Application of the climate analogue concept in assessing the probable physiological and haematological responses of Friesian cattle to changing and variable climate in the Kenyan Highlands

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Abstract

Friesian cattle are considered the most sensitive to climate change-induced thermal stress and remain the major dairy breed in Kenya. This study applied the climate analogue concept to predict probable physiological and haematological responses of Friesian cattle in the 2050s to understand their adaptability to a changing and variable climate. Njoro in the Kenya Rift Valley Highlands was used as the reference site and its 2050s climate analogue site was identified in Shawa, based on criteria of a similarity index of 0.8–0.9. Results suggest that Njoro in the 2050s will likely experience increasing temperatures, but changes in rainfall are uncertain. The increasing temperatures will probably be accompanied by mild thermal stress for Friesian cattle during the dry seasons or drought. The thermal humidity index differed between times of day, but not between the analogue sites. Except for rectal temperatures, the physiological and haematological responses differed between the analogue sites, but were within the normal ranges. It is concluded that Friesian cattle in Njoro in the 2050s will probably experience mild thermal stress in the afternoons during the dry seasons, expressed by slight increases in physiological and haematological responses, but will probably remain within the normal margins.

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Introduction

High ambient temperature can be a limiting environmental factor to the productive utilization of exotic dairy cattle breeds and their crosses in the tropics. The high environmental temperatures expressed as thermal stress cause reduced feed intake and impaired metabolism, which consequently translate to low milk yield, and suboptimal fertility and health performances (Abdelatif & Alameen, 2012; Rana *et al.*, 2014). As homeotherms, dairy cattle have thermal comfort zones, within which they maintain homeothermy and above which they become exposed to thermal stress. Ambient temperatures between 16 °C and 26 °C correspond to the thermal comfort zone of dairy cattle, and heat loss mechanisms (radiation, convection, and conduction) are sufficient for thermal regulation (Abdelatif & Alameen, 2012; Kucevic *et al.*, 2013; Das *et al.*, 2016).

When exposed to thermal stress, dairy cows adjust their physiological responses to increase heat dissipation to the environment, subsequently altering their haematological profiles. Physiological and haematological variations are therefore useful measures of comfort and adaptability of dairy cattle to thermal stress (Ganaie *et al.,* 2013; Das *et al.,* 2016). Widely used measurable physiological changes in cattle include skin and rectal temperatures, sweating, respiration and pulse rates (Farooq *et al.*, 2010; Ganaie *et al.,* 2013; Jian, Ke & Cheng, 2015), while haematological changes include packed cell volume (PCV), blood cell counts and haematimetric parameters measured by the mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) (Ashour *et al.*, 2011; Bhan *et al.*, 2012; Roland *et al.*, 2014;

Onasanya *et al.*, 2015). These responses are distinct and prolonged in temperate *(Bos taurus)* cattle breeds compared with tropical *(B. indicus)* cattle breeds, indicating poor adaptation to thermal stress by temperate breeds (Farooq *et al.*, 2010). The traits that increase the vulnerability of temperate breeds to thermal stress have been well documented, and include stocky body, thick skin, dense hair and a few poorly developed sweat glands (Hansen, 2004; Chan *et al.*, 2010; Jian *et al.*, 2013). The superior thermal regulatory ability of tropical breeds such as the zebu compared with temperate breeds such as Friesian in the tropics is the result of a combination of reduced heat production and increased capacity of heat dissipation (Hansen, 2004).

