on climate adaptation and resilience in smallholder poultry systems.

Chapter three focuses on farmers' knowledge, perceptions, and coping strategies in relation to climate variability. It is composed of two manuscripts: the first examines observed trends in climate variability alongside farmers' perceptions and understanding of these changes. The second evaluates the effects of climate variability on scavenging indigenous chickens, the coping strategies employed by farmers, and the socio-economic and demographic factors influencing adaptation decisions.

Chapter four discusses the effects of climate variability on the availability and nutritional quality of scavengeable feed resources for indigenous chickens. The chapter analyses seasonal patterns in feed resource composition and abundance.

Chapter five examines the effects of elevated temperature on the behavior and physiological responses (rectal temperature) of indigenous chickens. It describes results from controlled heat-exposure experiments and discusses how different temperature regimes influence thermoregulatory behaviors and body temperature regulation in distinct ecotypes.

Chapter six provides an overall summary of the thesis, integrating the main findings from all components of the study. It highlights the linkages among farmer perceptions, feed resource dynamics, and thermal responses of indigenous chickens under changing climatic conditions.

Chapter seven presents the general conclusions and recommendations derived from the study. The conclusions synthesize the key insights from the studies conducted, while the recommendations highlight practical interventions aimed at promoting climate-resilient indigenous chicken production systems in Uganda and outline priority areas for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 An overview of Uganda's poultry industry

Poultry is one of the fastest-growing livestock subsectors in many developing countries, Uganda inclusive (Moreki et al., 2025). According to the National Livestock Census 2021, Uganda's total poultry population stood at 57.8 million birds, representing a 54.5 % increase from the 37.4 million recorded in 2008 (UBOS, 2024). This growth reflects a steady upward trend that had been observed between 2007 and 2018, when the sector grew at an average annual rate of 2.4–3.3 % (UBOS, 2008, 2015, 2017, 2018, 2020a). Although the COVID-19 pandemic temporarily slowed this momentum around 2020, the sector managed to recover, and the poultry industry continues to contribute significantly to rural livelihoods and the wider economy (Akinola & Essien, 2011; Pius et al., 2021). For instance, the 2018 Annual Agricultural Survey reported sales of more than 25 million chickens, generating approximately UGX 342 billion, with the total national chicken stock valued at about UGX 2.5 trillion (UBOS, 2020a).

Chickens dominate Uganda's poultry subsector, accounting for over 90 % of the total poultry population and being kept in more than 70 % of households (UBOS, 2024). Indigenous chickens remain the most widespread, constituting 69.9 % of the national flock, while exotic and crossbred chickens account for 30.1 % (UBOS, 2024). Their predominance is attributed to their adaptability to local scavenging systems, resilience under low-input conditions, and cultural importance in rural households (FAO, 2018; Nakkazi et al., 2014). Exotic breeds such as broilers and layers are increasingly adopted in peri-urban and commercial settings, while crossbreeds, which are largely dual-purpose, are gaining attention for their productivity and faster growth rates as compared to the pure strains (Sharma et al., 2015; Taye et al., 2022). Consequently, the term poultry in Uganda is often used synonymously with chickens, as other species such as turkeys, ducks, and geese remain relatively minor in number and economic contribution.

The chicken population has also varied over time in terms of flock composition, numbers, and regional distribution across the country. Earlier livestock censuses showed that the eastern, northern, and Karamoja subregions successively held the highest chicken populations (UBOS, 2008, 2015). However, more recent assessments by the Zonal Agricultural Research and Development Institutes (ZARDIs) reveal a regional shift, with the Mukono ZARDI zone in the central region now recording the largest concentration of chickens (UBOS, 2020a, 2024). This transformation reflects the increasing dominance of commercial production systems, which are more common in urban and peri-urban areas. The shift towards fast growing, commercially oriented breeds is driven by rising demand for poultry meat and eggs both within Uganda and in the wider East African region (Guèye, 2025; Moreki et al., 2025; Pius et al., 2021).

2.1.1 Socio-economic importance of chicken in Uganda

Chickens make a substantial contribution to food security and nutrition through their eggs and meat which are the most consumed animal food source (Yussif et al., 2023). Chicken and their products are consumed by several cultures, religions and traditions unlike other livestock products (Alexandratos & Bruinsma, 2012). Chicken products are an affordable source of high-quality protein, energy, vitamins, minerals, antioxidants and other micro-nutrients which deliver several health benefits to the population (Moreki et al., 2025). With the known benefits and increased sensitization on health dieting, the consumption of chicken meat and eggs has almost tripled (FAO, 2019). Several projections show that the demand for chicken and chicken products will increase by over 200% by 2050 (FAO, 2017). Therefore, corresponding increase in production is necessary to match the demands.

In addition, chickens are a major asset in many Ugandan households in both rural and peri-urban settings, where they play multiple economic and social roles (Yussif et al., 2023). Chickens are often sold to generate quick cash for pressing needs such as school fees, scholastic materials, and medical bills (Alabi & Aruna, 2006; Moreki et al., 2025). Beyond their economic value, chickens play important social cultural roles including use in traditional ceremonies, rituals and as gifts during social functions. They also serve as a convenient means of offsetting debts and are commonly exchanged or gifted in community networks, thereby strengthening social ties. In contexts of uncertainty, chickens act as a form of financial insurance and a safety net for vulnerable families and a form of insurance (Mottet & Tempio, 2017). Their relatively short production cycles, low initial investment, and the existence of readily available local markets make them particularly important in poverty alleviation programs (Pius et al., 2021). As such, indigenous chicken production contributes not only to household income security but also to broader goals of rural development and resilience.

2.1.2 Marketing systems of chicken and chicken products

Marketing of chicken and chicken products operates through a mix of informal and formal channels, with strong seasonal fluctuations in demand often peaking around festivals and holidays (Aklilu et al., 2007; Conglin et al., 2023). Informal channels remain predominant in rural areas, where indigenous chickens are sold live or with minimal processing via village-level sales, farm-gate transactions, and local traders (Conglin et al., 2023; Pius et al., 2021). To access higher paying customers, some farmers sell their chickens in regional or urban markets, where demand is stronger and prices are higher, despite the added expense of transport and market fees (Natukunda et al., 2011). Recent studies in African poultry value chains reaffirm this pattern (Moreki et al., 2025). Smallholder producers often rely on informal, short marketing channels because of limited access to infrastructure, market information, or capital to meet formal sector standards (Aklilu et al., 2007; Moreki et al., 2025). Despite its prevalence, informal marketing faces constraints such as lack of cold chain, inconsistent supply volumes, and limited ability to engage with value-adding actors (Guèye, 2025; Moreki et al., 2025).

In urban and peri-urban settings, the formal marketing system predominates for commercial broilers and value-added chicken products (Guèye, 2025). Supermarkets, butcher shops, restaurants, and processing plants provide consumers with dressed birds, cut pieces, and further processed items (Moreki et al., 2025). The price of chicken in these formal markets is influenced by carcass weight, cut types, packaging, certification (e.g. Halal), and brand reputation (Conglin et al., 2023; Melesse, 2014). Offal, feet, heads, and other by-products find secondary markets such as pet food or feed ingredients for other livestock, increasingly pushing up demand for these parts. Processed chicken products are often frozen, transported under cold chain, and stored until retail sale. The intensification of poultry systems and urbanization trends are fueling growth in this formal sector though significant challenges remain in compliance with food safety standards, cold-chain logistics, and competition from imports (Guèye, 2025; Moreki et al., 2025).

2.2 Scavenging Indigenous chicken production in Uganda

The indigenous chickens in Uganda are dominantly reared under the scavenging production system (Waiswa et al., 2024) also known as the free range or back yard system. The production system has minimal labor requirements, as chickens move freely in search of feed and water (Pius et al., 2021). In many African communities, the scavenging chickens are owned and managed by women, youth and children (Tamasgen et al., 2025). Farmers provide shelter for the birds mainly at night (Waiswa et al., 2024), with many households even sharing their living space with the chickens (Tamasgen et al., 2025; Yussif et al., 2023). Mating of the chickens under this system is uncontrolled and occurs from the scavenging grounds (Melesse, 2014). When chickens start laying, at times a farmer provides a laying nest while in some cases chickens lay in unknown places and eggs are just picked when found. Indigenous chickens under free-range production start laying between five and six months of age, producing an average of 14 eggs per clutch (Tamasgen et al., 2025) with approximately three clutches per year (Yussif et al., 2023). Indigenous chickens incubate their eggs and brood the chicks. In summary, the scavenging production system is a low-input production system in which birds exhibit poor performance, largely constrained by inadequate health care and limited feed resources (Raphulu et al., 2015).

Among the constraints of scavenging chicken production, feed quantity and quality is the most critical (Tamasgen et al., 2025). For instance, the availability of scavenged feed fluctuates with season Goromela et al. (2008), and in many cases not nutritionally balanced to meet the requirements for the different chicken growth stages (Ncobela & Chimonyo, 2016). For example, grain which are among the major energy sources under the production system (Mwesigwa et al., 2015) are usually available in plenty during the harvesting period and scarce during the planting periods (Goromela et al., 2008). On the other hand, the insects and larval stages are more available during the rainy season compared to the dry season. In addition to maintenance, scavenging chickens require extra energy to sustain the scavenging activity. Recently, some farmers have initiated supplementation of indigenous chickens with by-products of cereal processing and household food waste (Waiswa et al., 2024; Yussif et al., 2023). However, these supplements are often deficient in essential nutrients, particularly proteins and minerals (Manano et al., 2017; Mbithe et al., 2016). Moreover, the adoption of balanced rations remains limited due to the high cost of available commercial concentrates and the prevailing belief that indigenous chickens can survive on low-quality feeds (Melesse, 2014).

Beyond feed challenges, disease control and management continue to pose serious constraints in the scavenging production system, further limiting the productivity of indigenous chickens (Tamasgen et al., 2025). The absence of biosecurity measures, coupled with free mixing of chickens of different age groups from different households during scavenging, increases disease spread among flocks (Waiswa et al., 2024). Many farmers neither deworm nor vaccinate their flocks (Singh et al., 2023), partly due to the small flock sizes they keep and the fact that vaccines are packaged for large-scale use, typically not less than 500 doses. This makes vaccination costs prohibitive for resource-constrained indigenous chicken farmers. Consequently, some farmers resort to ethnoveterinary practices, administering concoctions such as red pepper, wood ash, or cannabis (*Cannabis sativa*), often without standardized procedures or dosage (Melesse, 2014; Waiswa et al., 2024). In fact, a recent study by Yussif et al. (2023) found that many farmers were unable to identify the diseases affecting their chickens, leading to birds either recovering without treatment or dying before any intervention. This challenge is likely compounded by limited access to extension and veterinary services in indigenous chicken-producing communities (Tamasgen et al., 2025).

Chickens raised under the scavenging production system are highly exposed to environmental stressors such as extreme temperatures, prolonged droughts, heavy rains, and strong winds (Yussif et al., 2023). These stressors directly affect their scavenging capacity by limiting feed access and intake, while also impairing health, behavior, and productivity (Apalowo et al., 2024). For instance, high temperatures induce heat stress, which reduces feed intake (De Basilio et al., 2001), egg production, and growth rates, while increasing mortality (Asseng et al., 2021). Conversely, cold and wet conditions heighten the risk of respiratory infections and parasite infestations. Because these birds rely heavily on their immediate environment for survival, any fluctuation in climate or weather patterns significantly compromises their welfare and performance (Abioja & Abiona, 2020). Beyond environmental stressors, indigenous chicken production is further constrained by the low genetic potential of local breeds, characterized by slow growth (Mujyambere et al., 2022) low egg production, as well as increased losses due to parasite and predator attacks (Melesse, 2014), and limited support from extension service providers (Pius et al., 2021).

2.3 The Global context of climate variability and change

Climate variability and change is one of the most recently uttered environmental term globally. There is a strong scientific consensus that the global climate system exhibits a range of significant natural variability across a range of time scales (Cooper et al., 2008). The Intergovernmental Panel on Climate Change (IPCC) together with several academies of science have issued several declarations that confirm that the climate is changing (Rohman, 2013). Because scientific consensus is built on years of rigorous research, unlike everyday opinions or assumptions, it is unlikely that ongoing studies will overturn the well-established understanding that the climate indeed varies (Ghil, 2002). Through modeling scientists have also come to a consensus that the climate will continue to vary and the effects of the changes are likely to worsen. In addition, there is also wide agreement on the causes of climate variability, which are rooted both human induced and natural factors of the climate system

According to the IPCC, climate variability refers to short to medium-term deviations in climatic elements such as temperature, precipitation, and wind patterns around a long-term average, arising from natural internal processes within the climate system or in response to external forces (IPCC, 2021). Additionally, climate variability is also defined as variations in the mean state and other statistics such as standard deviations and the occurrence of extremes of the climate on all temporal and spatial scales beyond individual weather events (IPCC, 2012). Unlike climate change, which involves sustained directional shifts in climate over decades or centuries, climate variability encompasses natural variations that occur over months, years, or even decades (IPCC, 2012). It includes both the effects of natural internal processes within the climate system such as El Nino and La Nina events and external influences such as volcanic eruptions (Ghil, 2002). In agricultural contexts, particularly in rain-fed and extensive livestock production systems, climate variability is often observed through changes in the onset, duration, and intensity of rainfall seasons, increased frequency of dry spells, floods, and heatwaves, and greater unpredictability of seasonal cycles (Cooper et al., 2008; Thornton, 2010). These variations, even when not amounting to permanent climate change, can significantly disrupt farming calendars, water availability, feed production, and animal health.

In the context of climate-related research, it is important to distinguish between diurnal or seasonal changes and climate variability, as the two are often mistakenly used interchangeably. Seasonal changes refer to the predictable, cyclical patterns in weather and environmental conditions, such as wet and dry seasons for the case of tropical regions (Sivakumar, 2006). These changes occur due to the revolution of the earth on its axis for the diurnal and around the sun for the seasonal changes (Ghil, 2002). These changes follow a relatively stable annual rhythm and form the basis for traditional agricultural calendars. In contrast, climate variability describes irregular and unpredictable deviations from these seasonal norms, occurring over months to decades. It includes fluctuations in temperature and rainfall patterns, such as delayed season onset, shortened rainfall periods, prolonged droughts, or unseasonal floods, which may be influenced by larger climate phenomena like El Nino and La Nina (Nicholson, 2000). While seasonal changes are expected and planned for, climate variability poses greater challenges to farmers due to its erratic nature and potential to disrupt established agricultural and livestock systems, including scavenging chicken production. Understanding this distinction is critical for assessing the vulnerability and adaptive strategies of rural poultry production systems under changing climatic conditions.

2.4 Climate variability in Uganda

Uganda experiences two distinct rainfall seasons, a longer season from March to May (MAM), and a shorter season from September to November (SON), which occasionally extends into December (Kilama Luwa et al., 2021; Nsubuga et al., 2014). However, the rainfall patterns have become increasingly unpredictable, with changes observed not just between seasons, but also across years and even decades (Mukasa et al., 2020). Many farmers and researchers have observed a gradual decline in the amount of rain, especially during the critical March to May (MAM) growing season, alongside fewer rainy days overall (Mukasa et al., 2020). In some regions, farmers report that rains are now starting later and ending earlier, while others experience both early onset and early cessation making the growing season much shorter and harder to rely on (Egeru, 2012; Mubiru et al., 2018). However, not all studies point to the same trend. For example, research in the Lake Victoria basin between 2000 and 2015 found no major changes in seasonal rainfall amounts (Mugume et al., 2016), and another study by Okonya et al. (2013) found that farmers did not notice significant changes regarding on set of rains. Similarly, Mwaura & Okoboi, (2014) did not find much difference in rainfall volumes compared to earlier decades, although they warned that rainfall could decline in the future. Even the most recent study by Okirya and Du Plessis (2024) did not find significant changes in the trend of rainfall in three regions of the country in the previous three decades. These mixed findings show that rainfall variability in Uganda is not the same everywhere. Some places are clearly affected more than others making it important to consider local experiences when planning for agriculture and climate adaptation.

The near-surface temperatures in Uganda generally range between 15 °C and 30 °C, with an overall average of about 21 °C, while monthly averages vary from 21.7 °C in July to 23.9 °C in February (Nsubuga et al., 2014). Spatial variations in temperature are evident across Uganda, with the northern region being the hottest, experiencing an average temperature of 30 °C (Egeru et al., 2019), while the highland areas like the Mt. Elgon experiences cooler conditions, with average temperatures of approximately 21 °C (Kilama Luwa et al., 2021). Additionally, studies have reported an increase in temperatures over time, with some indicating a net rise of 0.14 °C to 0.8 °C in annual averages over the past two decades (Mubiru et al., 2018; Mwaura & Okoboi, 2014). For example, Uganda's Climate Change Department notes that since the 1950s the country's average temperature has increased on the order of 0.23 °C per decade, accompanied by a marked increase in the frequency of hot days and hot nights (MWE, 2022). Regional disparities exist in warming trends for example, western Uganda has warmed significantly faster than other regions, with an estimated increase of approximately 0.62 °C per decade between 1990 and 2018 (MWE, 2019). Whereas, in southwestern Uganda an increase of 0.4 °C for the minimum and a 0.2 °C for the maximum temperature has been observed (Mukasa et al., 2020). In summary, Uganda has experienced a steady rise in near-surface temperatures in the recent decades, consistent with global climate change patterns.

Furthermore, recent studies have identified cyclic patterns in Uganda's climate, suggesting that extreme rainfall events tend to reoccur every 12–18 years, while droughts occur roughly every six years (Mulinde et al., 2025). This cyclical behavior implies, for instance, that a period of flooding would eventually be followed by a relative decline in rainfall, or vice versa, reflecting a quasi-periodic rhythm of wet and dry phases. However, this expectation has not always materialized. For example, Mubiru et al. (2018) reported that rainfall continued to decline even after the expected 18-year turnaround, highlighting variations in these natural cycles. Similarly, historical analyses indicate that since the 1980s Uganda has experienced more frequent and prolonged droughts, often occurring outside the predicted six-year recurrence window (Mukasa et al., 2020; UNMA, 2022). These deviations from expected cycles suggest that while droughts and floods in Uganda may exhibit periodicity, the strength and reliability of such patterns are increasingly disrupted by broader climate variability and change.

In addition to climatic records, farmers have consistently reported changes in climatic variables, including increased incidences of floods, droughts, and landslides. In eastern Uganda, farmers noted shifts in wind patterns from predominantly east–west to nonspecific directions, accompanied by stronger but shorter wind episodes, reduced dark cloud cover, and less reliable signals for hailstones yet hail events still occur (Egeru et al., 2019). Local predictors of rainfall onset and cessation were also reported to be less dependable. Farmers trace climate change as far back as the 1960s, recalling floods in 1962–1963 that were less intense and more predictable, followed by a severe dry spell in the 1970s when rainfall also became increasingly erratic (Mubiru et al., 2018). Subsequent floods were observed in the 1990s, while more recent events, particularly in urban centers, have been intensified by poor drainage infrastructure (Mubiru et al., 2018). Farmers further associated the early 2000s with the emergence of new crop pests, diseases, and weeds linked to changing climate conditions (Mubiru et al., 2018). In the eastern region, droughts have become more frequent, with major episodes recorded in 2008, 2013, and 2016/2017 (Oriangi et al., 2019). Similar experiences of increasing climatic extremes have also been reported in other parts of the country (Mukasa et al., 2020).

In summary, literature confirms that Uganda, like many of sub-Saharan African countries, is experiencing marked variability in rainfall, temperature, and other climatic variables (Ngoma et al., 2021). Evidence from global assessments (IPCC, 2021), regional analyses (Nicholson, 2000), and national studies (Mubiru et al., 2018; Mukasa et al., 2020) consistently points to a general rise in temperature across time. These studies also report notable shifts in rainfall patterns and an increasing frequency of extreme weather events, including droughts, floods, and strong winds (Egeru, 2012; Kilama Luwa et al., 2021; Mwaura & Okoboi, 2014). While these changes are well-documented, their specific implications for scavenging chicken production remain poorly understood. This is concerning given that scavenging flocks depend almost entirely on their immediate environment for feed, water, and shelter, making them highly vulnerable to any changes in climatic cycles. The absence of baseline data linking climate variability to scavenging chicken production constrains both scientific inquiry and the development of targeted adaptation strategies.

2.5 Vulnerability of the scavenging chicken production system to climate variability

Vulnerability is a core concept in climate variability and change impact assessments, particularly relevant in understanding the risks faced by humans or systems. The Intergovernmental Panel on Climate Change (IPCC), defines vulnerability as “the propensity or predisposition to be adversely affected” and includes elements such as sensitivity to harm and limited capacity to cope and adapt (IPCC, 2023, 2021). This emphasizes that vulnerability is not just about exposure to hazards but also the inherent characteristics of a system that influence its ability to withstand or recover from climate-induced stresses. Recently Binita, (2015) and Thomas et al. (2019) defined vulnerability of a system to impacts of climate variability as its level of exposure, sensitivity and ability to adapt or recover from the climate shocks.

The scavenging production system is highly exposed to climate fluctuations. This is because of the free-range conditions where birds rely almost entirely on the natural environment for their feed, water, and thermal regulation (Singh et al., 2023). Therefore, any variations in such an environment will have a direct effect on the bird’s welfare, productivity and feed availability (Apalowo et al., 2024). For instance, during prolonged dry spells or droughts, the availability of insects, green vegetation, and spilled grains declines sharply (Nzioka et al., 2017). There is much evidence indicating that the ambient temperatures within the country have reached levels that trigger thermal stress in birds (Bhawa et al., 2023), which has an effect on feed intake and productivity (Asseng et al., 2021). The lack of permanent shelter further increases exposure to heat, rain, and predation among such birds (Melesse, 2014). As such, the scavenging production system of indigenous chickens is almost entirely dependent on climate dynamics, making it one of the most exposed livestock systems to climate shocks.

Sensitivity indicates the degree to which a system is affected by climate-related stressors. The scavenging production system is highly sensitive because any change in environmental conditions directly impacts chicken productivity and survival. This is because chickens are homeothermic animals that must regulate their body temperature within a narrow range, regardless of fluctuations in environmental temperature (Wasti et al., 2020). Although, indigenous chickens are more tolerant to certain environmental stressors than exotic breeds (Singh et al., 2023), they also remain vulnerable to extreme weather events. Additionally, variation in temperatures elevates the risk of disease outbreaks such as Newcastle disease, especially when combined with stress and poor nutrition (Sese et al., 2022). Sensitivity is further heightened by the system’s reliance on traditional, low-input practices. For example, Cooper et al. (2008) noted that farmers who depend entirely on rain-fed agriculture are among the most vulnerable to climate variability. In addition, for many scavenging chicken producing communities, biosecurity is poor, veterinary care is limited, and vaccines are rarely administered, making the birds even more susceptible to climate-induced stressors (Mubiru et al., 2018; UBOS, 2018; Yussif et al., 2023).

The adaptive capacity of the scavenging production system is generally low due to socio-economic and institutional constraints. Most farmers engaged in the scavenging production system of chickens are smallholders operating at subsistence level with limited income (Melesse, 2014). Arguably, this makes adaptation measures largely unaffordable. Such farmers also have minimal access to extension services, credit, and technologies such as improved housing, or supplemental feeding (Singh et al., 2023). Findings by Oriangi et al. (2019) indicated that the ability of a household to meet their daily expenditures significantly influenced the preparedness, recovery and adaptation to climate change. According to UBOS (2018), only 2.2% of Ugandan farmers use irrigation, an indicator of the overall low investment in adaptive strategies across agriculture. Similarly, adaptation options such as improved shelter for chickens, vaccination, or alternative feeding during seasons of feed scarcity are either unavailable or unaffordable to most households (Singh et al., 2023; Yussif et al., 2023). In addition, fluctuating market prices for poultry products discourage long-term investment, as farmers fear losses even when production improves (Conglin et al., 2023). Social safety nets and government support targeting smallholder poultry producers are also weak or absent, further limiting recovery after climate shocks.

The scavenging chicken production system is generally highly vulnerable to climate variability due to its high exposure, sensitivity, and limited adaptive capacity. The interplay of environmental dependence, socio-economic constraints, and minimal external support leaves both the system and the farmers who rely on it prone to significant losses during adverse climate events. Enhancing resilience will require targeted interventions such as improved extension services, affordable access to vaccines and housing materials. In addition, promoting supplementary feeding is essential to reduce vulnerability of the system.

2.5 Farmers’ perception of climate variability

Farmers' perceptions and understanding of climate variability is shaped by their lived experiences, and at times differ from scientific interpretations. While scientists define climate variability based on measurable deviations in temperature, rainfall, and extreme weather events over time (IPCC, 2012), farmers perceive it through the practical impacts on their farm activities and yields (Hubertus et al., 2023). Despite these differences, evidence shows that an increasing number of farmers and members of the public are beginning to understand climate variability in ways that align more closely with scientific perspectives (Mekonnen et al., 2021). This shift may be influenced by greater exposure to climate-related information, although gaps in communication between scientists and farming communities still persist.

Farmers often consider climate variability true only after experiencing a risk (Aryal & Marenya, 2021). For communities that have not yet faced such risks, the concept of climate variability may seem distant or irrelevant (Marie et al., 2020). Perceptions are shaped by lived experiences. For instance, a study in Ethiopia found that farmers viewed crop failure and water shortages, which they had experienced, as the strongest indicators of climate change. In contrast, increased flood occurrence, which they had not widely experienced, was ranked among the least important indicators (Marie et al., 2020). Beliefs about climate variability and change are also influenced by emotions rather than pure logic, and are further shaped by cultural and religious values. Consequently, farmer perceptions of climate variability and change emerge from an interplay of personal experience, emotions, and cultural worldviews.

The type of agricultural enterprise a farmer is involved in greatly influences how they perceive climate variability. For instance, crop farmers often interpret climate variability in terms of delayed onset or early cessation of rainfall, as these factors directly affect planting schedules and the length of the growing season (Asare-Nuamah & Botchway, 2019). In contrast, livestock farmers are more likely to associate climate variability with prolonged droughts, which lead to reduction in pasture and water shortages for their animals (Mbaziira & Haakon, 2023). In addition, the source of climate information significantly shapes farmers’ perceptions. Those who rely on personal experience interpret climate variations differently from those who receive information through external sources such as radio, extension agents or print media. According to Sesay et al. (2022), farmers who depend on their own observations are more likely to base their understanding of climate variability on practical, localized experiences rather than broader scientific or policy descriptions.

Although limited research has specifically examined the perceptions of scavenging chicken farmers regarding climate variability, available evidence would suggest that their awareness could be closely tied to the challenges faced in sustaining flocks under unpredictable weather conditions. Farmers often perceive and interpret variations in climate based on their direct impacts on livelihoods and production systems. Thus, for scavenging chicken producers this could be in relation to feed availability, disease outbreaks, and chicken survival rather than abstract meteorological trends. Their perceptions could also be shaped by cultural beliefs, religious values, and reliance on personal experiences, with limited access to external information sources such as extension services or media. As a result, understanding how these farmers perceive and respond to climate variability is critical for designing effective, context-specific adaptation strategies that build resilience within the scavenging poultry production system.

2.6 Factors influencing adoption of coping strategies to climate variability

Understanding the factors that influence farmers' adoption of coping strategies to climate variability has received increasing scholarly attention in recent years. Several studies have examined farmers' knowledge and perceptions of climate variability and change (Belay et al., 2022; Mbaziira & Haakon, 2023; Nyangoko et al., 2022). Others focused on the socio-economic and institutional factors that shape farmers' adaptation decisions (Aidoo et al., 2021; Below et al., 2012; Nyang'au et al., 2021). While such research has been extensive for various farming categories specifically, crop farmers (Dang et al., 2019), there remains a significant gap in literature regarding farmers rearing chickens under the scavenging production system. For instance, a recent review by Dang et al. (2019) noted that among the studies analyzing determinants of climate adaptation, none focused specifically on chicken farmers. This lack of information hampers the development of targeted interventions and contributes to the heightened vulnerability of these farmers to climate impacts. Due to limited literature on poultry-specific adaptation, much of the reference under this section is drawn from studies conducted in the crop sub-sector. Broadly, the factors influencing adoption of coping strategies to climate variability are categorized into five main areas: (i) demographic and socio-economic factors, (ii) access to resources, services, and technologies, (iii) institutional and political factors, (iv) social and cultural influences, and (v) cognitive and psychological aspects (Dang et al., 2019).

2.6.1 Influence of household socio-demographics factors on coping strategy adoption

Demographic factors contribute to the willingness of farmers to undertake certain practices as a means of coping to climate variability effects (Belay et al., 2022). For example, considering age, studies show that older farmers tend to have greater farming experience and awareness of climate variability, which enhances their ability to cope with its impacts. This is because experience, especially of a shock, as a great influence on their perceptions (Lujala et al., 2015) and adaptation. Contrary to that, other studies have indicated that older farmers are more conservative and thus less likely to adjust their farming practices to cope with variabilities (Gebre et al., 2023). For instance, Kinuthia et al. (2018) indicated that older farmers were less likely to adapt by diversifying their crops, practicing agroforestry or water harvesting. The same applies to studies that have considered farming experience as a determinant of coping. Kenyan pastoralists with a higher farming experience were more likely to cope (Silvestri et al., 2012), while farming experience negatively influenced coping among smallholder farmers in Ethiopia (Legesse et al., 2013; Nyang'au et al., 2021). This indicates that it's not just the age or the experience of the farmer but other factors like the coping strategy under study, the enterprise or location come into play (Aidoo et al., 2021).

Gender of the farmer in many communities affects the ownership and access to resources that are required for one to cope. For example, due to limitations of ownership and access to resources like land, many females do not adopt strategies like tree planting (Kisira et al., 2025). Essentially, multiple studies have reported limited coping of females as compared to males due to their social constraints (Belay et al., 2022; Below et al., 2012). In some African communities, females are not allowed to move, and this limits their access to information (Chaudhury et al., 2012). A recent study also indicated that females had lower likelihood to cope by crop diversification and use of early maturing crops (Gebre et al., 2023). However, some studies have reported incidences where females cope more than males especially in cases where they are more actively involved in the farming practice (Omodara et al., 2023). Therefore, it may not be gender as per say that determines coping but the underlying factors that gender influences (Kinuthia et al., 2018).

The education level of an individual has a great influence on how they comprehend information that is accessed. Previous studies have consistently reported education as a significant factor influencing the adoption of coping strategies (Kinuthia et al., 2018). In fact, Below et al.(2012) recommended education to be at the forefront of farmer's adaptation after finding a strong relationship between education and adaptation. However, its influence among poultry farmers, especially those practicing scavenging systems, remains inconclusive. For instance, several studies have documented low levels of formal education among poultry farmers (Kugonza et al., 2008; Yussif et al., 2023), with some reporting that the majority had not attained any formal education (Sesay et al., 2022). Interestingly, not all studies report a positive relationship between education and adaptation practices. For example, Omodara et al. (2023) found a negative influence of education on the use of organic manure among cassava farmers, suggesting that more educated farmers may not necessarily adopt all recommended practices. Regional differences also exist in the education levels of poultry farmers. In India, many chicken farmers had attained secondary-level education (Yhome et al., 2011), yet lacked specialized training in poultry production (George & Beena, 2018; Yhome et al., 2011). In contrast, a study by Popoola et al. (2019) in South Africa found that primary education was the highest level attained by most poultry farmers. These variations point to the complex and context-specific nature of education as a determinant of adaptation, warranting further investigation within scavenging chicken production systems.

Household size as a factor has been found to influence coping by many studies (Kinuthia et al., 2018; Nyang'au et al., 2021). This is because of the notion that the increase in the number of individuals in a household is associated with a greater availability of labor for implementing the coping strategies. Actually, Belay et al. (2022) pointed out that the likelihood of adapting increased by 3% for every additional productive member of the household. Some strategies are more labor intensive and, in many cases, neglected when labor availability is a challenge and hired labor cannot be afforded. For example, contour ploughing, mulching, manure application (Nyang'au et al., 2021) are usually adopted by households with more members (Bryan et al., 2013). However, some contradictions have been observed where household size has a negative impact on labor demanding technologies like staggering planting dates and terracing (Kinuthia et al., 2018). Although the scavenging chicken production system is generally less labor-intensive compared to other livestock systems, it remains important to investigate how household size influences the adoption of coping strategies, as household labor availability may still play a role in decision-making and implementation.

2.6.2 Influence of socio-economic factors on coping strategy adoption

Income and ownership or access to assets positively influences coping. Households with diverse livelihood sources and better access to multiple resources are more likely to better cope with climate shocks (Nyang'au et al., 2021). This is because most coping strategies have a cost implication. For example, adoption of supplementary feeding of livestock, fertilizer use, and irrigation has been found to be higher among households that are endowed with relatively higher financial resources (Aidoo et al., 2021). In fact, previous studies reported household income either on farm or off farm to positively influence adoption of agricultural technologies that increase resilience to climate variability and change (Belay et al., 2022). For instance, adopting irrigation technologies and new crop varieties was high among farmers with higher levels of income. While in the same study, change of planting dates was not influenced by household income levels.

Farmland size is one of the determinants of farmers' capacity to adopt coping and adaptation strategies in response to climate variability and change. It encompasses both owned and rented land available for agricultural use. Larger farm sizes are generally associated with a higher likelihood of adopting adaptation measures. Land is a key resource in implementing practices such as crop diversification, agroforestry, and mixed crop-livestock systems, all of which often require more space (Gebre et al., 2023). For instance, Belay et al. (2022) reported that the probability of farmers adapting increased by 16% with every one hectare increase in land size. Similarly, Bryan et al. (2013) observed that farmers with larger land holdings were more likely to adopt strategies such as tree planting and the use of improved crop varieties compared to those with smaller plots. However, other studies have shown contrasting results, where land size had a negative influence on adaptation, suggesting that the relationship may be context-specific and mediated by other factors such as labor availability, or type of the adaptation strategy. In Uganda, the pressure on land has intensified due to a rapidly growing population, which has been increasing at a rate of over 3% annually, reaching approximately 47 million (UBOS, 2020b). This population growth has led to increased land fragmentation and conversion of farmland into residential areas, reducing the average agricultural land per household to just 1.4 hectares (UBOS, 2018). The scavenging production system is one of the poultry production systems that requires relatively larger land holdings, given that chickens rely on free access to the environment most of the time. However, the specific influence of land size on the adoption of coping strategies among farmers practicing this system remains underexplored and warrants further investigation.

2.6.3 Influence of access to resources, services, and technologies on coping strategy adoption

Resources, services and technologies include but are not limited to access to credit, weather information and extension services through training. These factors have been extensively reported to influence adaptive capacity of farmers (Below et al., 2012). Most of the studies found access to resources, services and technologies to positively influence adaption (Aryal & Marenya, 2021), some of these being specific to poultry farmers (Adepoju & Osunbor, 2018). The Intergovernmental Panel on Climate Change (IPCC) also emphasized a clear understanding of inequalities in relation to resource access among communities during adaptation and risk management planning (IPCC, 2012). For instance, access to credit narrows the financial gap and gives the farmer the ability to invest in adaptation technologies (Belay et al., 2022). Therefore, despite some studies that reported access to resources to negatively influence adoption (Aidoo et al., 2021), several agreed to their positive influence (Gebre et al., 2023). This can be confirmed by the fact that in many cases farmers cite limited access to resources, and technologies as the major barriers to adaptation (Omodara et al., 2023).

Access to agricultural extension services increases farmers' awareness of variations in climate, its effects and adaptation strategies (Adeagbo et al., 2021). A study by Marie et al. (2020) showed that adoption of climate change adaptation strategies increased with access to climate information. Despite the great role of agricultural extension, many farmers are not in position to access the services especially in times of need. For example, In Uganda only 11.7% of farmers were able to receive agricultural advisory services by 2018 with only 11.9% having attended a farmer training (UBOS, 2018). The limited access to these services exposes farmers to impacts of climate variability. However, many poultry farmers especially those rearing chickens under the scavenging production system never get access to such services even the bare minimum of poultry production training (George & Beena, 2018). Lack of information about adaptation strategies has also been reported as one of the major hindrances to climate change adaptation among maize farmers in Nigeria (Coster & Adeoti, 2015).

Farmers are more likely to adopt strategies when they believe in and understand the changes they are experiencing. Access to weather and climate information has been shown to significantly and positively influence adaptation decisions (Kinuthia et al., 2018). For example, Bryan et al. (2013) reported that farmers in Kenya who had access to weather forecasts were more likely to adopt measures to cope with climate variability and change. However, although access to climate information is often cited as a key enabler of adaptation, findings by van Valkengoed and Steg (2019) revealed only a small positive relationship between climate knowledge and actual adaptation. Interestingly, their study found that risk perception was a stronger motivator of adaptive action. This suggests that adaptation is not driven solely by awareness or knowledge, but also by perceived effects of the variability.

Overall, the adoption of coping strategies to climate variability and change is shaped by a complex interplay of socio-economic, demographic, institutional, cultural, and psychological factors. While variables such as education, gender, income levels, land size, household labor availability, access to information, and extension services have been widely studied in crop-based systems, their influence within scavenging chicken production systems remains under-researched. The literature highlights both enabling and constraining roles these factors can play, often influenced by local context and resource availability. Given the growing threats of climate variability, there is a need to better understand how these determinants interact specifically within low-input, smallholder poultry systems, who are more exposed, sensitive and with limited adaptive capacity. This will help inform more targeted interventions and policy support aimed at enhancing the resilience of poultry keeping households in vulnerable communities.

2.7 Impacts of climate variability on the scavenging chicken production system and coping strategies

The scavenging chicken production system remains under-researched in the context of climate variability, despite its vital role in rural livelihoods and the broader poultry sector. This research gap is partly due to low investment in the system and the widespread perception that indigenous chickens are naturally resilient to environmental stress (Singh et al., 2023). Although these birds exhibit adaptive traits superior to exotic breeds, such assumptions have resulted in limited policy attention, technological innovation, and scientific investigation (Wasti et al., 2020). As a result, productivity within the system remains low (Pius et al., 2021), and farmers are often inadequately prepared to cope with the growing impacts of climate variability. Due to the scarcity of empirical studies focused on this sub-sector, much of the existing discussion draws from research on intensive systems and farmer experiences. Consequently, many coping strategies reported are based on practical knowledge rather than scientific validation, and their effectiveness in mitigating climate-related impacts remains largely unquantified.

High ambient temperature is a primary climate stressor for poultry, often leading to heat stress (Lara & Rostagno, 2013). While the exact thermal comfort range for indigenous scavenging chickens is not well defined, commercial poultry generally experience heat stress once temperatures go above 24 °C (Kpomasse et al., 2021). Exposure to heat beyond this comfort zone triggers reduction in feed intake as birds attempt to minimize metabolic heat production (Asseng et al., 2021). Consequently, growth rates, body weight gain, and egg production decline (Bekele, 2021). To cope with thermal stress, farmers employ adaptation measures aimed at cooling the birds, for example, reflective or insulated roofing, increasing airflow by using fans, using foggers, misting, providing drinking water and improving house ventilation (Campbell et al., 2022). In resource-limited scavenging systems where there is minimal housing of birds (Singh et al., 2023), farmers depend on provision of water and shade to protect birds (Yussif et al., 2023).

Climate variability, especially rising temperatures, have a positive influence on poultry disease and parasite challenges (Bhawa et al., 2023). Farmers in tropical regions often report higher outbreaks of contagious poultry diseases like Newcastle disease, avian influenza, and infectious bursal disease (Gumboro) during the hottest months of the year (George & Beena, 2018). This is because warmer, more humid environments favor the survival and proliferation of many pathogens, vectors, and parasites (Bhawa et al., 2023). Heat stressed birds experience immune suppression, making them more susceptible to infections (Kpomasse et al., 2021). The combined effect is an increase in disease incidence and morbidity under climate stress, which reduces overall flock performance and can cause significant mortality in severe cases (Asseng et al., 2021; Chen et al., 2013). As a coping strategy, proactive vaccination programs are widely recommended to build flock immunity ahead of high-risk seasons (George & Beena, 2018). In Sierra Leone however, low adoption of vaccination has been observed among backyard chicken farmers (Bhawa et al., 2023). Further, in Uganda the adoption levels of vaccination reported are as low as 7% in some regions of the country (Yussif et al., 2023). In addition to the limited information about the advantages of vaccination, commercial vaccine vials that are too large are thus costly for their small flock sizes.

