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ISSN: 2331-1932 (Online) Journal homepage: www.tandfonline.com/journals/oafa20

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**To cite this article:** Gad Kwizera , Christopher Mukasa & Davy David Okello Owiny (2026) Herd and shade characteristics associated with thermal stress management in cattle, Cogent Food & Agriculture, 12:1, 2719059, DOI: 10.1080/23311932.2026.2719059

**To link to this article:** https://doi.org/10.1080/23311932.2026.2719059



Published online: 19 Aug 2026.

COGENT FOOD & AGRICULTURE
2026, VOL. 12, NO. 1, 2719059
https://doi.org/10.1080/23311932.2026.2719059

ANIMAL HUSBANDRY & VETERINARY SCIENCES | RESEARCH ARTICLE
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# Herd and shade characteristics associated with thermal stress management in cattle

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**ABSTRACT**
Cattle production in Sub-Saharan Africa faces a variety of stresses which negatively affect cattle welfare and productivity. This study examined herd and shade characteristics associated with thermal stress management in Uganda's cattle corridor. A quantitative observational research design was adopted to study the phenomenon. Quantitative data were collected from 479 cattle–rearing households in the Lira, Soroti, and Kotido areas of the cattle corridor using a questionnaire. Data were analysed using multivariable logistic regression. Findings indicated that exotic breeds, white-coloured-coat cattle, patched-coloured-coat cattle, and the absence of a roof were significantly associated ($p < 0.05$) with thermal stress management in cattle. Farmers with indigenous cattle did not manage thermal stress. Whereas roofed structures, large canopy trees planted in pastureland, cooling measures such as fans and misters, and access to water at will are recommended practices, they were significantly lacking in the cattle corridor. Based on the findings, agricultural extension agents should refocus their training to address thermal stress in cattle, thereby optimising production and reproduction. This study uniquely examines how breed type, coat colour, and shade-related infrastructure are associated with thermal stress management practices, filling an important knowledge gap in tropical livestock adaptation research.

**ARTICLE HISTORY**
Received 21 May 2026
Revised 30 July 2026
Accepted 11 August 2026

**KEYWORDS**
Breed; cattle corridor; coat colour; roof; shelter

**SUBJECTS**
Agriculture & Environmental Sciences; Agriculture; Environmental Sciences

## Introduction

Livestock production remains a critical pillar of global agricultural systems and rural livelihoods, particularly in low- and middle-income countries where it contributes substantially to food security, employment, household income, asset accumulation, and resilience against shocks (Ed, 2021; Grace et al., 2018). Among livestock species, cattle are especially important because they provide milk, meat, manure, draught power, hides, and socio-cultural value. In many agrarian societies, cattle are not merely productive assets but strategic livelihood resources that buffer households against economic uncertainty and climatic variability. Consequently, cattle production remains one of the most important agribusiness enterprises globally and continues to underpin both subsistence and market-oriented farming systems, particularly in sub-Saharan Africa (Kweka, 2026; Vall et al., 2021).

In Uganda, the majority (92.7%) of households with cattle owned native cattle. Among households that own cattle, the average household had seven (7) animals (Uganda Bureau of Statistics [UBOS] & Ministry of Agriculture, Animal Industry and Fisheries [MAAIF], 2009). Furthermore, a typical household among cattle-owning households in the region, Karamoja sub-region, had the largest average cattle herd size estimated to be 21 cattle, while a typical household among cattle-owning households in the Eastern region had the smallest average cattle herd size estimated to be four (4) cattle.

One of the primary issues affecting the productivity, well-being, and health of dairy cattle is rising temperatures, which have led to major changes in the dairy industry in recent years (Talbi & Maklouf, 2025). The thermoneutral zone of cattle is relatively narrow and often lower than prevailing ambient

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conditions in tropical and subtropical environments. Within this zone, animals maintain body temperature without expending additional energy beyond maintenance requirements.

Under high temperatures and humidity, cattle must divert energy away from production toward thermoregulation (Meethal et al., 2018). This shift has important implications for both productivity and physiology. Thermal stress has been associated with reduced milk yield, depressed growth, poor feed efficiency, altered metabolism, reduced immune competence, and impaired reproductive performance (Farooq et al., 2010; Nardone et al., 2010). In severe cases, it can result in hyperthermia, organ dysfunction, collapse, and death (Randhawa et al., 2014). Thus, thermal stress is not only an animal welfare concern but also a major economic and management challenge in cattle production. Within this broader set of constraints, thermal stress has increasingly emerged as one of the most significant environmental threats to cattle productivity, welfare, and system sustainability, particularly under conditions of climate change and increasing climatic variability (Wolfenson & Roth, 2019).