The relationships between thermal regulation mechanisms and changes in ambient temperatures and relative humidity, known as the thermal humidity index (THI) have been studied (Schoen, 2005; Dikmen & Hansen, 2009; Gaafar *et al.*, 2011; Kucevic *et al.*, 2013; Mazzullo *et al.*, 2014). Several models have been developed, and their suitability analysed for use in assessing thermal stress levels in cattle (Schoen, 2005). The model that is mostly used, classifies thermal stress at four levels, namely thermal comfort zone, with THI values less than 72; mild at 72 to 78; high at 78 to 88; and above 88 as severe (Gaafar *et al.*, 2011; Abdelatif & Alameen, 2012; Das *et al.*, 2016). With a THI of 72+, primary autonomic responses, which are presented by vasodilation of surface blood vessels, are initiated to increase blood flow to the heat exchange surfaces of the skin for evaporative heat dissipation through sweating (Gebremedhin *et al.*, 2008). If sweating is overwhelmed, respiratory evaporative heat dissipation through elevated respiration rates begins and progresses to panting as THI exceeds 78 (Gomes *et al.*, 2011; Jian *et al.*, 2015).

Increase in respiration rates is commensurate with heightened pulse rates to supply more blood from the body core to heat dissipation surfaces. The elevated respiration rates increase ventilation, which affects the red blood cell (RBC) concentration and haematimetric parameters, while the sweating rate reduces electrolytes, hence blood volumes and induces changes in blood composition (Das *et al.*, 2016). Indirectly, thermal stress through the hypothalamus, pituitary and adrenal system trigger the immune system, causing changes in leukocyte profiles (Chen *et al.*, 2015). In prolonged and severe thermal stress, a reduced heart rate is typical as it is associated with reduced metabolic heat production (Farooq *et al.*, 2010). Incidentally, continued exposure to thermal stress involuntarily causes behavioural changes such as shade seeking and reduction in feed intake.

The temperate cattle breed that is most utilized in Kenya's dairy industry is the Friesian, because of its high milk yield potential, unselective feeding behaviour in zero-grazing production units and large body weight, which translated to a high salvage value (Bebe *et al.*, 2003; FAO, 2011). Like other temperate breeds that are poorly adapted to tropical conditions, the Friesian requires modifications in the management of the environment to ameliorate the effects of thermal stress (McManus *et al.*, 2009). However, with climate change, the highland regions in which the breed is utilized are projected to experience increasing temperatures and variable rainfall (Huho & Kosonei, 2013; USAID, 2010). Under such circumstances the comfort zone for the Friesian breed is likely to shift and expose the breed to adaptation difficulties related to thermal stress. Identifying the likely future climatic conditions for the regions in which Friesian cattle are utilized could be a milestone towards understanding the adaptation challenges the breed will experience.

The Consultative Group on International Agricultural Research's (CGIAR) Research Programme on Climate Change and Food Security (CCAFS) has developed a tool and online platform that help identify areas where climatic conditions today resemble the climate projected for a selected area (Ramirez-Villegas *et al.*, 2011). The tool works by using data for climate and bioclimatic variables for a chosen reference site to predict future climatic scenarios using global climate models (GCM) and SRES (Special Report on Emission Scenarios) for a specified timescale (Ramirez-Villegas *et al.*, 2011). The future climatic scenarios are then compared and mapped to areas (globally or locally) in which they exist currently to give the probable future analogue sites to the reference site (Ramirez-Villegas *et al.*, 2011). Using the two climate analogue sites (reference site and future climate analogue sites), comparative studies can be carried out to assess the adaptation opportunities and challenges to be expected (Ramirez-Villegas *et al.*, 2011).

This study applied the climate analogue concept to predict probable physiological and haematological changes for Friesian cattle in the 2050s when utilized in the Kenya Highlands with a climate similar to that of Njoro currently.