Prolonged high temperatures adversely affect the quality of chicken products (Mignon-Grasteau et al., 2015). Chickens under heat stress tend to consume less feed, leading to reduced intake of calcium, protein, and other nutrients essential for eggshell and egg formation (Butcher & Miles, 2022; Roberts, 2004). This results in thinner shells and lower internal egg quality. Additionally, panting the cooling mechanism for birds leads to excessive loss of carbon dioxide, causing respiratory alkalosis that disrupts calcium carbonate balance, thereby reducing the availability of ionic calcium needed for proper shell mineralization (Butcher & Miles, 2022; Mota-Rojas et al., 2021). Consequently, eggs laid during hot periods often have thin or soft shells (Kim et al., 2024; Mignon-Grasteau et al., 2015). Nutritional strategies such as increasing calcium and vitamin density in feed, supplementing with electrolytes like bicarbonate or potassium chloride, ensuring constant access to cool clean water, and adjusting feeding times to cooler hours can help mitigate these effects (Onagbesan et al., 2023). However, most of these recommendations may not be feasible under the scavenging production system unless strong efforts are put on sensitization of farmers.

Climate variability in scavenging systems is more than rising temperatures, it also includes unpredicted rainfall, floods and droughts, all of which affect chicken welfare, reproduction, immunity and the availability of natural feed resources (Abioja & Abiona, 2020). Indigenous chickens, which rely entirely on scavenging, face nutritional stress when variations in climate negatively impact feed resources (Ncobela & Chimonyo, 2016). This scarcity leads to nutritional stress causing weight loss, poor growth, and reduced egg production. Farmers cope by providing household scraps, agricultural by-products like bran, brewers’ grain, or limited amounts of purchased grains like maize and sorghum (Sesay et al., 2022). In some areas, farmers also provide termites to enhance the nutritional value of the feed (Pousga, 2007). Beyond feeding, farmers implement habitat-based adaptations to improve resilience. One such strategy is integrating trees and shrubs into the scavenging environment. These not only offer shade but also boost feed availability by attracting insects or dropping edible materials. Popoola et al. (2019) reported that in South Africa, leguminous trees are planted to provide both shade and protein-rich leaves or pods for chickens. These nature-based solutions contribute to stabilizing the scavenging production system under climate stress. Overall, combining feed supplementation with environmental modifications helps maintain flock productivity.

In conclusion, climate variability manifesting as higher temperatures, unpredicted rainfall, and more frequent extreme weather events poses multifaceted challenges to poultry kept under the scavenging production system. The impacts range from direct physiological stress on the birds to indirect effects like increased disease pressure and feed shortages. Key adaptation measures include improving shade and cooling to combat heat stress, vaccinating and managing diseases proactively, adjusting nutrition through supplementary feeding and diet enhancement, and choosing tolerant breeds or diverse species to build flock resilience. These strategies, often grounded in traditional knowledge but increasingly informed by research, are crucial for protecting the productivity of indigenous chickens under a changing climate.

2.8 Scavengeable Feed Resource for indigenous chickens

The term scavengeable feed resource (SFR) refers to all feed materials that free-ranging chickens can access within their scavenging environment. These resources can be derived from either household materials like food leftovers, kitchen waste, and spilled grains or naturally occurring environmental materials, including insects, worms, weed seeds, green forage, and crop residues scattered across homesteads, gardens, and nearby fields (Mujyambere et al., 2022).

Uganda is endowed with a diverse array of food and feed resources, many of which are accessible to poultry through scavenging. The composition of SFR fluctuates and is influenced by factors such as seasonality and agro-ecological region (Admasu et al., 2019; Prakash et al., 2020; Vasconcellos et al., 2010). Regional differences in SFR are largely attributable to variations in cropping systems and dietary habits as well as the kind of crop-livestock system in the particular region. For instance, studies from Tanzania (Mwalusanya et al., 2002) and Kenya (Nzioka et al., 2017) have shown maize and rice byproducts to dominate SFR, while in Sri Lanka, household food waste is more prevalent (Gunaratne et al., 1993). In Uganda, similar patterns may be observed across diverse agro-ecological zones, depending on dominant crops and human food preferences.

Seasonal variability plays a central role in shaping the composition of scavengeable feed resources (SFR) (Momoh et al., 2010). During the rainy seasons, the availability of arthropods and mollusks typically increases (Pinheiro et al., 2002; Vasconcellos et al., 2010). This is due to favorable environmental conditions such as higher humidity and temperatures and the abundance of food resources that supports their growth and reproduction (Materu et al., 2013). Conversely, the dry season often coincides with increased availability of grains, primarily resulting from post-harvest agricultural activities that leave behind residues and spilled grains accessible to scavenging poultry (Goromela et al., 2008). Additionally, some crops, particularly legumes and certain cereals, are planted exclusively in specific rainy seasons due to their moisture requirements. This seasonal crop calendar directly influences the type and quantity of feed resources available in the environment (Mekonnen et al., 2010).

Although the influence of bird age on the composition of scavenged feed resources remains debatable, some studies suggest that age plays a role in determining the quality and diversity of feed accessed by chickens (Mekonnen et al., 2010). Older birds are often reported to have more diverse and nutrient-rich crop contents, a pattern attributed to their superior foraging abilities, wider scavenging range, and learned behavior in identifying and prioritizing nutrient-dense feed items (Rashid et al., 2004). These birds may also be better at competing for limited feed resources, especially in mixed-age flocks, thereby gaining access to higher-quality dietary components such as insects, grains, and food scraps. Nonetheless, not all research supports this pattern. Other studies have reported no significant differences in the crop content of birds across age categories, suggesting that environmental availability and flock management practices may exert a greater influence on SFR composition than age alone (Momoh et al., 2010; Raphulu et al., 2015). However, according to Momoh et al.(2010) sex has an effect on crop content, laying hens have more calcium and minerals than growers as well as cocks. This inconsistency highlights the need for more controlled studies to disentangle the interactive effects of age, environment, and social dynamics on feed acquisition in scavenging systems.

The relative contribution of different feed types to the scavengeable feed resource (SFR) has changed over time. Earlier studies highlighted forage or vegetation as the dominant component of crop contents in scavenging chickens. For instance, Bird, (1948) and Wood,(Wood, 1956) reported that forage alone could constitute more than half of the crop contents, contributing up to 10% of the total dry matter intake. This occurred despite the limited capacity of chickens to digest high-fiber diets, underscoring the abundance and accessibility of vegetation in traditional scavenging systems. However, more recent studies suggest a shift in SFR composition, with grains and household food waste emerging as the primary contributors (Gunaratne et al., 1993; Nzioka et al., 2017). This transition is likely driven by reduced size of scavenging grounds, resulting in chickens staying closer to homesteads and relying more heavily on household food waste, particularly in rural and peri-urban areas. In addition to intentional supplementation done by farmers (Yussif et al., 2023).

The nutritional composition of SFR is highly variable and directly related to its constituents. SFR rich in legumes typically have higher crude protein content, while those composed of oilseed crops tend to have elevated crude fat and energy levels. Conversely, vegetation-dominant SFR is characterized by higher crude fiber, often exceeding optimal levels for poultry (NRC, 1994). Overall, most studies agree that the nutrient profile of SFR, particularly crude protein and mineral content, falls below the recommended dietary requirements for optimal poultry growth and productivity (Momoh et al., 2010; Tamasgen et al., 2025). The crude protein content of SFR has been reported to range between 6% and 14%, with metabolizable energy (ME) values between 2100 and 3400 kcal/kg (Mekonnen et al., 2010). Although some researchers have reported lower energy values (Nzioka et al., 2017; Rashid et al., 2004), others found the energy content to be adequate to meet maintenance needs for the different stages of growth (NRC, 1994).

In conclusion, the scavengeable feed resource base is a basis of the indigenous poultry production system in Uganda and other low-input rural settings. Its composition is dynamic and influenced by environmental, seasonal, geographical and dietary habits. While it provides a cost-free feed option, its nutritional adequacy is often insufficient to meet the requirements of productive poultry, particularly during critical growth or laying phases. As such, there is a need for targeted interventions, including supplemental feeding strategies, better utilization of locally available high-quality resources, and improved farmer education on nutrient requirements of poultry. Optimizing nutritional quality of SFR is vital for enhancing the productivity and sustainability of the scavenging poultry production system in the face of climate variability and land-use changes.

2.8.1 Methods for determining scavengeable feed resource base

Scavenging Feed Resource (SFR) is the major feed input for village chickens. According to Sonaiya, (2004) knowing the Scavenging Feed Resource Base (SFRB) can help in setting the carrying capacity for a flock on a given range through which one can monitor and improve productivity of scavenging chickens. However, measuring scavengeable feed resources (SFR) is challenging because the feed is not offered in predetermined quantities but is instead consumed as encountered by chickens during scavenging (Larsen et al., 2017). Several methods have been developed and used to study and determine the SFR. These include participatory, direct and indirect approaches (Nzioka et al., 2017; Sonaiya, 2004). Among the participatory approaches include surveys and focus group discussions with farmers to identify what their chickens eat during the different seasons of the year and if they do supplement them (Mwesigwa et al., 2015). While indirect approaches involve modelling to determine the carrying capacity of a range using performance data of the available flock. Direct techniques involve assessing the type and quantity of feed directly from the birds or the environment. Sonaiya, (2004) described three techniques of determining SFR using the direct assessment method. These include the Scavengeable Feed resource Inventory, Range coverage and Scavengeable Feed Resource Harvest.

The Scavengeable Feed Resource Inventory (SFRI) method involves quantifying all potential feed sources available in a chicken’s environment using field techniques like pitfall traps, transect walks, and quadrats to sample insects, seeds, plant material, and kitchen waste (Gunaratne et al., 1993). The strength of the SFRI approach lies in directly assessing the supply of environmental feed, helping to estimate the carrying capacity and seasonal variation in resource availability (Sonaiya et al., 2002). However, the method is labor-intensive, requires technical expertise, and may overestimate actual intake since not all available feed is consumed by chickens (Olukosi & Sonaiya, 2003; Sonaiya, 2004). Due to these practical challenges, full implementation of SFRI remains limited in field studies.

Range coverage methods assess how far and widely chickens forage to access feed, using techniques like visual observation of the scavenged distance, area mapping, and telemetry (Larsen et al., 2017). These data are vital for interpreting SFR, as resources outside the birds' roaming range are inaccessible. While such methods provide insights into spatial behavior and foraging efficiency (Larsen et al., 2017), they are often limited by technical challenges, high costs, and variability among individual birds (Dal Bosco et al., 2010). Visual observations may underestimate movement, and telemetry requires adequate sample sizes and duration. In addition, range coverage singly does not give the quantification of the available feed resource (Olukosi & Sonaiya, 2003). Due to these constraints, range coverage is underreported in earlier studies, highlighting a methodological gap that modern tools are gradually addressing.

Scavengeable Feed Resource Harvest (SFRH) measures the actual intake of scavenged feed by chickens, primarily through crop content analysis, sometimes complemented by gizzard analysis or direct observation of the diet (Mwalusanya et al., 2002; Rashid et al., 2004). This involves physical examination of the crop contents collected to identify, weigh, and analyze the feed components (Nzioka et al., 2017). It provides a direct, quantitative estimate of what chickens consume from the environment. Of all methods, crop content analysis is the most direct for determining the SFR. It provides information on what exactly is consumed by the chickens. Through using the crop content analysis both qualitative and quantitative insights into diet composition and nutrient content are obtained, helping to identify the exact nutritional deficiencies with the scavenged feed. It also reveals dietary selectivity, reflecting chickens' foraging choices, unlike other methods (Admasu et al., 2019). The technique has been used globally as a direct quantitative measure of SFR consumption (Gunaratne et al., 1993; Ncobela & Chimonyo, 2016).

In summary, a number of methods have been used globally to assess scavengeable feed resources (SFR) in indigenous chickens, each offering unique insights. Direct methods like crop content analysis yield precise data on intake but can be invasive and variable. Indirect approaches, such as modeling nutrient requirements, are easier to apply but rely on assumptions. While qualitative and participatory methods provide valuable local context but lack precision. Behavioral observations highlight the often-overlooked role of foraging behavior. Scavenged feed resource harvest always involves nutritional analyses which emphasizes that feed quality not just quantity is critical unlike other methods.

2.8.2 Effects of climate variability on scavenging chicken feed resource base

Variations in climate that include shifts in rainfall patterns, changes in season length, temperature fluctuations, and the occurrence of extreme events such as floods and droughts have direct impacts not only on the welfare of scavenging chickens but also on the availability of their feed resources.

Indigenous chickens just like any other chicken breeds, require adequate feed of the desired nutritional content to meet their maintenance and production requirements. Scavengeable feed resources are a major input in indigenous chicken production although no economic value is attached to these resources most times (Yussif et al., 2023). Several studies have reported inadequate feed availability and quality for scavenging chickens throughout the year in many countries (Goromela et al., 2008; Mekonnen et al., 2010). This availability and quality is influenced by several factors including season, grain sowing/harvest timing, land available for scavenging, flock size, farming activities, production system, and climate variability (Goromela et al., 2007, 2008). Therefore, adding to their genetic potential the feed factor greatly contributes to the lower growth and productivity of the indigenous chickens under the scavenging production system.

Of recent, farmers have embarked on supplementing scavenging, although the highest proportion of the diet is derived from the scavenging activity (Singh et al., 2023). The number of farmers in Uganda who supplement their indigenous chickens has increased from 49% in 2008 (Kugonza et al., 2008) to more than 90% in 2014 (Nakkazi et al., 2014). Most farmers take an initiative to supplement the birds with some resources like maize, sorghum, ground nuts among others depending on their availability (Yussif et al., 2023). Climate variability affects each of the feed resources differently, with the rise in temperatures and reduction in rainfall generally reducing the availability of crop origin feed resources (Nzioka et al., 2017). Previous studies have reported a 21% decline in agricultural productivity in Africa in the past four decades originating from changes in climate (Ortiz-Bobea et al., 2021). For example, an increase in temperature by 1 °C reduced maize yield by over 200kg per ha, with an additional mm of rainfall increasing maize yield by 2.4kg per ha (Mekonnen et al., 2021). Maize and its by-products are the primary energy source in rations for intensively managed chickens and a key supplement for scavenging flocks (Goromela et al., 2008; Nakkazi et al., 2014). Consequently, any reduction in maize productivity will affect its availability for both human food and poultry feed and likely raise prices, making supplementation unaffordable for many farmers of indigenous chickens.

Most studies show strong seasonality in scavengeable feeds, for example, some report scarcity in the dry season and abundance in the wet season (Minh & Ogle, 2005), whereas others document the opposite pattern (Goromela et al., 2008). Mekonnen et al. (2010) in Ethiopia found that the crop content of scavenging chickens was 17% higher in the dry season than in the wet season, while Goromela et al. (2008) in Tanzania reported the reverse. Yet in most parts of Uganda, Kenya, and Tanzania, cereals and by-products peak in the dry, post-harvest period (Nzioka et al., 2017). On the other hand, most studies found kitchen waste, forage and flowers and insects being more abundant in the rainy season than the dry season (Goromela et al., 2007, 2008; Momoh et al., 2010). This variation likely reflects geographical and agro-ecological differences that determine cropping patterns. Climate variability further disrupts planting and harvest cycles, tightening feed supplies (Gunaratne, 2013).

The quality of scavengeable feeds fluctuates with seasons which can be worsened by variations in climate. During the rainy season, diets typically show higher crude protein content driven by the abundance of insects and their life stages (Nzioka et al., 2017). While in the dry season metabolizable energy often rises with greater access to cereals, by-products, and oilseeds (Goromela et al., 2008). Yet overall, scavengeable resources frequently remain nutrient-deficient relative to poultry requirements (NRC, 1994). Rising temperatures further reduce the quality by accelerating plant maturation and increasing lignification of scavenged forages. This reduces digestibility of the scavenged feed, chickens being non ruminants (Bird, 1948). Compounding this, chickens are selective foragers that prefer succulent leaves, which are especially vulnerable to seasonal and thermal stress (Wood, 1956). The lignification renders such forage less palatable. Changes in rainfall patterns and rise in temperatures also cause changes in range of fauna and flora on which the indigenous chickens scavenge (Pinheiro et al., 2002).

2.9 Physiological mechanisms underlying heat stress in chickens

Heat stress disrupts normal cellular and metabolic processes in chickens, triggering a range of physiological responses aimed at maintaining homeostasis and survival. Among the most critical mechanisms involved are oxidative stress and the activation of cellular protective systems, particularly heat shock proteins (HSPs). These responses play a central role in determining the bird’s capacity to tolerate elevated temperatures and avoid irreversible cellular damage.

Exposure to high ambient temperatures disrupts cellular metabolism and mitochondrial function in chickens, leading to excessive production of reactive oxygen species (ROS) (Nawaz et al., 2021; Brugaletta et al., 2022). When ROS generation exceeds the bird’s antioxidant capacity, oxidative stress develops, resulting in damage to lipids, proteins, and nucleic acids. Heat-stressed chickens consistently exhibit elevated markers of lipid peroxidation, such as malondialdehyde, particularly in skeletal muscle, indicating membrane damage and impaired cellular integrity (Farag & Alagawany, 2018; Nawaz et al., 2021). Oxidative stress also affects the gastrointestinal tract, where heat-induced hypoxia and ROS destabilize intestinal tight junctions, increasing gut permeability and susceptibility to pathogen translocation (Brugaletta et al., 2022). Reduced activity of antioxidant enzymes under heat stress further exacerbates oxidative imbalance, making oxidative damage a key contributor to heat-related physiological dysfunction in poultry (Lara & Rostagno, 2013).

Heat shock proteins constitute a primary cellular defense mechanism against heat-induced damage in chickens. Under heat stress, elevated temperatures activate heat shock factor 1, leading to increased transcription and expression of several HSP families, notably HSP70 and HSP90 (Lara & Rostagno, 2013; Nawaz et al., 2021). These proteins function as molecular chaperones, stabilizing denatured proteins, preventing aggregation, and facilitating refolding, thereby preserving cellular structure and function. HSP70, in particular, is widely recognized as a reliable biomarker of heat stress in poultry due to its consistent upregulation during thermal challenge (Gouda et al., 2024). Acute heat stress induces HSP expression across multiple tissues, including muscle, liver, kidney, heart, and reproductive organs, reflecting a systemic protective response (Wang et al., 2018). Beyond protein protection, HSPs also modulate immune and inflammatory pathways, contributing to improved cellular resilience. Higher basal or inducible HSP expression, often observed in heat-tolerant and indigenous chicken breeds, is associated with enhanced thermotolerance and represents a potential target for genetic selection and nutritional interventions aimed at improving heat resilience in poultry production systems (Nawaz et al., 2021; Gouda et al., 2024).

2.9.1 Thermal regulation among chickens

Thermoregulation refers to the physiological and behavioral processes that enable chickens to maintain their body temperature within a narrow, safe range necessary for normal metabolism and welfare (Danforth & Burger, 1984). These processes are centrally coordinated by the hypothalamus, which acts as the primary control in the avian brain (Onagbesan et al., 2023)**.** By continuously integrating thermal signals from both the body and the external environment, the hypothalamus activates effectors that restore homeostasis (Asseng et al., 2021; Onagbesan et al., 2023)**.** When ambient temperatures rise above the neutral zone, it triggers a cascade of responses designed to reduce internal heat production and enhance heat dissipation (Mota-Rojas et al., 2021). Metabolic heat generation is primarily regulated by the thyroid hormones triiodothyronine (T_3) and thyroxine (T_4), which influence basal metabolic rate (Danforth & Burger, 1984; Ruuskanen et al., 2021). Under normal conditions, these mechanisms maintain the chicken's internal body temperature within 40.0 °C to 42.0 °C (Bhawa et al., 2023; Nichelmann & Tzschentke, 2002). Although thermal regulation in chickens involves responses to both cold and hot environments, the emphasis here is on heat stress, given its increasing relevance under rising ambient temperatures.

The thermal comfort or thermal neutral zone (TNZ) which is the range of ambient temperature within which chickens can maintain body temperature without spending extra energy on either heating or cooling differs with age and breed (Nichelmann et al., 1986; Ruuskanen et al., 2021). For example, chicks are less efficient in body heat regulation especially during the first 10 days of life (Nichelmann & Tzschentke, 2002). At this stage chicks are nearly naked with a low metabolic rate generating less heat production which they cannot even retain (Nord & Giroud, 2020). This makes their Biological Optimum Temperature (BOT) to be higher at that age, which thereafter reduces with age (Nichelmann & Tzschentke, 2002). This makes their TNZ to be higher between 32 °C and 35 °C at hatch, about 24°C at 3 to 4 weeks of age and about 21 °C thereafter (Bhawa et al., 2023; Hamissou Maman et al., 2019). This, therefore, necessitates the provision of an artificial source of heat to chicks during their early stages of growth. The amount or need for artificial source of heat reduces as birds grow developing feathers which insulate their bodies, and thus a reduction in TNZ. In addition, the metabolic rate of birds also increases with growth to a stage when they can produce enough heat to sustain their normal body temperature (Ruuskanen et al., 2021).

The normal body temperature of chicks is lower than that of adult chickens by 2–3 °C (Hamissou Maman et al., 2019).

Once ambient temperature rises above the upper critical temperature of the TNZ for instance beyond 24 °C (Asseng et al., 2021; Bhawa et al., 2023), birds must actively enhance heat loss to prevent body temperature from rising (Eberhart & Washburn, 1993). As ambient temperature approaches body temperature, the gradient for sensible heat loss through radiation, convection, and conduction reduces, making those pathways less effective measures of heat loss (Brugaletta et al., 2022). At that point, chickens increasingly rely on evaporative cooling, particularly panting to maintain a thermal balance. For example, around 30 °C, chickens transition to open-mouth panting as the primary means of cooling (Wasti et al., 2020). Radiative and convective losses also plateau because the air offers little thermal gradient when it is nearly as warm as the bird. The core body temperature begins to rise in scenarios when environmental conditions worsen, for example when ambient temperature nears the chicken's skin temperature (Nichelmann & Tzschentke, 2002). This is because in such cases the total heat load overwhelms the bird's cooling capacity. In other words, body temperature increases once the surrounding conditions exceed the bird's ability to dissipate heat (Borges et al., 2004).

The extent of the rise in body temperature is influenced by factors such as genotype, sex, body size, and acclimatization history (Onagbesan et al., 2023; Oni et al., 2025). Birds reared in consistently warm environments often exhibit smaller temperature increases under heat stress compared to those from cooler conditions (Nichelmann & Tzschentke, 2002; Playà-Montmany et al., 2023), while males tend to experience greater rises than females (Eberhart & Washburn, 1993). Acclimatized birds may stabilize their body temperature slightly above normal, whereas non-acclimatized birds continue to experience progressive increases (May et al., 1987; Nichelmann & Tzschentke, 2002). Previous findings have reported body temperature rise of up to 45.12 °C among broiler chickens exposed to 41 °C (Borges et al., 2004). However, mortality has been reported when body temperature reaches 46 °C (Muiruri & Harrison, 1991), indicating that chickens' physiological mechanisms for regulating heat become ineffective under extreme thermal stress.

Despite extensive research, most existing knowledge on thermal regulation in chickens is derived from studies on commercial strains under intensive production systems, for which the environmental conditions are closely controlled. Yet, indigenous chickens in scavenging systems are exposed to fluctuating ambient conditions, often without shelter, or artificial cooling (Yussif et al., 2023). Their thermoregulatory responses may therefore differ in threshold, efficiency, and resilience compared to commercial breeds, yet these differences remain largely undocumented. Particularly, the response of indigenous scavenging chickens to thermal load has not been scientifically established. This limits our understanding of their physiological limits and adaptive capacity under the natural, variable environments. Addressing this gap is critical, as effective management strategies for scavenging systems require evidence that reflects the realities and constraints of these birds' production environment.

2.9.2 Mechanisms of heat loss in chickens

Chickens regulate body temperature through a balance of heat production and heat dissipation, which occurs through a number of mechanisms. At thermoneutral conditions, they lose heat via sensible heat loss through convection, conduction and radiation from the exposed body parts (Playà-Montmany et al., 2023). However, as ambient temperature rises toward or above body temperature, the gradient for sensible heat loss reduces (Barnes et al., 2004; Brugaletta et al., 2022). In such conditions, chickens must resort to evaporative cooling to shed excess heat (Mota-Rojas et al., 2021). Below are brief descriptions of each mode of heat transfer by the chickens.

Heat loss by convection, involves the movement of air carrying away warmth from the body. Airflow over the chicken reduces the surface boundary layer and increases convective heat loss from exposed, well-perfused regions like the combs, wattles, legs, under-wing skin, thereby cooling the bird (Playà-Montmany et al., 2023). Chickens facilitate convective cooling by dust bathing or elevating their wings slightly outward, which exposes bare skin and allows air to circulate next to the body (Kim et al., 2021). Loss of heat through convection increases with existence of a breeze or air speed (Nichelmann et al., 1986). For example, under intensive production system fans are sometimes used. During heat stress, chickens may seek moving air or create it themselves by flapping their wings to enhance convective heat loss. However, this cooling method becomes less effective under conditions of high relative humidity.

Chickens can also transfer heat directly to objects in contact, a process known as conduction. The effectiveness of this mechanism depends on both the thermal conductivity of the contact surface and the temperature gradient between the bird and that surface (Playà-Montmany et al., 2023). Unlike broiler chickens with relatively bare breast areas, most chicken strains have feathered bodies that limit direct surface contact, making conduction a relatively minor pathway for heat loss (Nichelmann et al., 1986). Nevertheless, birds may either dust bathe or squat or press against cooler ground (Playà-Montmany et al., 2023), suggesting an instinctive attempt to exploit conductive cooling when possible (Li et al., 2015). In fact many studies have reported an increase in the time of sitting among heat stressed birds (Khalil et al., 2012; Wang et al., 2018). Under scavenging production systems, however, this route is often less effective on bare ground exposed to direct solar radiation, highlighting the importance of maintaining vegetation cover on scavenging grounds.

Radiation as a mechanism involves heat transfer via infrared radiation between the bird's body and cooler surroundings. It is a non-contact exchange measure that occurs as longwave infrared energy. Chickens lose heat by radiating it from their warm exposed body surfaces, especially the comb, wattles, face, underside of the wings and legs to cooler surroundings (Kim et al., 2021). In long legged and long billed species, these also act as surfaces for heat loss (Playà-Montmany et al., 2023). Heat loss through radiation can be enhanced by vasodilation in the comb and wattles, which increases blood flow to these appendages (Mota-Rojas et al., 2021).

During panting, heat from the blood is used to evaporate water, which carries away thermal energy. Above the upper critical temperature, evaporative cooling becomes the principal avenue of heat loss, as sensible methods lose effectiveness (Teeter et al., 1985). This occurs primarily via panting which is the evaporative cooling from the moist surfaces of the throat and respiratory tract. Panting involves increasing respiratory rate which consists of short, quick breaths done by opening the beak (Kim et al., 2021). The normal respiratory rates of adult chickens range from 20 to 59 breaths per minute under thermoneutral zone (Nyoni et al., 2019). However, studies report an increase of up to 300 breaths per minute among heat stressed broiler chickens (Kim et al., 2021). The effectiveness of panting as a cooling mechanism decreases as humidity increases, because the air's capacity to absorb additional water vapor is reduced under high humidity conditions (Brugaletta et al., 2022).

Physiologically heat loss by convection and radiation is enhanced through vasodilation. It involves the widening of peripheral blood vessels to channel warm blood from the body core to exposed surfaces such as the comb, wattles, skin, and shanks (Mota-Rojas et al., 2021). Studies show that peripheral vasodilation during heat exposure raises skin temperature significantly, improving the efficiency of sensible heat loss mechanisms (Mota-Rojas et al., 2021). In addition, breeds with larger combs, wattles, bills and legs often tolerate high temperatures better because these structures provide greater surface area for radiative and convective cooling (Playà-Montmany et al., 2023). Conversely, in cold conditions, vasoconstriction limits blood flow to these regions, resulting in heat conservation. Overall, the efficiency of heat exchange in chickens via the different mechanisms depends heavily on the temperature gradient between the bird and its environment.

2.9.3 Factors that influence susceptibility of chickens to heat stress

Stress is a biological adaptive response that enables animals to restore and maintain homeostasis when challenged by internal or external stimuli. In poultry, heat stress occurs when chickens experience a negative balance between the heat they produce and the heat they can dissipate to the environment (Onagbesan et al., 2023). This imbalance often increases under high ambient temperatures combined with other factors that may hinder cooling (Apalowo et al., 2024). Heat stress can either be acute, when birds are exposed for a short time or chronic in case exposure is persistent in nature. Heat stress is widely recognized as the number one environmental challenge in poultry production globally (Asseng et al., 2021). The imbalance is caused by both environmental and animal related factors.

Environmental factors that could contribute to the imbalance that results in heat stress include but are not limited to, ambient temperature, humidity, air flow and thermal radiation (Apalowo et al., 2024; Syafwan et al., 2011). Ambient temperature is ranked the highest contributor to heat stress of all the environmental factors (Bhawa et al., 2023). This is because as the ambient temperature rises, it contributes to both the body temperature and limits dissipation of heat through all thermoregulation mechanisms (Chen et al., 2013). Humidity and air flow on the other hand exacerbates heat stress by impairing the bird’s ability to cool via evaporation. Humidity of between 50 and 70% is conducive for sensible heat loss among chickens (Bhawa et al., 2023). Unlike the scavenging production system, under the intensive production system, the environment in the poultry house can be modified to facilitate heat loss. For example, installation of cooling systems in poultry houses, use of fans to increase air flow that enhances heat loss by convection radiation and evaporation. Although birds in the scavenging production system can seek shade, they become more susceptible to heat stress when such shelter is unavailable.

Thermal regulation in chickens is limited by their anatomical features. The absence of sweat glands prevents them from cooling through perspiration, forcing reliance on passive means such as radiation, convection, and conduction to dissipate heat. Furthermore, the dense feather covering that insulates most of the body not only traps heat but also restricts latent heat loss through the skin. Evidence for this comes from findings by Nichelmann et al.(1986), who showed that defeathered laying hens were able to raise their heat production at thermoneutral temperatures to more than double the level observed in feathered hens, demonstrating that the absence of feathers enhances the capacity for heat dissipation. Body size also plays an important role in thermoregulation. Large bodied chickens have a lower surface area to mass ratio, which reduces the relative area available for heat dissipation and increases susceptibility to heat stress (Eberhart & Washburn, 1993). Consequently, large, heavily feathered broilers are particularly prone to rise in ambient temperature, as they combine high body mass with thick insulation from plumage. Although some studies suggest that variations in body temperature are more closely linked to genetic factors than to body size alone, the interaction between size, feather coverage, and genotype remains a critical determinant of heat tolerance in chickens (Eberhart & Washburn, 1993).

The influence of genotype on thermotolerance in chickens has been documented by previous studies (Rosa et al., 2007). Certain genetic traits enhance heat tolerance in chickens regardless of body size. For example, the naked neck (Na) and frizzle feather (F) genes reduce feather coverage and insulation (Nichelmann et al., 1986), improving heat dissipation and enabling better performance under high temperatures (Asseng et al., 2021; Melesse et al., 2011). Laying hens carrying the naked neck gene produced more eggs with better quality in high ambient temperatures than their normal-feathered counterparts. On the other hand, the frizzle trait can be disadvantageous in cooler climates. The dwarf gene (dw) reduces mature body weight of chickens and potentially heat production (Onagbesan et al., 2023), but evidence of its thermotolerance benefits is mixed (Chen et al., 2013). Overall, substantial genetic variation exists in poultry heat tolerance, and breeding programs often cross commercial strains with heat-tolerant indigenous breeds to produce F1 offspring that combine improved tolerance to heat with good production performance. Although indigenous chickens are more tolerant, they are not immune to heat stress especially when temperatures soar beyond their acclimatization range (Tamzil et al., 2013).

Closely linked to genetics is the rate of metabolic heat production, which influences a bird’s capacity to tolerate high temperatures (Lara & Rostagno, 2013). Chickens with high metabolic rates, such as commercial broilers bred for rapid growth and modern layers selected for high egg production, generate substantial internal heat from digestion and growth (Ruuskanen et al., 2021). This elevated heat load makes them more prone to heat stress (Nichelmann & Tzschentke, 2002). For example earlier studies have reported broiler chickens to experience heat stress at temperatures as low as 25 °C (Cartoni Mancinelli et al., 2023) while layers heat stress sets in at 32 °C (Kim et al., 2021). In contrast, slow-growing indigenous chickens may generate less internal heat, potentially allowing them to tolerate higher ambient temperatures. However, this advantage could be offset by their higher activity levels during foraging (Lase et al., 2025).

Physical activity influences heat stress by adding to a chicken’s internal heat load through muscular work (Lara & Rostagno, 2013). In hot conditions, birds naturally reduce movement to lower metabolic heat production (Playà-Montmany et al., 2023; Wasti et al., 2020), often resting in shaded areas during the hottest periods. In fact many studies have reported reduced activity including walking, preening, foraging, feeding and standing among thermal stressed domestic and wild birds (Khalil et al., 2012; Playà-Montmany et al., 2023). This is because preference temperatures for birds during activity is lower than that at rest (Nichelmann & Tzschentke, 2002). For that reason, forcing activity, such as long walks to feed or water or handling during a high heat load, increases the risk of heat exhaustion. Therefore, scavenging chickens that depend on physical activities such as walking, foraging, and short flights to obtain feed, are more susceptible to heat stress.

Ready access to drinking water is a critical determinant of heat stress susceptibility in chickens. Water is essential for thermoregulation as it supports evaporative cooling and prevents dehydration (Onagbesan et al., 2023). Under heat stress, water intake increases sharply among chickens. For example, Bonnet et al. (1997) reported that water intake doubles among heat stressed chickens, while Bhawa et al. (2023) found that at 38 °C, chickens consume up to four times more water than at 21 °C. This increased water intake supports heat dissipation through panting, which results in substantial water loss via respiration, and also helps lower body temperature internally. Belay & Teeter (1993) further demonstrated that a 20% rise above basal water consumption can enhance respiratory heat loss per breath by nearly 30%. However, under scavenging production systems, chickens are often more susceptible to heat stress due to the frequent limitation of water supply.

Heat stress in chickens results from the interaction of environmental and animal-related factors, for which ambient temperature is the main cause. Susceptibility of chickens to heat stress is influenced by anatomical and physiological limitations, as well as traits such as genetic makeup, body size, metabolic rate, activity level, and hydration status. Breeding approaches, including the use of heat-tolerant genotypes can improve resilience. In summary, understanding the factors that influence heat stress susceptibility allows for targeted interventions.

2.9.4 Effect of heat stress on performance of chickens

The rise in ambient temperature stemming from climate variability has not spared chicken welfare, productivity and survival. Heat stress disrupts the bird’s homeostasis, leading to direct impacts on growth, reproduction, health, and immune function (Abioja & Abiona, 2020; Prince et al., 1961). Birds that are heat stressed cannot reach their genetic growth potential, resulting in substantial productivity losses (Bohler et al., 2021). The effects of heat stress on chickens are worse in the tropics where chronic high temperatures are experienced (Asseng et al., 2021). These effects are irreversible after long hours of exposure. Although the reported time to irreversible damage varies across studies, in some studies it has been reported as early as 42 hours of exposure (Chen et al., 2013), with this period depending on the ambient temperature.

Reduction in feed consumption among chickens is one of the most pronounced effects of heat stress documented by earlier studies (Lara & Rostagno, 2013; Muiruri & Harrison, 1991; Prince et al., 1961). The reduction in feed intake is a natural adaptation mechanism to minimize heat production from digestion (Apalowo et al., 2024; Brown-Brandl et al., 2001). In addition, birds spend more time on heat dissipating behaviors than eating (Khalil et al., 2012). Most studies have reported reduced feed intake when birds are exposed to temperatures above 30 °C (Donkoh, 1989; Mack et al., 2013) with some studies reporting decline at as low as 23 °C (Prince et al., 1961). Blood alkalosis which is a result of panting during heat stress has also been reported to depress appetite among broiler chickens (Teeter et al., 1985). Reduced feed intake irrespective of the dietary composition has been reported among heat stressed birds (De Basilio et al., 2001) with every degree increase in temperature causing up to 7g reduction in daily feed intake (Prince et al., 1961), other studies reporting 30% reduction in daily feed intake (Bonnet et al., 1997). Heat stress effects on feed consumption are accompanied by effects on feed utilization in chickens (Kim et al., 2024; Wasti et al., 2020).

Elevated ambient temperature depresses growth primarily by reducing voluntary feed intake and impairing nutrient utilization (Bonnet et al., 1997; Kpomasse et al., 2021). Prolonged heat exposure causes direct structural and functional injury to the gastrointestinal tract (GIT). Respiratory water loss during panting promotes dehydration, which compromises mucosal integrity in the ileum, duodenum, and jejunum, thereby reducing the absorptive surface area (Eberhart & Washburn, 1993; Teeter et al., 1985). Vasodilation further redirects blood flow from splanchnic tissues to the periphery, limiting oxygen and nutrient supply and suppressing digestive enzyme activity (Mota-Rojas et al., 2021). In addition, reductions in proventriculus and gizzard weights slow digesta passage, diminishing digestion and nutrient assimilation (Bonnet et al., 1997; Rostagno, 2020). Consistent with these mechanisms, early work reported up to a 50% reduction in weight gain in heat-stressed broilers (Bonnet et al., 1997). Later studies demonstrated villus atrophy and crypt denudation under chronic heat exposure, confirming the deterioration of gut morphology (Rostagno, 2020; Santos et al., 2015). Collectively, these physiological disruptions lower growth performance, productivity, and overall welfare in poultry (Lara & Rostagno, 2013).

During panting of heat stressed chickens carbon dioxide (CO_2) is exhaled at a rate faster than it is produced by metabolism (Barnes et al., 2004). This excessive CO_2 loss disrupts the blood's bicarbonate buffer system, which normally maintains the acid base balance (Teeter et al., 1985) as illustrated in the equation below. Reduced CO_2 levels lower the concentration of carbonic acid (H_2CO_3) and hydrogen ions (H^+) while increasing the proportion of bicarbonate ions (HCO_3^-) in the blood (Wasti et al., 2020). The resulting rise in HCO_3^- elevates blood pH, causing alkalinity of blood, a condition known as respiratory alkalosis (Teeter et al., 1985). To compensate, the kidneys increase excretion of bicarbonate ions HCO_3^- and retain more hydrogen ions (H^+) in an effort to restore acid base balance (Barnes et al., 2004). However, the adjustment by the kidney leads to metabolic acidosis. The simultaneous occurrence of respiratory alkalosis and metabolic acidosis impairs enzyme activity, disrupting normal metabolism, and compromising nutrient utilization. All of which contribute to reduced growth, feed efficiency, and overall performance of the birds.

$$CO_2+H_2O \leftrightharpoons H_2CO_3 \leftrightharpoons H^+ + HCO_3^-$$

Heat stress also impairs reproductive output and egg quality traits in laying hens. At elevated ambient temperatures, hens reduce feed intake and divert energy toward thermoregulation rather than egg formation (Kim et al., 2021; Lara & Rostagno, 2013; Yan et al., 2022). The accompanying panting-induced respiratory alkalosis lowers blood CO_2 and hydrogen ion concentration, which in turn disrupts carbonate availability and calcium metabolism required for proper eggshell calcification (Butcher & Miles, 2022). Consequently, hens experience reduced ovulation rates, smaller egg mass, thinner shells, and inferior internal quality indices such as albumen height and Haugh units (Kim et al., 2024). Elevated temperatures also suppress circulating reproductive hormones, particularly estradiol and luteinizing hormone, further compromising follicular development and oviposition frequency (Mota-Rojas et al., 2021; Yan et al., 2022). Experimentally, exposure to 32 °C has been associated with up to a 40% decline in egg production and marked reductions in shell thickness and strength in commercial layers (Mack et al., 2013; Melesse et al., 2011; Yan et al., 2022). Collectively, these physiological and endocrine disruptions illustrate how sustained heat stress impacts both productivity and reproductive efficiency in poultry.

Heat stress markedly increases thirst and water consumption in poultry. In broilers, water intake rises significantly between 30 and 35 °C compared to cooler conditions (Abbas et al., 2008; Belay & Teeter, 1993). Experimental chamber exposures between 24 and 41 °C have shown sharp increases in water use during hot periods (Lott, 1991). Similarly, in laying hens exposed to high temperature–humidity environments around 33 °C, pronounced panting and associated physiological changes indicate greater drinking to compensate for respiratory water loss (Kim et al., 2024). Extension data further suggest that broiler water use increases by approximately 12–13 % per 1 °C rise in ambient temperature and can even double during prolonged heat spells (North, & Bell, 1990). Mechanistically, panting accelerates evaporative water loss, leading to hyperosmolality and reduced plasma volume, which in turn activate hypothalamic osmoreceptors and baroreceptor pathways to stimulate thirst. Heat and dehydration also trigger the renin–angiotensin system, where angiotensin II acts as a key dipsogenic signal and arginine vasotocin contributes to water-balance regulation, jointly promoting drinking (Bohler et al., 2021).