In the cattle corridor of Uganda, both temperature and humidity are high, subjecting cattle to thermal stress. Cattle's physiological responses to thermal stress include changes in skin temperature, core (rectal) temperature, sweating, and respiratory rate. The measurement data used in this investigation are the physiological responses. Cattle will experience thermal stress more frequently due to climate change, and the hot and humid areas of the tropics, such as the cattle corridor, are the most vulnerable (Li et al., 2009). Thermal stress can cause vulnerable animals to die or have only modest effects. Hyperthermia, or thermal stress, results from exposure to warm weather. Environmental factors, individual animal vulnerability, and herd management together determine the degree of thermal stress each animal experiences. Numerous variables, including coat colour, sex, temperament, prior health history, acclimatisation, and condition score, have an impact on an individual animal's sensitivity (Brown-Brandl, 2018).

Management of thermal stress is key to improving the productive and reproductive efficiency in cattle in the hot, humid tropics. Similarly, efficient assessment and management of thermal stress are required to mitigate the decline in cattle fertility (Sammad et al., 2020). The use of fans, misters, an optimal shed structure, and ventilation has been shown to mitigate thermal stress (Ji et al., 2020). Management practices such as using cattle sheds and providing animals with access to drinking water can help mitigate the effects of thermal stress. Unless such practices are deliberately designed to manage thermal stress, they will still fall short of the required standards. High daytime temperatures and low nighttime relative humidity are the principal determinants of thermal stress in cattle (Hill & Wall, 2015). Access to tree shade and water points is a major means of managing thermal stress in cattle (Ebinghaus & Knierim, 2025; Shephard & Maloney, 2023; Vizzotto et al., 2015).

The study examined cattle-rearing households in the cattle corridor areas of Soroti, Lira, and Kotido with respect to thermal stress management practices. The factors associated with thermal stress management are an understudied area to which this study aimed to contribute. Specific consideration was made for herd and shade characteristics as key factors associated with thermal stress management. Housing structures, water availability for cattle, cattle waste management, and feed type and quality were among the key features examined during this study.

## Materials and methods

### *Study area*

The study was conducted in Uganda's cattle corridor, a semi-arid region covering 84,000 $Km^2$, accounting for about 35% of Uganda's land area (Kiggundu et al., 2019). The corridor spans Ntungamo in south-western Uganda, through Mubende and Nakasongola in central Uganda, Lango in the north, Teso in the east, and Karamoja in the north-east, supporting over 90% of the national cattle herd (Zziwa et al., 2021). It stretches further northwards to South Sudan and Ethiopia, and southwards to Rwanda. In Uganda, the corridor is home to about 90% of the national cattle herd (Owoyesigire et al., 2016). Lira, Soroti, and Kotido were selected because their average annual temperatures, which are a principal determinant of thermal stress in cattle, exceeded the national figure of 22.80 °C. In contrast, the Mubende and Mbarara cattle corridor areas had average annual temperatures below this figure (Uganda National Meteorological Authority [UNMA], 2022).

Uganda's cattle corridor is a semi-arid rangeland belt extending from south-western to north-eastern Uganda (Owoyesigire et al., 2016). The corridor is dominated by pastoral and agro-pastoral livelihoods and is recognised in national statistics as a climate-vulnerable livestock production zone (Uganda Bureau of Statistics [UBOS], 2024). The cattle corridor in Uganda is known for its vulnerability to unpredictable rainfall patterns and recurring severe droughts, which lead to water scarcity (Nimusiima et al., 2013). The region experiences two distinct rainfall seasons: the first, from March to May, and the second, from August to November. The annual rainfall ranges from 750 to 1200 mm, and the average daily temperature is between 18 and 35 °C. The semi-arid environment with irregular rainfall, sporadic droughts, and perennial grasses makes the cattle corridor ideal for raising livestock (Kiggundu et al., 2019).