Materials and Methods

Njoro (Figure 1) in the Rift Valley Highlands of Kenya was the selected reference study area because it has a high population of dairy farms that utilize Friesian cattle (1–3 cows/farm) (Omondi & Njehia, 2014). Njoro lies between latitude 00° 19' 00" S and longitude 36° 06' 00" E in Low Highlands (LH3) and Upper midlands (UM4) ecological zones with an altitude of 2168 m to 2800 m above sea level.
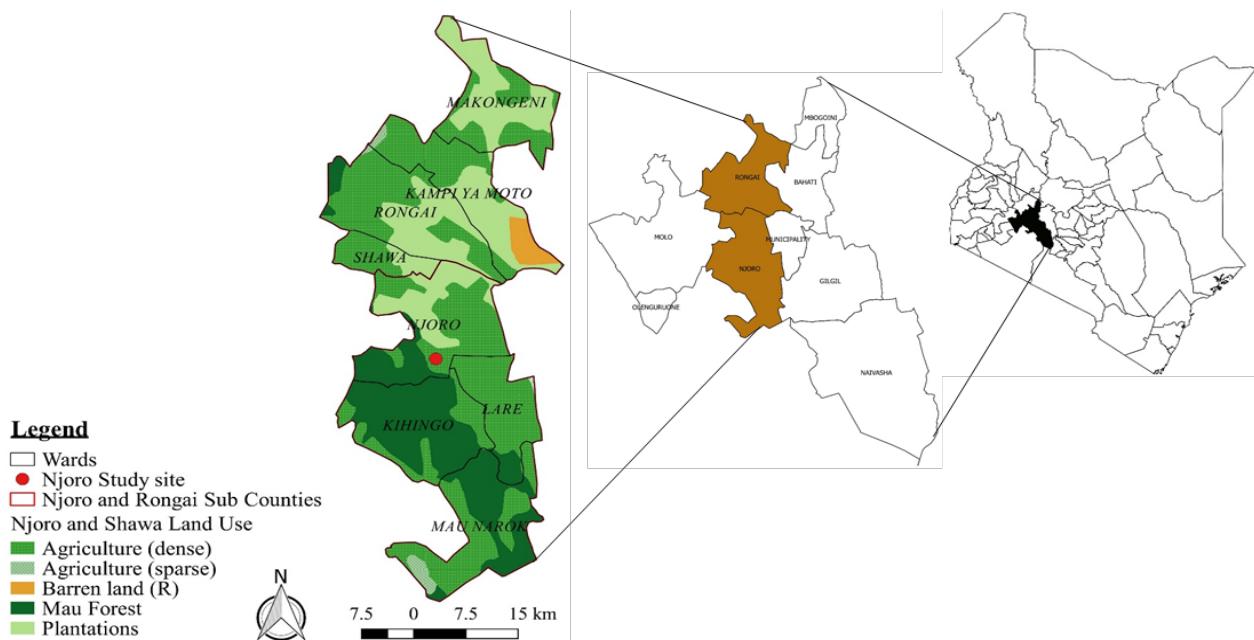
Figure 1 Study sites in Njoro and Shawa areas in Kenya

The CCAFS procedures and climate analogue tool online platform were applied with ensemble GCMs and SRES A1B to predict the analogue sites in the 2050s (Ramirez-Villegas *et al.*, 2011). Climate variables of interest were mean monthly temperature and total monthly rainfall, which were run separately or combined. When combined, a weight of 0.5 was used for each variable to ensure equal contribution in calculating the analogues. In each run, applicable rotations (none, monthly mean temperature, monthly rainfall or both) were applied to check for seasonality effects. The default resolution of 30 arc seconds was maintained, and the minimum threshold of similarity index was set at 0.5. A nine-month growing period from March to November was assumed to be the replica to Njoro currently. Shawa area (Figure 1) in the Rift Valley was identified as the probable future climate analogue site to Njoro in 2050s, since it had the highest similarity index (0.8–0.9) and was consistent in all runs. Shawa lies between latitude 00° 21' 00"and longitude 36.8° 08' 59.99" at an altitude of 1650 to 1850 m above sea level in the Lower Midlands (LM3) and Upper Midlands (UM3) ecological zones.

Weather data during the study period and long-term climate data were obtained from Egerton University in Njoro, Gogar Farm in Shawa, weather stations and Kenya Meteorological Department.