Overall, heat stress reduces feed intake, damages the gastro intestinal tract impairing nutrient utilization, while respiratory alkalosis and subsequent metabolic acidosis disrupt acid base balance and electrolyte stability. These combined effects impair digestion, depress feed efficiency, and ultimately slow growth and productivity in chickens.

2.9.5 Approaches to managing thermal stress in chickens

Heat stress poses a critical challenge to poultry production, especially in tropical and arid regions. Therefore, a lot of emphasis should be put on managing the effects of heat stress, which can be through several approaches. These include environmental regulation, stock density manipulation, feed and feeding management and water provision among others (Onagbesan et al., 2023). This section reviews environmental, managerial, and nutritional strategies emphasizing adaptations feasible for scavenging chickens.

2.9.5.1 Feeding management approaches

Feed restriction, aimed at reducing metabolic heat production, has been shown to improve tolerance to heat stress in poultry (Oni et al., 2025). This management practice involves either withdrawing feed or adjusting feeding schedules, and can be implemented during the early growth stages or at the onset of heat stress (Syafwan et al., 2011). For example, feed can be withheld during the hottest hours of the day and provided during cooler periods, such as early morning or late evening (Onagbesan et al., 2023). Experimental evidence indicates that five-day-old chicks deprived of feed for 24 hours subsequently exhibited greater heat tolerance in adulthood. Despite its potential benefits, feed restriction is generally not recommended for routine use, as it can slow growth rates and delay attainment of market weight, particularly in broilers (Syafwan et al., 2011). Moreover, re-feeding after a restriction period may provoke aggressive competition at feeders, leading to overcrowding and potential mortalities. Consequently, if adopted, feed restriction should be applied with strict monitoring and careful management to avoid negative impacts on bird’s welfare and productivity.

Given the limitations associated with feed restriction, alternative feeding regimes that maintain continuous access to feed while minimizing metabolic heat production have been investigated (Teeter et al., 1985). Among them include providing birds with a high energy, low-protein diet during the hotter parts of the day and a high-protein, low-energy diet during the cooler hours (Syafwan et al., 2011). A high energy diet, often supplemented with fats or oils, provides high caloric density that is required to sustain activities like panting while generating less metabolic heat as compared to high protein or fiber diets (Mota-Rojas et al., 2021). In fact, use of dietary fat as an energy source, rather than starch, is highly recommended because fat has a lower heat increment during metabolism compared to carbohydrates. In addition, high energy diets tend to reduce total feed intake (Nampijja et al., 2023), further minimizing heat production. On the other hand, while feeding a low protein diet, balancing of essential limiting amino acids like methionine and lysine is key to overcome case deficiency. The concept of dietary nutrient alteration has also been applied in the form of a dual feeding schedule, where the daily ration is divided into two distinct diets, one specifically for the hot and the other for cooler periods. For instance, studies have found such a feeding regime to reduce body temperatures and improve heat tolerance (De Basilio et al., 2001).

Another feeding approach that can reduce heat stress is wet feeding. During wet feeding, water is mixed with the feed in a ratio of about 1:1. This boost both feed and water intake and improves feed palatability under hot conditions, although evidence suggests the performance benefits of wet feeding are not explained by viscosity changes alone. Wet feeding also reduces viscosity, allowing the feed to flow through the gut more quickly. Studies report higher body weight gain when chickens are fed wet diets during periods of high ambient temperature. Despite the benefits, there should be limitations on the use of wet feed because it spoils quickly under hot environments favoring fungal growth and mycotoxin formation. In the end the practice might affect bird performance through mycotoxicosis (Santos & Van Eerden, 2021). Therefore, the wet diets should be prepared only at feeding times to reduce the spoilage risk.

When birds are heat stressed, they drink more water than usual. As a result, supplying clean and safe drinking water to birds is recommended and has been cited by farmers as an adaptation strategy they employ (Sesay et al., 2022). In fact, a higher proportion of farmers in northern and eastern Uganda, where temperatures are high, deliberately provide water to scavenging chickens compared to those in other regions (Yussif et al., 2023). The water offered should be of lower temperature than the ambient temperatures to combat the effects of heat stress. Water is one of the most neglected essential nutrients among indigenous chicken. Despite the adaptability of indigenous chicken to water shortages (Singh et al., 2023), availing them with water during heat stress would improve their performance and lessen the impacts of raised temperatures. During dry spells, indigenous chickens hardly find water which contributes to their low productivity. Restrictions of water supply affects the development of lymphoid organs which in turn has an impact on the innate immunity of birds. In addition, water restriction has negative effects on the renal functioning, digestion, immunity, and other vital body systems.

Feed supplementation specifically with antioxidant vitamins such as vitamin A, C and E together with minerals buffers chickens against heat stress induced strain by reducing oxidative damage, stabilizing membranes, and sustaining immune and epithelial functions (Abd El-Hack et al., 2019; Wang et al., 2018). Supplementing layer chickens with 16,000 IU/kg diet of vitamin A and 500mg/kg diet of vitamin E during summer improved the bird's immunity and egg production and quality indices (Abd El-Hack et al., 2019). Although chickens synthesize vitamin C, high thermal load can render it limiting. Its supplementation lowers corticosterone and supports performance and immune response among heat stressed broiler chickens (Saiz Del Barrio et al., 2020). The benefits of vitamin c supplementation on heat stress relief are increased when combined with minerals (Saiz Del Barrio et al., 2020). Dietary vitamin E also mitigates chronic heat stress in laying hens, enhancing egg production and egg quality indices (Barnes et al., 2004). In addition, co-supplementing vitamins C and E with appropriate electrolyte management (balancing dietary Na^+/K^+) helps counter panting induced alkalosis, limits oxidative damage, and reduces systemic stress (Barnes et al., 2004; Teeter et al., 1985). Phytogenic antioxidants like honey, propolis, olive oil/leaf extracts, coconut water, and orange peel extract have likewise been reported to alleviate heat stress via antioxidant activity (Fayed et al., 2024; Mota-Rojas et al., 2021).

Other feeding approaches that help alleviate effects of heat stress among chickens include addition of sodium bicarbonate ($NaHC_{03}$), ammonium chloride (NH_4C1) and potassium chloride (KCl) to either feed or water (Barnes et al., 2004). The electrolytes combat the effects of panting through reducing blood pH and maintaining dietary electrolyte balance (Borges et al., 2004). For instance, an earlier study by Teeter et al. (1985) reported reduced blood pH and improved weight gains among birds that were subjected to chronic heat stress when given 1% ammonium chloride and 0.5% sodium bicarbonate respectively. Since in many cases feed intake declines but with an increase in water intake during heat stress, providing the electrolytes in drinking water is a more effective strategy (Barnes et al., 2004). In addition, supplementing the diet of heat stressed birds with probiotics helps mitigate the adverse effects, as evidenced by improved weight gain, feed intake, and nutrient utilization (Wang et al., 2018).

2.9.5.2 Genetics and thermal conditioning

Genetic selection for heat tolerance is a key strategy that farmers can rely on to sustain chicken productivity under rising temperatures (Onagbesan et al., 2023). Smallholders already recognize this value, often preferring local ecotypes or heat-tolerant breeds in scavenging systems, and some spread climate risk by keeping multiple poultry species or native chicken breeds (Sesay et al., 2022; Singh et al., 2023). Specific genes that enhance heat tolerance include the naked neck gene, which in homozygous form reduces feathering by up to 40% around the neck and improves heat dissipation (Nawaz et al., 2021). Naked neck and frizzle chickens have been shown to perform better under high temperatures than fully feathered birds (Nichelmann et al., 1986). Other genes such as frizzle (F), dwarf (Dw), and slow feathering (K) also contribute to heat tolerance, with the partially dominant frizzle gene reducing feather intensity and facilitating heat loss (Fathi et al., 2013). Frizzle chickens, like naked neck types, have been reported to maintain productivity at high ambient temperatures compared to normal-feathered birds (Zerjal et al., 2013). Therefore, in tropical scavenging chicken communities, emphasis should be placed on adopting and commercializing these heat tolerant genetic resources.

Thermal conditioning of chicks at a young age helps increase the birds heat tolerance at later stages of growth (Nord & Giroud, 2020; Onagbesan et al., 2023), through reduced body temperature (De Basilio et al., 2001) and enhanced temperature regulatory mechanisms (Madkour et al., 2022; Onagbesan et al., 2023). During the first week after hatch, chicks are poor homeotherms because the central thermoregulatory control and effector capacity are still maturing (Nichelmann & Tzschentke, 2002). They approach full homeothermy by about the tenth day of life (Nord & Giroud, 2020). Therefore, if chicks are exposed to high temperatures during this period, their tolerance to heat stress during the adult stages increases (Abioja & Abiona, 2020). In fact, Oni et al. (2025) found chickens that were exposed to 38 °C in their early growth stages to have a higher growth performance than conventionally reared broiler chicks under heat stress. However, the thermal conditioning temperatures investigated in previous studies have ranged widely, from 10 °C to 40 °C (Li et al., 2015; Nichelmann & Tzschentke, 2002; Youssef et al., 2014). Thermal conditions enhance heat tolerance through enhanced synthesis of HSP70 (Liew et al., 2003; Taouis et al., 2002).

Reducing the stocking density during hot days helps in lessening the effects of heat stress among chickens (George & Beena, 2018; Sesay et al., 2022). This is because each of the birds dissipates heat to the surrounding, raising the ambient temperature. In smallholder and scavenging systems crowding often occurs under night shelters or in case of limited shade during daytime. This would therefore call for expanding shade area or increasing perch space. Field surveys from West Africa similarly list right stocking density among farmers' preferred climate adaptation measures.

Collectively, effective management of heat stress in chickens is inherently multifactorial and works best when environmental, nutritional, and health-support measures are combined. Across systems, the foundation is to reduce the heat load and improve heat loss which can be achieved through enhancing air movement and ventilation, lowering stocking density, modifying diets and feeding schedules, water management and early-life thermal conditioning. Under ascavenging system, where infrastructure is limited, farmers typically rely on heat-tolerant local breeds and simple shelter improvements for example constructing thatched-roof houses to minimize raise in house temperatures (George & Beena, 2018). In addition to ensuring reliable water supply, and planting trees to expand shaded foraging areas, enlarging night shelters and shaded spaces to effectively reduce crowding at critical times. Given persistent extension gaps that have historically prioritized crops and ruminants while tackling adaptation, scaling low-cost, context-appropriate interventions like shading, water provision, stocking density management, and targeted nutrition offers the most immediate pathway to safeguard welfare and productivity of scavenging flocks under rising temperatures.

CHAPTER THREE

ASSESSMENT OF FARMERS' PERCEPTIONS OF CLIMATE VARIABILITY AND THEIR COPING STRATEGIES

Abstract

Indigenous chickens (IC) are vital to rural households in Uganda for food security and poverty alleviation. However, variations in climate threaten their productivity. This study examined farmers' knowledge and perceptions of Climate Variability (CV) in relation to 20 years (2003–2022) meteorological data, farmers' coping strategies and factors that influence coping. Data were collected from 271 purposively selected IC farmers, 10 key informants, four focus group discussion sessions, and local station climate records. Analytical methods included descriptive statistics, chi-square tests, ordered probit regression, and the Modified Mann-Kendall test for trend analysis. Qualitative data were analyzed following thematic content analysis methods. Results revealed a significant positive trend in monthly minimum temperatures, but not in annual or seasonal rainfall, or average and maximum temperatures. Annual rainfall ranged from 1019.5 ± 7.58 mm to 1721.8 ± 11.25 mm, with an average of 1311.9 ± 9.14 mm. Temperature averages were 24.68 ± 1.52 ºC (mean), 19.05 ± 1.22 ºC (minimum), and 30.31 ± 2.46 ºC (maximum). Most farmers (84.1%) were aware of CV, noting decreases in annual rainfall (63.8%), length of the first (67.3%) and second (50.6%) rainy seasons, and hailstones (49.4%). Many also perceived increases in dry (91.1%) and rainy (71.2%) season temperatures. Farmers' perceptions aligned with climate data for rising monthly minimum temperatures but not declining rainfall. Farmers perceived rising temperatures to have caused to a 46% reduction in scavenging time, reduced egg production (8.7%) and hatchability (5.2%), and increased disease incidence and mortality. Coping strategies included providing drinking water (96.3%), shade (62.5%), feed supplementation (37.5%), and vaccination. Probit regression showed that gender, access to training and weather information increased the likelihood of coping but education, age and flock size decreased it. These findings underscore the need for targeted, climate-responsive interventions that combine improved climate education, timely and localized weather information, and strengthened farmer capacity to interpret seasonal patterns, alongside enhanced access to key resources such as water, high-quality feed supplements, and poultry production training.

Key words: Adaptation; Climate change; Indigenous chickens; Perceptions; Resilience Scavenging production system

3.1.1 Introduction

Climate variability can be assessed using several parameters, but majority of studies often concentrate on temperature and precipitation as the most informative (Caffrey et al., 2013; Mihiretu et al., 2021; Owoyesigire & Mpairwe, 2020). Climate variability is a global challenge (Roco et al., 2015) and Uganda is no exception. In Uganda, poultry production is dominated by free-range, dual-purpose, disease tolerant, locally adapted, scavenging indigenous chickens which constitute 85% of the national flock (UBOS, 2020). These chickens contribute 55% of chicken consumed in the country (FAO, 2018). The scavenging production system, also referred to as the free-range or backyard system is a low input system where birds scavenge for 90% of their feed resource (Anyona et al., 2023), with minimal or no supplementary feeding (Mulungu & Kangogo, 2022). Consequently, due to over dependence on the environment, the free-range production system is vulnerable to variability and changes in climate.

Climate variability has significant impacts on the poultry industry (Lara & Rostagno, 2013). For instance, a rise in temperature causes heat stress in birds, which reduces their productivity (De Basilio et al., 2001) in the form of reduced feed intake, compromised immunity. This subsequently reduces growth rates and egg production (Rojas-Downing et al., 2017). The variations in climate also influence distribution of poultry diseases posing a significant threat to poultry health (Escarcha et al., 2018). In Uganda, climate variability has mostly been characterized by an increase in temperature, reduction in intensity and amount of rainfall, with an increase in the frequency of extreme events like droughts and floods (Twinomuhangi et al., 2021). The near-surface maximum temperature in the country has increased by 0.9℃ and 2℃ for minimum temperatures (Caffrey et al., 2013; Obubu et al., 2021). Also, while future projections indicate an increase in temperatures between 1.8℃ and 6℃ by 2080 under different representative concentration pathways (RCP 4.5 / RCP 8.5) (Egeru et al., 2019; Mubialiwo et al., 2020), the annual rainfall is also expected to reduce by between 24.9 mm (RCP 4.5) and 164.6 mm (RCP 8.5) during the same period (FAO, 2016).

Human perceptions are crucial in influencing how people individually and collectively respond to the impacts of climate variability. Prior research conducted in 34 African countries indicates that Uganda has the highest proportion of farmers acknowledging variations in climate (Selormey et al., 2019). Despite the increasing awareness and acceptance of climate variability and change (Snaibi et al., 2021), there are disparities in these perceptions, and these differences affect farmers' adaptive capacity. Variation in farmers' perceptions of climate variability is influenced by the nature of agricultural enterprise (Nyangoko et al., 2022), geographical location (Roco et al., 2015), previous climatic risk experience (Lujala et al., 2015), in addition to other social demographic factors (Belay et al., 2022; Snaibi et al., 2021). Moreover, farmers' perceptions of climate variability tend to be subjective, and hence, insufficient for drawing conclusions about climate variations in a given area. Consequently, making informative conclusions from farmers' perceptions necessitates a comparison with observed climate data.

Despite increasing temperature trends, the response of scavenging chicken systems to climate variability remains poorly understood, as existing research has largely focused on intensive production systems where thermal regulation is more easily managed. In free-range systems, particularly in Uganda, there is limited empirical evidence on how indigenous chicken farmers perceive climate variability, how these perceptions align with observed climatic data, and how farmers respond to emerging thermal challenges. While smallholder farmers are likely employing both deliberate and unconscious coping strategies to buffer the effects of heat stress, the nature and determinants of these responses have not been systematically examined. Addressing these knowledge gaps is critical for sustaining IC productivity under the scavenging system. Therefore, this study assessed farmers' knowledge and perceptions of climate variability, perceived effects of rising temperatures and identified the coping strategies employed and factors influencing their adoption. In addition, farmers' perceptions were compared with observed climate data with the aim of informing context-specific, climate-resilient poultry interventions.

3.1.2 Materials and methods

3.1.2.1 Description of the study area

The study was conducted in Soroti District, located in the eastern part of Uganda with coordinates 1^{o} 15'N and $2\ ^{o}$ 00' N; 33^{o} 00'E and 33^{o} 45'E (Figure 2). Soroti district is found in the low-lying Kyoga plains agro-ecological zone known to be highly vulnerable to climate variability and change (FAO, 2016). The area has the highest number of households rearing indigenous chickens under the scavenging production system (UBOS, 2008, 2020). Soroti district receives 1250 mm of rainfall annually and has two rainfall seasons (Majaliwa et al., 2015). The first rainy season lasts from March to May, with an average of 473 mm, peaking in April and the September-November season (358 mm) with a milder peak in October or November (Majaliwa et al., 2015).

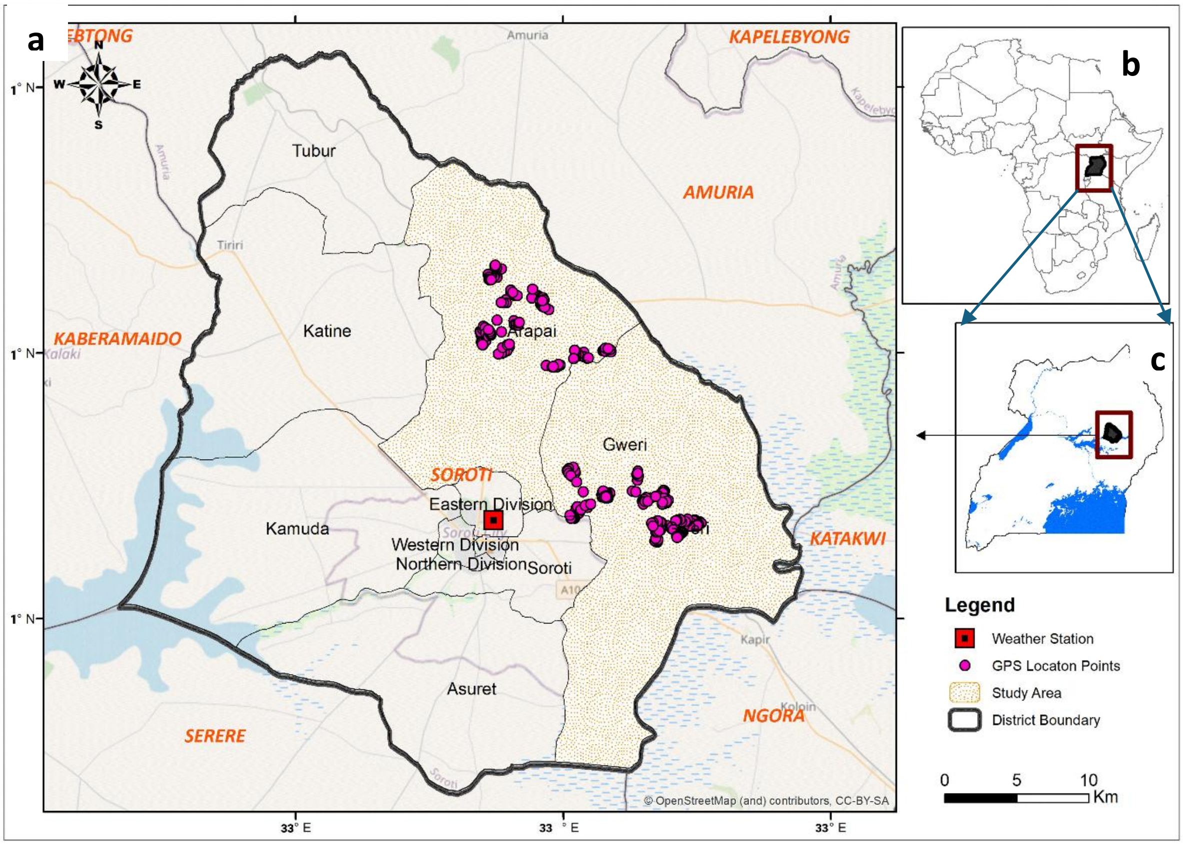


Figure 2: Geographical location of the study area a) Soroti district, showing location of Arapai and Gweri sub-counties, b) Africa showing location of Uganda, c) Uganda showing location of Soroti district.

3.1.2.2 Study design and Sampling of respondents

A convergent parallel mixed methods design was employed in which data was collected through a cross-sectional survey, Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs). A total of 271 households engaged in indigenous chicken rearing were selected from 18 villages within two sub-counties, Gweri and Arapai, using a multi-stage purposive sampling design. In the first stage, one sub-county was purposively selected from each of the two counties in Soroti District, based on the indigenous chicken population, with preference given to those with the highest numbers. In the second stage, three parishes were chosen within each selected sub-county using the same criterion. In the third stage, three villages where indigenous chicken keeping was most prominent were purposively selected from each parish. In the fourth stage, households were purposively selected from household lists, with the assistance of local leaders and parish chiefs, based on two criteria: (i) active involvement in indigenous chicken rearing and (ii) at least ten years of continuous residence in the village. Finally, simple random sampling of households from the eligible list was conducted to select the final households for interview. The final sample size was calculated to achieve a 95% confidence level with a 5% margin of error, using Equation (i), which is commonly applied to estimate sample sizes for proportions (Israel, 1992).

$$n_0 = \frac{z^2 pq}{e^2} \qquad (i)$$

Where n_0 is the sample size, z is the critical value at 95%, p is the estimated proportion of the attribute present in the population, q is 1-p and e is the desired level of precision. This gave a sample of 384 farmers.

Given that the population of indigenous chicken-keeping households in the two sub-counties is finite, a correction for sample size was applied using Equation (ii), which accounts for finite population adjustments (Israel, 1992). The population of 5,626 households that were keeping Indigenous chickens, had stayed in the area for more than 10 years, with household heads of 30 and above years were targeted (UBOS, 2017).

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \qquad (ii)$$

Where n is the corrected sample size and N is the population size, the resultant sample of 359 respondents was obtained. However, a total of 271 (75.5%) were obtained due to changes in the administrative structure of the study areas. Specifically, at the time of data collection, Gweri Sub-County was subdivided into three smaller sub-counties of Gweri, Awaliwal, and Aukot. Since no census data were available for the newly created Gweri Sub-County at the time, the sample size calculations were based on statistics from the former larger Gweri Sub-County. Moreover, during fieldwork, district and sub-county officials recommended that the study be limited to the newly constituted but smaller Gweri Sub-County administrative boundaries, as the other areas had become independent administrative units. Given the homogeneity of indigenous chicken farmers, achieving a sample size above 70% of the target is considered scientifically acceptable under such circumstances (Amin, 2005).

The total number of households sampled from villages of the different parishes was determined based on the number of households rearing indigenous chickens in the sub counties. That is, an average of 13 households per village (44.3%) from Arapai sub-county and an average of 16 households (55.7%) from each village in Gweri sub-county were sampled. The study preferred household heads as respondents because, these are primary decision-makers on agricultural practices and coping strategies. They therefore significantly influence household perceptions of climate variability (Babyenda et al., 2024; Nabikolo, 2014). In cases where household heads were unavailable, other household members were considered.

3.1.2.3 Data collection and analysis

3.1.2.3.1 Secondary data

To make comparison between farmers' perceptions and climatic data, observed daily rainfall, minimum and maximum temperatures for the period 2003 to 2022 was obtained from the Uganda National Meteorological Authority (UNMA) Soroti station.

3.1.2.3.2 Primary data

Data required to determine farmers' knowledge and perceptions of variations in climatic variables were collected using a pre-tested semi-structured questionnaire. To explore farmers' opinions under an interactive environment and to obtain detailed explanation of farmers' perceptions, four Focus Group Discussions (FGDs), and 10 key informant interviews (KII) were conducted. The sample size for both the KII and FGD was determined based on recommendations of Muellmann et al. (2021). The key informants interviewed included a natural resource officer (n=1), an agricultural officer (n=1), animal production officer (n=1), entomology officer (n=1), experienced IC farmers (n=2) and community leaders (n=2) and Elders (n=2). Meanwhile, one FGD was conducted for the community leaders (n=2) together with technical personnels who included poultry vaccinators (n=2), veterinary officers (n=2), extension officers (n=3), representative from an NGO (n=1) and managers of local hatcheries (n=2). In each of the sub-counties one farmer FGD was conducted with 12 participants each (6 females and 6 males). In addition, one FGD was conducted for only females, a decision taken as a result of observing dominance by males in the mixed sex FGDs. The tools were administered in the local language (Ateso) for clarity to respondents, and responses were recorded in English. For that purpose, highly trained research assistants local to the area were used for data collection.

3.1.2.4 Data analysis

3.1.2.4.1 Rainfall and temperature trend analysis

Monotonic trends of both rainfall and temperature were determined using non-parametric Modified Mann-Kendall (MMK) test for trend analysis, with significance of the trends determined at 95% confidence interval. The choice of the MMK test was guided by significance of some lag-1 autocorrelation coefficient. The MMK test values are either positive indicating an increasing monotonic trend or negative indicating a decreasing trend. The MMK test trend analysis was performed using the equations detailed in (Hamed & Rao, 1998). In addition, the Theil-Sen's slope estimator was employed to determine the extent of changes in the trends of rainfall and temperature data. These analyses were done using R statistical software 4.5.2.

3.1.2.4.2 Rainfall and temperature variability analysis

The Standardized Temperature Index (STI) was calculated to obtain variations in average temperatures between years of the study period. The STI was calculated by obtaining the difference of the annual average and the long-term average divided by the standard deviation of the long-term average using equation iii (Etana et al., 2020);

$$STI = \frac{T_A - T_M}{\delta} \qquad (iii)$$

Where T_A is the average temperature of a year; T_M is the long-term (2003-2022) mean average temperature and δ is standard deviation of the long-term average temperature.

To detect variability in rainfall, through analyzing the frequency and intensity of dry and rainy years, the Seasonal Rainfall Anomaly Index (SRAI) was calculated. The positive and negative anomalies for SRAI were computed using equations (iv) and (v) obtained from (Etana et al., 2020) as indicated below;

For above normal seasonal rainfall, $SRAI = +3\left[\frac{RF-M_{RF}}{M_{H10}-M_{RF}}\right]$ (iv) and

For below normal seasonal rainfall $SRAI = -3\left[\frac{RF-M_{RF}}{M_{L10}-M_{RF}}\right] \qquad (v)$

Where RF is the amount of rainfall during a particular season in a given year; M_{RF} is the long term (2003-2022) mean rainfall for that same season; M_{H10} is mean rainfall of the 10 wettest seasons in the historical data for the same season; and M_{L10} is the mean of 10 driest seasons in the historical data set for the same season.

3.1.2.4.3 Analysis of farmers' perceptions of climate variability

Quantitative data from the survey were managed using the SPSS software program for Windows, version 27 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics such as means, standard deviations, frequencies, and percentages were generated were calculated. For purposes of analysis, awareness was treated as one component of knowledge, while perceptions captured farmers' views on specific changes of climatic parameters. A chi-square test was performed to determine the relationship between categorical variables. In addition, an ordinal probit regression was conducted using STATA 15.0 to examine the relationship between perception of CV and the predictor variables that included age, sex, and education level. Perception of climate variability was measured on a five -level (1-5) ordinal scale with the highest-level (5) indicating perception 'to a greater extent'**.** Prior to estimation, model diagnostics were conducted. Collinearity among predictors was checked using an Ordinary Least Squares auxiliary regression to compute Variance Inflation Factors. All values were below 10 and tolerance exceeded 0.1, confirming no multicollinearity problems. The parallel line assumption was tested and not violated, and model fit statistics confirmed the adequacy of the specification. Since all diagnostics were satisfactory, the ordered probit regression was carried out as described. Statistical significance was determined at α = 0.05.

Probit regression was used to assess the influence of various socio-economic and demographic factors on farmers' perceptions and their adoption of coping strategies. This analysis was performed using STATA 15.0 software, with each factor modeled as a binary dependent variable (1 if the factor was mentioned, 0 otherwise). The probit model equation (i) was derived from the underlying latent variable model, as described in (Maddala, 1983).

The probit regression model used in this study is represented as follows:

$$y* = \beta_0 + X\beta + \varepsilon \dots\dots\dots\dots\dots (i)$$

Where $y*$ is the latent variable, X denotes a set of explanatory variables, β are parameters to be estimated, and ε is the error term. Since the β parameters do not have a direct interpretation, marginal effects were calculated at the mean of each variable, that is the marginal effects at the i^{th} variables were calculated following formula in equation *(ii)* below by (Maddala, 1983);

$$\frac{\partial p(y=1)}{\partial X_i} = \emptyset(\beta_X) + \beta_i \ldots\ldots\ldots\ldots (ii)$$

Where;

$\emptyset$ is the cumulative normal density function

The interpretation of the marginal effects involves assessing how the probability of adopting a particular coping strategy change when the independent variable of interest increases by one unit, while keeping all other variables at their mean values. The marginal effects were computed as shown in equation (*iii)* below:

$$\Delta p(y=1) = \emptyset(\beta_1) - \emptyset(\beta_0) \ldots\ldots\ldots. (iii)$$

Thus, the marginal effect represents the change in probability between the scenario where the dummy variable is set to 1 and when it is set to 0, while holding all other variables at their mean values.

In this study, the dependent variables were the farmers' coping strategies, namely: supplementation, water provision, and provision of shade (Table 1). These variables were binary, indicating whether a farmer implemented the strategy (1) or not (0). Each coping strategy was regressed on a set of independent variables selected based on (Dang et al., 2019). The explanatory variables (as shown in Table 1) included factors such as age, gender, education level, access to credit, household size, farmland size, flock size, access to weather information, and training in poultry production, among others.

The empirical probit model was specified as follows in equation *iv*:

$$c_i = (\gamma X_i) + \varepsilon \ldots\ldots\ldots. (iv)$$

Where,

C_i = the coping strategy chosen by the ith farmer, X_i= the vector of explanatory variables of probability of coping with high temperatures by the ith farmer, γ = the vector of the parameter estimates of explanatory variables hypothesized to influence the probability that the farmer is coping with high temperature. Thus, the linear specification of the probit regression model, which was estimated using STATA 15.0 software was given as in equation *v*;

$$C_i = \gamma_0 + \gamma_1 age + \gamma_2 gender + \gamma_3 education \dots\dots\dots\dots + \gamma_{11}\ w.forecast + \varepsilon \dots \text{(v)}$$

Table 1:Description and measurement of variables hypothesized to influence choice of coping strategies among farmers rearing scavenging chicken in Soroti district

Variable	**Description and type of variable**	**Expected sign**
Dependent variables		
Coping strategies		
Feed supplementation	Respondent supplements chickens Dummy=1 yes; 0 otherwise	
Water provision	Respondent provides chickens with water Dummy=1 yes; 0 otherwise	
Shade provision	Respondent provides chickens with shade Dummy=1 yes; 0 otherwise	
Independent variables		
Age	Age of the respondent: Continuous: measured in years	+/-
Gender	Gender of the respondent: Female=1 Male= 0 otherwise	+/-
Education	Highest education level of the respondent: 0=No education, 1=Primary, 2= Secondary, 3=Tertiary	+/-
Household size	Total number of persons in the household: Discrete	+/-
Flock size	Total number of chickens reared: Discrete	+/-
Number of chickens sold	Total number of chickens sold annually: Discrete	+
Farmland size	Size of land farmed: Continuous: measured in acres	+/-
Credit	Respondent has access to credit: Dummy= 1 Yes. 0 otherwise	+
Training	Respondent has attended training in chicken production: Dummy= 1 Yes. 0 otherwise	+
Weather information	Farmer has access to weather information: Dummy= 1 Yes. 0 otherwise	+/-
Weather forecast	Farmer can predict weather: Dummy= 1 Yes. 0 otherwise	+/-

Qualitative data were transcribed verbatim from the local language (Ateso) to English and then back-translated to ensure accuracy of the translation. The data were systematically coded and analyzed using the ATLAS.ti software. A thematic analysis approach was employed following an inductive process in which themes emerged directly from the data to capture recurring patterns related to IC farmers' perceptions of climate variability and their coping strategies related to chicken rearing. The analysis followed both content and narrative procedures, allowing for an in-depth exploration of how farmers know and perceive variations in climate. Key themes were refined through an iterative process, ensuring consistency and validity. Qualitative findings from FGDs and KIIs were triangulated with quantitative survey results to provide a more comprehensive understanding of farmers' perceptions of climate variability.

3.1.3 Results

3.1.3.1 Rainfall and temperature trends

The Modified Mann-Kendall (MMK) test indicated no statistically significant trends in rainfall, and in average and maximum temperatures, across annual, seasonal, and monthly scales ($p > 0.05$). In contrast, a significant increasing trend was observed in monthly minimum temperature ($p = 0.01$). Although not statistically significant, the MMK values across most rainfall and temperature variables suggest a weak positive trend over time (Table 2).

Table 2: Rainfall and temperature trends of Soroti district 2003-2022

Variable	MMK	Slope	*p-value*
Annual rainfall	8.00	4.91	0.82
Seasonal rainfall	78.00	0.52	0.79
Monthly rainfall	711.00	0.04	0.56
Annual Av. temperature	12.00	0.00	0.72
Seasonal Av. Temperature	5.60	0.00	0.82
Monthly Av. Temperature	4.43	0.01	0.72
Annual Min. temperature	40.00	0.00	0.21
Seasonal Min. temperature	3.73	0.00	0.12
Monthly Min. temperature	3.03	0.00	**0.01**
Annual Max. temperature	30.00	0.02	0.35
Seasonal Max. temperature	1.96	0.01	0.42
Monthly Max. temperature	1.51	0.00	0.22

3.1.3.2 Rainfall variability

There was variation in annual and monthly rainfall over the study period (Figure 3). The calculated long-term average rainfall received in the twenty years was 1311.9±9.14 mm with the least 1019.5±7.58 mm received in the year 2021 and the highest 1721.8±11.25 mm in 2019 (Figure 3a). The area received lower than the long-term average annual rainfall for ten years (2004, 2005, 2007, 2008, 2009, 2013, 2014, 2016, 2017 and 2021) within the study period. Monthly rainfall varied between less than 0.1 mm and above 300 mm, with most months having below 150 mm (Figure 3b). Results of SRAI indicated both positive and negative anomalies confirming inter-seasonal rainfall variability (Figure 4). The highest positive anomaly, exceeding 3, was observed for the SON season.

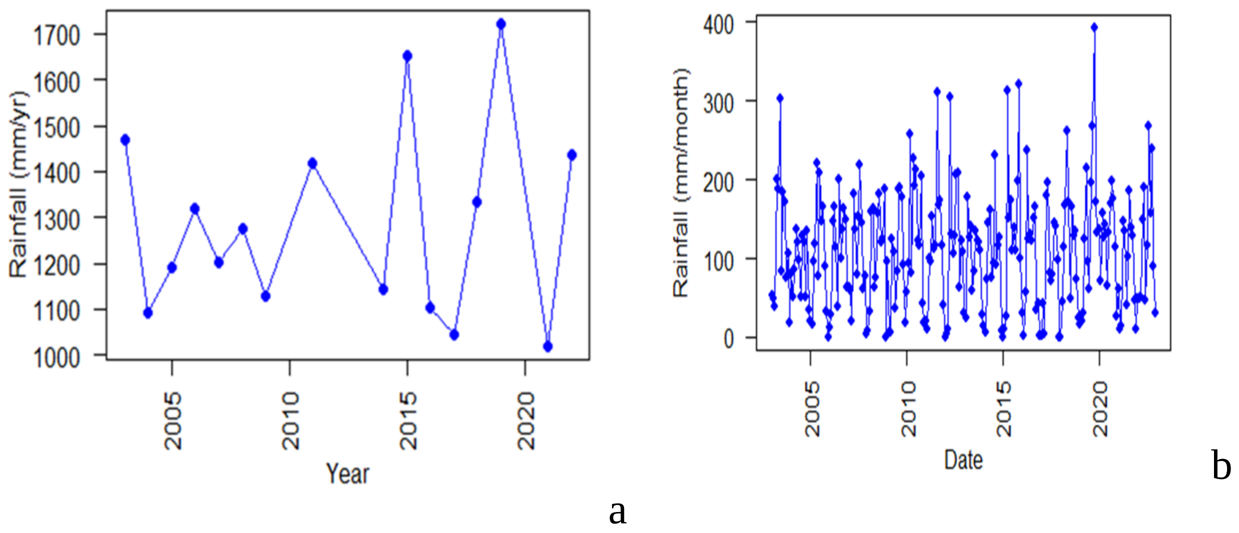


Figure 3: (a) Annual rainfall; (b) Monthly rainfall for Soroti district from 2003 to 2022

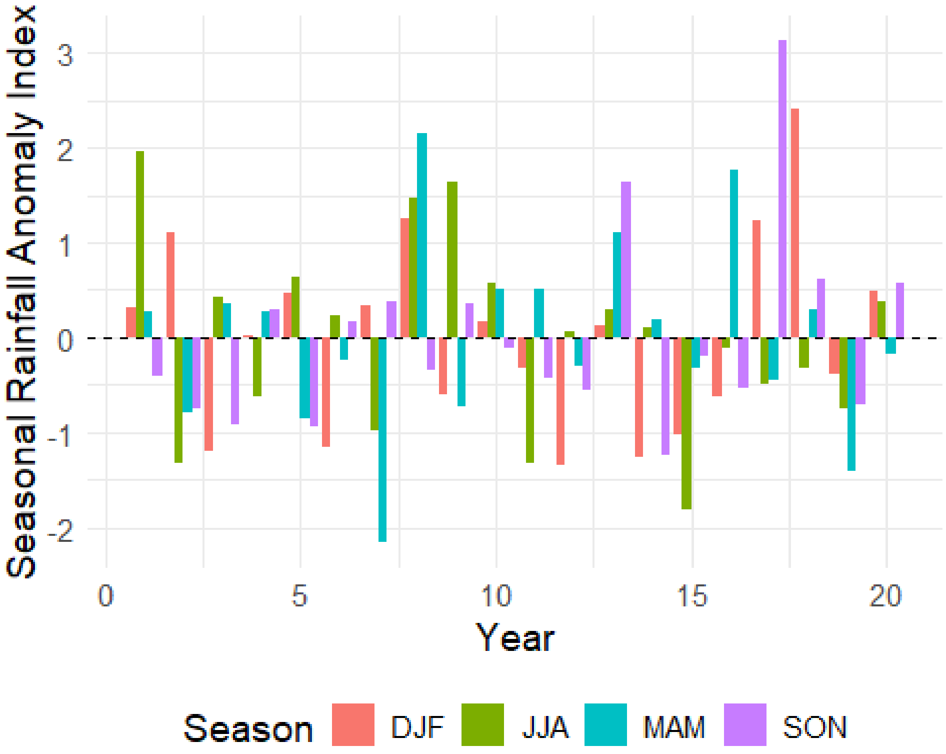
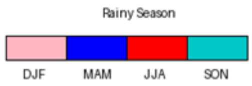


Figure 4: Seasonal Rainfall Anomaly Index (SRAI) for Soroti District between 2003–2022 across the four rainfall seasons (DJF, MAM, JJA, SON).

The long-term average distribution of monthly rainfall showed two rainfall seasons for Soroti (Figure 5). However, there were variations in the distribution between years with an observed reduction in rainfall received in March, one of the months of the first rainy season. The reduction was observed in 2003, 2007, 2009, 2012, 2015, 2016, 2017, 2019, 2021 and 2022 as compared to the long-term average (Figure 6).