### Study design

This study utilised a quantitative observational research design to collect quantitative data from cattle–farming households. The design is appropriate for documenting trends and patterns, including thermal stress management in the animal's real-life environment (Boyko, 2013). Furthermore, observational research is suitable for understanding new and unfamiliar phenomena.

### Study population and sample size

The study population comprised cattle–rearing households selected using systematic random sampling, as it reduces the chances of partiality in the household selection (Maduekwe & de Vries, 2019). Households practising extensive, semi–intensive, and intensive systems of cattle production participated in the study. According to the National Livestock Census of 2008, the number of households keeping cattle was 48,070 in Soroti; 44,960 in Lira and 22,460 in Kotido, totalling 115,490 households (UBOS & MAAIF, 2009). Since the population of the respondents was known, the Krejcie and Morgan (1970) formula for determining sample size was used (Uakarn, 2021). Thus, the sample size was calculated as follows:

$$n = \frac{X^2 Np(1-p)}{e^2(N-1) + X^2 p(1-p)}$$

where $n$ = sample size
$N$ = population size
$e$ = acceptable sampling error ($e=0.05$)
$X^2$ = Chi square, df = 1 and reliability level 95% ($X^2=3.841$)
$p$ = population proportion (Assumed to be 0.5)
Hence, $n = \dfrac{3.841 \times 115490 \times 0.5(1-0.5)}{0.05^2(115490-1) + 3.841 \times 0.5(1-0.5)}$

$$n = \frac{110899.27}{289.68}$$

$$n = 382.8$$

$$\textit{Therefore}, \boldsymbol{n} = 383 \text{ households}$$

Applying the proportionate by size method of distribution of respondents $\left(n = \dfrac{\textit{Target population in a stratum}}{\textit{Total target population in all the strata}}\right)$; the number of households to participate in the study was determined as follows;

$$Soroti = \frac{48070}{115490} \times 100 = 41.6\%$$

$$Lira = \frac{44960}{115490} \times 100 = 38.9\%$$

$$Kotido = \frac{22460}{115490} \times 100 = 19.5\%$$

To enhance statistical power and improve the precision of parameter estimates, the calculated sample size was increased by 25% (1.25). The distribution of 479 households was proportionate by size, with 41.6% (199) for Soroti, 38.9% (186) for Lira, and 19.5% (≃94) for Kotido.

## *Data collection*

The lists of cattle farmers in the study area were obtained from veterinary officers at the district, city, and/or municipal levels. This enabled the use of systematic random sampling to select the cattle–rearing households. In total, 479 households were selected during data collection, with only one member per household. Quantitative data regarding thermal stress management practices were collected using a researcher-administered questionnaire and observation tools.

Written informed consent was first obtained from the participants before administering the questionnaire or interview guide. The informed consent stated the purpose for which the findings of the study would be used, ensuring anonymity, confidentiality and voluntary participation. All the participants signed the consent forms.

## *Measurement of variables*

The variables used in this study were measured to achieve the study objective of determining the herd and shade characteristics associated with thermal stress management in cattle. The variables were categorised as dependent and independent, and their measurement was guided by the conceptual understanding and observation of thermal stress management practices.

The dependent variable was thermal stress management in cattle, defined as whether the household deliberately practised measures to minimise the effects of thermal stress on cattle. This variable was operationalised as dichotomous, with respondents who reported implementing at least one thermal stress mitigation strategy coded 1 and those who did not coded 0. The practices considered included providing shade, using shelters, improving access to water, and other management actions to reduce the exposure of cattle to thermal stress.

The independent variables consisted of selected herd and shade characteristics. Presence of exotic breeds was measured as a binary variable indicating whether the household kept at least one exotic or crossbred animal (1 = Yes, 0 = No). This variable was included because exotic breeds are generally considered more susceptible to thermal stress than indigenous breeds. The presence of white-coloured coat cattle was also measured as a binary variable (1 = Yes, 0 = No) to indicate whether the herd included cattle with predominantly white coats. This was based on the assumption that coat colour is associated with absorption of solar heat and farmer perceptions of heat tolerance. Similarly, the presence of patched-coloured coat cattle was measured dichotomously (1 = Yes, 0 = No) to assess whether mixed or patched coat patterns were associated with thermal stress management decisions.

The study also included roofing material as a shade-related independent variable. This variable captured the type of roofing used in cattle shelters or shade structures and was measured as a nominal categorical variable with three categories: grass, iron sheets, and none. In the regression model, grass roofing served as the reference category because it represented a common traditional form of shade provision in the study area. Households in the “none” category were those that did not provide any roofed shelter or roof-based shade for cattle.