A commercial dairy farm that keeps Friesian cattle breed was identified in each site to access animals to measure physiological and haematological indicators. Ngongongeri Farm was selected in Njoro and Gogar Farm in Shawa. Each farm had more than 200 mature Friesian cows of different physiological status. Thirty mature healthy and nongravid Friesian cows were selected from two age groups (young cows aged 4 ± 1 years and old cows aged 7 ± 1 years) in each farm. The age groups were used to assess their susceptibility to thermal stress. Cows in both farms were exposed directly to climatic stress in semi-intensive management practices. They were allowed to graze freely during the day and supplemented with total mixed ration in the morning and evening after milking. The cows in Gogar farm had *ad libitum* access to water, while those in Ngongongeri had timed watering in the morning, noon and evening.

The study was carried out in March 2016 in the hot season. The physiological parameters were taken twice a day (07:00 and 14:00) for four days, while blood samples were taken only on the last day. Physiological response variables were rectal temperature (RT), respiratory rate (RR), heart rate (HR) and sweating rate (SR). Rectal temperature was measured with a digital thermometer placed against the rectal walls, and readings were taken after the thermometer completion beep. Heart rate and RR were determined using a clinical stethoscope for one minute each. Sweating rate was measured using a technique described by Schleger & Tuner (1995) and adapted by McManus *et al.* (2009). Three discs of about 0.5 cm^2, cut from Whatman #1 filter paper soaked in 10% aqueous solution cobalt chloride and dried, were placed on a shaved area of about 5 cm^2 on the lumbar vertebra. The average time taken for the discs to change colour from blue to pink was observed using a stopwatch. Sweating rate was then calculated using Schleger &

Tuner's (1995) equation SR = 384466.901/t (g m^{-2}h^{-1}), with **t** being time in seconds taken by the disc to change colour (McManus *et al.*, 2009).

To determine haematological parameters, about 10 mL of whole blood was collected through coccygeal venipuncture into vacutainer tubes with EDTA on the fourth day, when physiological parameters were measured. Samples were chilled and transported to the Biotechnology Research Centre of Kenya Agricultural and Livestock Research Organization (KALRO), within 24 hours for analysis. Automated blood analysis using Coulter haematological analyser (AC$^{.}$T diff Beckman Coulter™) was used to investigate hematological parameters, packed cell volume (PCV), blood cell counts (white blood cells (WBC), red blood cells (RBC) and platelets (Plt)), haemoglobin (Hb) concentration; and haematimetric parameters (mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC)). Manual differential leucocytes counts were used to determine leukocyte types (lymphocytes, monocytes, eosinophils, and basophils) in percentages from a thin Wright's stain smear under optical microscope targeting fields of 100 cells.

Analysis of variance with the general linear model (GLM) procedures of SAS (2008) was used to determine the mean differences in climate variables (monthly total rainfall and mean temperatures), THI, physiological response variables (RR, RT, HR, and SR) and haematological variables (BCV, BCC and haematimetric parameters) between the climate analogue sites, by fitting the model:

$$Y_{ijk} = S_i + T_j + E_{ijk}$$

Where: Y_{ijk}= climate variables, THI, physiological and hematological response variables
S_i= fixed effect of sites
T_j= time of day
E_{ijk}= random error component associated with Y_{ijk}

THI was determined using the model:

$$THI = (1.8)T_a - (1 - RH)(T_a - 14.3) + 32$$

Where: T_a = average ambient temperatures
RH = average relative humidity as a fraction

The THI indices were classified, namley THI less than 72 indicated Friesian cattle were within the thermal comfort zone; 72 ≤ THI < 78 in mild thermal stress;, 78 ≤ THI < 89 in severe thermal stress; 89 ≤ THI < 98 in very severe thermal stress: and 98 < in danger the zone (Gaafar *et al.*, 2011; Abdelatif & Alameen, 2012; Musari *et al.*, 2014; Das *et al.*, 2016).

Regression analysis for climate variables against time in years was used to obtain trend regression coefficients.