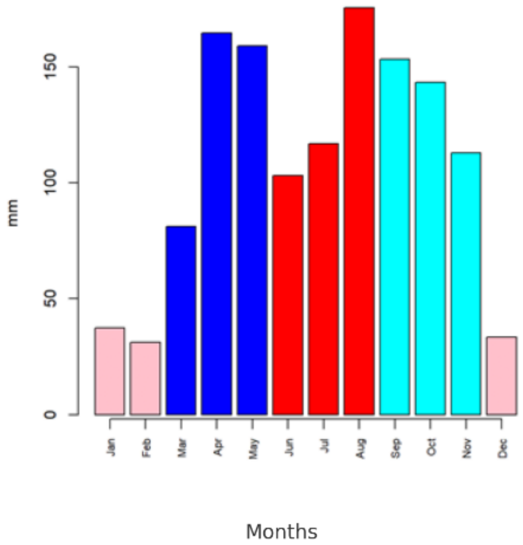


Figure 5: Long term (2003-2022) monthly rainfall distribution of Soroti district

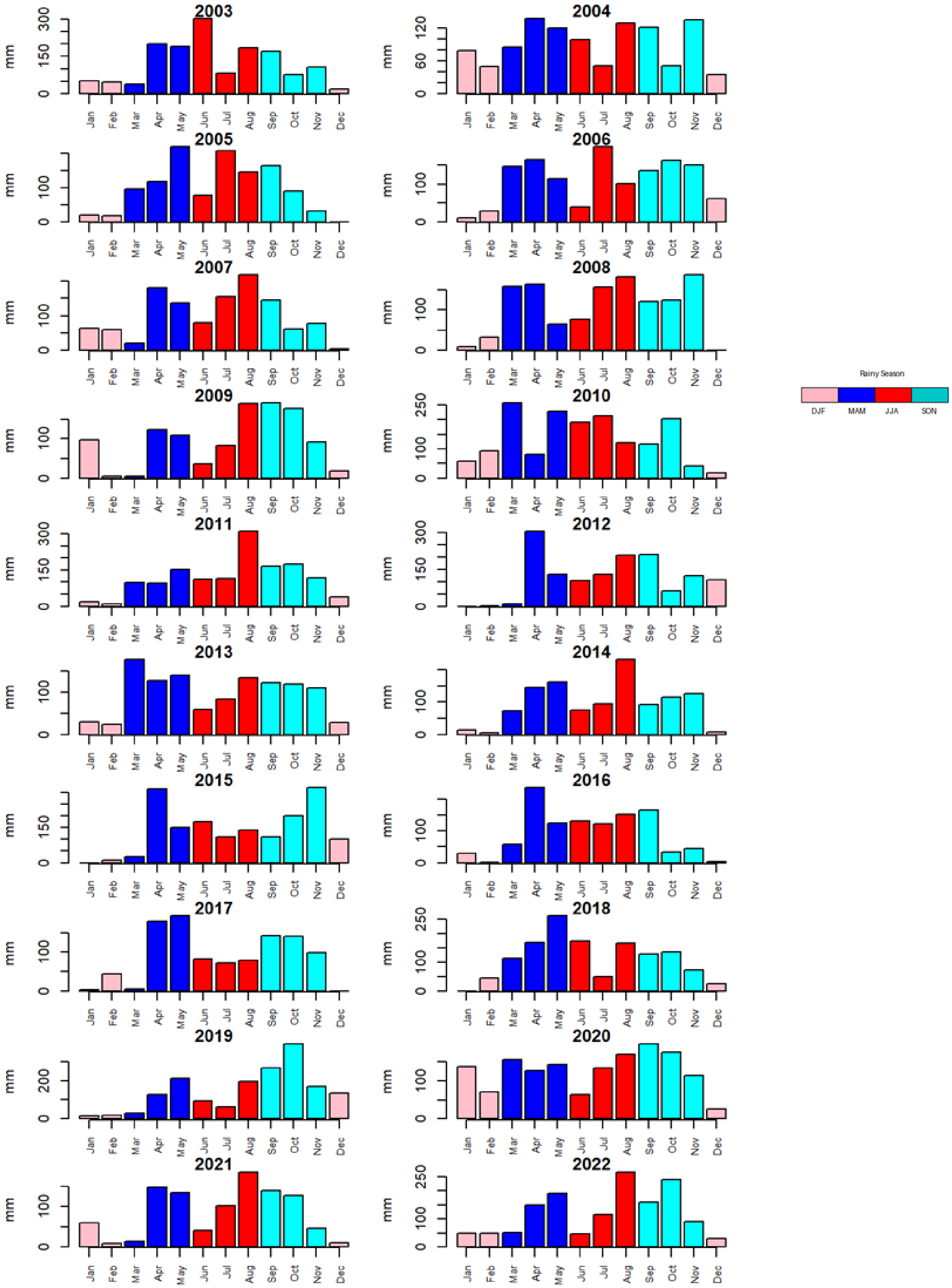


Figure 6: Monthly rainfall distribution for Soroti District from 2003 to 2022, with each panel representing one year.

3.1.3.3 Temperature variability

There was variation in the average, minimum and maximum temperature between years and seasons (Figure 7a, b, c and d). Over the 20-year period, the mean, minimum, and maximum temperatures averaged 24.68 ± 1.52 °C, 19.05 ± 1.22 °C, and 30.31 ± 2.46 °C, respectively. The highest average temperature was observed in 2005 (25.09ºC) with more years being above the long-term average in the second decade than in the first decade. The decade average, minimum and maximum temperatures for seasons varied from the long-term seasonal temperatures (Table 3). The DJF average, minimum and maximum temperatures were higher than the long-term means by 0.08, 0.09 and 0.07 ºC respectively in the 2003-2012 decade and reduced by the same values in the 2013-2022 decade. Conversely, the MAM and JJA average, minimum and maximum temperatures were lower than the long-term MAM and JJA means in the 2003-2012 decade and increased in the 2013-2022 decade. Unlike the maximum SON temperatures, the average and minimum SON temperatures reduced in the 2003-2012 decade and increased in the 2013-2022 decade.

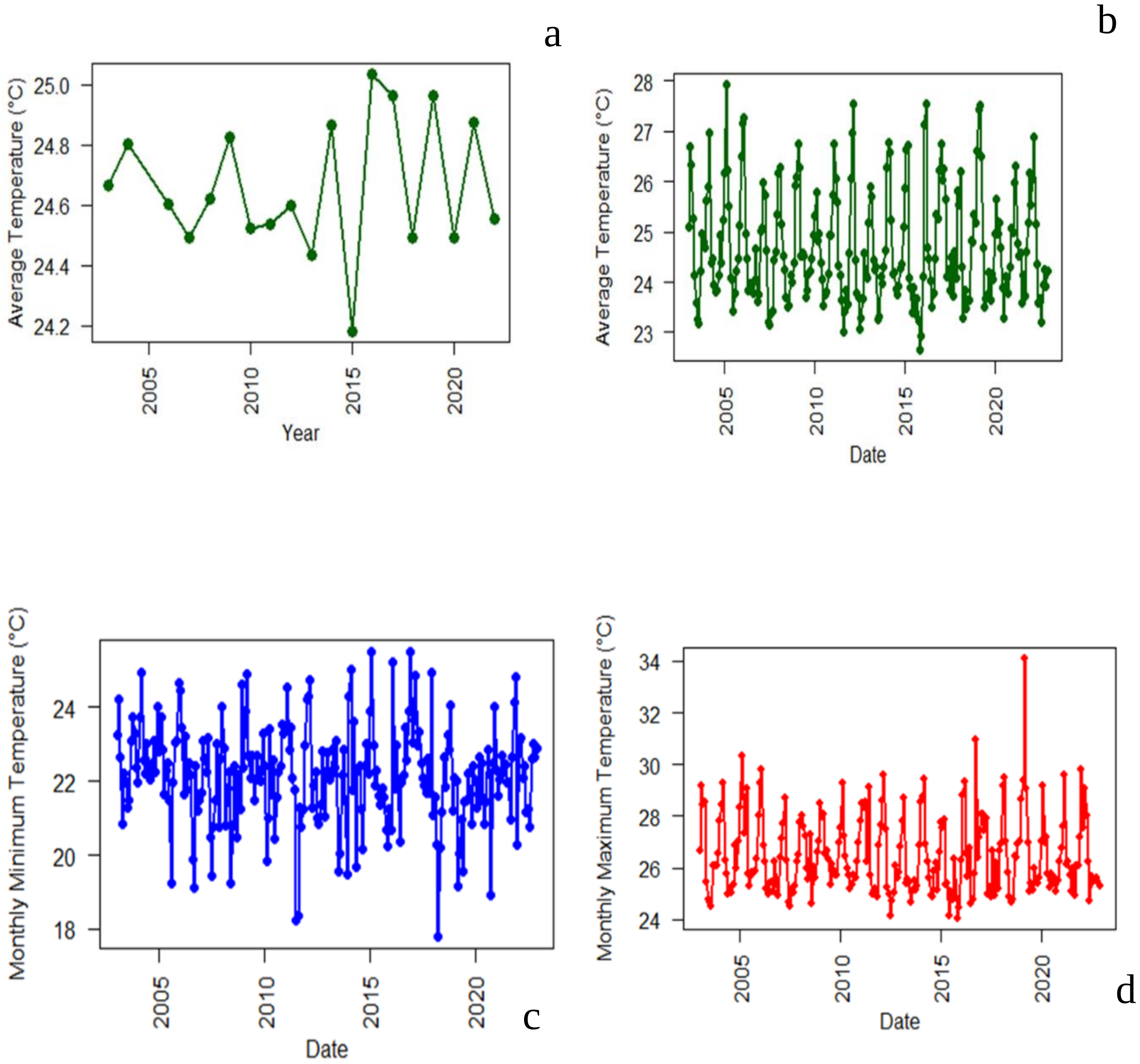


Figure 7: (a) Annual average temperature, (b) monthly average temperature (c) monthly minimum temperature (d) monthly maximum temperature for Soroti between 2003 and 2022.

Table 3: Seasonal average, minimum and maximum temperatures of Soroti district 2003-2022

		Season			
Variable	**Period**	**DJF**	**MAM**	**JJA**	**SON**
Average temp. (°C)	2003-2022	25.69± 1.48	25.11±1.65	23.70±0.98	24.24±1.01
	2003-2012	25.77±1.47	25.06±1.57	23.64±1.02	24.25±0.99
	2013-2022	25.61±1.48	25.16±1.73	23.76±0.94	24.23±1.04
Minimum temp. (°C)	2003-2022	19.22±1.33	19.56±1.26	18.72±1.03	18.70±1.04
	2003-2012	19.31±1.21	19.48±1.15	18.64±0.95	18.68±0.82
	2013-2022	19.13±1.43	19.63±1.37	18.80±1.09	18.72±1.22
Maximum temp. (°C)	2003-2022	32.15±2.38	30.67±2.61	28.68±1.60	29.77±1.62
	2003-2012	32.22±2.38	30.66±2.43	28.64±1.62	29.82±1.61
	2013-2022	32.08±2.39	30.68±2.79	28.72±1.58	29.73±1.62

DJF-December, January, February; MAM- March, April, May; JJA- June, July, August and SON- September, October, November

Results indicated that a higher number of days experienced maximum temperatures of ≥30 °C (Figure 8). Across both decades analyzed, the frequency of days with maximum temperature ≥30 °C remained consistently higher than those below 30 °C (Figure 8a). On an annual basis, more than half of the days in most years recorded maximum temperatures ≥30 °C, with 2016 registering as many as 266 days (Figure 8b). Seasonally, the DJF and MAM periods exhibited a greater proportion of days with maximum temperatures ≥30 °C (Figure 8c), whereas the JJA season had comparatively fewer hot days. Overall, within the study area six months of the year had a higher number of days experiencing temperatures ≥30 °C (Figure 8d).

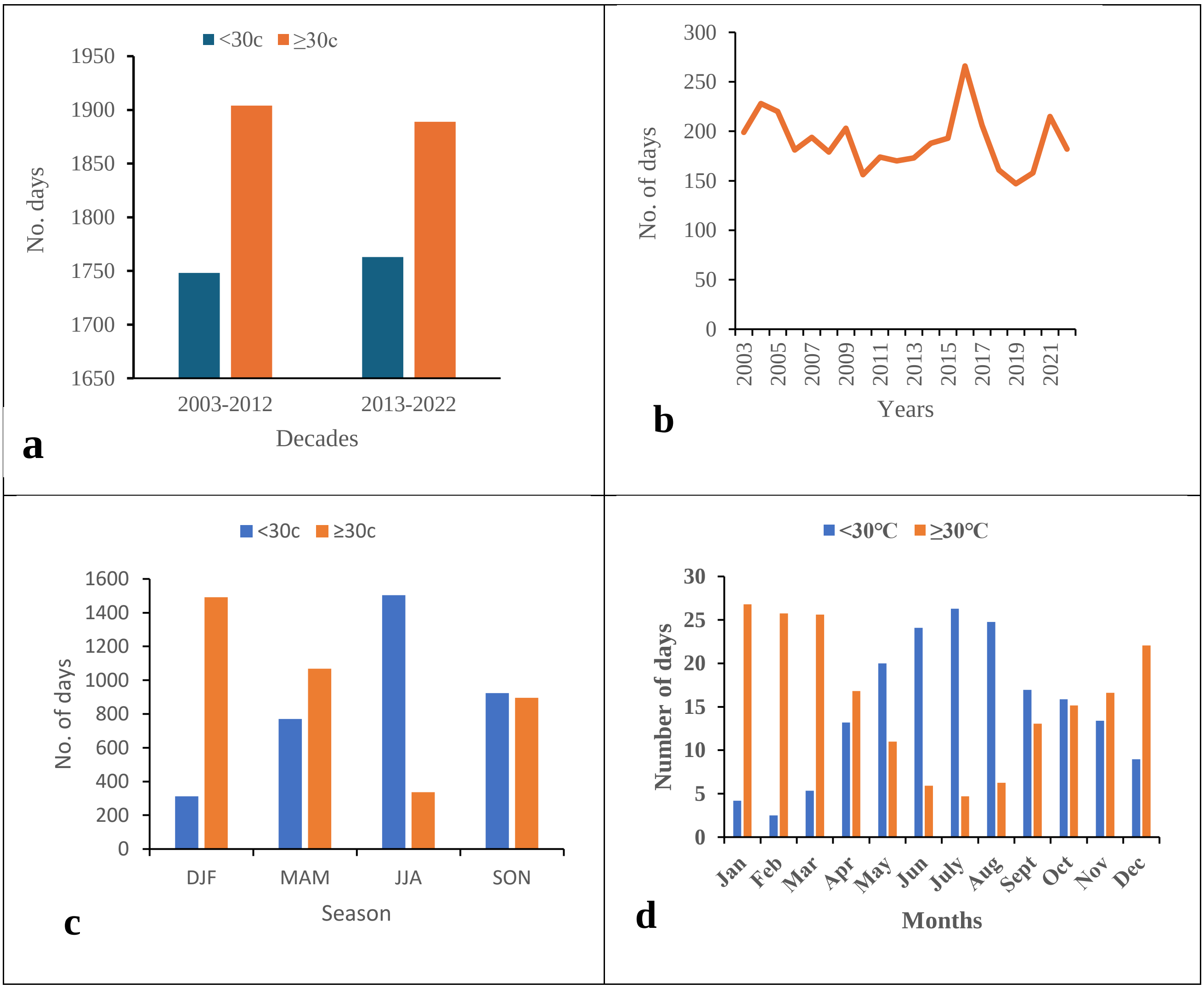


Figure 8: Number of days experiencing ≥30℃ in a) Decade, b) Year, c) Season d) Month

Standardized Temperature Index values indicated higher variability of monthly and annual temperatures from the long-term average (Figure 9). Variations in both directions of cooling (negative STI) and warming (positive STI) were observed. Although the lowest indices were observed in 2016 and 2018, more years in the second decade had indices with higher positive values than in the first decade.

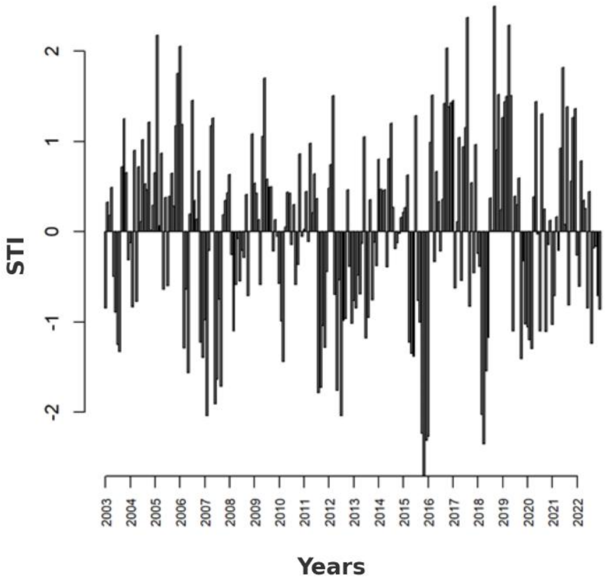


Figure 9: Standardized Temperature index for Soroti district (2003-2022)

3.1.3.4 Description of scavenging chicken production system in Soroti district

The results showed that scavenging chicken production in Soroti is dominated by indigenous chicken (IC) breeds, with only 4% of farmers raising Kuroiler hybrid chickens. Most households (79%) provided some form of shelter for their chickens, though this was primarily for nighttime use. The shelters varied, with chickens sharing the farmers’ houses, kitchens, or temporary structures. However, in 21% of households, chickens received no shelter at all throughout their lives. Chickens typically left their night shelters at sunrise to begin foraging and returned at sunset, with an average of 13 hours spent scavenging daily (FGD). During this time, they foraged for a variety of feed sources, including forage, insects, cereals, legumes, roots, tubers, household food waste, and other inert materials. Occasionally, farmers would supplement the chickens' diets, mainly with kitchen waste. All farmers allowed their scavenging chickens to incubate their eggs and brood their chicks.

Scavenging chicken production in Soroti is generally small-scale, with flock sizes ranging from 1 to 276 birds and an average flock size of 42 ± 39.8 chickens. Although a few farmers occasionally vaccinated their chickens, most (83.4%) relied on herbal concoctions to manage chicken diseases, while some used human medicine. Farmers reported that human medicine was cheaper, more accessible, and could be purchased in any desired quantity, unlike veterinary drugs. However, this practice is ethically questionable and should be strongly discouraged.

3.1.3.5 Respondents' characteristics

Majority of respondents were male (64.2%), and most were between 36 and 60 years old (67.5%) (Table 4). Chi-square analysis revealed a significant association between gender and education level ($\chi^2 = 14.723$, $p = 0.002$), access to credit ($\chi^2 = 4.727$, $p = 0.030$), and access to training ($\chi^2 = 11.844$, $p = 0.001$) among farmers rearing scavenging chickens. Despite only 16.6% of farmers having received formal training in poultry production, a higher proportion of males (28.9%) than females (6.6%) had been trained. Furthermore, males had significantly greater access to both credit and training compared to females. Most farmers (84.9%) reported being able to predict weather changes, and labor for managing scavenging chickens was primarily provided by women above 18 years of age (93.7%).

Table 4:Characteristics of farmers rearing scavenging chickens

Parameter (n=271)	**Level**	**Male**	**Female**	**Pooled**	χ^2	**p-value**
Respondent's age	Youth (30-35 years)	30	11	41	3.969	0.137
	Adults (36-60 years)	119	64	183		
	Elderly (61 years+)	25	22	47		
Education	No formal education	17	21	38	14.723	0.002*
	Primary	103	63	166		
	Secondary	42	9	51		
	Higher	12	4	16		
Access to credit	Yes	142	68	210	4.727	0.030*
	No	32	29	61		
Training in poultry	Yes	39	6	45	11.844	0.001*
	No	135	91	226		
Weather forecast ability	Yes	152	78	230	2.339	0.126
	No	22	19	41		
Labor for Scavenging Chickens	Children	2	3	5	1.883	0.390
	Men above 18	9	3	12		
	Women above 18	163	91	254		

*Statistically significant ($p<0.05$)

3.1.3.6 Knowledge of climate variability among indigenous chicken farmers

Results showed that a higher proportion of farmers knew about climate variability (Table 5). Chi square analysis revealed that there was a significant relationship ($\chi^2=4.913$, $P=0.027$)

between sex of respondents and knowledge about climate variability. In contrast, the relationship between education level and respondents' age with knowledge of climate variability was not significant. A higher proportion (90.7%) of female respondents knew about climate variability than males.

Table 5: Knowledge of climate variability among indigenous chicken farmers

		Knowledge of climate variability					
		No		**Yes**			
Attribute	Level	Freq.	%	Freq.	%	Chi-square	p-value
Sex	Male	34	19.5	140	80.5	4.913	**0.027***
	Female	9	9.3	88	90.7		
Education	No formal education	6	15.8	32	84.2	0.881	0.830
	Primary	24	14.5	142	85.5		
	Secondary or higher	13	19.4	54	80.6		
Respondent's age	Youth (Up to 35 years)	8	19.5	33	80.5	0.625	0.732
	Adults (36-60 years)	27	14.8	156	85.2		
	Elderly (61 years+)	8	17.0	39	83.0		

*Statistically significant (p<0.05)

3.1.3.7 Perception of climate variability among indigenous chicken farmers

Results indicated that perception of climate variability is significantly influenced by sex, education level, and age (Table 6). Sex had a statistically significant association with climate variability perception. Being female reduced the likelihood of perceiving that the climate varied to a greater extent by 84%. Overall, the level of education had a statistically negative influence on perception at both primary and secondary level, but not at higher levels. Individuals with primary and secondary education levels were 50% and 59% less likely, respectively, to perceive climate variability to a greater extent compared to those with no formal education. Among males, the likelihood of perceiving climate variability to a greater extent decreased with education, though this effect was not statistically significant (p>0.05). Similarly, for females, education reduced the likelihood of perceiving climate variability, although this was significant only at the primary level (p<0.05). Females that had attained primary education were 79% less likely to perceive climate variability to a greater extent compared to those with no formal education. Unlike education, age had a positive influence on perception of climate variability although only significant (p<0.05) for males. Male respondents between 36 and 60 years of age had a 59% higher likelihood to perceive climate variability to a greater extent than those below 36 years. This likelihood increased to 88% among males above 60 years of age.

Table 6: Ordered probit model results for indigenous chicken farmers' perception of climate variability

Variable	**overall**			**Males**			**Females**		
	Coef.	**95% Conf. interval**		**Coef.**	**95% Conf. interval**		**Coef.**	**95% Conf. interval**	
		lower limit	**Upper Limit**		**lower limit**	**Upper Limit**		**lower limit**	**Upper Limit**
Sex									
Female	-0.843 *	-1.171	-0.515						
Educ (Ref=No formal educ.)									
Primary	-0.497*	-0.934	-0.059	-0.27	-0.894	0.354	-0.791*	-1.423	-0.158
Secondary	-0.591*	-1.127	-0.054	-0.433	-1.133	0.267	-0.799	-1.767	0.17
Higher	-0.435	-1.181	0.311	-0.111	-1.023	0.801	-1.163	-2.702	0.377
Age group (30-35years)									
Adults (36-60)	0.433	-0.006	0.872	0.592*	0.068	1.116	0.008	-0.835	0.851
Elderly (>60)	0.485	-0.062	1.033	0.883*	0.2	1.567	-0.234	-1.225	0.757
/cut1	-2.589	-3.3	-1.879	-2.327	-3.355	-1.298	-2.435	-3.536	-1.333
/cut2	-0.349	-0.948	0.25	0.02	-0.75	0.79	-0.197	-1.199	0.805
/cut3	-0.275	-0.873	0.323	0.096	-0.673	0.865	-0.127	-1.129	0.875
/cut4	1.163	0.545	1.781	1.521	0.72	2.322	1.478	0.385	2.572
N	228			140			88		
LR chi2(6)	32.57			9.66			7.46		
P value	0			0.086			0.189		

*Statistically significant (p<0.05)

Most the farmers characterized climate variability as; a decrease in annual rainfall (63.8%), reduced rainfall intensity (75.3%), and a shortened duration of both the first (67.3%) and second rainy seasons, as well as a decline in hailstone occurrence (49.4%) (Table 7). Although most farmers perceived a reduction in rainfall for both seasons, a relatively higher proportion (43.5%) perceived an increase in the length of the second rainy season. Additionally, a higher proportion of farmers perceived an increase in frequency of drought (79%), dry and rainy season temperatures (91% & 71% respectively), wind intensity of both the dry (71.5%) and rainy season (44.9%) and floods (38%). Whereas more male respondents perceived an increase in both dry and rainy season temperatures, a high percentage of females (43%) perceived a decrease in rainy season temperature. A higher proportion of female respondents than males had not observed changes in rainfall and temperatures. On the contrary, more male respondents opined that they had observed no change in wind intensity, lightning and thunder and hailstones than females. These perceived variations were consistently reported in both the FGD and KII. For instance, one female farmer reported that:

"*The rains now come very late and very little. For example, we used to start planting crops in March but these days we wait for the rains until April. Some farmers even miss out on the season. These changes have brought hunger to our area".*

In addition, during a key informant interview, a natural resource officer confirmed the climatic variations in the area in his excerpt below:

"The variation in rainfall seasons in Soroti is real and is seemingly taking Soroti from two to one rainfall season, the rains are currently so unpredictable. For instance, the first rainy season was between March and May but recent rains delay up to end of April, in some areas serious rains are received as late as May. December used to have very few rainy days and January almost none, but currently we get many rainy days in December and some rainy days even in January which are typically known dry months". (Male KI)

Table 7: Indigenous chicken farmers’ perceptions of climate variability

Parameter		**Percentage responses**											
		Male				**Female**				**Pooled**			
		↑sed	↓sed	No change	Do not know	↑sed	↓sed	No change	Do not know	↑sed	↓sed	No change	Do not know
Rainfall	Annual rainfall	29.9	70.1	0.0	-	46.4	52.6	1.0	-	35.8	63.8	0.4	-
	Intensity of 1st rains	25.9	73.6	0.6	-	18.6	78.4	3.1	-	23.2	75.3	1.5	-
	Intensity of 2nd rains	40.2	58.0	1.7	-	42.3	47.4	10.3	-	41.0	54.2	4.8	-
	Length of 1st rains	31.0	67.8	1.1	-	22.1	66.3	11.6	-	27.9	67.3	4.8	-
	Length of 2nd rains	43.9	52.0	4.0	-	42.7	47.9	9.4	-	43.5	50.6	5.9	-
	Flood Frequency	42.1	35.7	22.2	-	41.9	29.7	28.4	-	38.0	37.5	24.5	-
	Drought frequency	87.9	5.2	4.0	2.9	63.9	16.5	13.4	6.2	79.3	9.2	7.4	4.1
Temp.	Dry season temps	94.8	2.9	2.3	0.0	84.5	14.4	1.0	0.0	91.1	7.0	1.8	0.0
	Rainy season temps	82.8	10.9	6.3	0.0	50.5	43.3	6.2	0.0	71.2	22.5	6.3	0.0
Wind	Intensity of dry season	77.3	14.0	8.7	-	61.1	30.5	8.4	-	71.5	19.9	8.6	-
	Intensity of rainy season	49.1	32.2	17.5	1.2	37.2	52.1	10.6	0.0	44.9	39.2	15.1	0.8
Others	Lightning and thunder	34.7	30.1	26.0	9.2	45.7	29.8	20.2	4.3	38.6	30.0	24.0	7.5
	Hailstones	14.5	50.6	19.2	15.7	28.0	47.3	15.1	9.7	19.2	49.4	17.7	13.6

↓sed- decreased, ↑sed increased

3.1.3.8 Perceived causes of climate variability

Most (>50) farmers attributed climate variability to human activities, particularly poor farming practices such as tree cutting and swamp reclamation. Others perceived the variations to be caused by pollution and supernatural forces whereas some believed that whatever was happening was within the realm of normal and anticipated climatic variations (Figure 10). Chi square analysis revealed a non-significant relationship (χ^2=48.6939, P =0.094) between the sex of respondents and their perceptions about the cause of climate variability. These results were supported by the FGDs, with discussants citing deforestation for charcoal production, agriculture and human settlement driven by population growth as contributors to climate variability. In addition, swamp reclamation, majorly for agriculture, was frequently cited by key informants and discussants as a contributor to variations in climate. In this case much reference was made to a local swamp known as Awoja swamp. Regarding pollution, discussants and key informants identified the frequent use of herbicides, pesticides, acaricides, and fertilizers as major contributors. A few also mentioned fumes from industries, as highlighted in the excerpt below;

'Many farmers of recent frequently use chemicals to control pests and weeds because farmers are lazy, but these chemicals spoil the environment and that is why we're seeing these problems of a very long drought' (Male KI).

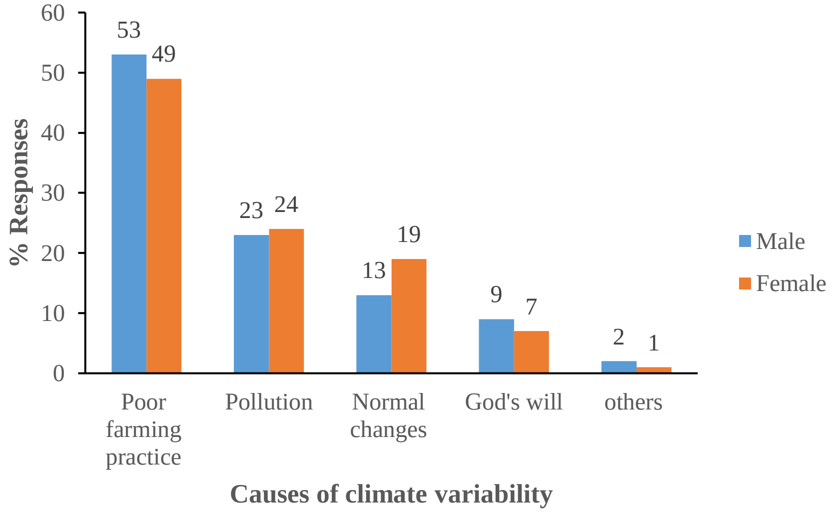


Figure 10: Perceived causes of climate variability by indigenous chicken farmers

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3.1.3.9 Perceived effects of high temperature on performance of scavenging chickens

Farmers reported that high temperatures had various effects on the productivity of scavenging chickens (Table 8). These effects ranged from behavioral changes to reduced productivity. Nearly all farmers (97.4%) observed that chickens reduced their typical activities such as moving, flying, ground scratching, and foraging, instead spending more time resting under shade. During focus group discussions, it was highlighted that scavenging time decreased by approximately 46% during the dry season when temperatures are high. This was emphasised by a key informant in the following excerpt:

"Previously, chickens would scavenge the whole day, returning home late in the evening. Lately, they stay near the homestead under shade, spending less time looking for food and more time resting, especially during the dry season. They start seeking shade at 10:00 a.m. and resume foraging at 4:00 p.m." (Female KI)

Farmers also noted other behavioral changes in scavenging chickens during high temperatures, such as increased water intake, dust bathing, wing elevation, and panting responses. In addition, over 60% of farmers believed that rising temperatures reduced egg hatchability. Farmers perceived a significant ($p<0.05$) decline in egg production (8.7%) and hatchability (5.2%) over the past decade (Table 9). Other reported effects included increased disease incidence, higher flock mortality, and reduced egg weight. A veterinary officer interviewed during a key informant interview confirmed that chicken diseases, particularly Newcastle disease, had increased in recent years, especially during the dry season:

"I have worked in this area for the past twelve years, and chicken diseases—especially Newcastle—are on the rise, particularly during the dry season. Despite some chickens now being vaccinated, a recent initiative by The Teso Initiative for Peace (TIP) trained community vaccinators and equipped them with coolers and vaccines. However, farmers still report significant losses due to disease." (Male KI)

Table 8: Perceived effects of high temperatures on scavenging chicken performance

Behavioral effects	**Freq.**	**%**
Reduced activity[a]	263	97.4
Increased water intake	218	80.7
Dust bathing	145	53.7
Elevate wings	84	31.1
Pant	79	29.3
Other[b]	7	2.6
Production effects		
Reduced egg hatchability	170	63.4
Increased disease incidence	157	58.6
Reduced egg production	150	56.0
Reduced weight gain	146	54.5
Increased egg spoilage	127	47.4
Increased mortality	121	45.1
Reduced feed intake	113	42.2

[a] Movement, flying ground scratching, foraging; [b]Chickens abandon eggs halfway during hatching, chickens become dull, isolate themselves.

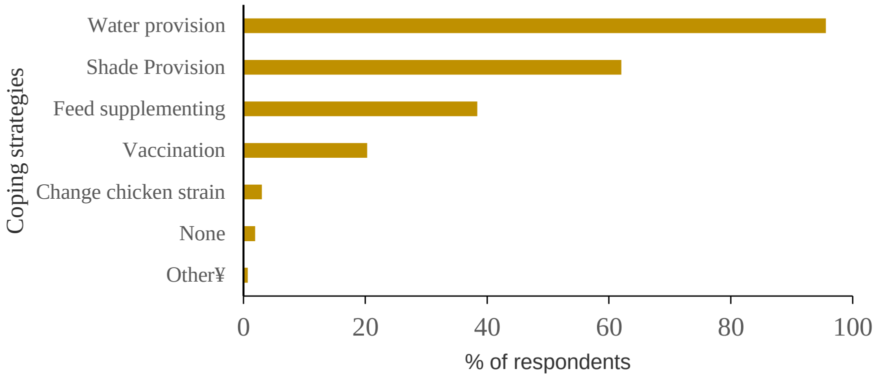
Table 9: Perceived reduction in scavenging chicken egg production and hatchability

Parameter	**Last 10 years**	**Currently (2023)**	**SEM**	**P-value**
Average no. of eggs laid	15	14	0.3347	0.000*
No. of eggs set for hatching	14	12	0.3174	0.000*
Hatchability	90	85	0.9374	0.000*

*Statistically significant (p<0.05)

3.1.3.10 Coping strategies employed by scavenging chicken farmers

While some farmers did not adopt any coping strategies, a significant number implemented one or more approaches (Figure 11). Majority (96.3%) of farmers coped by providing water to their chickens, shade and supplementing their birds.



¥putting moist sand under set eggs for hatching, raising broody nests off the floor, releasing birds so early in the morning.

Figure 11: Strategies employed by farmers rearing scavenging chickens to cope with high temperatures

Among the farmers who copped by providing water, 87% supplied water consistently throughout the dry season, with most (98%) sourcing it from boreholes and ensuring it was clean and fresh (98.3%; Figure 12). However, some farmers resorted to using wastewater, and 34% indicated that their water sources were affected by seasonal changes.

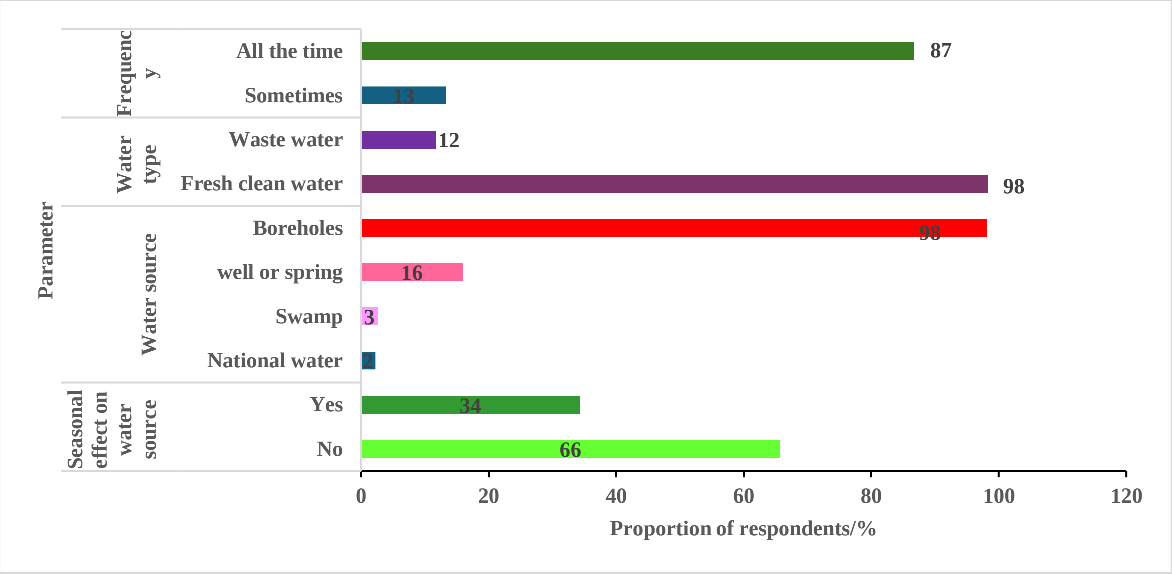


Figure 12: Water source, availability, type and frequency of water supplementation

Other strategies adopted by farmers included vaccination to reduce the disease incidence, raised nests off the floor to allow for proper aeration, placed moist sand under nests for natural egg incubation, changing chicken breeds, and releasing chickens earlier in the morning to maximize feeding time. Figure 13 shows some of the coping strategies employed by farmers.

Figure 13: Coping strategies employed by farmers (a) A farmer supplementing chickens with household leftovers, (b) Watering point constructed under a shade (c) Chicken laying and broody nests raised off the ground (d) Temporary structure to provide shade to chickens

3.1.3.11 Factors Influencing the choice of coping strategy among scavenging chicken farmers

The probit regression analysis revealed that several factors significantly influence farmers' ability to cope with high temperatures (Table 10). The provision of shade for chickens was notably influenced by gender, flock size, and farmland size, while its implementation as a coping strategy reduced with age and the number of chickens sold annually. For instance, being female increased the likelihood of providing shade by 18.7%, while a one-year increase in farmer’s age reduced this likelihood by 0.5%. Larger farmland sizes increased the probability of using tree planting as a shading strategy.

Feed supplementation, as a strategy for enhancing feed security, was positively influenced by gender, training in poultry production, access to weather information, and the number of chickens sold annually. Conversely, the likelihood to cope by supplementing feed is reduced with education level, flock size, and the farmer's ability to forecast weather changes. Training in poultry production also increased the likelihood of coping through supplementation.

The total number of chickens reared, access to weather information, and the ability to predict weather changes significantly increased the likelihood of providing water as a coping strategy. In contrast, the likelihood of implementing the strategy reduced with farmland size. Farmers with access to weather information and the ability to predict weather changes were 7.5% and 13.4% more likely to provide water, respectively, while a one-acre increase in farmland size reduced the likelihood of water provision by 1.7%. Contrary to literature, household size and access to credit did not significantly influence the choice of any coping strategy.

Table 10: Factors influencing coping with high temperatures among farmers rearing scavenging chickens

	Shade provision		**Feed Supplementation**		**provision of water**	
Variable	dy/dx	P>z	dy/dx	P>z	dy/dx	P>z
Age	-0.005	0.034*	0.001	0.704	0.000	0.845
Gender	0.187	0.001*	0.197	0.001*	0.012	0.720
Education						
primary	0.140	0.111	-0.241	0.003*	0.054	0.363
secondary	0.170	0.110	-0.172	0.089	0.094	0.128
higher	0.262	0.050	-0.286	0.034*	0.044	0.592
Training in poultry	0.092	0.223	0.172	0.034*	-0.043	0.449
Flock size	0.002	0.013*	-0.003	0.005*	0.001	0.042*
Weather forecast knowledge	0.119	0.146	-0.152	0.049*	0.134	0.023*
Farmland size	0.036	0.004*	-0.011	0.303	-0.017	0.001*
No. of chickens sold	-0.002	0.021*	0.004	0.001*	0.000	0.549
Weather information access	0.032	0.437	0.119	0.003*	0.075	0.026*
Household size	-0.012	0.134	-0.002	0.812	0.005	0.358
Access to credit	0.043	0.562	0.017	0.810	-0.018	0.603

*Significant at p<0.05

3.1.4 Discussion

3.1.4.1 Climate variability in Soroti district

Results of the trend analysis, although not statistically significant, suggest modest increases in both rainfall and temperature over the study period, with a significant upward trend in monthly minimum temperature, indicating warmer nights. Considering the Seasonal Rainfall Anomaly Index (SRAI), most seasons fell within the near-normal class with occasional moderate wet or dry episodes and rare extreme anomalies, ($|RAI| \mid \geq 2$) (Khalil, 2022). This pattern highlights inter-annual and inter-seasonal variability rather than a persistent shift in mean rainfall, consistent with earlier studies in Soroti and other parts of Uganda (Kilama Luwa et al., 2021; Ngoma et al., 2021; Obubu et al., 2021). In contrast, (Nsubuga & Rautenbach, 2018) reported increases in both minimum and maximum temperatures, with minimal or no long-term change for annual rainfall totals. The Standardized Temperature Index showed frequent fluctuations around the long-term mean, with years from 2015 to 2019 experiencing pronounced positive deviations, reflecting episodes of elevated thermal stress. Together, the SRAI and STI results demonstrate that while overall trends remain modest, rainfall and temperature extremes occur episodically. The observed warmer nights and occasional drought or flood years pose significant implications for agricultural systems, warranting mitigation measures to minimize future increases beyond projected values.