While herd characteristics reflect cattle’s perceived susceptibility to thermal stress, shade-related variables reflect households’ physical capacity to provide protective infrastructure. Their measurement, therefore, enabled a meaningful assessment of the factors associated with thermal stress management under field conditions.

### *Data analysis*

In Stata/SE Version 18, quantitative data were analysed using a multivariable logistic regression. Multivariable logistic regression was used because the dependent variable—thermal stress management—was binary, making it the most appropriate analytical technique. The method enabled estimation of the likelihood of thermal stress management occurring in relation to selected herd and shade characteristics. A multivariable approach was particularly necessary because the study involved several potentially interrelated explanatory variables, including breed type, coat colour, and roof availability. By including these variables in a single model, the analysis estimated the independent effect of each factor while controlling for potential confounding. This improved the accuracy and interpretability of the findings and enabled the study to generate adjusted odds ratios to identify the most important predictors of thermal stress management in cattle.

## Results

### *Composition of cattle*

Indigenous, exotic, and crossbreed cattle were found on the farms and reared for various purposes, such as meat, milk, and draught. Farmers kept cattle of variable coat colours, including white, patched, black and brown. Cattle on the farm were at various ages and physiological states, including calves, lactating cows, and in-calf cows.

Regarding animal characteristics, farms with more white-coated cattle were more likely to implement good thermal stress management practices compared with those without white-coated cattle (24.4% vs 12.7%; COR = 2.22, 95% CI: 1.36–3.60, $p=0.001$). Conversely, farms with patched coat-colour cattle were significantly less likely to implement good practices (13.4% vs 30.1%; COR = 0.36, 95% CI: 0.22–0.57, $p<0.001$). White cattle coat colour was associated with a 2.22 times higher likelihood of good practices (COR = 2.22, $p=0.001$), while patched coat colour was associated with a 64% lower likelihood of good management (COR = 0.36, $p<0.001$). The presence of crossbreeds, dry cows, in-calf cows, lactating animals, and black- or brown-coat-coloured cattle was not significantly associated with the quality of thermal stress management practices ($p>0.05$). Farms with indigenous breeds were 92% more likely to have poor thermal stress management practices than farms without indigenous breeds (COR = 0.08, $p<0.001$). Those with exotic breeds were 13.16 times more likely to have good thermal stress management (COR = 13.16, $p<0.001$). Participants were 50% less likely to have good management practices (COR = 0.50, $p=0.004$) if they had calves on their farms. Table 1 shows the herd characteristics of cattle farms in the cattle corridor.

Thermal stress management practices were generally poor across most farms, with most farms reporting poor practices regardless of herd characteristics. However, some herd composition variables were significantly associated with the likelihood of adopting good thermal stress management practices.

### *Shade characteristics*

The farms in the cattle corridor were observed for housing structures, with a standard being a height of 5.6 metres. The locations of the high sides of the housing structures were also observed and recorded, as the orientation of the house determines the inflow of solar radiation and air currents. Windbreaks and roofs were observed on farms with housing structures.

Respondents with houses and at a height of 5.6 metres had the highest level of good thermal stress management, with 92.3% showing good practices. Those with houses below 5.6 metres in height were less likely to adopt good practices, with CORs of 0.01 compared with 0.03 for those above ($p<0.001$). According to the results, respondents with shaded feeding/water facilities were more likely to have good practices, while those with exposed facilities were 89% less likely (COR = 0.11, $p<0.001$). The location of the high side of the shade structure also impacted management practices: those facing east or west were significantly less likely to have good practices (COR = 0.20, $p=0.034$; COR = 0.11, $p=0.017$, respectively). Evidence of air circulation in the house was associated with better practices. The availability of