Results
Smallholder farms in Njoro used cut-and-carry zero-grazing and semi-zero-grazing production systems compared with Shawa, where more farms utilized semi-zero grazing and free grazing systems (Figure 2)
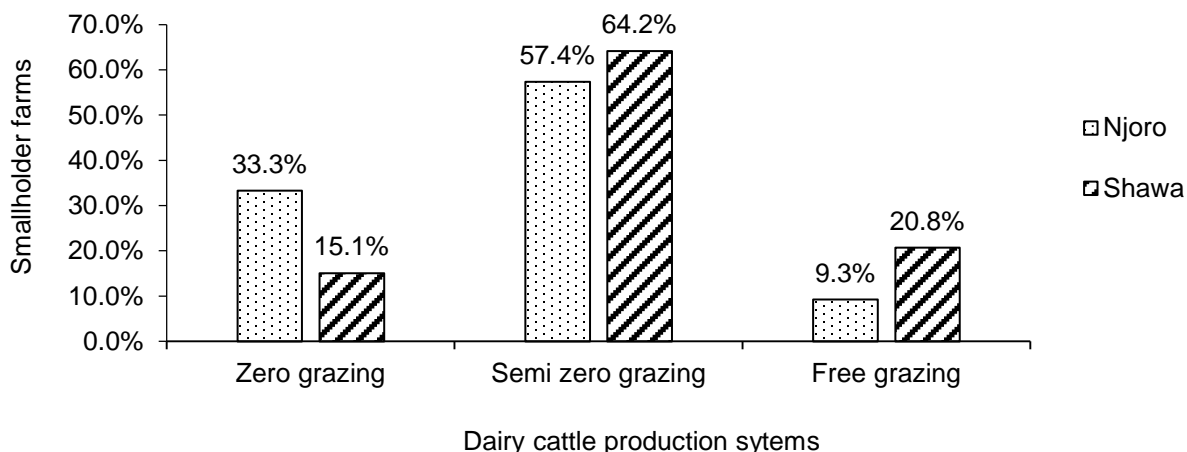
**Figure 2** Dairy cattle production systems in Njoro and Shawa

Using rainfall data for 50 years and temperature data for 30 years, the climatic variables differed between the climate analogue sites (Table 1). Njoro had higher monthly rainfall and the lowest temperatures relative to Shawa.

Table 1 Climatic variables for the climate analogue sites

Analogue sites	Monthly total rainfall (mm)	Monthly mean temperatures (°C)	Monthly minimum temperatures (°C)	Monthly maximum temperatures (°C)
Njoro	86.3 ± 2.14^a	16 ± 0.12^a	10.2 ± 0.16^a	23.3 ± 0.20^a
Shawa	80.8 ± 2.11^b	18.5 ± 0.13^b	11.5 ± 0.17^b	25.5 ± 0.20^b

^{ab} Means with different letter superscripts within a column differ at $P < 0.05$