3.1.4.2 Indigenous chicken farmers' perceptions of climate variability

Chicken farmers exhibited strong knowledge of climate variability, encompassing both general awareness and perceptions of changes. This result is informed by extreme events like droughts encountered by farmers within the study area in the past (Lujala et al., 2015; Nabikolo, 2014). In contrast to the present findings, a higher proportion of farmers reported an increase in the frequency of flood occurrences in the study by Kisauzi (2014). This variation could be attributed to the difference in the years under consideration (Lujala et al., 2015). Farmers' perception of the extent of climate variability suggests that sex, age and education play a role in shaping climate change perceptions. On the other hand, some farmers were not aware of and perceived no variability in climate. This suggests that such farmers are less likely to adopt any mitigation measures. For farmers that perceived climate variability as a reality, they associated it to poor farming practices as the main cause. Such acceptance shows a sense of responsibility on the part of the farmers and could therefore signal a sense of willingness to contribute to finding and adopting appropriate solutions to avert the situation. On the contrary, farmers that indicated that climate variability is a natural phenomenon would be less likely to adapt to the changes. However, the global scientific consensus clearly attributes recent climate change primarily to anthropogenic greenhouse gas emissions from fossil fuel combustion, agriculture, and land-use change (IPCC, 2023). While farmers' perceptions of tree cutting and swamp reclamation as drivers align with elements of this understanding, other perceived causes such as supernatural forces are less supported by empirical scientific evidence. Therefore, these findings warrant greater sensitization of chicken farmers on issues of climate variability and the need to increase the resilience of the scavenging chicken production system to the changing environment.

3.1.4.3 Comparison of station results and farmers' perceptions

Farmers' perceptions of inter-seasonal and inter annual climate variability aligned with meteorological variability results, notably the minimum temperature but not rainfall trends. The consistency between climatic data and farmers' perceptions of increased temperatures may be attributed to the direct effects of high temperatures on chicken productivity for example perceived poor egg hatchability, reduced egg production, slow growth, increased disease incidence and chicken mortality (Nampijja et al., 2025). In addition, indirect effects like the perceived decline in food crop yields which influences scavengeable feed resource availability have also been reported (Nyang'au et al., 2021). Notably, more female farmers who are typically care takers of chickens and food crop producers demonstrated greater knowledge of climate variability, with their perceptions being more aligned to the meteorological data than those of their male counterparts. Results from the FGDs and KIIs also indicated that female's perceptions connected more with food, and the scavenging chicken production and management.

On the other hand, the discrepancy with rainfall data could indicate that farmers' perceptions are shaped by factors beyond annual totals. Studies from Ethiopia and Ghana show that farmers often perceive a declining trend in rainfall, citing delayed onset, earlier cessation, shorter duration, and more frequent droughts, even when meteorological records indicate relatively constant totals (Asare-Nuamah & Botchway, 2019; Hubertus et al., 2023). These findings suggest that farmers assess rainfall by its usefulness within crop cycles rather than by aggregate volumes. In our study area, such shifts during the critical MAM season likely reduced crop harvests and residues, and these are key feed sources for scavenging chickens

(Admasu et al., 2019), thereby reinforcing perceptions of declining rainfall despite station records. At the same time, demographic differences were evident, with female farmers, youth, and persons with higher education perceiving only small changes, aligning more closely with station records. While this reflects some awareness, farmers are nevertheless unable to reliably project the onset, duration, and cessation of rainfall because of ongoing variability, and these uncertainties directly affect their agricultural calendars.

Sensitization efforts should therefore prioritize building capacity in interpreting and using information on rainfall timing and distribution, since these parameters strongly determine planting dates, crop choice, and feed resource availability. Such targeted communication delivered through gender-responsive platforms for women (Jost et al., 2016; Tall et al., 2018), ICT-based tools for youth (Below et al., 2012), and simplified formats for farmers with lower education (Tall et al., 2018) would help ensure that timely weather information is more accessible and actionable in a rain-fed production system.

3.1.4.4 Perceived effects of high temperature on performance of scavenging chickens

The behavioral changes reported among scavenging chickens during high temperatures, are similar to those reported for heat-stressed intensively reared chickens (Abioja and Abiona, 2020). In commercial broiler chickens, heat stress occurs when temperatures exceed 30 °C (Quinteiro-Filho et al., 2010). Soroti's average maximum temperature of 30.31 °C (Nampijja et al., 2024) is high enough to induce heat stress in commercial lines. However, since the threshold temperature for heat stress in scavenging chickens remains undefined, this study cannot definitively conclude that these chickens are experiencing heat stress. Further research is required to establish a specific heat stress threshold for scavenging chickens.

The reported reduction in growth, egg production and hatchability have long-term consequences for flock size. If left unaddressed, these challenges could pose a serious threat to the scavenging chicken population. Other reported effects included increased disease incidence, higher flock mortality, and reduced egg weight. Such results have been previously reported among smallholder chicken producing communities (Sesay et al., 2022). The optimal temperature range for chicken weight gain and egg production is between 18 and 22 °C (Charles and Walker, 2002). However, Nampijja et al. (2025) reported an average temperature of 24.68 °C in Soroti, which exceeds this range and may explain the perceived reduction in productivity. The reduced growth and egg production perceived in this study could also be attributed to lower feed intake due to decreased scavenging time, as highlighted by both the current study and earlier research by (Nampijja et al., 2023).

During focus group discussions, farmers suggested that the very high nest temperatures that accumulate during natural egg incubation specifically during periods of high temperatures contribute to reduced hatchability by causing hens to abandon their eggs. However, this assertion requires scientific validation. Hatchability is known to decrease when eggs are stored at temperatures above 18 °C (Özlü et al., 2021), which is even lower than Soroti's minimum temperature of 19.05 °C (Nampijja et al., 2024). Thus, improper storage conditions may be a factor in the reduced hatchability perceived by farmers. Additionally, hatchability declines when incubation temperatures exceed 37.5°C (French, 2000), but the current study cannot attribute farmers' perceived reduction in hatchability to this, as the effect of environmental temperature on natural incubation remains unexamined.

The increased disease incidence, particularly during the dry season, highlighted by both key informants and focus group participants, aligns with findings from earlier perceptual (Sesay et al., 2022) and empirical studies (Abioja and Abiona, 2020). These results demonstrate that farmers are aware of the impact of high temperatures on scavenging chicken production and are well-positioned to adopt coping strategies if tailored to their specific production systems.

3.1.4.5 Coping strategies employed by scavenging chicken farmers

A result that some farmers never adopted any coping strategy is consistent with observations by Wheeler and Lobley, (2021) in the United Kingdom, while the predominance of water provision is in line with findings in Nigeria (Adepoju and Osunbor, 2018). During the Focus Group Discussions, farmers detailed the challenges of the dry season on water availability, describing reductions in water quantity, restricted access (often limited to early morning hours), deterioration in water quality, and, in some cases, the complete drying up of water sources. Notably, water provision, while a critical strategy for managing heat stress, is highly sensitive to climate variability (FAO, 2016). The reliance on seasonal water sources underscores the limited adaptive capacity of some farmers. This seasonal vulnerability in water access has also been reported among smallholder farmers in Kenya (Kalele et al., 2021). Additionally, replenishing electrolytes lost through panting by adding salts like sodium chloride to water is a beneficial practice that can enhance water intake (Abioja and

Abiona, 2020). However, none of the farmers reported employing this strategy, likely due to a lack of awareness of its advantages.

The use of food waste and cereals as a supplement is consistent with previous studies that found household food waste and cereals to significantly contribute to scavenging chickens' diets (Admasu et al., 2019). However, these feed sources become scarce during severe droughts (Mekonnen et al., 2021), as evidenced by a reduction of up to 81 kg per acre in maize yield for every degree increase in temperature (Mekonnen et al., 2021). Predictions for Uganda suggest that maize yields could decrease by 50% due to climate change (Nimusiima et al., 2018), highlighting the limitations of relying on food waste as a long-term feed strategy for scavenging chickens in the face of climate shocks.

Although a decline in egg hatchability was one of the most perceived effects of high temperatures, very few farmers employed specific coping strategies to address this challenge. Among the strategies employed included raising nests off the floor to allow for proper aeration and placing moist sand under nests for natural egg incubation. Although this indigenous practice was unfamiliar to many and has not been previously reported in the literature, it represents valuable knowledge that warrants further investigation and documentation. Similar coping strategies aimed at temperature and humidity regulation through use of fans, foggers, tunnel ventilators have been observed in commercial chicken lines (Abioja & Abiona, 2020). This underscores the adaptability of scavenging chicken farmers who, within their means, have developed approaches to manage temperature-related challenges. However, the limited range of coping strategies and the suboptimal implementation are unlikely to provide adequate protection for scavenging chickens under the increasingly frequent and severe climatic extremes projected in the future.

3.1.4.6 Factors Influencing the choice of coping strategy among scavenging chicken farmers

Understanding the factors that influence is crucial for enhancing the resilience of farmers in managing the challenges posed by rising temperatures. Gender played a significant role, as farmers reported that chickens sought shade between 11:00 a.m. and 4:00 p.m. (FGD), a period when most men were typically away from home (Chaudhury et al., 2012), especially during dry seasons. However, this finding contrasts with earlier studies, which indicated that women are less likely to cope with climate variability (Belay et al., 2022). The discrepancy may arise from differences in the type of coping strategies considered, as the current study found that women often provided temporary shades, a simpler adaptation mentioned during FGDs and KIIs. The reduced likelihood to cope associated with age aligns with findings from Kenya, where older crop farmers were less likely to adopt agroforestry (Kinuthia et al., 2018), and from Nigeria, where older poultry farmers showed similar trends (Adepoju and Osunbor, 2018). Since agroforestry, identified as a key shading source, was a coping strategy, the reluctance of older farmers could be attributed to a conservative approach toward new practices.

Feed supplementation, as a strategy for enhancing feed security, was positively influenced by gender, training in poultry production, access to weather information, and the number of chickens sold annually. Conversely, the likelihood to cope by supplementing feed is reduced with education level, flock size, and the farmer's ability to forecast weather changes. Similar findings have been reported among smallholder farmers in Kenya (Gebre et al., 2023) and small-scale poultry farmers in Nigeria (Adepoju and Osunbor, 2018). However, contrary to many studies that found females less likely to adapt to climate change (Shikuku et al., 2017; Belay et al., 2022), or those reporting no significant gender influence (Silvestri et al., 2012), this study observed a strong influence of gender. This could be due to the nature of the supplements provided, primarily household food waste and cereal leftovers (Admasu et al., 2019), which are typically managed by women in their roles related to food preparation and post-harvest handling of cereals. Furthermore, women were responsible for almost all management practices related to chicken production, as indicated by 93.7% of respondents, who reported that women above the age of 18 years managed the chickens. Training in poultry production also increased the likelihood of coping through supplementation, a result consistent with previous findings (Gebre et al., 2023). This emphasizes the critical role of training in disseminating knowledge and promoting adaptation strategies. Larger farmland sizes increased the probability of using tree planting as a shading strategy in a study by Bryan et al. (2013), and this was one of the key sources of shade for chickens in this study.

The influence of education on adopting coping strategies is ambiguous in the literature. While some studies report higher adoption rates among educated farmers (Kinuthia et al., 2018), which contrasts with the current study, others report similar results (Omodara et al., 2023). In this study, many women responsible for chicken care had lower levels of education or none at all and likely relied on experience rather than formal knowledge. Moreover, poultry production is not taught at the primary education level, which most farmers in this study had attained. Additionally, farmers with larger flocks were less likely to supplement feed, probably due to the scarcity of available supplements for larger flocks.

The total number of chickens reared, access to weather information, and the ability to predict weather changes significantly increased the likelihood of providing water as a coping strategy. In contrast, the likelihood of implementing the strategy reduced with farmland size. Farmers with access to weather information and the ability to predict weather changes were 7.5% and 13.4% more likely to provide water, respectively, while a one-acre increase in farmland size reduced the likelihood of water provision by 1.7%. These findings align with previous studies (Belay et al., 2022; Gebre et al., 2023) that reported a positive influence of access to weather information, though some studies present contradictory results (Omodara et al., 2023).

Contrary to literature, household size and access to credit did not significantly influence the choice of any coping strategy (Shikuku et al., 2017; Belay et al., 2022). This may be explained by the small flock sizes, with an average of 41.8 ± 39.8 chickens per household. Additionally, scavenging systems require less labor compared to other livestock management or crop production strategies like mulching, terracing, and manure application (Nyang'au et al., 2021). These findings are consistent with (Nabikolo, 2014). However, they contrast with studies by Shikuku et al. (2017) and Belay et al. (2022) which reported positive influence household size. Similarly, Adepoju and Osunbor, (2018) and Kinuthia et al. (2018), found that the likelihood of coping increased with household size increased. The lack of influence from credit access could be attributed to the fact that most coping strategies did not incur direct costs. For instance, 94.5% of farmers accessed water at no cost, feed supplements were sourced from household waste or harvested cereals, and the shades provided were temporary and locally made.

3.1.5 Conclusions and recommendations

3.1.5.1 Conclusions

Scavenging chicken farmers in Soroti District demonstrated strong knowledge and perceptions of climate variability. Climatic data, supported by the Seasonal Rainfall Anomaly Index (SRAI) and the Standardized Temperature Index (STI), similarly revealed variability in rainfall and temperature, with generally positive but non-significant trends. Farmer perceptions of rising minimum temperatures were consistent with meteorological and STI results, while perceptions of decreasing rainfall showed less agreement with station data. The majority of farmers attributed the causes of climate variability to poor farming practices and pollution. Farmers perceived noticeable behavioral changes and reduced productivity in their chickens, including decreased foraging time, reduced egg production, and higher disease incidence, which they attributed to higher temperatures. In response, a range of coping strategies were adopted, including providing shade, water and feed supplements. However, the adoption of these strategies was influenced by gender, access to training and weather information increased the likelihood of coping but education, age and flock size decreased it

3.1.5.2 Recommendations

It is worth noting that this study relied on climatic data from a single synoptic station (UNMA Soroti). This was the case because the station is officially mandated to collect weather data and has the most consistent and reliable long-term source data for the district. While adequate for trend analysis, future studies could complement such data with gridded products, satellite observations, or additional stations to better capture localized spatial variability.

Despite the observed variability in climatic data, not all farmers perceived these changes. This underscores the need for sensitization initiatives to enhance farmers' awareness of climate variability and to provide timely, accurate weather information and forecasts. Further research is also essential to strengthen farmers' capacity to anticipate the onset, duration, and cessation of seasons amidst the prevailing variability.

The findings underscore the need for targeted interventions to support farmers in coping with climate variability as well as emphasizing the importance of conducting scientific investigations to validate indigenous knowledge employed in copying with climate variability. Training programs on effective poultry management, along with improved access to reliable weather forecasts, are critical in enhancing farmers' resilience. Furthermore, for policy makers investing in infrastructure to ensure reliable water supply, providing subsidies for high quality chicken feed supplements and supporting sustainable solutions, such as solar-powered egg incubators and communal indigenous chicken vaccination programs, can significantly improve the adaptive capacity of farmers. Ultimately, addressing these challenges will help safeguard the productivity of scavenging chickens. Further research should determine the effect of high ambient temperatures on IC and validate farmer indigenous coping strategies.

3.1.6. Ethical consideration

Ethical approval for this study was obtained from the Makerere University College of Agricultural and Environmental Sciences Research Ethics Committee (CAES-REC; Approval No. CAES-REC-2023-2). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (‘World Medical Association Declaration of Helsinki’, 2013) and the relevant national guidelines and regulations. Written informed consent was obtained from all participants prior to any study-related interactions. Participants were informed about the purpose of the study, their voluntary participation, their right to withdraw at any time, and assurances of confidentiality and data protection.

CHAPTER FOUR

EFFECT OF CLIMATE VARIABILITY ON AVAILABILITY AND NUTRITIONAL QUALITY OF SCAVENGEABLE FEED RESOURCES

Abstract

Meeting the nutritional requirements of scavenging chickens is fundamental to optimizing their productivity. This study assessed the seasonal variation in availability and quality of scavengeable feed resources. A total of 120 chickens, 4-5 months old, were purchased from farmers in Soroti district, Uganda. These were slaughtered across four seasons and their crop contents were physically characterized and chemically analyzed. Data were analyzed using a linear mixed-effects model (LMM) and mean comparisons adjusted using Tukey’s test. Results showed significant ($P<0.05$) seasonal differences in feed availability and quality. Overall, insects constituted the most abundant component of the crop content, followed by plant leaves. Kitchen waste constituted the highest weight proportion and was significantly ($P<0.001$) more abundant in both wet seasons, while cereals was significantly ($P=0.040$) abundant in the first dry season, and legumes ($P<0.001$) in the second dry season. Nutrient composition of the scavenged feed was influenced by available feed resources. The second dry season crop contents had significantly ($P<0.001$) higher crude fiber (13.13±1.02), ether extract (17.34±1.11), and crude protein (20.84±1.59) but lower calcium (0.37 ± 0.01). Except for the second dry season, crude protein content was below the recommendations for chickens. Across all seasons, crude fiber levels exceeded the acceptable limits for chickens, while metabolizable energy and the calcium-to-phosphorus ratio remained below recommended levels. The quantity and quality of scavengeable feed are highly seasonal, with persistent deficits in minerals, protein and metabolizable energy during the first dry season and both wet seasons. Priority should therefore be given to developing and providing season-specific, nutrient-dense, low-fiber supplements to bridge these nutritional gaps and enhance year-round flock productivity

Keywords: Crop content; Local chickens; Poultry; Relative abundance and Seasonality

4.1 Introduction

Productivity of scavenging chickens is largely determined by the availability and quality of feed resources in their environment (Tamasgen et al., 2025). In many cases, these chickens face nutritional deficiencies in terms of both quantity and quality of feed (Momoh et al., 2010), resulting from seasonal variations in feed resource availability and factors that limit access (Mwalusanya et al., 2002). For example, the movement of these chickens is limited by high temperatures (Nampijja et al., 2024). In such a case the chickens fail to access even what could be available in the environment. In addition, farmers rarely incur a cost in buying nutritionally balanced feed or concentrates to supplement these chickens (Ncobela & Chimonyo, 2016). Most farmers who supplement depend on household kitchen waste (Nampijja et al., 2025), which in many cases is nutritionally deficient (Nakkazi et al., 2014). The situation is exacerbated by seasonal variations that affect both the quantity and quality of scavengeable feed resources (Admasu et al., 2019; Mwalusanya et al., 2002). For example, Insects, along with their various growth stages, serve as some of the key protein sources for scavenging chickens (Prakash et al., 2020). However, their abundance and survival are highly dependent on environmental conditions (Silva et al., 2011), which have recently exhibited significant variation specifically in Uganda (Nampijja et al., 2024). Not only the protein sources but also the abundance of energy sources like cereals is affected by the growing season (Mekonnen et al., 2010) and variations in climate. Additionally, variations in the feed resource base are influenced by local food crops, which greatly contribute to scavengeable feed resources in many farming households (Yussif et al., 2023).

Improving the nutrition of scavenging chickens requires an understanding of the local feed resource base and its seasonal dynamics. This is because the availability and quality of Scavenged Feed Resources (SFR) are strongly influenced by agroecological and climatic conditions (Nzioka et al., 2017; Rashid et al., 2004). Studies assessing SFR have been conducted in several countries, including Ethiopia (Hayat et al., 2016; Mekonnen et al., 2010), Tanzania (Goromela et al., 2008; Mwalusanya et al., 2002), Sri Lanka (Gunaratne et al., 1993), Kenya (Nzioka et al., 2017). These studies consistently demonstrate substantial spatial and seasonal variability in the types and nutritional composition of scavenged feeds. However, despite the importance of ICs in Uganda, systematic evidence on the availability and nutritional quality of SFR across seasons remains limited. This lack of context-specific information constrains the development of targeted supplementation strategies suited to different climatic periods. Several approaches exist for assessing SFR, including household feed inventories, range assessments, and crop content analysis (Sonaiya, 2004; Sonaiya et al., 2002). Among these, crop content analysis provides direct insight into the feeds actually selected by chickens while scavenging. Therefore, this study aimed to determine the seasonal availability and nutritional quality of scavenged feed resources using crop content assessment, with the hypothesis that the availability and composition of scavenged feeds vary across seasons.

4.2 Materials and methods

4.2.1 Description of the study area

The study was conducted in Soroti District, eastern Uganda (Detailed description of the study area and map is given in chapter 3 section 3.1.2.1). The area is characterized by distinct seasonal and annual variations in rainfall and temperature (Nampijja et al., 2024). These variations influence crop-growing seasons and harvest yields. Mixed crop livestock farming is practiced in the area, with almost every household rearing local chickens. Among the major crops grown in the area are maize, millet, sorghum, beans, ground nuts, soybean, cassava, sweet potato and orange fruits.

4.2.2 Study design sampling of households and selection of chickens

A repeated cross-sectional design was employed to capture seasonal variations, with data collected across four seasons of the year. This design was appropriate because the scavengeable feed resource harvest (SFRH) method of data collection used is destructive, necessitating the use of different individuals at each sampling period. Data was collected in four seasons that included; the long dry season (December, January and February- Dry 1), long rains (March April May- Wet 1), short dry season (June July August-Dry 2) and the short rains (September October November-Wet 2). Data was collected at the beginning, mid and end of each season.

Households from which chickens were obtained were randomly sampled and birds between 4 and 5 months of age of both sexes were randomly selected. This age group was targeted to reduce age-related variability but ensuring that selected birds were mature enough to scavenge effectively. The selection procedure was conducted with guidance of a veterinary officer to ensure the sampled birds were healthy. A total of 120 chickens, both males and females in a ratio of 1:1, 30 per season were purchased from farmers, with the sample size guided by earlier studies (Dugassa et al., 2023; Gunaratne et al., 1993).

4.2.3 Physical examination of the crop content to determine feed resource availability

Scavengeable feed resource was determined through assessing the Scavengeable Feed Resource Harvest (SFRH) following procedures described by (Sonaiya, 2004; Sonaiya et al., 2002). The procedure involved slaughtering chickens to remove and examine the crop content. Chickens were caught between 10 and 11 am from the scavenging grounds in the different seasons in 2023. According to Fox & Feltwell (1978) chickens feed in a four-hour cycle, so the time chosen aimed at slaughtering chickens at the peak of the first cycle of feeding. The captured chickens were weighed using a digital scale with a precision of 0.01kg. Birds were then slaughtered by exsanguination, following procedures approved by the Institutional Animal Care and Use Committee (IACUC). The crops were removed and weighed before being opened for analysis. They were then carefully opened to expose the content. The crop content was removed from the crop sac, visually examined and separated into its components, as illustrated in figure 14. The proportions of the crop contents were recorded by both weight and number. An analytical balance with a precision of 0.0001 g was used for weighing. Non-biodegradable materials (plastic, cloth pieces, and sisal) were removed, and the samples were maintained under a cold chain before delivery to the Animal Nutrition Laboratory, School of Agricultural Sciences, Makerere University, for nutrient analysis.

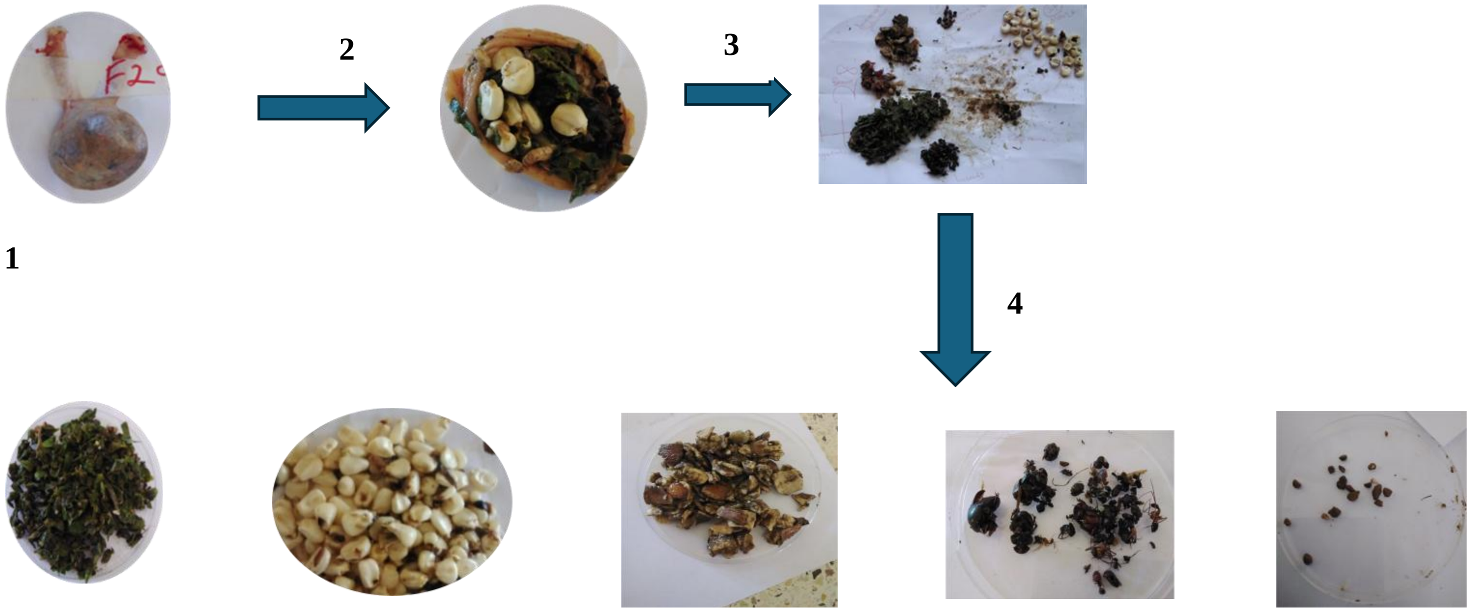


Figure 14: Schematic representation of the procedure undertaken to examine the crop contents of scavenging chicken.

1. Full crop; 2. opened crop; 3. crop contents separated by individual components and 4. individual crop contents ready for counting and weighing

4.2.4 Chemical analysis to determine the nutritional quality of the crop content

4.2.4.1 Proximate analysis

Dry matter (DM) content of fresh samples was determined by oven-drying samples at 65 °C for 72 h to constant weight and calculating the DM as a proportion of dry weight to fresh weight. The dried samples were then milled to pass through a 1 mm sieve using a FOSS Cyclotec laboratory mill. Subsequently, proximate analysis of feed samples for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), and ash was conducted using the standard methods of the Association of Official Analytical Chemists (AOAC, 2000). Crude protein was analyzed using the Kjeldahl method, where 0.3 g of sample were digested with concentrated sulfuric acid in presence of a catalyst on a pre-heated digestion block at 400 °C (FOSS Tecator DT220, Hoganas, Sweden), distilled with sodium hydroxide using a Kjeldahl digestion and steam distillation unit (Kjeltec^{TM} 2300 Auto distillation, Hoganas, Sweden), and the released ammonia was titrated against 0.1 M HCl. Crude protein was calculated as N × 6.25 (Method 984.13). Ether extract was determined using a FOSS Soxtec apparatus (model ST 243, Tokyo, Japan), in which samples were continuously extracted with petroleum ether (40–60 °C), and the recovered fat residue was dried and weighed (method 920.39). Crude fibre was analyzed using the FOSS Fibertec (FT122- Hoganas, Sweden), in which 2 g of milled sample were sequentially digested with diluted sulfuric acid (1.25%) followed by dilute sodium hydroxide (1.25%), and the insoluble residue was incinerated to constant weight (method 978.10). Ash content was obtained by incinerating 2 g of sample in porcelain crucibles in a muffle furnace at 550 °C for at least 4 h (method 942.05). All nutrient contents results were determined and expressed on a dry matter basis.

Metabolizable energy (ME) was estimated from proximate composition using the equation $ME = (3951 + 54.4EE - 88.7CF - 40.8Ash)$ (Wiseman & Lessire, 1987). Whereas Nitrogen free extract was calculated using the equation below.

$$NFE(\%) = 100\%DM - (CP + EE + CF + Ash)$$

Where: EE is % ether extract, CF is % crude fiber, Ash is %ash

4.2.4.2 Mineral analysis

Calcium (Ca) and phosphorus (P) in feed samples were analyzed according to AOAC method 985.01 (AOAC, 2000). The finely ground feed sample was initially ashed in a muffle furnace at 550 °C. The resulting ash was dissolved in diluted hydrochloric acid and filtered to remove insoluble residues. Calcium and phosphorus concentrations were quantified using atomic absorption spectroscopy (AAS) and UV–visible spectrophotometry, respectively. For AAS, calibration curves were prepared from certified standard solutions (0–10 mg/L). The method detection limits were approximately 0.02 mg/L for calcium and 0.05 mg/L for phosphorus, consistent with AOAC-validated procedures. Instrument performance and analytical accuracy were verified by analyzing reagent blanks and quality control standards after every five samples, in accordance with AOAC (2005) and ISO/IEC 17025:2017 guidelines for internal quality control. The results were expressed as mg/100 g of feed.

4.2.5 Statistical analysis

All statistical analyses were conducted to evaluate the effects of season and sex on; (i) the availability of scavenged feed resources, (ii) the proportional composition of crop contents, and (iii) the nutritional quality of scavenged feed resources in ICs. The bird was considered the experimental unit for availability and compositional data, while pooled laboratory samples were treated as the unit of analysis for nutrient composition.

Descriptive statistics were computed for all quantitative variables. The proportions of each feed category within crop contents were normalized to ensure they summed to unity. Outliers and zero values were inspected to verify biological plausibility. Normality of continuous variables (e.g., crude protein, ether extract, crude fibre, mineral concentrations, metabolizable energy) was evaluated using the Shapiro–Wilk test and normal probability plots. Homogeneity of variances across seasons was assessed with Levene’s test.

Because households introduce potential clustering, linear mixed effects models (LMM) were used. The general model form used is as indicated below:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + u_k + \varepsilon_{ijk}$$

where:
Y_{ijk}= response variable (e.g., proportion of insects, weight of kitchen waste, crude protein, metabolizable energy),
μ= overall mean,
α_i= fixed effect of the ith season (Dry 1, Wet 1, Dry 2, Wet 2),
β_j= fixed effect of sex (j = male, female),
$(\alpha\beta)_{ij}$= interaction term of season × sex,
u_k = random effect of household,
ε_{ijk} = residual error.

Seasonal and sex effects on proximate and mineral composition (CP, EE, CF, ash, Ca, P, NFE, ME) were tested using the same LMM framework. For each nutrient, least-square means and their standard errors were obtained. Pairwise seasonal comparisons were adjusted by Tukey’s honest significant difference (HSD) procedure. When residuals failed normality after transformation, non-parametric Kruskal–Wallis tests were used as confirmatory analyses. All results are reported as least-square means ± standard errors. Significance was accepted at $p < 0.05$.

4.3 Results

4.3.1 Seasonal variation in availability of scavenged feed resource

The effect of season on availability of scavengeable feed resources depended on the sex of the chicken (P = 0.005). However, overall feed resource availability did not differ significantly with sex (P = 0.2275). The abundance of specific feed resource categories within the crop varied significantly across seasons (P = 0.005; Figure 15). For all seasons, insects as a category of feed resource were the most abundant (>30%) in the crops of scavenging chickens, this was followed by plant leaves (vegetation) contributing >19%. The abundance of cereals in the crop was higher (P=0.040) in the first dry season. Whereas legume grain was most abundant (P<0.001) in the second dry season than the other seasons.

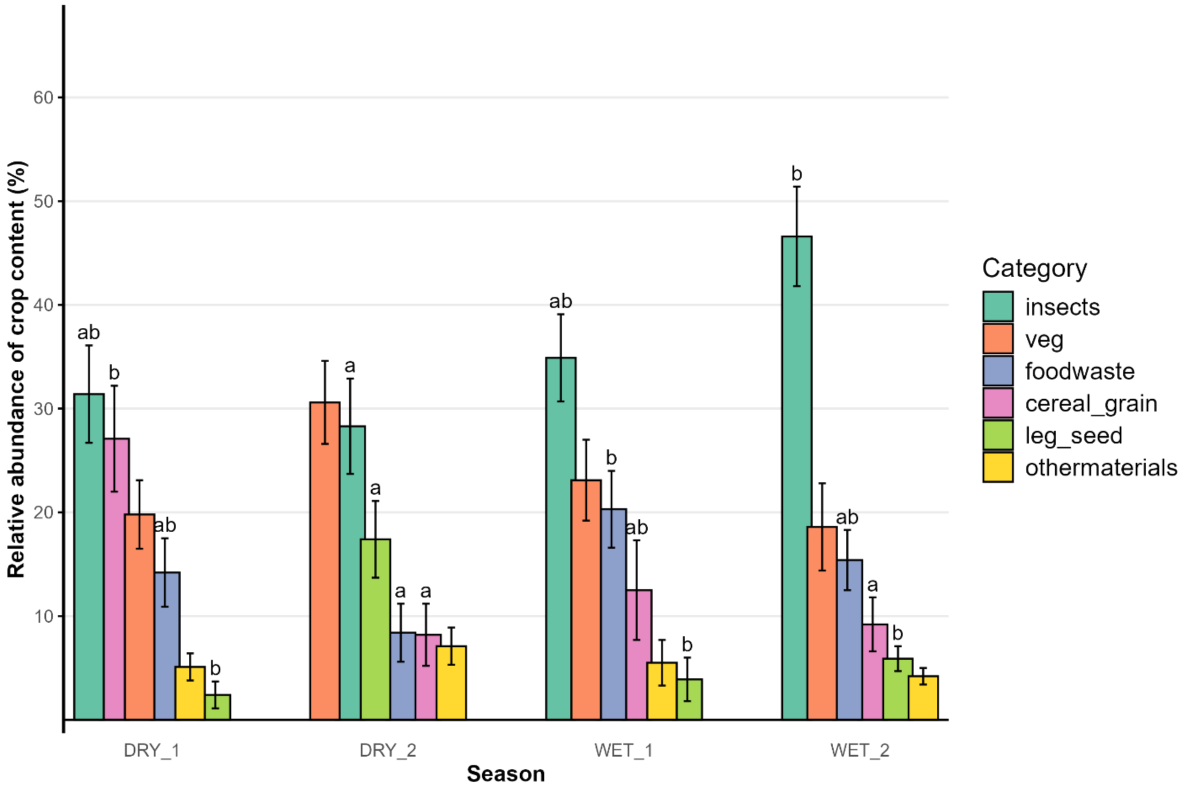


Figure 15: Seasonal variation in availability of scavenged chicken feed resources.

Letters indicate Tukey-adjusted significance between seasons (α = 0.05) within each category. Different letters denote significant differences, while bars without letters are not statistically

The abundance of the different components of each feed category within the crop significantly ($P<0.05$) varied with season (Figure 16). Among cereals, scavenging chickens in the study area majorly fed on sorghum, maize, cereal byproducts, millet and rice in that order (Figure 16a). Kitchen waste consumed was composed of cassava, sweet potato, bread made of several flour including cassava, sweet potato, millet and maize (Figure 16b). Among crops, cassava and sweet potato were found in the fresh, dried and cooked form as well as their peelings. Cassava was most abundant in the crop in the two dry seasons and first wet season whereas sweet potato was significantly abundant in the second wet season. Among the other kitchen waste components found in the crops of chickens included cooked beans, onions, tomatoes, rice, fish and fish components like bones, scales and offals. The major legume seeds that were scavenged included ground nuts, peas and soybeans (Figure 16c). Peas were significantly higher in the first wet season with ground nuts being significantly lower in the same season than for the rest of the seasons. Scavenging chickens fed on a variety of insect species (Figure 16d), with black ants, termites, and larval stages of different insects being the most abundant in the chicken crops. Black ants were significantly more abundant during the two dry seasons and the first wet season, whereas termites were significantly more abundant during the second wet season. Classified as other insects included sugar ants, bees, ticks, safari ants, earthworms, cockroaches and weevils. Chickens scavenged on almost the same proportion of legume and grass leaves in the wet seasons (Figure 16e). However, in the first dry season chickens scavenged on significantly ($P<0.05$) higher grass than legume leaves and the reverse was true for the second dry season. Chickens also scavenged on other materials that included non-biodegradable materials, egg and snail shells, wood pieces and feathers (Figure 16f). Chickens scavenged on significantly higher non-biodegradable materials in the first wet season which constituted more than 60% of the other products consumed.

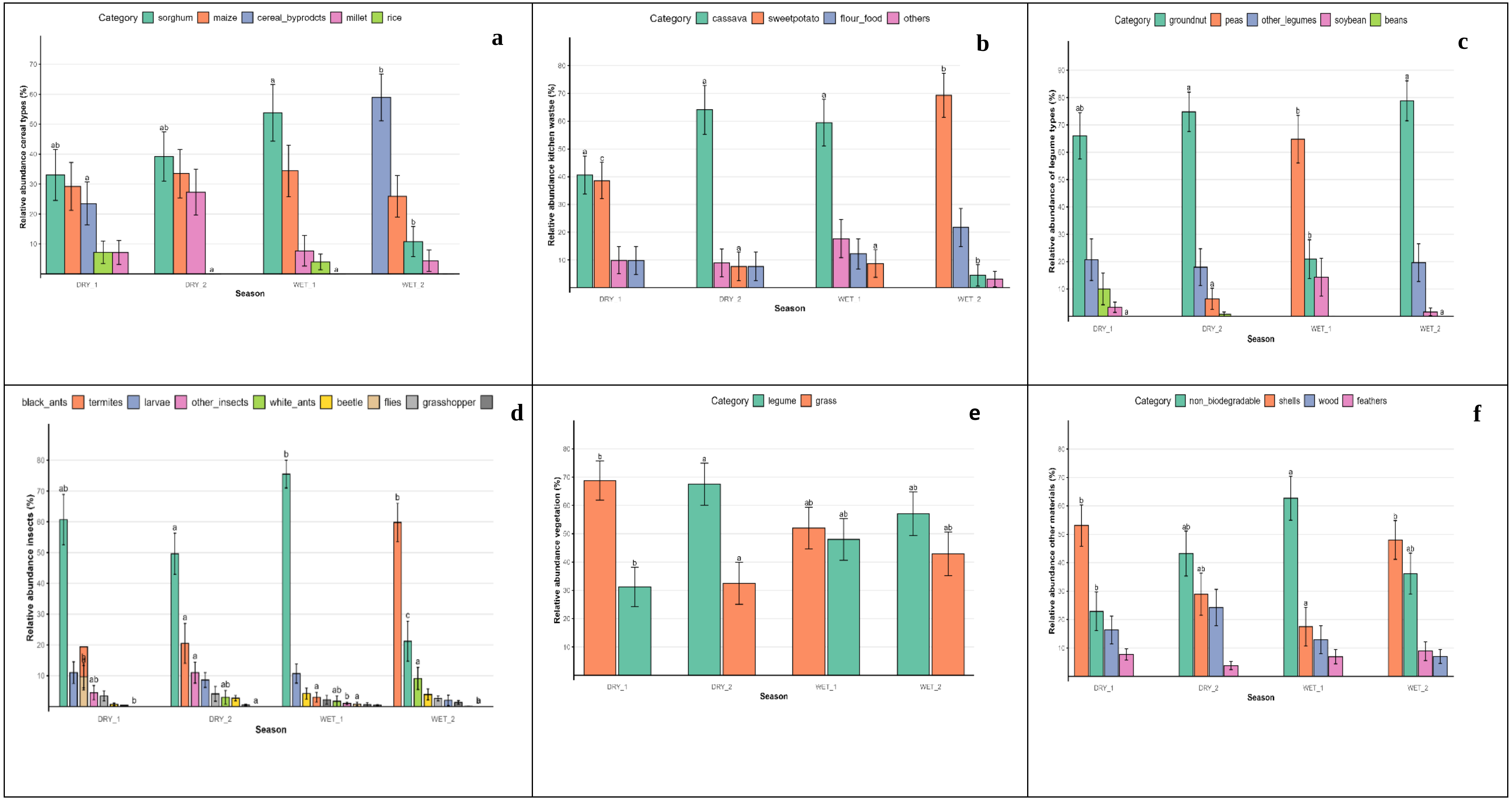


Figure 16: Proportions of different categories of scavenged chicken feed resources. Letters indicate Tukey-adjusted significance between seasons (α = 0.05) within each category. Different letters denote significant differences, while bars without letters are not statistically significant

4.3.2 Variation in Scavenged Feed Resource quantity and quality

Season significantly influenced the weight proportions of scavengeable feed resources, and this effect varied with the sex of the chicken (P = 0.005). Nonetheless, the overall differences between sexes were not significant (P = 0.4315). The weight proportions of scavengeable feed resources also showed significant seasonal variation (P = 0.005) (Figure 17). Significant differences were observed in the weight proportions of kitchen waste, legume seeds and plant leaves (Veg) but not with other materials. Although insects were the most abundant in the crops in all seasons as observed in the previous result, they had a small contribution to the weight of the crop content. Kitchen waste constituted a significantly (P<0.001) higher (49%) proportion of the crop content in the first dry and both the wet seasons. Whereas plant leaves (veg) within the crop content was significantly (P= 0.011) higher in the second dry and wet season constituting more than 30 and 20% respectively. Legume grain constituted the highest proportion (>30%) of the crop content weight in the second dry season which was significantly higher (P= 0.000) than the first dry and wet seasons.