**Table 1.** Herd characteristics of cattle farms.

| Variable | Frequency *n*(%) | Thermal stress management | | COR(CI) | *p*-value |
|---|---|---|---|---|---|
| | | Good *n*(%) | Poor *n*(%) | | |
| Indigenous breeds on the farm | | | | | |
| No | 37 (7.74) | 25 (67.6) | 12 (32.4) | Ref | |
| Yes | 41 (92.26) | 62 (14.1) | 379 (85.9) | 0.08 (0.04–0.16) | <0.001 |
| Exotic breeds on the farm | | | | | |
| No | 443 (92.68) | 63 (14.2) | 380 (85.8) | Ref | |
| Yes | 35 (7.32) | 24 (68.6) | 11 (31.4) | 13.16 (6.14–28.19) | <0.001 |
| Crossbreeds on the farm | | | | | |
| No | 454 (94.98) | 81 (17.8) | 373 (82.2) | Ref | |
| Yes | 24 (5.02) | 6 (25) | 18 (75) | 1.54 (0.59–3.99) | 0.379 |
| Calves on the farm | | | | | |
| No | 155 (32.36) | 40 (25.8) | 115 (74.2) | Ref | |
| Yes | 324 (67.64) | 48 (14.8) | 276 (85.2) | 0.5 (0.31–0.80) | 0.004 |
| Dry cows on the farm | | | | | |
| No | 140 (29.23) | 31 (22.1) | 109 (77.9) | Ref | |
| Yes | 339 (70.77) | 57 (16.8) | 282 (83.2) | 0.71 (0.44–1.16) | 0.172 |
| In-calf cows on the farm | | | | | |
| No | 298 (62.21) | 55 (18.5) | 243 (81.5) | Ref | |
| Yes | 181 (37.79) | 33 (18.2) | 148 (81.8) | 0.99 (0.61–1.59) | 0.951 |
| Lactating animals on a farm | | | | | |
| No | 178 (37.16) | 37 (20.8) | 141 (79.2) | Ref | |
| Yes | 301 (62.84) | 51 (16.9) | 250 (83.1) | 0.78 (0.49–1.24) | 0.295 |
| Coat colour–black | | | | | |
| No | 119 (24.84) | 20 (16.8) | 99 (83.2) | Ref | |
| Yes | 360 (75.16) | 68 (18.9) | 292 (81.1) | 1.15 (0.67–1.99) | 0.611 |
| Coat colour–brown | | | | | |
| No | 133 (27.77) | 23 (17.3) | 110 (82.7) | Ref | |
| Yes | 346 (72.23) | 65 (18.8) | 281 (81.2) | 1.11 (0.66–1.87) | 0.706 |
| Coat colour–white | | | | | |
| No | 245 (51.15) | 31 (12.7) | 214 (87.3) | Ref | |
| Yes | 234 (48.85) | 57 (24.4) | 177 (75.6) | 2.22 (1.37–3.59) | 0.001 |
| Coat colour–patched | | | | | |
| No | 143 (29.85) | 43 (30.1) | 100 (69.9) | Ref | |
| Yes | 336 (70.15) | 45 (13.4) | 291 (86.6) | 0.360 (0.22–0.58) | <0.001 |

windbreaks did not show a significant association with the level of management of thermal stress (COR = 0.82). The shade characteristics of farms in the cattle corridor are shown in Table 2.

### *Multivariable logistic regression of farm factors associated with thermal stress management in cattle*

A multivariable logistic regression model was used to identify herd and housing characteristics associated with farmers' implementation of thermal stress management practices. The model included breed composition, coat colour, and roofing material as predictors of thermal stress management in cattle. Table 3 shows the multivariable logistic regression of farm factors associated with thermal stress management in cattle.

Farms with exotic breeds had 3.56 times higher odds of implementing thermal stress management practices compared with farms without exotic breeds (AOR = 3.56, 95% CI: 1.37–9.28, $p = 0.009$). Farms with calves had 49% lower odds of practising thermal stress management than farms without calves (AOR = 0.51, 95% CI: 0.27–0.94, $p = 0.031$). The presence of white-coated cattle was significantly associated with thermal stress management (AOR = 2.04, 95% CI: 1.14–3.68, $p = 0.017$). Furthermore, the roofing material showed mixed associations with thermal stress management. Iron sheet roofs were not significantly associated with thermal stress management compared with grass roofs (AOR = 0.89, 95% CI: 0.16–5.02, $p = 0.894$). Farms with no roofed shelter had 90% lower odds of implementing thermal stress management than farms with grass-roofed shelters (AOR = 0.10, 95% CI: 0.04–0.27, $p < 0.001$). The geographical location was significantly associated with thermal stress management practices. Farms in Lira District had 2.57 times higher odds of practising thermal stress management than those in Soroti (AOR = 2.57, 95% CI: 1.33–4.96, $p = 0.005$). Conversely, farms in Kotido District had 76% lower odds of implementing thermal stress management than farms in Soroti (AOR = 0.24, 95% CI: 0.07–0.86, $p = 0.029$).