Annual rainfall trends from 1964 to 2013 (Figure 3) showed a higher increase in Njoro (3.30 mm, $R^2 = 0.044$) compared with Shawa (1.00 mm, $R^2 = 0.005$). The increase was greatest in the October–November–December short rain season (Figure 4) with Njoro (2.03 mm, $R^2 = 0.099$) having a higher increase than Shawa (0.95 mm, $R^2 = 0.021$). Unlike Shawa, which had a weak increasing trend (0.04 mm, $R^2 = 0.000$), Njoro showed a declining trend for March–April–May season rainfall (-0.29 mm, $R^2 = 0.001$) (Figure 5).
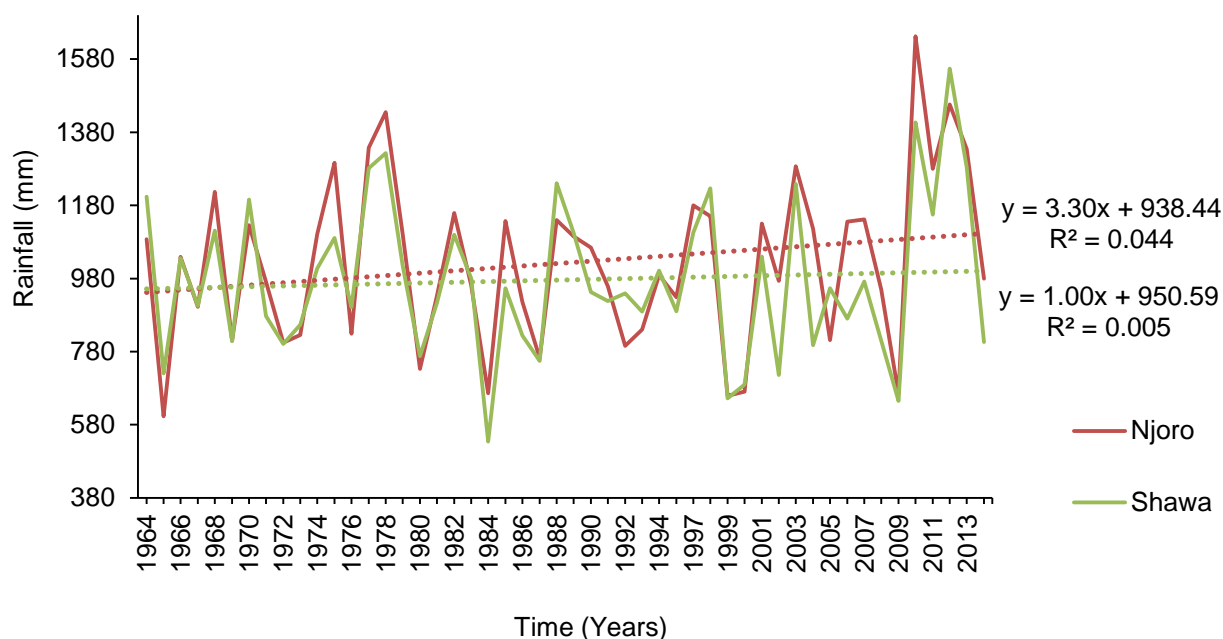
Figure 3 Total annual rainfall trend for Njoro and Shawa

Temperature trends for Njoro and Shawa agreed with model predictions (Table 1) of increasing temperatures (Figure 6). Shawa (0.08 °C, $R^2 = 0.806$) showed a higher rate of increase for mean annual minimum temperature compared with Njoro (0.02 O°C, $R^2 = 0.294$). On the other hand, Njoro (0.03 °C, $R^2 = 0.301$) had a higher increase in mean annual maximum temperature compared with Shawa (0.02 °C, $R^2 = 0.070$). This resulted in a higher rate of increase in mean annual temperature in Shawa (0.05 °C, $R^2 = 0.561$) than in Njoro (0.03 °C, $R^2 = 0.514$).