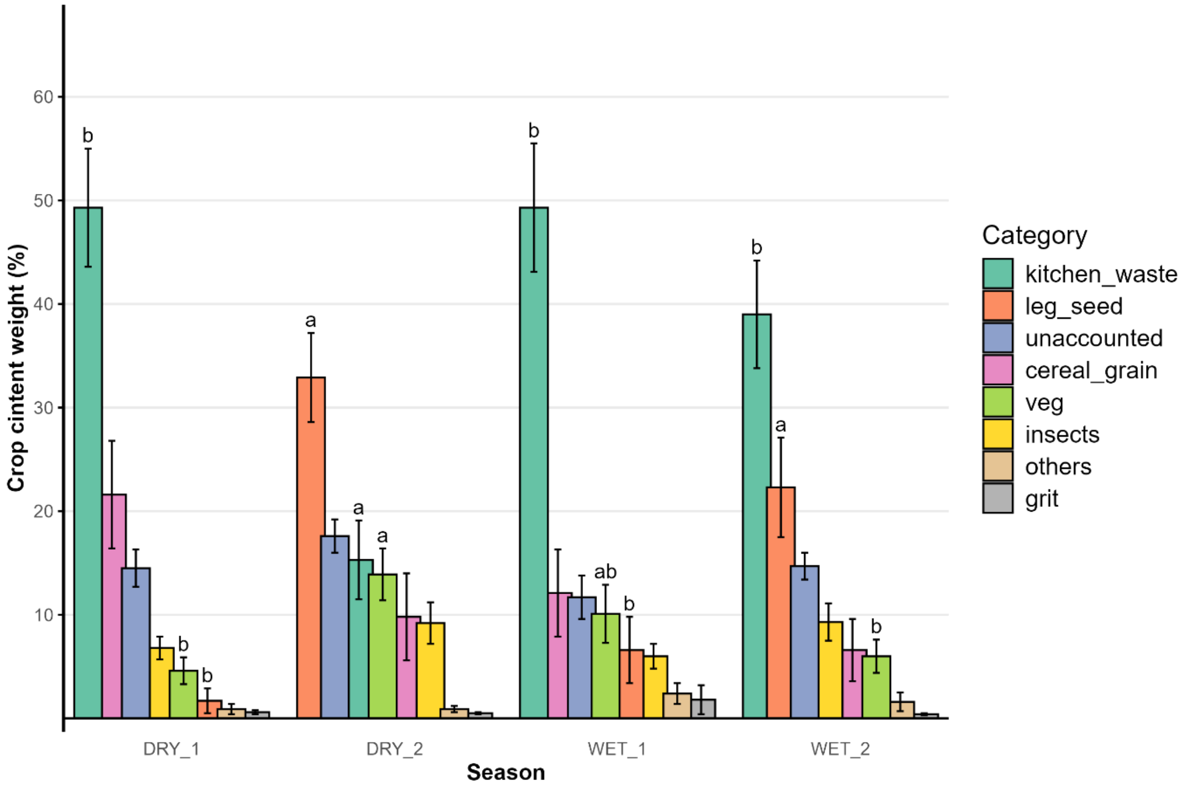


Figure 17: Proportions of the crop content weight of feed categories. Letters indicate Tukey-adjusted significance between seasons (α = 0.05) within each category. Veg stand for plant leaves. Different letters denote significant differences, while bars without letters are not statistically significant

Within seasons, significant differences between males and females were observed for all parameters except carcass percentage (Figure 18). For live weight males were heavier than females for all the seasons apart from the first dry season (Figure 18a). Whereas for crop weight, it was only during the first dry season that the pullets had heavier crops than cockerels (Figure 18b). Crop weight as a percentage of live weight differed only in the first dry season, females having heavier crops than males (Figure 18d).

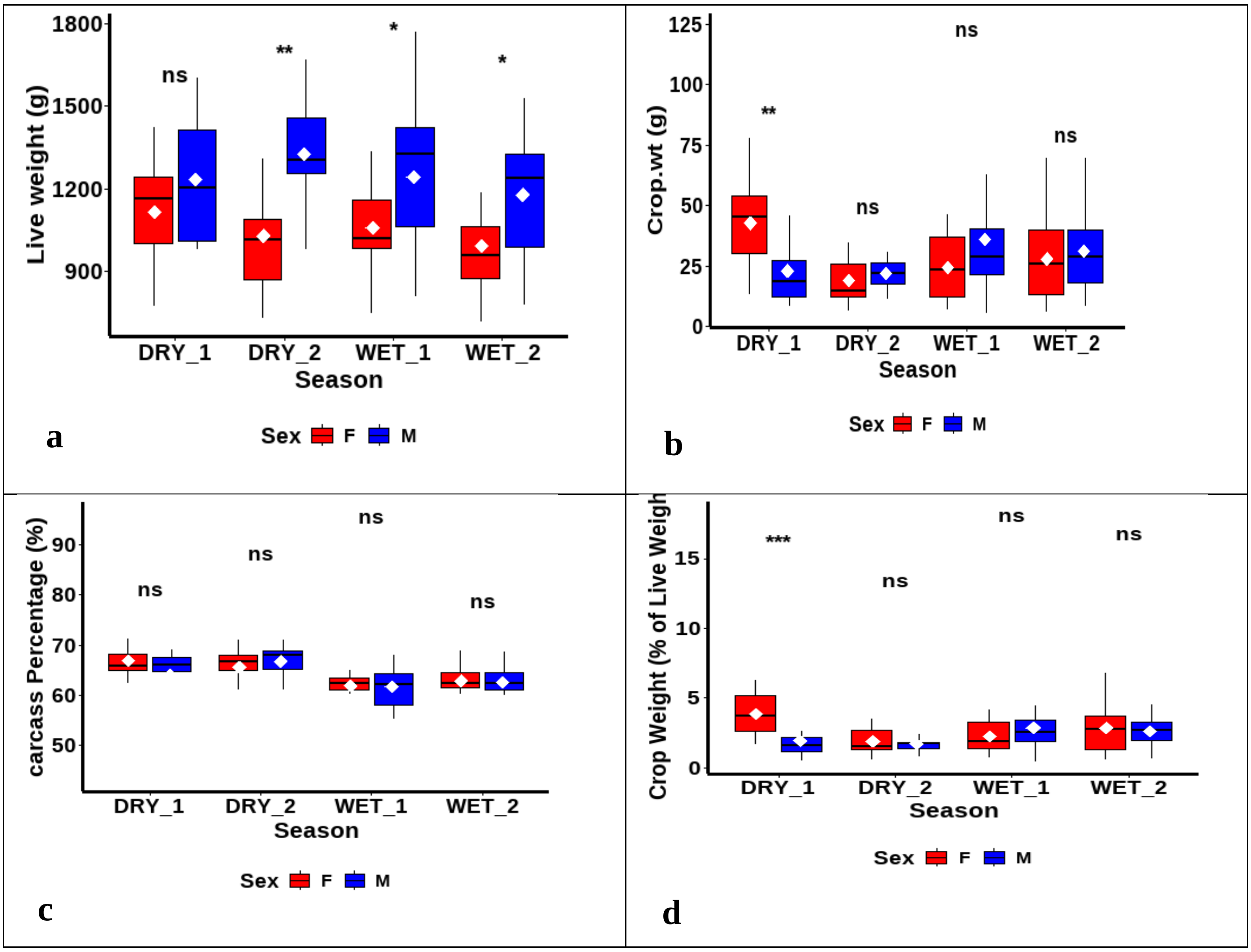


Figure 18: a) Live weight, b) crop weight, c) carcass percentage variations with season by sex. Asterisks indicate significance levels (P < 0.05, ** P < 0.01, *** P < 0.001).*

Results of nutritional analysis revealed that the quality of the crop content varied with season and sex but the interaction between sex and season was not significant (Table 11). The crop content of the second dry season was significantly higher in crude fiber, ether extract and crude protein, but lower in calcium content as compared to other seasons. The crop content of the first wet season had significantly (P<0.001) higher phosphorus with significantly lower crude fiber and ether extract than all other seasons. There was no variation in the ash content and metabolizable energy of the crop content in all the seasons. The crop content of chickens did not significantly differ with sex apart from ether extract which was significantly higher for females and NFE that was higher among male chickens.

Table 11:Variation of nutritional composition of scavenged feed resources with season

	Sex		Season				P-value	
Parameter (%DM)	Female	Male	Dry 1	Dry 2	Wet 1	Wet 2	Sx	S
Lab DM	96.70 ± 0.24^{a}	96.47 ± 0.23^{a}	95.73 ± 0.13^{b}	97.45 ± 0.17^{a}	95.98 ± 0.12^{c}	95.48 ± 0.20^{cd}	NS	*
Fresh DM	49.88 ± 1.03^{a}	47.91 ± 1.89^{a}	51.42 ± 1.04^{a}	46.37 ± 1.76^{b}	50.25 ± 1.59^{a}	52.59 ± 1.32^{a}	NS	*
Ash	17.59 ± 1.53^{a}	19.14 ± 1.53^{a}	17.20 ± 1.85^{a}	17.40 ± 1.85^{a}	21.21 ± 1.85^{a}	19.44 ± 1.85^{a}	NS	NS
CF	6.97 ± 0.73^{a}	8.98 ± 0.73^{a}	9.09 ± 1.02^{b}	13.13 ± 1.02^{c}	3.70 ± 1.02^{a}	5.97 ± 1.02^{ab}	NS	***
EE	9.42 ± 0.79^{b}	6.88 ± 0.79^{a}	4.25 ± 1.11^{ab}	17.34 ± 1.11^{c}	2.79 ± 1.11^{a}	8.21 ± 1.11^{b}	*	***
CP	13.51 ± 1.22^{a}	14.20 ± 1.22^{a}	12.84 ± 1.59^{a}	20.84 ± 1.59^{b}	8.61 ± 0.92^{a}	13.11 ± 1.59^{a}	NS	***
P	1.23 ± 0.30^{a}	1.01 ± 0.30^{a}	0.70 ± 0.34^{a}	0.24 ± 0.34^{a}	2.79 ± 0.34^{b}	0.76 ± 0.35^{a}	NS	***
Ca	0.86 ± 0.10^{a}	0.75 ± 0.10^{a}	1.55 ± 0.11^{c}	0.37 ± 0.11^{a}	0.53 ± 0.11^{ab}	0.77 ± 0.11^{b}	NS	***
NFE	49.21 ± 3.68^{a}	60.50 ± 3.68^{b}	60.61 ± 4.32^{b}	46.92 ± 4.32^{a}	61.66 ± 4.32^{b}	50.19 ± 4.321^{ab}	**	**
ME Kcal/kg	2691.53 ± 81.3^{a}	2566.56 ± 81.3^{a}	2574.06 ± 112.00^{a}	2810.08 ± 112.00^{a}	2501.00 ± 112.00^{a}	2631.05 ± 112.00^{a}	NS	NS

Means with different superscripts within a row and variables are significantly different at ($P<0.05$)*; Asterisks indicate significance levels* (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$)*.Sx= sex; S= season*

4.4 Discussion

4.4.1 Seasonal variation in availability of scavenged feed resource

Seasonal variations significantly influenced availability and weight proportions of Scavenged Feed Resources (SFR). The significantly higher abundance of insects followed by vegetation in the crop content in all seasons may not only indicate availability but could be pointing to some level of preference. This is because vegetation is more abundant in the scavenging grounds specifically during the wet seasons than insects. Insect abundance in chicken crops peaked in wet seasons, consistent with reports from Kabale (Nyeko et al., 2002) and other subtropical ecosystems (Pinheiro et al., 2002; Vasconcellos et al., 2010). This result can be attributed to increased food availability, favorable environmental conditions that influence insect growth, breeding and survival (Kaspari & Weiser, 2000; Silva et al., 2011) among other factors (Kishimoto-Yamada & Itioka, 2015). Insects were dominated by black ants and termites which maintained consistently higher abundance across all seasons compared to other insect groups. This finding can be explained by the opportunistic feeding behavior of black ants that allows them access food year-round in addition to benefits of being social insects that increase their survival (Jackson & Ratnieks, 2006). This pattern aligns with findings by Pinheiro et al. (2002), who reported Hymenoptera species to be present in all seasons studied and among the most abundant (Silva et al., 2011; Vasconcellos et al., 2010).

The abundance of termites in the second wet season could be explained by high decaying vegetation which supports termite colonies and provides abundant food, softer soils allow burrowing which makes easier access to food and supports activity on the surface (Materu et al., 2013). In addition, farmers also collect termite mounds and break them for chickens, a practice that has also been reported in Burkina Faso (Pousga, 2007). The relatively high abundance of vegetation in the crops, even during dry seasons, suggests that these periods were not severe enough to eliminate vegetation entirely. However, such a finding is highly dependent on the length of the dry season as vegetation abundance could decline markedly during prolonged dry spells. For instance, the significantly lower abundance of legume vegetation in the chicken crops during the first dry season underscores this vulnerability, since legumes are particularly sensitive to water stress (Balehegn et al., 2022). The current finding aligns with earlier findings that reported up to 10% of the crop content to be constituted by vegetation (Bird, 1948). Although insects and vegetation were the most abundant in the crops, their contribution to crop content weight was lower than that of kitchen waste, cereals and legumes. This is because these are lighter in weight.

The significantly higher crop weight observed in the dry season likely reflects greater availability and accessibility of feed resources. The highest proportion of the crop content in the dry season was cereals and legumes. This can be explained by the fact that these feed resources are harvested and post-harvest handled during these seasons. Although the quantities significantly reduced in the long dry season (Dry 1), implying that the length of the dry season has an influence on these feed resources. In such cases scavenging chickens get easy access to the grains and legumes from the drying grounds unlike in the wet season when most grains and legumes are planted. The observed content of these SFR in the wet seasons could be spill overs from the dry seasons. This also suggests that the SFR base is influenced by farming activities as it is observed that legumes and cereals are more scarce during periods of planting and weeding, the wet seasons and abundant during periods of harvesting and drying (Mekonnen et al., 2010). This result contradicts many previous findings that reported a higher crop weight in the wet season (Minh & Ogle, 2005; Nzioka et al., 2017) but similar with those of (Goromela et al., 2008; Pousga et al., 2005). The cereal grains which included maize, sorghum, millet and rice and legumes mainly groundnuts found in the crops of scavenging chickens represent food crops grown in the area. In this study, crop weight as a percentage of live body weight was slightly below the optimal range of 3–5% (Quesenberry

& Hillyer, 1994), likely due to limitations in feed access associated with the free-range production system.

Kitchen waste, although not the most abundant in the crop, contributed the highest percentage of the crop content in terms of weight in the wet seasons. The significantly higher weight proportion of kitchen waste observed in the two wet seasons can be attributed to the lower availability of cereals and grains in the scavenging grounds and high availability of household food during these periods, specifically cassava and sweet potatoes. Therefore, chickens resort to depending on the kitchen waste. Such a result could also imply that households are more food secure during the wet season since what is given to chickens is usually leftover (Nampijja et al., 2025). This could also imply that food security translates into scavenged feed security as well. The high proportion of kitchen waste in the first dry season could be explained by the intentional supplementation done by farmers (Nampijja et al., 2025). The result of high content of kitchen waste in the diet of scavenging chickens in the wet seasons is consistent with previous findings in Nigeria (Momoh et al., 2010; Sonaiya, 2004) and Tanzania (Goromela et al., 2008). However, the observed contribution of kitchen waste to crop content is lower than the amount reported in South Africa (Raphulu et al., 2015). The variation could be attributed to the differences in seasons whereby South Africa experiences winter, spring and autumn during which seasons scavenging chickens could entirely depend on kitchen waste.

The observed non-degradable material ingested by scavenging chickens in this study is evidence of their existence in scavenging grounds. This also implies poor waste management by households rearing scavenging chickens. Similar results of non-biodegradable material ingestion in chickens have been reported in Mexico, with up to 11 and 45 particles of plastic found in crop and gizzard respectively (Huerta Lwanga et al., 2017) and in Kenya (Nzioka et al., 2017). In addition, the ingestion of non-biodegradable material such as plastic limits feed intake in chickens (Ryan, 1988) and alters gut microbiota (Zou et al., 2023) which affects growth performance of the scavenging chickens. This study therefore recommends proper waste management within scavenging areas to prevent the direct negative effects of waste consumption on chickens and the potential indirect health risks to humans.

4.4.2 Variation in Scavenged Feed Resource nutritional quality

The variation in the type of feed resource by season clearly explains the observed differences in nutritional content of the Scavenged Feed Resource (SFR). This result is consistent with previous studies (Raphulu et al., 2015). The higher crude protein, crude fiber and ether extract of crop content in the second dry season can be attributed to the higher consumption of legumes specifically, ground nuts. Groundnuts, which was the most dominant legume in the crops of scavenging chickens have a crude protein content above 30% (Chowdhury et al., 2015) and crude fat content of up to 53% (Musa et al., 2010). High crude protein content of SFR in the dry season was reported in Burkina Faso (Pousga et al., 2005). Crude protein content of 20% that is observed in the second dry season is sufficient for growing Ugandan local chickens (Magala et al., 2012), indeed some studies have reported higher body weights of chickens during the dry season (Ncobela & Chimonyo, 2016). During the same season, chickens consumed unshelled ground nuts, which explains the significantly high crude fiber content of the SFR. Although results of the crude fiber content are consistent with those of previous findings (Mekonnen et al., 2010; Pousga et al., 2005), it exceeded the levels recommended for poultry species (NRC, 1994). High crude fiber content limits feed intake and utilization in chickens (Nampijja et al., 2023). This could explain the commonly reported poor performance of scavenging chickens (Nakkazi et al., 2014; Ssewannyana et al., 2008). Further, general poor performance under the production system can be supported by the very low crude protein content in the other seasons of the year which were below the requirements for scavenging chickens (Liu et al., 2015). Except for the second dry season, metabolizable energy values were slightly below the recommended levels for growing chickens (NRC, 1994). This accompanied with low protein content of less than 14% in the same seasons would affect the protein energy ratio and further explain the low performance registered for chickens under the scavenging production system. The higher ME value during the second dry season, in line with the recommendation by Magala et al. (2012) for growing Ugandan chickens was expected due to the observed high ether extract of the crop content for the season. Results of ME align with findings by Admasu et al. (2019) but differed from (Nzioka et al., 2017; Tamasgen et al., 2025) who reported higher values and (Hayat et al., 2016; Momoh et al., 2010) who reported lower values for SFR. The variation can be attributed to the difference in feed resource types in the study areas.

The low crude protein content in the wet seasons and the first dry season (<14%) can be attributed to the low crude protein content of kitchen waste (Sonaiya, 2004) which contributed the highest percentage of the crop content. Kitchen waste consisted mainly of cassava, sweet potato and bread of different flours. A previous study by Manano et al. (2017) reported a crude protein content of Ugandan cassava varieties to range between 0.7% and 1.5%, while that of sweet potato varied between 4.2% and 6.5% (Mbithe et al., 2016). This main dietary composition could also explain the lower crude fiber observed in the seasons. Although laboratory analysis was not done for each feed component, literature indicates that cassava and sweet potato have low crude fiber content (Manano et al., 2017; Mbithe et al., 2016). Results of crude protein of crop content are within the previously reported ranges (Nzioka et al., 2017) but higher than values found by Gunaratne et al. (1993) and Tamasgen et al., (2025). The crude protein content observed in the first dry season and the two wet seasons was lower than recommended for Ugandan local chickens (Magala et al., 2012). The two dry seasons are both harvesting seasons, but the difference in the nutritional content of the crop observed among them could be attributed to the crops harvested and the length of the season. The first dry season is a long dry season implying that availability of feed resources reduces with the length of the season. The observed variations necessitate season specific supplementation of scavenging chickens.

Scavenging chickens obtain essential minerals such as calcium and phosphorus from sources including green leafy vegetables, eggshells, snail shells, and termites. For example, when vegetation accounts for 10% of the total dry matter intake, it can supply 10% of the required calcium and 12.5% of manganese (Bird, 1948). Many of these materials were identified among the SFR during the physical crop content examination in this study. The significantly higher calcium content observed in the first dry season corresponded with the higher proportion of eggshells and snail shells in the chicken crops in that season. In contrast, crop contents from the second dry season and the first wet season failed to meet calcium and phosphorus requirements of growing chickens, a result that can directly be attributed to the lower proportion of shell content in the diet scavenged. In addition, the recommended calcium-to-phosphorus ratio was not achieved in either of the wet seasons (NRC, 1994). These findings highlight the need to provide mineral supplementation during such periods. Although this assessment was based on growing chickens, the challenge is likely even greater for layers, which have higher calcium requirements.

Crop contents of chickens reflect not only the availability of nutrients in the environment, but also the selective feeding habits of birds, because the scavenging environment contains more than what is observed in the crop. In addition, crop nutrient contents at any time may not accurately indicate total daily feed intake or utilization of nutrients. For instance, in this study birds were captured between 10 and 11am, anticipating the peak of the first feeding cycle for scavenging chickens (Fox & Feltwell, 1978). The present results provide a useful basis for designing supplementation rations and programs for scavenging chickens at all stages of growth, since only minor differences are expected in crop content between growers and layers. (Mekonnen et al., 2010). However, the study findings are applicable mainly to areas with similar cropping systems and seasonal patterns, and therefore may not be generalized to the entire country.

4.5 Conclusions and recommendations

From this study it can be concluded that the availability and quality of scavenged Feed Resource (SFR) vary with season of the year. The dry seasons have more feed resources in the form of legumes and cereals but less in insects, but these SFR reduce with the length of the dry season. On the other hand, wet seasons are dominated with kitchen waste and insects. The nutritional quality of crop content is significantly influenced by the type of scavenged feed resource. In all seasons the crude fiber content of the SFR was higher than the recommended limit for chickens. The first dry season crop content was sufficient in minerals but deficient in crude protein and metabolizable energy. While the second dry season crop content was sufficient in crude protein and metabolizable energy but deficient in Calcium and Phosphorus. Both the wet season crop content was deficient in protein, metabolizable energy and Calcium.

Based on the observed seasonal variation in feed resource availability and quality, supplementation programs for scavenging indigenous chickens should be season-specific to address prevailing nutritional gaps. For instance, protein- and energy-rich supplements are recommended during the first dry season and both wet seasons, while calcium-rich feed sources should be prioritized during the second dry season and both wet seasons. Additionally, low-fiber supplements should be emphasized given the high crude fiber content of scavenged feeds. However, as this study was conducted in a single study area, the findings may not fully capture feed resource dynamics under different cropping systems and agricultural practices. Therefore, future studies should evaluate the effect of targeted supplementation strategies on ICs and extend the research to areas with different cropping systems to improve generalizability of results.

4.6 Ethics approval

All procedures described in the experimental study were reviewed and approved by the Institutional Animal Care and Use Committee of the School of Veterinary Medicine and Animal Resources (SVAR-IACUC 270/2025). All animal handling procedures were conducted following approved guidelines and in compliance with the Ugandan guidelines on experiments on living animals.

CHAPTER FIVE

EFFECT OF ELEVATED AMBIENT TEMPERATURES ON BEHAVIOURAL RESPONSES OF LOCAL CHICKENS

Abstract

Chickens under the scavenging production system are highly vulnerable to variations in the environment, especially rising temperatures. This is because farmers have limited control over the environment in which they scavenge. This study evaluated the effects of elevated temperatures on local chicken behavior and body temperature. Two local chicken ecotypes one from a cold region (KAB) and the other from a hot region (SOR) were studied. A total of 12 pullets, 6 from each region between 4 and 5 months, were exposed to 30 ℃, 33 ℃, 36 ℃, and 39 ℃ in a heat chamber. Each temperature was studied for 3 days and in each day the birds were exposed for two hours. A Camlife Image Recording instrument V11.50 was used to observe and record the behavioural responses that included panting, wing elevation, walking, standing, feeding, sitting and drinking. Rectal temperature was measured using a thermometer. Data were analyzed using a linear mixed-effects model, and mean comparisons adjusted using Tukey's test. Results showed significant ($P<0.05$) increase in body temperature, time spent in thermoregulatory behaviour and reduced latency to thermoregulatory behaviour which differed among ecotypes. The KAB ecotype had a higher rise in body temperature, displayed thermoregulatory behaviours earlier and spent more time in heat dissipating and less time in heat generating behaviours than the SOR ecotype. Across ecotypes, the latency to thermoregulatory behaviours decreased with increasing temperature, while the time spent performing thermoregulatory behaviours increased with temperature.

Results indicate that local chicken ecotypes are susceptible to effects of elevated temperature with the SOR ecotype being more tolerant than the KAB ecotype.

Keywords: Environmental control; Heat stress; Latency; Chicken ecotypes; Time budgets; Thermoregulation response.

5.1 Introduction

Thermal stress is a major environmental challenge for poultry production (Brugaletta et al., 2022), particularly in regions with extreme or fluctuating temperatures such as Uganda (Nampijja et al., 2025). Heat stress compromises growth, feed intake, reproduction, immune function and overall welfare of chickens, but its impact varies with genetics, age and management (Lara & Rostagno, 2013; Wasti et al., 2020). In scavenging production systems, local chickens interact directly with the environment and generate additional metabolic heat during foraging activities (Khalil et al., 2012). However, under heat load, birds reduce locomotion and feed intake (Playà-Montmany et al., 2023), this further limits their feed access and productivity (Wasti et al., 2020). The practical thermoneutral zone for chickens lies between 18–25 °C (Asseng et al., 2021), with heat strain emerging from the 25 °C upward (Cartoni Mancinelli et al., 2023). Notable performance losses are commonly reported above 30 °C (Apalowo et al., 2024). These thresholds differ by strain, age and housing (Nichelmann et al., 1986; Nichelmann & Tzschentke, 2002). Evidence from African indigenous ecotypes show variable physiological and behavioural responses, underscoring the need for strain and context-specific data in East Africa (Khondowe et al., 2021). For instance, Tanzanian local chicken ecotypes exhibited heat stress when exposed to 32 °C, with notable variation in responses among ecotypes (Khondowe et al., 2021). The Kenyan local chickens also displayed signs of heat stress when exposed to 35 °C (Srikanth et al., 2019), although considerable thermotolerance was reported among them (Kennedy et al., 2022). Although indigenous chickens display considerable plasticity and may even transmit adaptive traits across generations, this flexibility has limits (Ruuskanen et al., 2021). Exposure to extreme developmental conditions can predispose birds to phenotypes that later prove disadvantageous, while high baseline thermal tolerance may actually reduce their capacity for further acclimatization (Nord & Giroud, 2020; Ruuskanen et al., 2021). However, for Ugandan local ecotypes, controlled studies are scarce, and to identify traits that can respond to selection, more research is required on genetic variation in thermoregulation and its plasticity (Khondowe et al., 2021). This study therefore set out to assess physiological and behavioural responses of Ugandan local chickens under graded temperature regimes, providing baseline evidence needed to guide future selection and adaptation strategies.

5.2 Materials and methods

5.2.1 Description of the geographical areas from which the chicken ecotypes studied were sourced

5.2.1.1 Soroti district

Soroti District, located in the Teso sub-region of eastern Uganda (1°15′–2°00′N, 33°00′–33°45′E), experiences a tropical savanna climate characterized by bimodal rainfall. A recent study reports annual rainfall of the area to range from 1019.5 ± 7.58 mm to 1721.8 ± 11.25 mm, with an average of 1311.9 ± 9.14 mm (Nampijja et al., 2024). The March-May (MAM) season has an average of 473 mm, peaking in April and the September-November (SON) season with an average of 358 mm with a milder peak in October or November (Majaliwa et al., 2015). The areas' annual mean annual air temperature is 24.68 ± 1.52 ºC, and the mean minima of 19.05 ± 1.22 ºC and maxima of 30.31 ± 2.46 ºC. The December January February (DJF) season receives the highest temperatures of up to 32.22±2.38 ºC.

5.2.1.2 Kabale district

Kabale District, in Uganda's Kigezi Highlands (29°45′–30°15′E; 1°00′–1°29′S), lies at high elevation, giving it a cool, wet highland climate. Long-term observations show bimodal rainfall with a primary wet season from March to May (MAM) and a secondary wet season from September to November (SON) (Kangume, 2015; Kisira et al., 2025). Annual totals typically range from about 900 to 2100 mm, peaking around 160mm in April and averaging about 180 mm in (Kangume, 2015; Ndemere et al., 2025). The mean temperatures are cool for the tropics at about 18 °C, with average maxima between 23.7 and 24.8 °C and minima ranges of 10.7 and 12.3 °C, consistent with high-elevation conditions (Ndemere et al., 2025). Morning relative humidity commonly ranges from 90 to 100% and early-afternoon values from 42 to 75% (Twagiramaria et al., 2018).

5.2.2 Experimental site and ethical approval

The experiment was conducted at Makerere University Agricultural Research Institute Kabanyolo (MUARIK). The ethical approval under this study was as described in chapter four section 4.6.

5.2.3 Management of birds

To compare environmental adaptation differences among local chickens, pullets were obtained from two areas with different climatic conditions. Genetic analysis was not conducted because the study focused on functional and epigenetic adaptation to contrasting thermal environments, and chickens from Kabale and Soroti are already documented as distinct ecotypes (Beyihayo et al., 2022). Birds were transported overnight to minimise the effect of thermal stress during transit. Upon arrival at the experimental site, the birds were quarantined for 14 days during which they were observed for any signs of disease or abnormal behaviour. Birds were dewormed and vaccinated against Newcastle Disease. All birds were housed in a well-ventilated experimental poultry house from where they were given adlib access to clean water and a grower ration containing 16% CP and 2800Kcal/kg of feed ME. The grower diet was fed to birds both during the acclimatisation and the experimental period. The house was fitted with perches and the floor filled with coffee husks to a depth of 8cm.

5.2.4 Experimental design

A total of twelve pullets, six of each ecotype, aged 4–5 months with an average weight of 1084.9 ± 75.6 g, were used in the study. The sample size was guided by previous studies on physiological stress responses (Xie et al., 2014) and by adherence to the 3Rs principle as approved by the ethical committee (SVAR-IACUC 270/2025). The experiment followed a repeated-measures design in which temperature served as a within-subject factor and ecotype as a between-subject factor. Birds were tested in three consecutive rounds (batches), each comprising two pullets from each ecotype (four birds in total). The heat chamber measured 2 M X 2M X 1.5M and was fitted with a heater, fan and humidifier. Within the heat chamber each bird was housed individually in a cage equipped with a feeder and nipple drinker connected to a calibrated transparent container for monitoring water intake.

Prior to exposure, birds were acclimatized for seven days at 28.45 ± 2.85 °C and 65.88 ± 10.96 % relative humidity (RH). They were then sequentially exposed to four temperature treatments (30, 33, 36, and 39 °C), all maintained at a constant relative humidity of 62.17 ± 7.29 %. To avoid heat stress irreversible damage (Li et al., 2015), each temperature was maintained for 2 hours per day over three consecutive days, during which behavioural and physiological responses were recorded. To prevent cumulative heat-stress effects and allow recovery, the chamber was returned to room temperature for the remainder of each day, as described by Adu-Asiamah et al. (2021).

Feed and water were available ad libitum during the exposure periods but were withdrawn at 19:00 hours until the next day's heat exposure. Chickens were maintained under a 13 L: 11 D photoperiod provided exclusively by natural daylight.

5.2.5 Instrument calibration

Prior to the start of each experimental batch, the heat chamber was calibrated to ensure accurate temperature and humidity regulation. Chamber readings were verified using a bulb thermometer and a digital temperature–humidity meter (hygro-thermometer) placed at bird height. The two instruments were used concurrently to compare displayed values, and necessary adjustments were made to the chamber's control settings to align with the reference readings. Calibration was repeated before changing from one temperature treatment to the next to ensure consistency across all runs.

The clinical thermometer for rectal temperature measurement was calibrated daily against a standard laboratory thermometer in a constant-temperature water bath (Reece, et al., 2020). Any deviations exceeding ±0.1 °C were corrected to ensure measurement accuracy and consistency.

5.2.6 Data collection

A Camlife Image Recording Instruments V11.50 (camera) was used to observe the birds and the amount of time spent panting, elevating wing, walking, standing, feeding, siting, drinking (Table 12) as well as concurrent combinations of these behaviours during the experimental period. In addition, the latency to panting, wing elevation, sitting, and drinking for each bird was recorded. Rectal temperature of experimental birds was measured to 0.1℃ at the start and end of each temperature regime by inserting a thermometer up to a depth of 3cm in the rectum of the chicken. The amount of water and feed consumed during the period of exposure to experimental treatments and four hours after were recorded. A photo of the experimental chamber is presented in figure 19 below.

Table 12: Behavioural ethogram

Behaviour	**Description**
Panting	The pullet's beak is open and the respiration rate is abnormally rapid.

Wing elevation	A space can be seen between the bird’s wings and body
Drinking	Bird’s beak is in contact with the nipple drinker
Eating	Bird’s beak is inside the feeder and the bird is pecking on the feed
Standing	Both feet are in contact with the ground, no other body part is touching the floor surface, with the bird’s posture in an upright position.
Sitting	Most of the ventral region of the bird’s body is in contact with the floor. No space is visible between the bird and the floor, we considered the bird to be sitting when it remained in that position for more than 60 seconds
Walking	Bird is in the process of taking multiple steps

Adapted from Kim et al.(2021) and Mack et al.(2013)

μ= overall mean,

Figure 19:The experimental chamber

5.2.7 Statistical analysis

Data were analyzed using a linear mixed-effects model approach in R software (version 4.x; R Core Team, Vienna, Austria). Temperature served as a within-subject (repeated) factor, while ecotype was treated as a between-subject factor. The effects of temperature, ecotype, and their interaction were evaluated using the following model;

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + u_k + v_{l(k)} + \varepsilon_{ijkl}$$

where:

Y_{ijk}= response variable (latency, time budgets to thermoregulatory behavior),

μ= overall mean,

α_i= fixed effect of the *ecotype*

β_j= fixed effect of temperature

$(\alpha\beta)_{ij}$= interaction effect between temperature and ecotype,

u_k = random effect of batch,

$v_{l(k)}$= random effect of a bird nested within a batch,

ε_{ijkl} = residual error.

Estimated marginal means (EMMs) were obtained and pairwise comparisons among temperature levels were adjusted using Tukey’s test. Normality was assessed using quantile-quantile (Q–Q) plots and the Shapiro Wilk test which both suggested non violation.

5.3 Results

5.3.1 Latency to onset of heat stress related behavior

The ecotype × temperature interaction was not significant across all behaviours, whereas the main effect of ecotype and temperature were significant for latency to heat stress responses (Table 13). Across ecotypes latency to all behaviours reduced with an increase in temperatures. KAB chickens panted earlier than SOR at 33℃ (13.91±3.4 Vs 29.69±4.7) 36℃ and (3.90±1.1 Vs 13.47±2.7). The KAB ecotype also elevated wings earlier than SOR at 36℃ and 39℃. No significant differences were observed between ecotypes for the latency to drink and sit at all temperatures studied, panting at 30℃ and wing elevation at 30℃ and 33℃. Although slight variation occurred, the general sequence for responding to elevated temperatures involved drinking water first, followed by panting, wing elevation and finally sitting.

Table 13: Latency to onset (minutes) of behavioural responses to elevated temperatures in chickens

		Temperature				*P*-value		
Behaviour	**Ecotype**	**30°C**	**33°C**	**36°C**	**39°C**	**E**	**T**	**E*T**
Drinking	KAB	5.25±1.0^{a}	2.03±0.5^{b}	2.87±0.6^{ab}	2.92±0.9^{ab}	*	*	ns
	SOR	7.21±1.3^{a}	3.06±0.9^{a}	5.76±1.7^{a}	4.18±2.1^{a}			
	KAB vs SOR	ns	Ns	ns	ns			
Panting	KAB	41.41±9.9^{a}	13.91±3.4^{b}	3.90±1.1^{c}	4.16±1.1^{c}	ns	***	ns
	SOR	36.31±10.5^{a}	29.69±4.7^{ab}	13.47±2.7^{bc}	4.43±1.3^{c}			
	KAB vs SOR	ns	*	**	ns			
Wing elevation	KAB	29.25±8.1^{a}	14.89±3.5^{ab}	6.82±1.4^{b}	4.30±1.1^{b}	**	***	ns
	SOR	52.16±11.5^{a}	16.25±3.0^{b}	14.10±2.5^{b}	11.35±3.0^{b}			
	KAB vs SOR	ns	Ns	*	*			
Sitting	KAB	76.01±7.1^{b}	87.43± 10.1^{b}	64.21±8.5^{b}	27.66±2.9^{a}	ns	***	ns
	SOR	70.14±8.5^{b}	76.40±5.5^{b}	59.84±5.6^{b}	34.88±4.5^{b}			
	KAB vs SOR	ns	Ns	ns	ns			

Means with different superscripts within a row and are significantly different at (P<0.05); *Significance levels *p < 0.05; **p < 0.01; **p < 0.001; E = ecotype effect; T = temperature effect; E*T = interaction. KAB=Kabale ecotype; SOR=Soroti ecotype.

5.3.2 Influence of ambient temperature on time budgets for thermoregulatory behaviors

The effect of temperature on time taken drinking, panting and elevating wings depended on ecotype (Table 14). The time taken feeding reduced with temperature and significantly differed among ecotypes at 39 °C for which KAB spent 26 percent less time feeding than SOR. The time chickens spent sitting increased with temperature. For example, both ecotypes spent >70% more time sitting at 39 °C as compared to 30 °C.

Table 14: Time (minutes) taken in each of the activities during heat exposure

		Temperature				***P*-value**		
Behaviour	**Ecotype**	**30°C**	**33°C**	**36°C**	**39°C**	**E**	**T**	**E*T**
Feeding	KAB	62.80±3.9^{a}	61.00±3.7^{a}	48.60±2.6^{b}	25.05±2.4^{c}	ns	***	ns
	SOR	66.49±3.5^{a}	59.50±4.8^{a}	43.62±4.6^{b}	33.83±3.0^{b}			
	KAB vs SOR	ns	ns	ns	*			
Walking	KAB	10.23±1.7^{c}	16.43±2.51^{b}	24.17±3.8^{a}	11.18±2.2^{c}	ns	**	ns
	SOR	11.90±2.9^{a}	12.30±2.8^{a}	17.91±4.2^{a}	10.90±2.0^{a}			
	KAB vs SOR	ns	ns	ns	ns			
Standing	KAB	9.71±1.6^{a}	9.24±1.7^{a}	10.75±0.9^{a}	7.91±2.0^{a}	ns	ns	ns
	SOR	8.88±1.6^{a}	10.27±2.5^{a}	12.04±2.1^{a}	10.68±2.2^{a}			
	KAB vs SOR	ns	ns	ns	ns			
Sitting	KAB	13.06±3.0^{b}	9.48±3.7^{b}	12.12±2.9^{b}	52.00±4.5^{a}	ns	***	ns
	SOR	8.22±2.1^{c}	7.99±2.2^{c}	21.35±3.8^{b}	42.19±6.5^{a}			
	KAB vs SOR	ns	ns	ns	ns			
Drinking	KAB	12.37±0.7^{b}	16.24±1.2^{ab}	20.72±1.5^{a}	19.82±2.3^{a}	**	**	*
	SOR	13.50±1.1^{a}	14.73±0.8^{a}	15.09±1.0^{a}	14.21±1.3^{a}			
	KAB vs SOR	ns	ns	*	*			
Panting	KAB	11.38±2.7^{b}	29.53±8.0^{b}	100.77±6.7^{a}	118.24±1.2^{a}	***	***	***
	SOR	6.01±1.6^{c}	36.40±6.0^{b}	52.42±7.9^{b}	78.19±8.0^{a}			
	KAB vs SOR	ns	ns	***	***			
Wing elevation	KAB	37.35±5.8^{c}	78.89±11.0^{b}	112.39±1.8^{a}	119.93±0.1^{a}	***	***	*
	SOR	9.19±3.0^{c}	46.64±8.4^{b}	49.32±8.8^{b}	86.80±6.4^{a}			
	KAB vs SOR	***	**	***	***			

Means with different superscripts within a column and are significantly different at ($P<0.05$); *Significance levels *$p < 0.05$; **$p < 0.01$; **$p < 0.001$; ns= not significant; E = ecotype effect; T = temperature effect; E*T = interaction; KAB=Kabale ecotype; SOR=Soroti ecotype.