**Table 2.** Shade characteristics of the housing units for cattle.

| | | Thermal stress management practices | | | |
|---|---|---|---|---|---|
| Variable | Frequency *n* (%) | Good *n*(%) | Poor *n*(%) | COR(CI) | *p*-value |
| Height of the house | | | | | |
| At 5.6 M | 13 (2.71) | 12 (92.3) | 1 (7.7) | Ref | |
| <5.6M | 17 (3.55) | 14 (82.4) | 3 (17.6) | 0.01 (0.002–0.102) | <0.001 |
| >5.6M | 5 (1.04) | 2 (40) | 3 (60.0) | 0.03 (0.009–0.12) | <0.001 |
| None | 444 (92.69) | 60 (13.5) | 384 (86.5) | 0.23 (0.038–1.432) | 0.116 |
| Status of feeding/water facilities | | | | | |
| Shade | 22 (4.59) | 13 (59.1) | 9 (40.9) | Ref | |
| Exposed | 266 (55.53) | 48 (18.0) | 218 (82.9) | 0.11 (0.044–0.29) | <0.001 |
| None | 191 (39.87) | 27 (14.1) | 164 (85.9) | 0.74 (0.45–1.25) | 0.267 |
| Location of the high side of the shade structure | | | | | |
| Northern | 25 (5.22) | 17 (68.0) | 8 (32.0) | Ref | |
| Southern | 6 (1.25) | 3 (50.0) | 3 (50.0) | 0.47 (0.07–2.86) | 0.414 |
| Eastern | 13 (2.71) | 4 (30.8) | 9 (69.0) | 0.20 (0.05–0.88) | 0.034 |
| Western | 10 (2.09) | 2 (20) | 8 (80.0) | 0.11 (0.02–0.68) | 0.017 |
| None | 425 (88.73) | 62 (14.6) | 363 (85.4) | 0.08 (0.33-0.19) | <0.001 |
| Availability of windbreaks around the house | | | | | |
| Yes | 392 (81.84) | 74 (18.9) | 318 (81.1) | Ref | |
| No | 87 (18.16) | 14 (16.1) | 73 (83.9) | 0.82 (0.44–1.54) | 0.544 |
| Roofing material used | | | | | |
| Grass | Ref | | Ref | | |
| Iron sheets | 0.07 (0.036–0.142) | <0.001 | 0.66 (0.13–3.36) | 0.621 | |
| None | 0.11 (0.03–0.44) | 0.002 | 0.10 (0.04–0.22) | <0.001 | |

**Table 3.** Multivariable logistic regression of farm factors associated with thermal stress management in cattle.

| Predictor | Adjusted odds ratio | Standard error | z-value | *p*-value | 95% confidence interval |
|---|---|---|---|---|---|
| Presence of exotic breeds | | | | | |
| No | 1 | | | | |
| Yes | 3.56 | 0.49 | 2.60 | 0.009 | [1.37, 9.28] |
| Calves on the farm | | | | | |
| No | 1 | | | | |
| Yes | 0.51 | 0.31 | −2.15 | 0.031 | [0.27, 0.94] |
| Presence of white-coloured coat cattle | | | | | |
| No | 1 | | | | |
| Yes | 2.04 | 0.30 | 2.39 | 0.017 | [1.14, 3.68] |
| Roofing material | | | | | |
| Grass | 1 | | | | |
| Iron sheets | 0.89 | 0.88 | −0.13 | 0.894 | [0.16, 5.02] |
| None | 0.10 | 0.49 | −4.59 | <0.001 | [0.04, 0.27] |
| District | | | | | |
| Soroti | 1 | | | | |
| Lira | 2.57 | 0.33 | 2.82 | 0.005 | [1.33, 4.96] |
| able_fKotido | 0.24 | 0.64 | −2.19 | 0.029 | [0.07, 0.86] |

*Model diagnostics: $N = 461$; LR $\chi^2(7) = 123.88$, $p < 0.001$; AIC = 332.81; BIC = 365.88; McFadden $R^2 = 0.281$; Pearson goodness-of-fit $p = 0.272$; Hosmer–Lemeshow $p = 0.091$; AUC = 0.814; maximum VIF = 1.58.*