The daily THI during the study period differed ($P = 0.0001$) only between times of the day (07:00 and 14:00), being higher in the afternoons (Table 2) in both sites, but did not differ between sites.
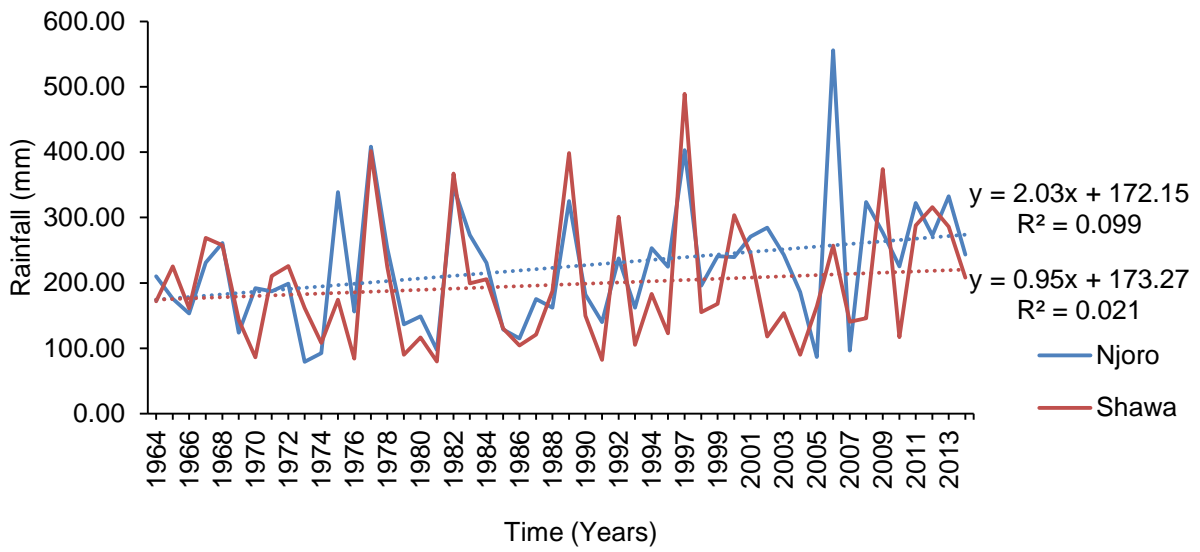
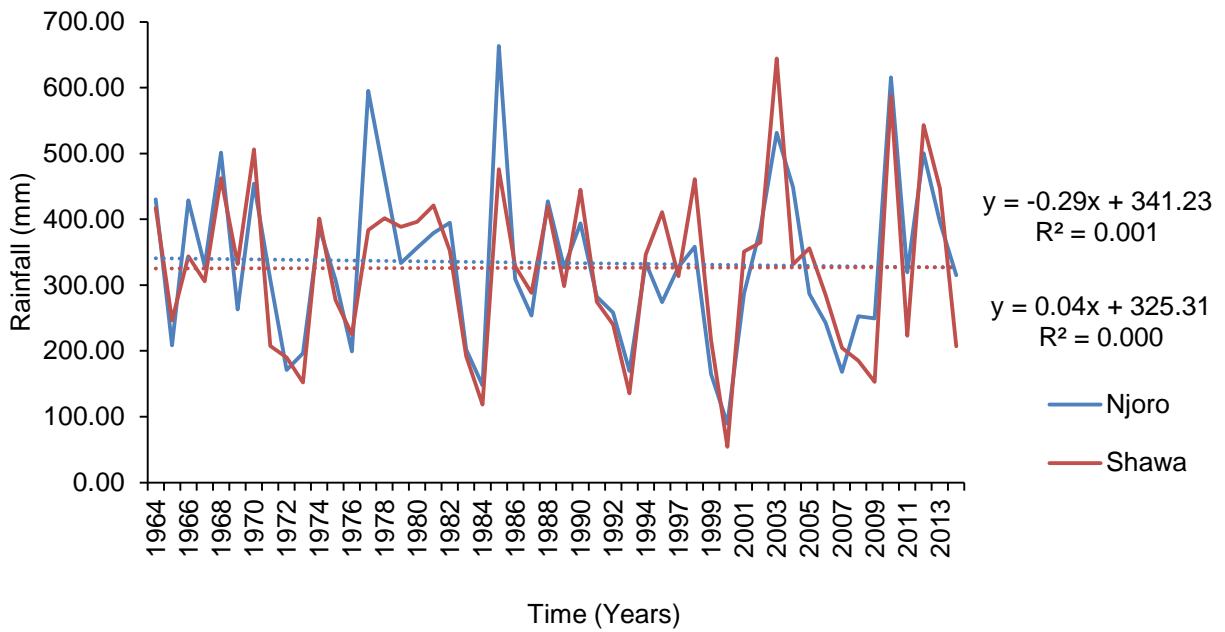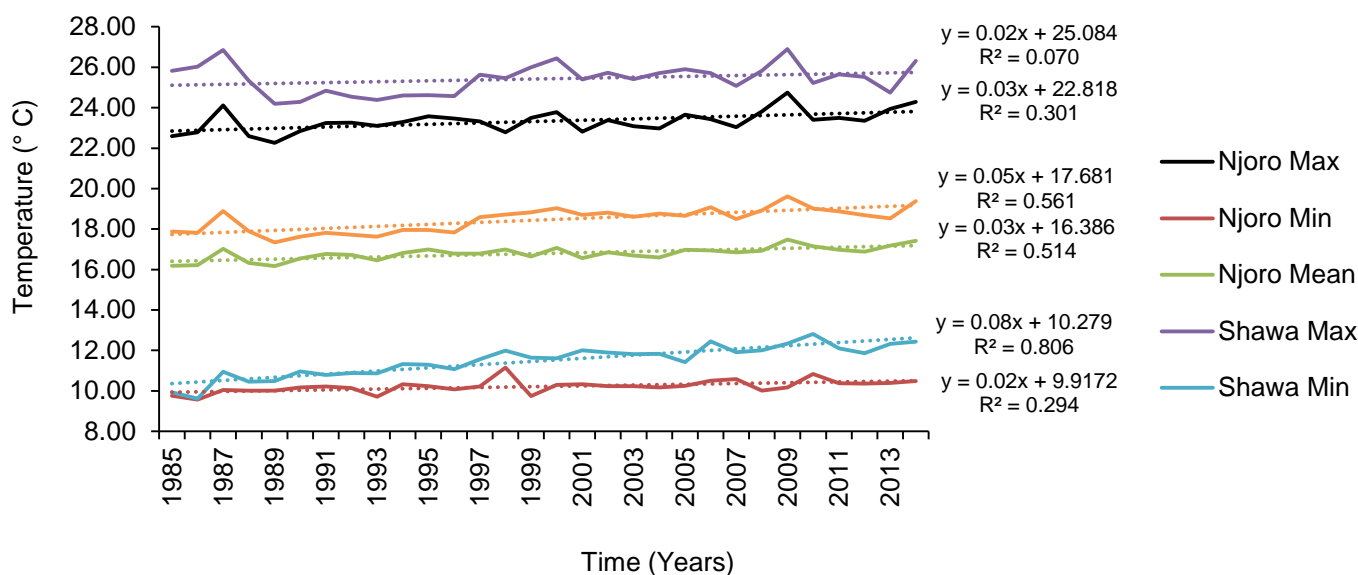**Figure 4** October, November and December seasonal total rainfall trend for Njoro and Shawa