5.3.3 Proportion of observation time (%) in thermoregulatory behaviours

Ambient temperature influenced the duration that birds allocated to each behavior (Figure 20). As temperature increased, the proportion of time spent feeding, walking, and standing decreased, whereas time in wing elevation, panting, sitting, and drinking increased (Figure 20a). Across all temperatures, KAB allocated less time to heat producing behaviors that is feeding, walking and more to thermoregulatory behaviors (wing elevation, panting, drinking) than SOR. Quantitatively, feeding in KAB declined from 40% at 30 °C to 7% at 39 °C, while SOR declined from 54% to 14% over the same temperature range. At 30 °C, KAB spent 71% more time with elevated wings than SOR.

As temperature increased, birds frequently used multiple in thermoregulatory behaviors concurrently (Figure 20b–d). From 33 °C onward, birds spent more than 40% of the time of exposure with both elevated wings and panting. While elevating wings, birds spent a greater proportion of time drinking than during panting. Sitting co-occurred more with panting than with wing elevation. While panting, chickens allocated less time to feeding than when elevating wings. Across all temperatures, KAB spent a greater proportion of time displaying multiple thermoregulatory behaviors than SOR. (Figure 20d).

Figure 20: Proportion of time (%) in thermoregulatory behaviours a) Single activity b) with elevated wings c) with panting d) with panting and elevated wings.

5.3.4 Feed and water intake during and after thermal conditioning

While increase in ambient temperature reduced the time chickens spent feeding, the overall quantity of feed consumed did not differ significantly during and after heat exposure (Figure 21a and 21b). There was no significant variation in the amount of feed consumed during and after heat exposure between ecotypes at different temperatures.

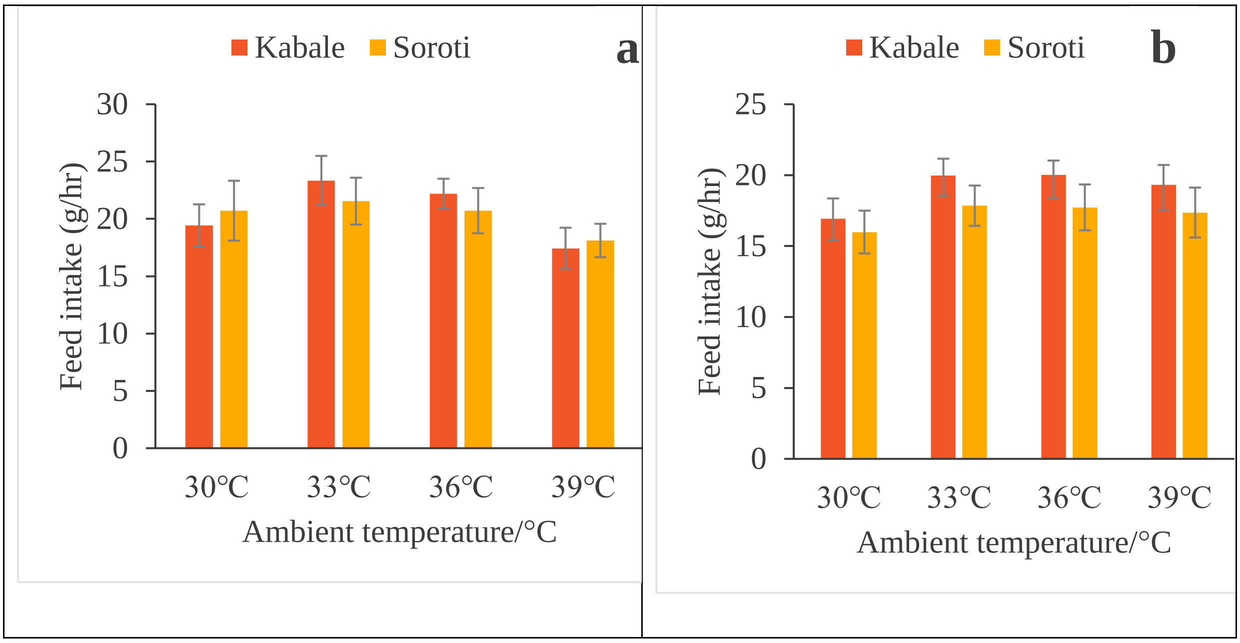


Figure 21: Effect of elevated temperature on feed intake a) during thermal exposure b) after thermal exposure

During the two-hour heat exposure, the amount of water consumed was not significantly influenced by temperature and ecotype (Figure 22a). In the subsequent four hours post-exposure period, ecotype significantly influenced the amount of water consumed (Figure 22b). The KAB ecotype consumed significantly more water than SOR at 33 °C, 36 °C, and 39 °C.

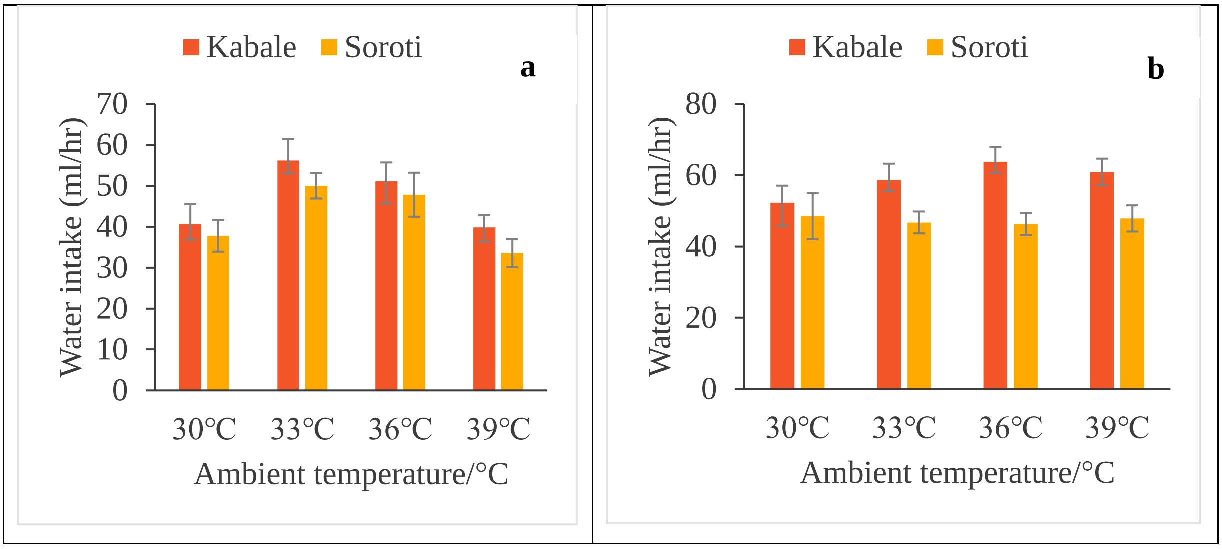


Figure 22: Effect of elevated temperatures on water consumption a) during thermal exposure b) after thermal exposure

5.3.5 Effect of elevated temperatures on body temperature of indigenous chickens

Chicken body temperature increased with ambient temperature (Figure 23a). At 39 °C, the KAB exhibited a significantly higher body temperature than the SOR. Specifically, the body temperature of KAB rose by 0.24 °C higher than that of SOR (Figure 23b).

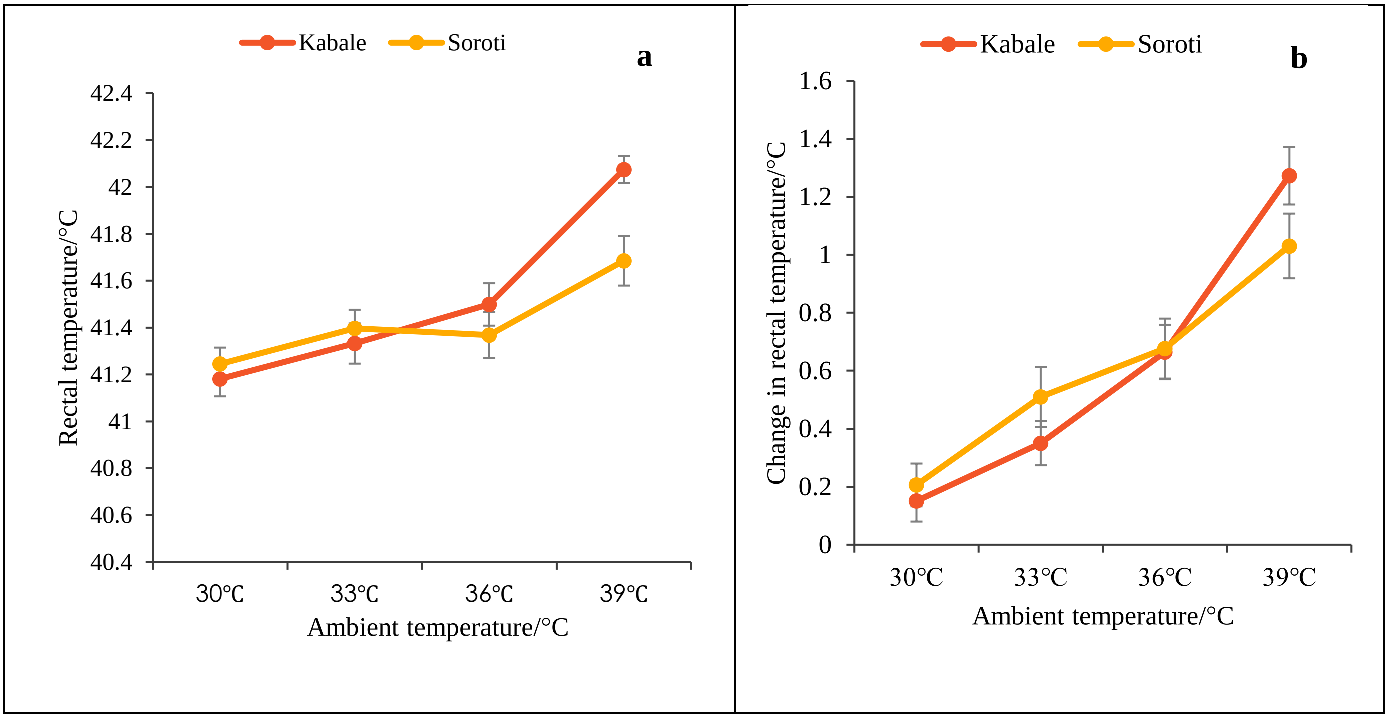


Figure 23: Effect of elevated temperatures on body temperature

5.4 Discussion

Thermoregulation is central to homeostasis. Endotherms keep core temperature stable by balancing metabolic heat production with heat exchange to the environment (Nichelmann & Tzschentke, 2002). When ambient temperature rises above the thermoneutral range, birds adjust through behavioural and physiological mechanisms (Wasti et al., 2020). In our experiment, birds relied first on behavioural routes for heat loss.

5.4.1 Latency to onset of heat stress-related behavior

Across ecotypes and temperatures studied, birds showed a sequence of responses that involved drinking water first, then panting, wing elevation, and finally sat. This pattern matches the sequence described by Nichelmann et al. (1986) and Nichelmann and Tzschentke (2002), with our added observation that drinking water came before the physiological effectors. Drinking water likely occurred in addition to activities described and came first probably because water had been briefly withheld before the experiment in addition to increase in thirst due to heat stress (Wurtz et al., 2024). Furthermore, Nichelmann et al. (2002) described thermoeffector responses for which drinking of water is not. Evaporative heat loss via panting followed, which is a rapid response that can be initiated within seconds by brainstem breathing circuits and does not rely on slow hormonal changes (McKechnie et al., 2016). Next, dry heat loss was activated as birds lifted their wings to expose axillary skin and reduce feather insulation, improving convective and radiative exchange (Kahl, 1971). The vasodilatory response is under vascular and neural control and, unlike panting, generally unfolds over minutes (Nolan et al., 1978). Finally, metabolic heat production is reduced by longer sitting consistent with slower endocrine adjustments such as lower thyroid-driven metabolism (Wasti et al., 2020). Ruuskanen et al. (2021) noted that behavioural responses to heat stress are typically immediate, corroborating the sequence observed in the present study. However, species differences exist with regards to the sequence of activities that are used for heat dissipation. For example, in dunlin (*Calidris alpina*), the heat-stress response began with bill exposure, unipedal standing, and sitting with panting appearing later which was infrequent, and occurred in only a few individuals (Playà-Montmany et al., 2023). The latency to panting at 30°C reported in the current study is within the range for chickens under heat stress that had not received electrolytes in their diet Borges et al. (2004). Latency to panting and wing elevation among local Indonesian chicken exposed to 35°C (Lase et al., 2025) correspond with those of 36°C for the current study. Generally, the latency for heat stress response behaviour varies with species, age, ambient temperatures among other factors (Barnes et al., 2004).

5.4.2 Time budgets in a thermoregulatory response

As temperature increased, both ecotypes spent more time panting, elevating wings, drinking, and sitting, reflecting greater heat load through well-established thermoregulatory behaviours in chickens (Cartoni Mancinelli et al., 2023). Panting and wing elevation dominated the behavioural responses consistent with earlier studies (Cartoni Mancinelli et al., 2023; Teeter et al., 1985). In contrast, other species of birds such as the dunlin mainly rely on different strategies for heat dissipation, other than elevating wings and panting (Playà-Montmany et al., 2023). Latency and duration of behaviours differed for example birds drank water first, but spent more time elevating wings, then panting, and least time drinking water. A similar pattern of duration of thermoregulatory behaviour has been reported among broiler chickens (Cartoni Mancinelli et al., 2023).

Wing elevation facilitates convective heat loss when birds are standing, but its effectiveness reduces during sitting as reduced airflow beneath the wings limits heat dissipation (Kahl, 1971). This likely explains why birds spent less time elevating wings while seated and relied more on panting. Unlike wing elevation, panting is posture-independent and thus remains effective regardless of body position. Although increased panting enhances heat dissipation, it comes at a high caloric cost for the bird (Mota-Rojas et al., 2021) and predisposes them to respiratory alkalosis (Barnes et al., 2004). This challenge is compounded by reduced feed intake under elevated temperature exposure, which limits the replenishment of electrolytes and energy lost through panting, ultimately impairing bird performance.

Drinking supports evaporative cooling by sustaining panting and the amount of heat lost per breath (Belay & Teeter, 1993), but this was not maintained for long periods as panting. This may be attributed to the placement of the nipple drinkers, which required birds to stand in order to access water (May et al., 1997), whereas under high thermal load birds tended to remain seated and inactive (Apalowo et al., 2024). The amount of water consumed in the current study corresponds with results reported among layers exposed to 30 and 33°C (Kim et al., 2024) but lower than findings among broiler chickens (Bhawa et al., 2023; Bonnet et al., 1997).

While seated, birds lose heat through conduction in addition to reducing metabolic heat (Lase et al., 2025). The reduction in time spent feeding, walking, and standing with corresponding increase in time spent seated observed in this study is consistent with earlier reports (Khalil et al., 2012; Li et al., 2015; Mack et al., 2013). This represents an adaptive strategy to limit metabolic heat production and reduce body temperature (Lara & Rostagno, 2013). Birds generally show lower preference temperatures for physical activity, which are closer to their biological optimum (Nichelmann & Tzschentke, 2002). Thus, any rise above this range is expected to suppress locomotor and feeding behaviours (Lase et al., 2025). Although the SOR ecotype spent significantly more time feeding at 39°C than KAB, this did not translate into higher feed intake. Mack et al. (2013) similarly reported that longer feeding time did not result in greater crop fill or weight gain. Hocking (1997) also showed that broilers consumed more than layers despite spending a comparable proportion of time feeding. These findings suggest that factors beyond time allocation, such as pecking efficiency, feed characteristics, or physiological regulation, may influence actual intake. Feeding time alone is therefore a weak predictor of consumption in chickens. The ability to maintain some feed consumption under elevated temperature could, however, contribute to sustaining electrolytes and bicarbonates lost through panting (Barnes et al., 2004). On the other hand, even when feed intake is maintained at higher temperatures, heat stress adversely affects digestion and metabolism. (Santos et al., 2015).

Physiologically, heat stress activates the hypothalamic pituitary adrenal (HPA) axis, leading to elevated corticosterone, while the hypothalamus simultaneously increases secretion of corticotropin-releasing factor (CRF) (Beckford et al., 2020). Elevated CRF suppresses appetite by inhibiting orexigenic neuropeptide Y pathways (Ruuskanen et al., 2021), thereby reducing feed intake. In addition, a decline in circulating triiodothyronine (T_3) and thyroxine (T_4) (Burger et al., 1980) lowers metabolic heat production, which further limits thermal load (Nawaz et al., 2021). These mechanisms together explain the observed reduction in feeding behaviour with increasing temperatures.

In conclusion the simultaneous display of multiple behaviours at high temperatures reflected the increasing thermal load, a response that was more pronounced in the KAB than in the SOR ecotype. Such variation suggests differences in thermoregulatory capacity between the two ecotypes.

5.4.3 Change in body temperatures

The rise in rectal temperature with increasing ambient temperature observed in this study is consistent with earlier findings in chickens (Nichelmann & Tzschentke, 2002; Oni et al., 2025; Playà-Montmany et al., 2023). An early increase in rectal temperature has been associated with shorter survival time, indicating reduced tolerance to heat stress (Chen et al., 2013). The observed increases of 0.4 °C at 33 °C and 0.7 °C at 36 °C in the studied birds are consistent with the findings of Kim et al. (2024) and Lase et al. (2025) respectively. In contrast, chickens in the present study maintained rectal temperatures approximately 3°C lower than broilers and Indonesian local chickens exposed to thermal stress (Borges et al., 2004; Tamzil et al., 2013), suggesting a capacity to buffer more effectively against acute heat stress.

Rectal temperature differences among ecotypes further highlighted variation in thermal tolerance. KAB chickens, originating from a cooler region, exhibited significantly higher body temperatures than SOR birds under the same heat load. This pattern could suggest epigenetic adaptation found in both chickens and muscovy ducks (Nichelmann & Tzschentke, 2002).. Embryonic exposure to cold promotes heat production later in life, while prenatal heat challenges enhance tolerance to high temperatures (Nichelmann & Tzschentke, 2002; Ruuskanen et al., 2021). Earlier evidence also showed that acclimatized birds stabilize body temperature slightly above normal, whereas non-acclimatized birds continue to show progressive increases (May et al., 1987). The smaller rise in rectal temperature among SOR birds from the hotter region indicates relatively greater heat tolerance, consistent with the positive correlation between body temperature change and thermal stress tolerance (Chen et al., 2013). By contrast, KAB birds from the cooler region exhibited a larger increase in rectal temperature under the same thermal load, suggesting lower tolerance to heat stress.

In conclusion, both ecotypes experienced heat stress when exposed to elevated temperatures, showing similar behavioural sequence of response. However, the magnitude of these changes differed with ecotype. KAB chickens from the cooler region exhibited earlier onset of thermoregulatory behaviours, spent more time in heat dissipating activities, less time in heat generating behaviours, and showed a greater rise in body temperature compared to SOR chickens. Severe heat stress was evident in KAB birds at 33°C, indicating a lower heat threshold and reduced tolerance to thermal load. By contrast, SOR birds from the hotter region maintained smaller increases in body temperature and delayed the onset of heat dissipating behaviours, demonstrating relatively greater tolerance to elevated temperature. These findings align with previous evidence that acclimatisation to hot environments enhances heat tolerance in poultry (Khalil et al., 2012). The findings further underscore the influence of ecological origin on thermal adaptability in indigenous chickens.

5.5 Limitation of the Study

The sample size was sufficient to detect physiological and thermoregulatory responses under controlled conditions (Xie et al., 2014). However, the number of birds used per ecotype restricts representation of the full genetic variability within indigenous chicken ecotypes. The findings nevertheless provide robust insight into within-ecotype physiological responses under elevated ambient temperature.

Birds were exposed to controlled chamber conditions that may not fully reflect their natural scavenging environment, where factors like wind velocity and behaviours like, perching, shade seeking, dust bathing also influence thermoregulation. For example, dust bathing was the third commonly cited behaviour among scavenging indigenous chicken during periods of high thermal load, but the chamber conditions could not allow birds to display it.

5.6.1 Conclusions and recommendations

5.6.1 Conclusion

Both SOR and KAB ecotypes exhibited clear behavioral and physiological responses to increasing ambient temperature, confirming that the tested conditions induced heat stress among local chickens. The sequence of behavioral responses that involved drinking, panting, wing elevation and finally sitting was consistent across ecotypes, but the magnitude and timing differed. Time spent in heat generating activities like feeding reduces with increase in ambient temperatures whereas that spent in heat dissipating activities like panting, drinking and wing elevation increase with increasing temperatures. Chickens spend more time with elevated wings while feeding and drinking water. On the other hand, when seated chickens spend more time panting. Body temperature increased with ambient temperature in both ecotypes, KAB experienced a higher rise in body temp than SOR. KAB chickens, originating from a cooler region, displayed earlier onset of thermoregulatory behaviors, spent more time in heat dissipating activities, and showed a higher rise in rectal temperature, indicating a lower heat threshold and reduced tolerance to heat stress. SOR chickens, from a hotter region, maintained smaller increases in rectal temperature and delayed the onset of heat dissipating behaviours, demonstrating greater heat tolerance. These findings support the concept of ecotype specific adaptation, with prior environmental exposure shaping thermal tolerance capacities.

5.6.2 Recommendations

Provide cool, clean water in shallow drinkers where birds naturally congregate within the scavenging grounds during hot periods for directly cooling the body and sustaining panting among birds. Provide abundant shade and perching areas so birds can stand and elevate wings without obstruction to improve airflow under the wings. Plant and maintain vegetation in scavenging areas to provide cooler surfaces, enabling birds to dissipate heat through conduction when sitting, rather than on bare ground that is often heated by solar radiation. Shift supplementary feeding to the coolest hours that is early morning or evening to compensate for reduced feeding when temperatures are high. Offer nutrient-dense rations when heat is forecast, avoid high fibre supplements that add gut heat load. Supplementation with electrolytes and energy-dense feeds may help offset respiratory alkalosis effects, energetic cost of panting and compensate for reduced feed intake during hot conditions. Indigenous chickens from hotter regions like the SOR should be prioritised in breeding and conservation programs targeting resilience to climate variability, given their higher heat tolerance. Future studies should consider field conditions to validate chamber findings and lager sample size per ecotype

CHAPTER SIX

SYNTHESIS

6.1 Introduction

The scavenging production system of indigenous chicken has for many years remained a low input low output system, a characteristic that increases its vulnerability to impacts of climate variability. To gain a holistic understanding of these impacts this study examined three interrelated aspects (i) how farmers perceive climate variability, the way it affects scavenging indigenous chicken production and coping strategies employed; (ii) the influence of seasonal changes on scavenged feed resource (SFR); and (iii) the effects of elevated temperature on indigenous chickens. Findings confirm climate variability in Soroti district as reflected in both meteorological records and farmers' perceptions presented in chapter three. Results of the study revealed that climate variability exerts both direct and indirect effects on scavenging indigenous chicken. The direct effects of CV arise from elevated temperatures which directly influence thermoregulatory behaviours and chickens' welfare. Whereas the indirect effects occur through nutritional stress resulting from fluctuations in the availability and quality of SFR. The discussion below synthesizes how climate-driven fluctuations in feed resources and elevated temperatures jointly influence the scavenging production system.

6.2 Climate variability and its impact on SFR: Linking farmer perceptions to scientific evidence

One clear outcome of this research is that climate variability, particularly seasonal rainfall fluctuations, strongly affects the availability and quality of scavenged feed resources (SFR) for indigenous chickens. The findings confirm that both the quantity and nutritive value of SFR vary markedly across seasons, consistent with previous reports that natural feed resources for free-range chickens are inherently seasonal (Mekonnen et al., 2010; Nzioka et al., 2017). Farmers' perceptions captured in this study generally resonated with these observations, although some deviations were noted regarding the timing of feed scarcity and abundance. Results showed that over 70% of crop contents by weight comprised food origin materials intended for human consumption, confirming farmers' claim that scavenging indigenous chicken rely heavily on household food resources (Yussif et al., 2023). On the other hand, while farmers perceived SFR to be most insufficient during the dry season and more abundant during the rainy season, the crop content analysis did not fully support these views. A plausible explanation is that the dry seasons coincide with harvest periods, during which chickens gain access to abundant post-harvest residues and grains in the scavenging grounds, whereas rainy seasons provide only limited spill overs from active crop fields (Goromela et al., 2008).

Nevertheless, farmers' perceptions of feed scarcity in the dry season may hold true depending on its duration (Minh & Ogle, 2005). This study revealed significant variation between the two dry seasons. For example, the longer dry season was associated with low availability and nutritional quality of scavenged feed resources, unlike the shorter dry season where resources were comparatively adequate. These findings underscore the fact that the inherent seasonality of SFR is further exacerbated by climate variability (Mekonnen et al., 2021). For instance, when dry spells extend beyond normal cycles, they constrain feed availability and quality, thereby escalating nutritional stress in scavenging (Thornton & Herrero, 2015).

In addition to food origin resources, farmers indicated that scavenging indigenous chicken also feed on insects, most frequently citing termites. This perception corresponded with the crop content analysis, although the most abundant insect identified was not termites but black ants. Farmers' emphasis on termites is likely influenced by their deliberate efforts to collect and provide them to chickens, a common practice reported in other smallholder systems (Kingori et al., 2010a; Pousga, 2007). Termites were however, the second most abundant insect group observed in the crop contents, confirming their significance as a scavenged feed resource. Both farmers and the entomology officer interviewed during the key informant discussions perceived insects to be most abundant during the rainy season, and this aligned with the crop content results. Nevertheless, the contribution of insects as a feed resource appears to be at risk due to increased use of insecticides for crop pest control, as highlighted in the perception study (EFSA, 2015). Such practices may partly explain the lower abundance and diversity of insect species recovered from crop contents (Huis, 2013). Indeed, some farmers reported declining availability of termites and other scavengeable insect species in recent years, consistent with broader observations on the impact of chemical pest control on non-target insect populations (van Huis, 2013).

Beyond seasonal fluctuations in availability, the present study highlights that the nutritional quality of scavenged feed resources is inherently inadequate. Crop content analysis across all seasons revealed consistent deficiencies in at least one of the major limiting nutrients that is protein, energy, or essential minerals (Ca and P). Demonstrating that scavenging alone cannot sustain the dietary requirements of indigenous chickens for optimal productivity. Farmers reported offering supplements such as kitchen waste and cereals, but these supplements are often low in key nutrients. Moreover the availability of these supplements depend on household crop yields which are vulnerable to climate variability (Kingori et al., 2010a; Mekonnen et al., 2021). Such nutritional gaps provide a reasonable explanation for farmers' observations of reduced growth rates, poor egg production, and lower hatchability outcomes reported in the current study. Such findings are also widely reported in poultry systems facing dietary imbalances and environmental stress (Mwalusanya et al., 2002; Nzioka et al., 2017).

Although farmers did not specifically comment on egg quality, the consistently low calcium concentrations in crop contents across all seasons suggest that nutritional deficiencies compromise egg shell integrity in scavenging indigenous chicken (Roberts, 2004). This limitation is likely a contributing factor to the reduced hatchability reported by farmers in the same study (King'ori, 2011). The problem of poor shell quality may be further aggravated by heat stress (Bekele, 2021; Kim et al., 2024), which was both reported by farmers and confirmed in the thermal stress experiment. The panting response during heat stress accelerates the loss of blood electrolytes such as bicarbonates, thereby impairing calcium deposition and weakening egg shells (Mack et al., 2013). These findings imply that the reproductive performance of scavenging indigenous chicken is constrained by both nutrient deficiencies and climate induced stress. Farmers could partly mitigate these effects through provision of targeted mineral supplements such as crushed limestone or bone meal, in addition to implementing measures that help birds cope with heat stress.

6.3 Perceived and observed thermoregulation in scavenging indigenous chicken s

Climate variability in relation to temperature changes was highlighted both in farmers' perceptions and in the meteorological station records. Farmers consistently reported a general increase in temperature, whereas the station data indicated a more specific rise in minimum temperatures over time. This discrepancy may be explained by the limited capacity of farmers to differentiate between minimum and maximum temperature trends, leading them to perceive changes as an overall increase in heat conditions.

Chickens displayed clear signs of thermal stress when exposed to temperatures ≥30°C, which corresponds to the observed station maximum of 30.31 ± 2.46°C. This implies that scavenging indigenous chicken s are already experiencing thermal stress under current climatic conditions, particularly during the DJF season when temperatures reach up to 32°C. Seasonal data further showed that maximum temperatures ranged from 28.7°C in JJA to 32.08°C in DJF, with more than half of the year experiencing ≥30°C. This indicates that scavenging indigenous chicken s are exposed to potential heat stress conditions throughout most of the year. While the average and maximum temperatures showed no significant upward trend possibly due to the short observation period, national and global data consistently report a gradual rise in temperatures (IPCC, 2021; UNMA, 2022). Climate projections further indicate that temperatures will continue to increase in the coming decades, thereby placing scavenging indigenous chicken s at greater risk of heat stress and its associated negative impacts on welfare and productivity (FAO, 2016).

The thermal stress experiment revealed that chickens displayed a sequential pattern of behavioural responses to heat stress, beginning with drinking water, followed by panting, wing elevation, and finally sitting. Of these, the highest proportion of time was spent in wing elevation, followed by panting, drinking, and sitting. On the other hand, most farmers identified reduced activity as the primary behavioral response of chickens to elevated temperature, followed by increased drinking, dust bathing, and wing elevation, while few mentioned panting. Dust bathing, however, was not observed in the experimental setup, likely because the controlled chamber conditions did not favour this behaviour. The difference between farmers' perceptions and the experimental results can be explained by the fact that farmers reported field observations without measurement, whereas the experiment provided quantifiable evidence of the relative importance of each behaviour. The limited reporting of panting by farmers could be attributed to this behaviour being overlooked. Panting occurs early and persists throughout heat exposure, as shown in the thermal experiment. Because Soroti experiences maximum temperatures of ≥ 30°C most of the year, which are conditions under which scavenging indigenous chicken s become heat stressed, farmers frequently observe chickens panting. They may therefore perceive it as a normal behaviour rather than a specific response to elevated temperature. This implies a knowledge gap that may limit timely intervention. Therefore, farmers should be sensitized on detailed thermal stress behaviour recognition like panting so they can consider timely implementation of necessary adaptive measures such as shade provision and cool drinking water (Lara & Rostagno, 2013). Despite these variations, both farmers' perceptions and experimental observations consistently pointed to similar thermoregulatory behaviours. This convergence provides strong evidence that scavenging indigenous chicken s are already living under conditions of high thermal load.

The thermal stress study indicated that the first adaptation response employed by chickens under a high heat load is increased water intake, confirming that water plays a central role in thermoregulation (Bhawa et al., 2023). The fact that more than 90% of farmers reported providing water to their chickens as a coping strategy suggests that this practice supports better resilience to thermal stress. However, a large proportion of farmers relied on seasonal water sources, which may limit availability during peak dry periods when heat load is extreme. In addition, some farmers indicated that they provided waste water, likely reflecting either scarcity during certain periods or limited awareness of the influence of water quality on intake (Abbas et al., 2008; Ebrahimi et al., 2024). Although this study did not directly assess water quality effects, previous findings show that both water temperature and quality influence intake and thermoregulation (Borges et al., 2004). For instance, Abbas et al.(2008) reported that broiler chickens consumed significantly different amounts of water depending on its quality and source, highlighting the critical role of water characteristics in regulating intake. McKechnie & Wolf (2010) demonstrated through modelling that projected increases in maximum air temperatures will raise avian evaporative water requirements by 150–200%, potentially reducing survival times during extreme heat events in the absence of adequate water. These findings imply that unless reliable access to clean and cool water is ensured, scavenging indigenous chicken s will remain highly vulnerable to the effects of rising temperatures.

Panting, which was consistently observed among chickens in the thermal chamber experiment, is an important evaporative cooling mechanism that facilitates heat dissipation (Brugaletta et al., 2022). However, it comes at a high energetic and physiological cost (Kim et al., 2021). The rapid breathing associated with panting increases muscular effort and caloric expenditure, diverting energy away from growth and production (Mack et al., 2013; Mota-Rojas et al., 2021). In addition, panting disrupts the acid base balance by increasing carbon dioxide loss. This in turn impairs eggshell formation and reduces overall metabolic efficiency (Borges et al., 2004; Kim et al., 2024). These costs are compounded by the fact that heat stressed chickens reduce their physical activity, including foraging and feed intake (Lase et al., 2025). This further limits nutrient acquisition during periods of elevated temperature and reduces the ability to replenish lost electrolytes (Lara & Rostagno, 2013).

Indeed, farmers reported that feeding time was reduced by up to 46% during hot periods, confirming the extent of this limitation. Limited access to clean, high-quality water further exacerbates the challenge, as sustaining panting under such conditions elevates the risk of dehydration and mortality, particularly during prolonged heat events (IPCC, 2021; McKechnie & Wolf, 2010). Although no mortality was observed under the thermal experiment, farmers reported higher mortalities during periods of high temperatures. Therefore, other factors other than heat stress could have contributed to the perceived mortality. Consequently, while panting is a vital short-term survival strategy, over-reliance on it in the absence of adequate water resources enriched with electrolytes undermines productivity, reproductive performance, and the long-term resilience of scavenging indigenous chicken s to climate variability.

No chickens were observed drinking water while seated, which may explain why drinking water was not sustained for as long as panting. This limitation could be due to the positioning of the drinkers, which were elevated, requiring birds to stand in order to access water. Previous studies indicate that posture influences thermoregulatory behaviours, with chickens often preferring to remain seated under heat stress as a means of reducing activity and conserving energy (Playà-Montmany et al., 2023; Wasti et al., 2020). If water sources are not accessible from this posture, birds may rely more heavily on panting, a less efficient but posture-independent cooling mechanism (Mack et al., 2013). This suggests that management factors, such as the placement of waterers, can inadvertently influence how birds cope with heat stress. Farmers should therefore consider providing shallow or ground-level drinkers, preferably placed in shaded areas where chickens tend to rest during periods of high ambient temperature. Such management adjustments would not only encourage sustained water intake but also improve the birds' capacity to dissipate heat through evaporative cooling, thereby reducing the risk of dehydration and productivity losses (Onagbesan et al., 2023).

The reported reduction in scavenging time in the perception study corresponds with the observed decline in feeding activity and the increased time spent sitting by chickens under high thermal load. Sitting reduces activity to lower metabolic heat production while also allowing some heat dissipation through conduction (Li et al., 2015). Thermoregulation, therefore, comes at the expense of other vital behaviours. The increased thermal stress-induced inactivity observed in this study implies reduced access to feed and water, which heightens vulnerability to nutritional stress. This is particularly concerning since scavenging depends on active behaviours such as walking, scratching, and short flights (Lase et al., 2025). Reduced activity also elevates the risk of predation, as birds spend less time maintaining vigilance against predators (Bestman & Bikker-Ouwejan, 2020; Zimmer et al., 2011). Farmers reported higher incidences of predation during the dry seasons, which they mainly attributed to reduced vegetation cover. Nevertheless, the findings suggest that thermal stress-induced inactivity may have been a contributing factor.

The nutritional profile of scavenged feed resources across seasons revealed important implications for thermal stress. In three of the four seasons, both protein and energy levels were below the recommended requirements for poultry (NRC, 1994). Such deficiencies limit the reserves needed to support thermoregulation, since maintaining body temperature under heat stress requires additional energy for physiological and behavioural responses (Mota-Rojas et al., 2021). When nutrients are insufficient, chickens struggle to replace electrolytes lost during evaporative cooling. This also limits their ability to sustain the metabolic adjustments required to cope with heat stress (Lara & Rostagno, 2013). Therefore, if farmers do not adopt targeted supplementation strategies such as providing electrolyte-enriched drinking water, the productivity and survival of scavenging indigenous chicken s under soaring temperatures will remain at serious risk. Since no farmer mentioned this practice in the study, it highlights a clear knowledge gap.

All seasons were also characterised by higher crude fibre content than the recommended limit for poultry. Although scavenging indigenous chicken s are relatively adapted to fibrous diets, fibre is poorly digested and requires longer fermentation in the hindgut (Leeson & Summers, 2001). This process not only reduces the efficiency of nutrient utilization but also generates additional body heat, thereby increasing the metabolic heat load (Asseng et al., 2021; Brugaletta et al., 2022). Under high ambient temperatures, this added heat production exacerbates thermal stress and forces chickens to rely more on energy-costly thermoregulatory responses such as panting and reduced activity. The consequence is a trade-off where less energy is available for productive functions. As a result, the combined effects of nutrient deficits and excessive fibre compromise the birds' ability to thermoregulate effectively. They also suppress feed efficiency and, in turn, reduce growth, egg production, and overall productivity (Wasti et al., 2020). These factors leave scavenging indigenous chicken s increasingly vulnerable to the impacts of climate variability (Bekele, 2021; Bhawa et al., 2023).

In contrast, the dry season diet contained about 20% crude protein, which exceeded requirements (Kingori et al., 2010b). While this might seem beneficial, excess protein contributes to higher metabolic heat production through deamination, increasing the risk of thermal stress under already hot dry-season conditions (Leeson & Summers, 2001). However, a larger proportion of dietary energy in this season was derived from oils, mainly from groundnuts. Because oils provide metabolizable energy with a lower heat increment compared to fibre and protein (Mota-Rojas et al., 2021), they could partly moderate the heat load while still supporting energy supply (Leeson & Summers, 2001; Syafwan et al., 2011). Overall, this indicates that while most of the year is marked by nutrient insufficiency, the dry season presents a different challenge of excess protein interacting with high temperatures, underscoring the year-round link between nutrition and thermal stress in scavenging indigenous chicken s.

In conclusion, this study demonstrates that climate variability significantly affects the productivity and survival of indigenous scavenging indigenous chicken s through interconnected pathways involving feed resource availability, nutritional quality, and thermal stress. Seasonal rainfall and temperature changes influenced the availability and quality of scavenged feed, with most seasons showing deficiencies in protein, energy, and minerals, alongside excess fiber. In the dry season, although diets contained higher protein and oil-derived energy, the benefits could be offset by the additional metabolic heat generated from excess protein digestion, thereby increasing heat stress risks. Thermal stress responses such as panting, drinking, sitting, and wing elevation confirmed that chickens are already coping with heat load, but these behaviors occur at the cost of reduced feeding activity and vigilance, which heightens both nutritional stress and predation risk. Limited access to clean and reliable electrolyte enriched water further constrains ability of the birds to dissipate heat, increasing the likelihood of dehydration and productivity losses. Taken together, these findings show that the productivity, reproductive performance, and survival of scavenging indigenous chicken s are constrained not by a single factor but by the interaction of nutritional inadequacy and thermal stress, both of which are driven by climate variability. With projected rises in temperature, these risks are expected to intensify, posing a serious threat to the long-term resilience, productivity, and survival of indigenous chickens under the scavenging production system.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATION

7.1 General conclusions

Based on the findings of this study, it can be concluded that;

1. Farmers perceived noticeable climate variations, characterized by declining rainfall, shortened rainy seasons and increasing temperatures.
2. Slow growth, lower egg production and higher disease incidence were cited among the effects of high temperatures on chicken productivity.
3. Farmers coped by providing drinking water, shade and feed supplementation, whose adoption was influenced by gender, age, flock size, weather information access, training and resource access
4. The availability and quality of SFR were strongly season-dependent, with dry seasons providing more cereals and legumes but fewer insects, while wet seasons were richer in insects and food waste.
5. Crop content presented persistent deficiencies in CP ME and Ca during the long dry season and the wet seasons, Ca & P during the short dry season. Crude fibre content in all seasons exceeded the acceptable limits for chickens
6. Time budgets allocated to thermoregulatory behavior differed among IC ecotypes, with KAB ecotype showing earlier onset and longer duration of heat-dissipating behaviors than the SOR ecotype.
7. The effect of elevated ambient temperature on body temperature differed among IC ecotypes, with KAB chickens showing a greater rise in body temperature.

7.2 General recommendations

To enhance resilience of indigenous chickens scavenging production system the following recommendations are proposed;

1. **Farmers**

Climate variability knowledge enhancement;

i. Enhancing farmer awareness and timely access to reliable weather forecasts to anticipate temperature extremes and rainfall changes for proactive planning.

Enhancing scavenging indigenous chicken nutrition

ii. Prioritize energy and protein-rich supplements during the long dry and wet seasons
iii. Provide calcium- and phosphorus-rich supplements such as crushed limestone or bone meal throughout the year.
iv. Reduce crude fibre content in supplementary feeds to balance the high fibre load of scavenged resources.