## Discussion

The findings of this study reveal that 92.69% of the cattle–rearing households in the cattle corridor never had a housing structure for cattle. This could be due to the traditional cultures of pastoral communities, with large numbers of cattle and no housing structures, especially among the transhumant communities. This is largely due to their significant dependence on rangeland vegetation for pasture, which requires them to shift grazing areas over the seasons (Byakagaba et al., 2018). According to a study by Saatci et al. (2004), cattle are believed to spend longer periods in housing due to variations in climate and altitude. Farmers undertook deliberate measures to protect the white-coloured cattle from thermal stress. Conversely, farmers rearing patched coloured coats were less likely to implement thermal stress management practices. As opined by Shephard and Maloney (2023), coat colour influences the absorption of solar radiation, ultimately affecting the heat load on the animal. Therefore, white and patched-coloured cattle were believed to absorb less solar radiation and thus tolerate the high temperatures of the cattle corridor (Mehany et al., 2025; Shephard & Maloney, 2023). Moreover, Brown-Brandl (2018) identified coat colour as one of the factors influencing thermal stress in cattle.

The study findings demonstrated that the absence of roofs in the study area, indicating a lack of housing structures, was common in the cattle corridor, possibly due to the extensive production system's transhumance characteristics. This indicated a lack of deliberate measures to manage thermal stress, despite the cattle corridor experiencing high ambient temperatures and humidity (Owoyesigire et al., 2016). This could be explained by farmers with no-roof structures and/or no structures who were less likely to undertake thermal stress management practices. The lack of housing structures in this semi-arid climate, with scant forest cover, increases the risk of thermal stress in cattle. Besides, Hasan et al. (2026) identified shade availability as one intervention to manage thermal stress. In temperate areas, cattle may experience thermal stress when grazing in summer, and providing shade can reduce this stress (Veissier et al., 2018). To address the need for shade, Toledo et al. (2022) further demonstrated that cows relieved of thermal stress during the dry period produced more milk during the subsequent lactation, had a stronger immune response during the transition phase, and gave birth to calves that were larger and healthier. This is an area that cattle farmers in the cattle corridor could capitalise on to enhance thermal stress management. The need for shade in the semi-arid cattle corridor cannot be overemphasised in the face of climate change. The importance of providing enough shade for all cattle to use the resource simultaneously was highlighted by the fact that cows were more inclined to use the shade structures during times of day when ambient solar radiation was at its peak (Tucker et al., 2008). Sullivan et al. (2011) suggested that shade provision could increase feed efficiency and improve animal welfare.

In Indonesia, native cattle were more preferred by farmers because they were less demanding and less prone to issues than most improved and/or crossbred cattle. The study found that 92.68% of households in the cattle corridor owned indigenous breeds, with a lower preference for exotic breeds. This aligns with the 92.7% of indigenous breeds reported in the 2008 National Livestock Census, but is higher than the 80.6% recorded in the 2021 Census. In Uganda, Nganda/Zebu and Ankole cattle make up 70% and 30% of the total indigenous herd, respectively (Agriterra, 2012). A study on the characterisation of extensive beef cattle systems in the United Kingdom indicated a strong preference towards cattle breeds generally considered hardy or native. In a study conducted in Kayunga district, Uganda, the production system was identified as mainly pastoralist, focusing on livestock husbandry, particularly native breeds such as Nganda, Ankole, and Karamoja. The increase in the production of exotic breeds, which are more vulnerable to thermal stress, justifies the higher odds of farmers with exotic breeds managing thermal stress. This is because the production system remains largely extensive, despite the need for exotic breeds to have planned housing systems. The introduction of shade trees into extensive systems is recommended to allow cattle to seek shade during periods of thermal stress (Shephard & Maloney, 2023).

Although several confounders were adjusted for, unmeasured confounding such as the proportions and intensity of each colour, and the breed associated with each colour cannot be ruled out. This could affect the results of the study.

## Strategic implications and conclusions

### *Strategic implications*

The findings of this study carry significant strategic implications for livestock production systems, climate adaptation planning, and agricultural extension services in cattle production systems. By demonstrating that thermal stress management is strongly associated with breed type, coat colour, and shade-related infrastructure, the study underscores the need to treat thermal stress as a constraint to cattle production. In practical terms, this means that thermal stress management should be integrated into livestock development planning, especially in regions characterised by high ambient temperatures and climate variability. The study suggests that interventions aimed at improving cattle productivity and welfare cannot be fully effective without managing environmental conditions, as these conditions pose a real threat.

One of the most important strategic implications of the study is the need to reorient livestock farmers to consider robust thermal stress management practices, especially in areas experiencing climate variability. Extension agents need to provide targeted training on identifying thermal stress symptoms, understanding the risks associated with prolonged heat exposure, and exploring practical mitigation options available to farmers. This is particularly important in correcting the widespread assumption that indigenous breeds are sufficiently heat-tolerant and therefore do not require active thermal stress management, when in reality, prolonged heat burden can still compromise their reproductive and productive performance.

In the face of climate change with increasing environmental heat burden, strategic adaptation efforts should include improving access to shade, enhancing water availability, promoting tree-based grazing environments, and encouraging housing designs that provide sufficient protection against environmental heat. In this regard, thermal stress management should be recognised not merely as an animal-comfort issue but as a critical adaptation strategy for safeguarding milk production, growth rates, fertility, and herd survival under changing climatic conditions. The finding that farmers were more likely to manage thermal stress in exotic cattle reflects recognition of these breeds' greater vulnerability to thermal stress. The results indicate the need for thermal stress management interventions in breed investment.

A further strategic implication is the urgent need to invest in affordable, scalable thermal stress mitigation infrastructure. The study found that recommended adaptive measures, such as roofed shade structures, large canopy trees, cooling devices, and unrestricted access to water, were significantly lacking in the cattle corridor. This indicates that thermal stress management is not only a matter of farmer awareness, but also of resource availability and infrastructural support.

## Conclusions

This study concludes that thermal stress management in the cattle corridor of Uganda is significantly associated with cattle breed type, coat colour, and shade-related structural conditions. The higher likelihood of thermal stress management among farmers keeping exotic breeds and patched-coloured cattle suggests breed-based interventions to address thermal stress. Indigenous cattle are considered hardy and well adapted to the hot tropical climate, encouraging deliberate thermal stress management for the exotic breeds. At the same time, the limited attention given to indigenous cattle indicates a potentially risky belief that local breeds are sufficiently heat-tolerant, despite the adverse effects of thermal stress on production and reproduction.

The study also highlights substantial deficits in shade, including the absence of roofed shelters or no shade provided at all. These shortcomings point to a broader need to integrate thermal stress management into routine livestock husbandry and climate adaptation programming. This may include, but is not limited to, extension programmes on thermal stress management and establishment of model farms for routine thermal stress management training. The findings contribute original evidence to tropical livestock adaptation research by demonstrating how herd characteristics impact farmers' responses to thermal stress management.

## Acknowledgements

The District Production Officers for Lira, Soroti and Kotido, City Production Officers for Lira and Soroti, Kotido Municipality Production Officer and the cattle farmers in Soroti, Lira and Kotido. GK is the corresponding author and conceptualised the research project; analysed and interpreted the data. ODDO participated in the conceptualisation of the idea and the study design, the interpretation of findings, and the monitoring of the project's progress. CM participated in the conceptualisation of the idea and the study design, the interpretation of findings, and the monitoring of the project's progress.

## Author contributions

CRediT: **Gad Kwizera**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft; **Christopher Mukasa**: Conceptualization, Methodology, Project administration, Validation, Visualization, Writing – review & editing; **Davy David Okello Owiny**: Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

## Ethics statement

The study was approved by Gulu University Research Ethics Committee (GUREC) and Uganda National Council for Science and Technology (UNCST) under reference GUREC-2023-540.

As required under the ethical principles of the Declaration of Helsinki, all participants filled an informed consent form prior to participation in the study. The consent form specified the rights of the participants regarding the risks and benefits of participation, privacy and confidentiality and voluntariness.

## Disclosure statement

The authors declare that they have no competing interests.

## Open scholarship

This article has earned the Center for Open Science badges for Open Data. The data are openly accessible at https://doi.org/10.6084/m9.figshare.32337117.

## Funding

No funding was received for the study.

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## Data availability statement

The data that support the findings of this study are openly available in figshare at https://doi.org/10.6084/m9.figshare.32337117.

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