Improving chicken thermal tolerance

v. Provide cool, clean, and accessible drinking water, shaded areas with vegetation cover where chickens congregate.
vi. Schedule supplementary feeding during the cooler hours of the day like early morning or evening.
vii. Promote use of nutrient-dense, electrolyte-rich rations during hot periods while avoiding high-fiber supplements that increase gut heat load

2. **Policy**

i. Promote household food security initiatives to enhance availability of scavenged feed resources.
ii. Promote policies that ensure reliable year-round water supply
iii. Prioritize breeding and conservation of indigenous chicken ecotypes from hotter regions.

iv. Provide subsidies or incentives for high-quality feed supplements and affordable climate adaptation technologies such as solar-powered incubators and communal vaccination programs.
v. Strengthen farmer training programs on poultry management under variable climates.

3. Research

Future studies should consider

i. complementing station data with gridded products, satellite observations, or additional stations to better capture localized spatial variability
ii. assessing the effects of targeted supplementation strategies on performance of scavenging ICs and extend the study to areas with different cropping systems
iii. validating farmer perceptions of the effects of high temperatures on growth performance, egg production and hatchability
iv. assessing thermal stress responses under field conditions to validate chamber findings
v. a larger sample size for each ecotype for thermal stress studies

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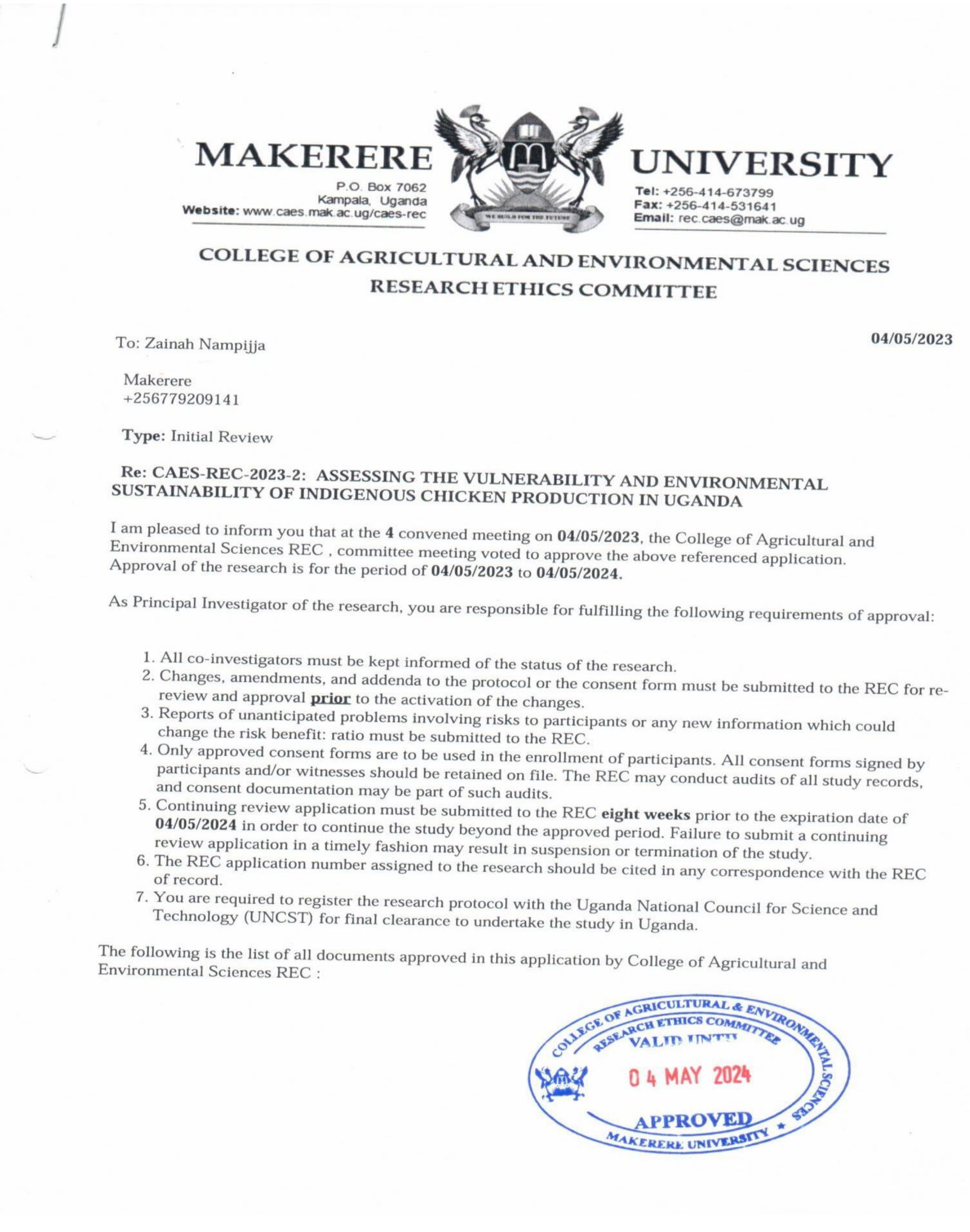
APPENDICES

1.1 Appendix 1: Ethical approval



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COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
RESEARCH ETHICS COMMITTEE

04/05/2023

To: Zainah Nampijja

Makerere
+256779209141

Type: Initial Review

Re: CAES-REC-2023-2: ASSESSING THE VULNERABILITY AND ENVIRONMENTAL SUSTAINABILITY OF INDIGENOUS CHICKEN PRODUCTION IN UGANDA

I am pleased to inform you that at the **4** convened meeting on **04/05/2023**, the College of Agricultural and Environmental Sciences REC , committee meeting voted to approve the above referenced application. Approval of the research is for the period of **04/05/2023** to **04/05/2024.**

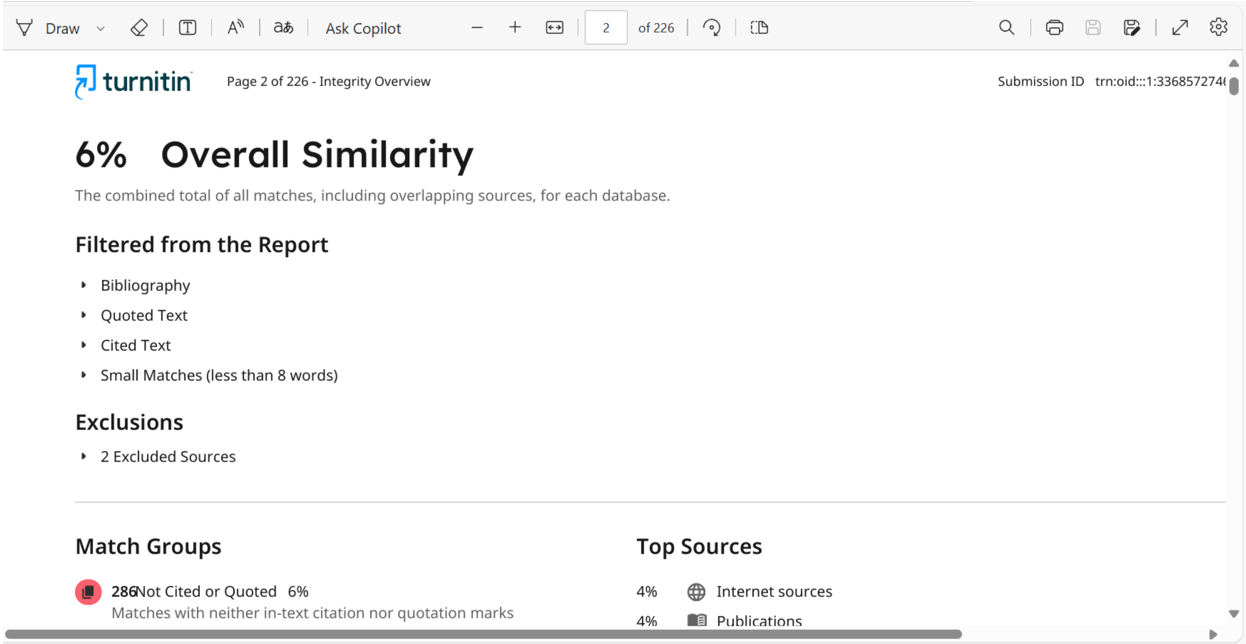
As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **04/05/2024** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by College of Agricultural and Environmental Sciences REC :

COLLEGE OF AGRICULTURAL & ENVIRONMENTAL SCIENCES
RESEARCH ETHICS COMMITTEE
VALID UNTIL
04 MAY 2024
APPROVED
MAKERERE UNIVERSITY

1.2 Appendix 2: Similarity report



turnitin Page 2 of 226 - Integrity Overview Submission ID trn:oid:::1:336857274

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1.3 **Appendix 3: Outputs**

1.3.1 Newspaper article

PHOTOS BY GEORGE BITA

The Central Processing Facility under construction at the Kingfisher oil drilling site. In the background is a rift valley escarpment with depleted forest cover

OIL SECTOR

IN APPARENT PREPARATION FOR ANY EVENTUALITY, EMBANKMENTS CONSTRUCTED FROM BOULDERS AND METALLIC SHIELDS ARE BEING BUILT ALONG THE SHORELINE ADJACENT TO OIL RIGS IN THE AREA.

y reveals that the
nent has so far spent
ated $23m in land
sation, as well as project

oil sector is a multi-million
ent that cannot be wasted
of natural disasters like
. Government is ensuring
ures are in place to avoid
amities," energy minister
nkabirwa says.

ING THE THREAT

Democratic Republic of
ide of River Semuliki,
e embankments that stop
w. So, whenever water

volumes rise, they affect only us. It is time we have similar protection on our side," William Kasoro, the Ntoroko district chairperson, says.

He says Ntoroko district needs government funding of sh850m to set up barriers that can prevent future flooding in the area.

Samuel Ojok, the co-ordinator of the land resettlement committee of the Tilenga project, says Project Affected Persons (PAPs) have been given food, as well as vocational skilling to curb dependency on tree cover.

Ojok says felling trees fuels soil erosion, which boosts the sedimentation of Lake Albert, as well as increases water levels, causing flooding.

He says all the PAPs of the Tilenga project have been given 5,000 litre rain harvesting tanks.

Ojok believes trapping rain water reduces the runoff that would eventually contribute to rising water levels in Lake Albert.

Aminah Bukenya, the head of corporate affairs at China National Offshore Oil Company (CNOOC) managing Kingfisher drilling site, says there are plans to plant over 3,000 trees on the almost bare escarpment to curb increased runoff, which cause sedimentation in the lake.

HAVE YOUR SAY Write to us on climate change on greenug@newvision.co.ug

Uganda loses $281m to climate change effects on local chicken annually

BY ZAINAH NAMPIJJA

Nampijja

Uganda is grappling with the effects of climate change, and studies have revealed that annual temperatures have risen by 1.3°C since 1960. Future forecasts also suggest a potential increase of up to 6°C by 2080. Taking an example from Soroti, eastern Uganda, where the majority of local chickens are found, the average temperatures were found to be over 30°C, which is well above 22°C, which allows for optimal performance of chickens.

Additionally, changes in seasonal rainfall amounts, duration and intensity of droughts, as well as increased occurrence of floods, have been observed. These conditions reduce the amounts of water and feeds available and increase the occurrence of diseases, ultimately reducing productivity and threatening livelihoods that depend on agriculture, including those that keep local chickens on free-range. Keeping local chickens in Uganda is considered a gateway out of poverty. Over 40% of households keep local chickens, especially under the responsibility of women. They provide household food security, income used to purchase other household goods and school fees, as well as support social functions. Nationally, local chickens constitute 87.7% of the 47 million chickens and contribute 55% of all meat consumed.

Thus, local chickens have a significant contribution to Uganda's economy, through supporting all individuals along the value chain, including those involved in hatcheries, feed production and processing, distribution and marketing. Our studies showed that the threat of climate change could lead to an annual loss of $281b, resulting from losses due to unhatched eggs.

Based on the Uganda Bureau of Statistics' estimates of 2018, 16.7% (5,186,777) of local chickens were laying hens. Based on the observation that local chickens produce 15 eggs per clutch on average, and up to three clutches annually, these chickens could potentially lay 23,340,465 eggs per year..

This results in a loss of 20,228,430 eggs annually and, consequently, 35,788,761 potential chicks (obtained from both the eggs not laid and a reduction in hatchability of the laid eggs). The eggs lost are valued at sh10.114b (each egg valued at sh500). Calculating the value of chickens lost, including eggs not laid and not hatched, amounts to $281m, excluding chicken mortalities linked to climate change.

Despite the above, farmers who keep local chickens in Soroti are already implementing some coping strategies, such as providing water and feed supplements, temporary shade, modifying laying nests and vaccinating birds, which are helping to minimise the effects of climate change. However, these strategies are still susceptible to climate change effects because they rely on seasonal water sources and scarce food waste.

To increase the adaptive capacity and reduce vulnerability of livelihoods that depend on local chickens, we recommend the following: (1) promote the use of artificial solar-powered incubators to maintain hatchability of local chicken eggs; (2) promote vaccination programmes to curb endemic diseases such as Newcastle disease; (3) proactively allocate resources to research aimed at improving chicken genetics and breeding for thermal-tolerant indigenous chicken strains; and (4) promote educational initiatives that provide information on nutritional strategies, support tools and early warning systems.

The writer is a PhD student at Makerere University College of Agricultural and Environmental Sciences. For her PhD research, she is exploring the effects of climate variability on local chickens reared under the free-range production system in Soroti.

1.3.2 Published article

Tropical Animal Health and Production (2025) 57:97
https://doi.org/10.1007/s11250-025-04333-7

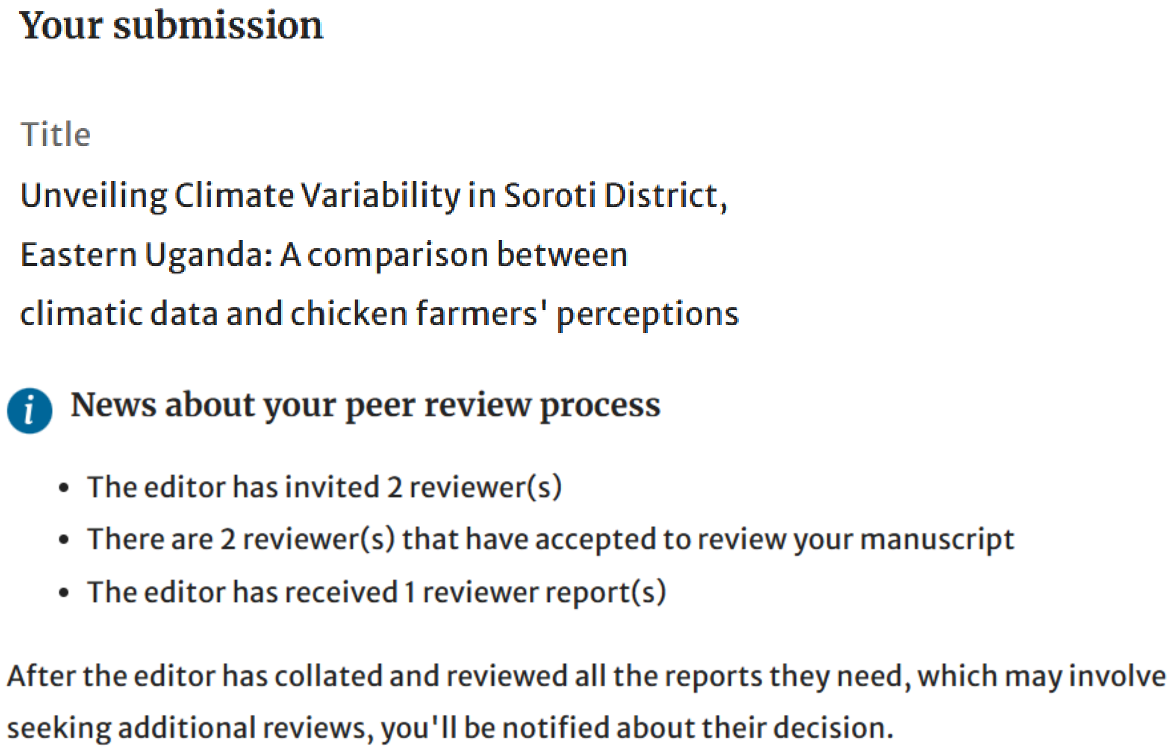
REGULAR ARTICLES

Impact of rising temperatures on scavenging chicken production in Uganda: farmer perceptions, challenges and coping strategies

Zainah Nampijja[1] · Sadhat S. Walusimbi[1] · Emmanuel Zziwa[1] · Donald R. Kugonza[1] · Muhammad Kiggundu[2] · Kanifa Kamatara[1] · Gorettie N. Nabanoga[3] · Yazidhi Bamutaze[4] · Charlotte J. Nakakaawa[5] · Lein Haakon[5]

Received: 11 October 2024 / Accepted: 18 February 2025

1.3.3 Manuscript under review



Your submission

Title

Unveiling Climate Variability in Soroti District, Eastern Uganda: A comparison between climatic data and chicken farmers' perceptions

News about your peer review process

- The editor has invited 2 reviewer(s)
- There are 2 reviewer(s) that have accepted to review your manuscript
- The editor has received 1 reviewer report(s)

After the editor has collated and reviewed all the reports they need, which may involve seeking additional reviews, you'll be notified about their decision.

1.4 Appendix 4: Tools used in data collection

1.4.1 Survey questionnaire

CHICKEN FARMERS TOOL

Date of interview……………………….Interviewer ID………..Questionnaire ID………..

Section A: House hold head and respondents' Demographic data

1. What the;
   - I. Age of the H'H ……………………
   - II. Sex a. Male b. Female
   - III. Education a. No formal b. Primary c. Secondary d. Higher level
   - IV. Religion a. Muslim b. Catholic c. Protestant d. born again e. none
   - V. Sub county……………………Parish………………Village…………………..
   - VI. Contact of H'H ………………………………
   - VII. Respondent's age ……………………………..
   - VIII. Contact of respondent………………………

Section B: Flock, household characteristics and production system

2. How many people are in your household?

Category	Number of people
Men above 18	
Women above 18	
Children below 18	

3. For how long have you been rearing indigenous chickens?................................
4. How many indigenous chicken do you rear by category and production system?

Category	**Number of bird**	**Production system**
Chicks		
Pullets/cockerels		
Hens		
Cocks		

5. Have you ever reared kuroilers? a. Yes b. No
6. Who majorly takes care of the chickens?
   a. Men above 18 b. Women above 18 c. Children d. Hired labor
7. How big is your land on which the chickens can freely scavenge………………acres
8. Do you provide any sort of housing to the birds?
   a. Yes b. No
9. Have ever received any training in chicken production?
   a. Yes b. No
10. From where/whom do you access information about chicken production?
    a. Extension/ agric officer/govt d. Radio
    b. Friend/relatives/fellow farmer e. Television
    c. NGO/development agent f. Other…………………………
11. In case you wanted to borrow money, can you find a source to access credit?
    a. Yes b. No
12. What are some of the sources from which you can obtain credit?
    a. Friend/relative d. Bank
    b. Village saving groups e. Money Lender
    c. Credit SACCO f. Other…………………………………

13. Any other poultry species reared in the household?

Poultry species	Number of bird
a.Ducks	
b. Turkeys	
c. Pigeons	
d. Guinea fowl	
e. Other ……………….	

Section C: Feeding practice, feed availability and quality

14. What are the major feed resources available for indigenous free ranging chicken in the area? (tick the major 4) and rank them in order of importance

    a. Cereals
    b. Cereal by-products
    c. insects & their growth stages
    d. kitchen waste
    e. vegetation & vegetables
    f. legumes
    g. Roots and tubers
    h. Others specify……………………….

15. Within what distance do your birds scavenge? (enumerator probes and he is shown where birds scavenge and makes an estimate of the radius of the area in meters)
    …………………………………………………………………………………….
16. With how many households do your chickens scavenge? (give number of households)
    ……………………………………………………………….
17. Do you supplement your chickens? a. Yes b. No
18. If yes what do you supplement your birds with? (up to 4 while ranking)

    a. Cereals
    b. cereal by-products
    c. Fish
    d. Cotton seed cake
    e. Soya bean
    f. Cassava flour
    g. Purchase feed
    h. Roots and tubers
    i. Insects
    j. Others specify…………………………….

Intensive production system (if not practicing intensive go to question 25)

19. Do you buy mixed feed?
    a. Yes b. No
20. If yes, do you add any ingredients in the purchased feed?
    a. Yes b. No
21. If yes, what ingredients do you add?
    a. Maize
    b. Maize bran
    c. Soy
    d. Fish
    e. Other…………………………………
22. In what proportions do you add these ingredients?

Quantity of purchased feed	Quantity of ingredients added
e.g 50kg	10kg broken maize and 5kg maize bran

23. If you do not buy mixed feed what do you feed your intensively reared birds on?

a. Concentrate b. mix my feed c. household waste d. other……………

24. If farmer mixes his feed ask, How do you mix your diets (capture farmer's formula)

Ingredient	**Quantity added**
Broken maize	
Maize bran	
Fish	
Cotton	
Cassava flour	
Soybean	
Other specify…………………	

For all farmers irrespective of the production system

25. Which of the feed resources are most affected by season? Rank 1 most affected.
    a. Cereals
    b. Cereal by-products
    c. insects & their growth stages
    d. kitchen waste
    e. vegetation & vegetables
    f. legumes
    g. Roots and tubers
    h. Others specify……………………….

26. During which months of the year are feed resources most abundant? tick all that apply and rank?
    January
    February
    March
    April
    May
    June
    July
    August
    September
    October
    November
    December

27. During which months of the year are these feed resources scarce? tick all that apply and rank
    January
    February
    March
    April
    May
    June
    July
    August
    September
    October
    November
    December

28. Are there any feed resources for chickens that have totally disappeared?
    a. Yes b. No
29. Which feed resources are these and what caused their disappearance?

Feed resource	Cause for its extinction
a. Very small termites b. Termites c. Other……………….	a. Environmental degradation b. Population increase c. Increase it other predators d. Changes in climate e. Other………………………………

30. Have you observed some new feed resources being eaten by indigenous chickens?
    a. Yes b. No
31. If yes, which feed resources are these?
    a. Nakatti
    b. Sodom Apple
    c. Fruits

d. Maize bran
e. Other…………………………..

Section D: Water access and availability

32. Do you provide water to the chickens intentionally? (If no go to qn 38)
    a. Yes b. No
33. How often do you provide water to chickens?
    a. All the time
    b. Some times
    c. Rarely
    d. Never
34. What type of water do chickens take?

a. Fresh clean water	d. Left over water provided to other livestock
b. Waste water from domestic use	e. Other specify…………………………….
c. Rain water	

35. What is the source of water that is given to chickens or used at home?

a. Boreholes	d. River
b. Wells/spring well	e. National water/taps
c. Swamp	f. Other specify…………………………….

36. Is the water source affected by season?
    a. Yes b. No
37. If yes, what happens to the water and the water source during the bad season?
    a. Water becomes dirty
    b. Water source dries up
    c. Water becomes very little
    d. Water can be accessed during specific times of the day
    e. Other …………………………………..
38. What do you do to the chickens during period of water scarcity?
    a. I continue to give
    b. Stop giving water
    c. Give waste water
    d. Purchase some water for them
    e. Nothing
    f. Other …………………………
39. How much is a 20l jerry can of water during the rainy season………………………
40. How much is a 20l jerry can of water during the dry season………………………….

Section E: Reproduction of the birds

41. At what age do your indigenous chickens start to lay
    a. 5 months
    b. 6 months
    c. 7 months
    d. 8 months
    e. 9 months
42. On average how many eggs do hens lay in a clutch and how many do you sell, consume and give back for breeding?

Number of eggs laid	No. of eggs for hatching	No. of eggs sold	No. of eggs consumed	No. of chicks that hatch out of the eggs set

43. Considering the past 10 years, how many eggs would indigenous chickens lay and how were they utilized

Number of eggs laid	No. of eggs for hatching	No. of eggs sold	No. of eggs consumed	No. of chicks that hatch out of the eggs set

44. What could be the cause in the difference in the number of eggs laid and hatched?

Cause of difference in number laid	Cause of difference in number hatched
a. Change in management b. Change in feed resource availability c. Change in disease prevalence d. Changes in climate e. Other……………………………	a. Change in management b. Change in feed resource availability c. Change in disease prevalence d. Changes in climate e. Other………………………………

45. What are the differences in the physical appearance of eggs laid **CURRENTLY** in comparison to those that were laid in the past 10 years? (compare current with past)

a. eggs are smaller	b. eggs are bigger
c. eggs are soft shelled	d. eggs are thick shelled
e. eggs have a shorter shelf life	f. eggs have a longer shelf life
g. No difference	h. Other ……………………………….

46. What causes the observed difference?
   a. I do not know
   b. Changes in climate
   c. Changes in chicken ecotypes
   d. Feed scarcity
   e. Other……………………………………………………………….

47. What differences have you observed among chicks hatched currently with those that were hatched 10 years back?

a. chicks are bigger than past	f. chicks are smaller than past
b. chicks are stronger	g. chicks are weaker
c. chicks grow faster	h. chicks grow slowly
d. chicks have stronger immunity	i. chicks have low immunity
e. No difference	j. other specify …………………………

48. What causes the observed difference?
   a. I do not know
   b. Changes in climate
   c. Changes in chicken ecotypes
   d. Feed scarcity
   e. Other……………………………………………………………….

49. How do you rate the survival and growth chicks in the different seasons

Season when hatched	Mortality rate					Growth rate of chicks				
	Very low	low	Moderate	High	Very high	Very low	low	Moderate	High	Very high
Dry season										

Rainy season										

Section F: Health management

50. At what stage do you register the highest mortality of birds?
    a. Chicks
    b. Pullets/cockerels
    c. Hens
    d. Cooks

51. What are the major causes of deaths of chickens in different seasons

Season	Challenges with chicks (rank)
Dry season	a. High diseases prevalence b. Predators and parasites c. Weather condition d. Feed scarcity e. Water scarcity f. Other………………………………………..
Rainy season	a. High diseases prevalence b. Predators and parasites c. Weather condition d. Feed scarcity e. Water scarcity f. Other………………………………………..

52. During which months are diseases and predators most prevalent?

Season when diseases are most prevalent	Season when predators are most prevalent
a. Dry season b. Wet season	a. Dry season b. Wet season

53. Why are they prevalent in those seasons

Reason for prevalence of disease in that season	Reasons for prevalence of predators in that season
……………………………………………… …………………………………………….. ………………………………………………	……………………………………………… ……………………………………………… …………………………………………....

54. How has the disease & predator prevalence changed when compared to 10 years back

Prevalence	Changes over time				
	Slightly increased	Greatly increased	No change	Slightly reduced	Greatly reduced
Disease					
Predator					

55. What could have caused the difference in the prevalence observed

Cause of observed change in diseases	Cause observed change in predators
a. Changes in bird’s immunity b. Changes in climate c. Reduced/increased vaccination d. Changes in treatment used e. Other…………………………	a. Changes in vegetation cover b. Changes in the predators of chicken predators c. Changes in population d. Other …………………………………..

56. What are the major diseases and predators for the indigenous chicken, and how do you control them? (rank the 3 major)

	Control and treatment
Major diseases in the area a. Newcastle (high death, discharge) b. Coccidiosis (Brown/bloody stool) c. Flue/cough d. Fowl pox (bruises on the head) e. Infectious bronchitis d. Other…………………………….	a. Vaccination b. Use of herbs c. Use of vet drugs d. Use of human drugs e. Maintaining hygiene f. None g. Other………………………….
Major predators a. Wild birds b. Stray dogs c. Wild cats d. Rats e. Others……………………………..	a. Clear bushes b. Kill c. Poison d. Guards e. Use dogs f. Other……………………………

57. What do you use for treatment of some chicken diseases?

Name of the herb	Effectiveness of the herb
a. Neem tree b. Aloevera c. Wild onion d. Red pepper e. Marijuana f. Human medicine g. Other………………………	a. Very effective b. Less effective c. Not effective d. Don’t know

58. Are medicinal herbs affected by season?

a. Yes b. No

59. If yes, how are they affected?

a. Dry up
b. Completely disappear
c. Other……………………

Section G: Climate change & variability (knowledge, attitudes, perceptions and adaptation strategies)

60. Are you aware of any changes in climate? a. Yes b. No
61. To what extent do you believe that the climate is changing?
    a. Not changing at all
    b. To a small extent
    c. Not sure
    d. To a great extent
    e. To a greater extent
62. What is your perception on the following climate change parameters in this area and their causes? Tick the appropriate

Parameter	**Description**	**Increased**	**Decreased**	**No change**	**Doesn't know**
Precipitation	Annual rainfall				
	1st rains (March – May) intensity				
	2nd rains (Sept – Nov) intensity				
	Length of rain season (1st)				
	Length of rain season (2nd)				
	Floods				
	Frequency of droughts				
Temperature	Dry season temperatures				
	Rainy season temperatures				
	Length of 1st dry season (June – August)				
	Length of 2nd dry season (Dec – Feb)				
Wind	Intensity in dry season				
	Intensity in rainy season				
Others	Lightening and thunder				
	Land slides				
	Hailstones				
Give years when you experienced severe droughts in the last 30 years (may give range e.g 1996, 1997) …………………………………………………………					
Give years when you experienced excess rainfall (floods) in the last 30 years ………………………………………………………….					

63. What do you think are the major causes/drivers of the observed changes in climate parameters? (multiple answers, rank)
    a. God's will
    b. Pollution from outside the community
    c. Farming practices within community e.g deforestation, swamp clearing, bush burning
    d. Changes are just normal and expected
    e. High population
    f. Other…………………………………………………
64. Do the observed changes in climatic parameters affect indigenous chicken production?
    a. Yes b. No

65. What are the effects of high temperatures on chicken production? Tick all that apply

a. reduced feed intake b. reduced weight gain c. reduced egg production d. reduced egg hatchability	e. increased mortality f. increased disease incidence g. increased egg spoilage h. other………………………………..

66. During which months of the year do you experience the highest temperatures? (Rank) Paper 3

January	April	July	October
February	May	August	November
March	June	September	December

67. What adaptation/coping measures do chickens and farmers employ during periods of high temperatures?

Coping strategy for birds	**Farmer's coping strategy (What the farmer practices)**
a. Resting under shade b. Reduce activities c. Drink much water d. Elevate wings e. Pant f. Dust bathing g. Other …………………	a. Providing drinking water b. Driving them to a shade c. Supplementary feeding d. Change breed e. Provide a structure f. Change production system g. None h. Other………………….

68. What else can farmers do to reduce on the effects of heat stress in indigenous chickens?
    a. Plant trees
    b. Provide water
    c. Driving them to a shade
    d. Supplementary feeding
    e. Change breed
    f. Provide a structure
    g. Change production system
    h. Other…………………………………
69. What factors limit adoption of climate change mitigation and adaptation measures
    a. Lack of knowledge about benefits
    b. Negligence among farmers
    c. Lack of funds to use in some implementing some strategies
    d. Limited skills to implement the adaptation measures
    e. Poor perception, thinking that they can rear chickens like their great grand
    f. Other ………………………………………………
70. What should be done to increase the adoption of climate change mitigation and adaptation measures among indigenous chicken farmers?
    a. Increased sensitization
    b. Training farmers
    c. Monitoring farmers adaptation
    d. Provide incentives
    e. Other…………………………………………………..
71. To what extent do you agree that chickens contribute to climate change
    a. Not at all
    b. To a small extent
    c. Neither agree nor disagree
    d. To some extent
    e. To a greater extent

72. Are there means/ features you use to tell if a long time change in weather events or a calamity is to occur e.g drought, flood?
    a. Yes b. No
73. If yes, which are these means/ features?

a. Changes on some plants	d. Appearance of a clear sky
b. Existence of some birds	e. Format in which stars appear in the sky
c. Direction of wind	f. Other……………………………………

74. Where or from whom do you usually get the information about weather?
    a. Fellow farmers/neighbor/friend
    b. Radio
    c. Television
    d. Mobile phone
    e. Local community leaders
    f. Extension/development agents/Environmental officers
    g. Meteologists
    h. Other…………………………………………..

Section H: Crop management

75. How much land do you farm on, for all crops?.........................
76. What tillage option do you use on your land?

Tillage option	Acreage
Zero tillage	
Reduced tillage	
Full tillage	

77. Do you apply fertilizers on your crops? a. Yes b. No
78. If yes, which fertilizer and to which crops?

Crop	Fertilizer applied	Amount/ acre	Yield/ acre	Acres planted on average
e.g beans & maize	Urea	50kg	200kg beans 400kg maize	3

79. On average how much food crops do you produce per year? Paper 3

Food crop	Quantity produced/year
Maize	
Sorghum	
Millet	
Beans	
Green gram	
Sweet potato	
Cassava	
Soybean	
Ground nuts	
Cow peas	
sunflower	
Other specify……………………..	

80. Do you mechanize any of the ergonomic practices?
    a. Yes
    b. No

81. If yes, which practice?
    a. Land preparation
    b. Planting
    c. Weeding
    d. Fertilizer application
    e. Harvesting
    f. Other specify……………………………………..

82. How much fuel do you use per acre of land during the mechanization process?

Practice	Amount of fuel/ acre	No. of acres usually operated
Land preparation • First ploughing • Second ploughing		
Planting		
Weeding		
Fertilizer application		
Harvesting		
Other specify		

83. Do you use any pesticides? a. Yes b. No

84. If yes which pesticides and at what rate?

Pesticide	Amount/ acre	No. of acres applied

85. Do you use any herbicides? a. Yes b. No

86. If yes, which herbicides and at what rate?

Herbicide	Amount/ acre

87. What do you use the residues for at the end of the growing season?
    a. Make animal feed
    b. Leave them in the garden
    c. Use them as mulch in other gardens
    d. Burn them

Section I: Manure management

88. What do you majorly use the indigenous chicken droppings/ manure for?
    a. Manure in the garden
    b. Feed for pigs
    c. Nothing, just pour way
    d. Sale
    e. Other…………………………………………..

89. How do you manage your manure from chickens? tick all that apply and Rank (if only daily spread go to qn 79)

a. Daily spread
b. Range management
c. Poultry manure with litter
d. Poultry manure without litter

90. If not daily spread, for how long is the manure kept before use?
a. In a week
b. In a month
c. In four months
d. After six months
e. Other specify …………………………….

91. How is the manure kept before use?
a. Open space
b. Under a pit
c. On ground but covered
d. Other………………………………………………

Section J: Energy (fuel) utilization

92. Do you at some point do artificial brooding of chicks at the farm? (if no go to qn 83)
a. Yes b. No

93. If yes, what energy source do you use for brooding?
a. Charcoal
b. Electricity
c. Briquettes
d. Solar
e. Paraffin

94. Why do you choose to use that source of energy?
a. Easily accessible
b. Cheap
c. Efficient
d. Other……………………………..

95. How much energy do you use in brooding a batch of indigenous chickens?

Energy source	Quantity used per brooding cycle	Number of birds brooded	Unit cost of energy source e.g a sack of charcoal
Charcoal			
Electricity			
Briquettes			
Solar			
Paraffin			
Other ……………..			

96. Do you provide light to your indigenous chickens? (If no go to qn 87)
a. Yes b. No

97. If yes, what energy source do you use for lighting?
a. Electricity
b. Paraffin
c. Solar
d. Other specify………………………………

98. How much do you spend on lighting indigenous chicken houses per month?

Lighting source	Quantity used/month	Amount spent per month
Electricity		
Paraffin		
Solar		

99. Why do you choose that source of energy for lighting and not any other?
   a. Easily accessible
   b. Cheap
   c. Efficient
   d. Other……………………………………………..

Section K: Marketing of chicken and eggs

Q No.	Question	Rank responses
100.	Where do you sale your products (chickens &eggs)	a=Farm gate b=local market c=Informal livestock market d=transport them to urban centers e=other…………………………………..
101.	Which of the chicken products do you mainly sell	Rank 3 products mostly sold a=eggs b=chicks c= pullets/cockerels d=hens d=cocks
102.	What is the average price of your products	a=an egg…………………………….. b=a chick ……………………………….. c= pullet/cockerels……………………………. d=hen………………………………………. d=cock ……………………………………..
103.	On average how many chickens do you sale in a year	………………………………….
104.	What is the average market weight for the chickens	a=Hens…………………………. b=Cocks………………………….
105.	Who determines the price of the products	a=Seller b=Buyer c=government d=Negotiation b/n seller and buyer e=Other..................................
106.	What do you use the money from sale of chickens for?	a. school fees & scholarstics b. Medication for H'H members c. buy food & other basic needs d. pay wages f. Chicken requirements e. other……………………………….
107.	Are there any constraint in marketing of indigenous chicken products?	a. Yes b. No
108.	If yes, what are they?	a. low prices/exploitation/price fluctuations b. Birds rejected due to size c. birds rejected due to diseases d. Low sales in dry season due to weight loss d. other…………………………
109.	What needs to be done to improve marketing of	a. Sell in groups

	indigenous chicken products?	b. Government should dictate prices c. Value addition on chickens d. Educate buyers and sellers e. Other……………………………………

1.4.2 KII guide

CHECKLIST FOR KII

Environmental/ natural resource officers

- Are there differences in the temperatures or rainfall in the different sub-counties in soroti district?
- Is the climate of Soroti changing?
- If yes, how has it changed over time?
- Are indigenous chicken farmers contributing to these changes? And how?
- What are some of the calamities faced in the district within the last so years (30)
    - Name calamity and year
- Which of these could have affected indigenous chickens?
- Which copping strategies did farmers employ or how did the authorities help out farmers to recover from these calamities
- Which are the hottest months in the year?
- Which are the coldest months of the year?

Veterinary officers/ Agricultural/ animal production officers

- Which sub-counties are known for indigenous chicken population?
- Are there sub-counties in which some projects that were giving out kuroiler chickens operated?
- Are there any NGO's or government programs that have promoted chicken production in the district, which ones are they. Which chickens were promoted and in which sub-counties?
- Are there differences in crop grown in these sub-counties?
- Which are the most common poultry diseases in the district?
    - In which months are these diseases most prevalent and why?
- Are there local herbs farmers could be using in treatment of these diseases? Which ones are these?

  - Are these herbs effective
- Are there any specific diseases that are most prevalent during the dry /hot period? If yes which diseases are these?
- Why do you think they are most prevalent during the hot periods?
- What are the major causes of indigenous chicken mortality during the dry and wet seasons?
- What are the major predators for indigenous chickens in the district?
  - When are they most prevalent and why?
  - How are they controlled/ what should be the best way to control them?
- How is the trend of disease and predator prevalence over time, what has changed?
- How does climate change/ specifically high temperatures influence indigenous chicken productivity?
- What copping strategies do farmers employ
- What copping strategies do chickens employ
- Any recommendations of heat stress adaptation measures that farmers can undertake to reduce the effects of heat stress on indigenous chickens?
- What could be limiting adoption of coping strategies by farmers?
- What should be done to increase adoption of coping strategies to climate change among indigenous chicken farmers?

1.4.3 FGD checklist

1. **Feed resources availability**
    - Which feed resources are available for indigenous free ranging chickens?
    - What feed resources do you supplement the scavenging chickens with?
    - Which of the feed resources is most affected by season
    - Which months of the year are feed resources most abundant? Why
    - Which months of the year are feeds resources most scarce? Why
    - Are there any feed resources that have totally disappeared? Which ones?
    - Are there any new feed resources for chickens that have emerged? Which ones?
2. **Disease prevalence, control and treatment**
    - What are the most common indigenous chicken diseases in the area?

- How do you control or treat diseases?
- During which months are diseases most prevalent? Why
- How has the disease prevalence changed over time?
- What could have caused the change in disease prevalence?
- What herbs are used in the treatment of these diseases?
- How has the availability of these herbs changed over time? Are there some that are extinct/ have disappeared?

3. Predation

- What are the major predators for indigenous chickens in the area?
- During which months of the year are predators most prevalent, and why?
- How has the predator prevalence changed over time?
- Are there changes in climate in the area, which changes are these?

4. Climate, climate change and its effects on indigenous chickens

- How was the climate of soroti the previous 10 years? Have you observed any changes?
- What causes these changes in climate? Rank options
- Do these changes affect indigenous chickens?
- During which months of the year do you experience the highest temperatures?
- What is the effect of high temperatures on chicken production?
- Which copping strategies do chickens employ during high temperatures, how do they behave?
- What copping strategies do you employ for the wellbeing and survival of indigenous chickens?
- What are the factors limiting the adoption of climate change mitigation and adaptation measures?
- Are there means you use to tell if a long time change in weather events or a calamity is to occur e.g drought, flood? If yes which means are these?