Figure 5 March, April and May total rainfall trend for Njoro and Shawa

Figure 6 Maximum, minimum and mean temperatures for Njoro and Shawa

Table 2 Thermal conditions for four days during the observation study in Njoro and Shawa

Climate variables	Climate analogue sites	Time of the day	
		07:00	14:00
Wet bulb temperatures (°C)	Njoro	14.8 ± 0.57	15.7 ± 0.45
	Shawa	12.7 ± 1.64	17.1 ± 1.16
Dry bulb temperatures (°C)	Njoro	19.7 ± 0.88	26.6 ± 1.43
	Shawa	19.0 ± 1.38	28.7 ± 1.81
Mean minimum temperature (°C)	Njoro	11.8[a] ± 0.52	18.3[a] ± 0.70
	Shawa	13.0[b] ± 1.40	26.6[b] ± 0.80
Mean maximum temperature (°C)	Njoro	27.3[a] ± 1.17	27.6[a] ± 0.26
	Shawa	19.0[b] ± 1.40	29.8[b] ± 0.59
Mean temperature (°C)	Njoro	19.5[a] ± 0.46	23.0[a] ± 0.43
	Shawa	16.0[b] ± 1.25	28.2[b] ± 0.29
Relative humidity (%)	Njoro	56.2[a] ± 9.60	26.0[a] ± 7.07
	Shawa	66.9[b] ± 9.03	28.8[a] ± 10.86
Thermal humidity index	Njoro	64.8 ± 0.96	66.9 ± 0.50
	Shawa	60.2 ± 1.81	73.3 ± 1.26

[ab] Means with different letter superscripts for each variable within a column differ (*P* <0.05*)* between the analogue sites

Of the physiological response indicators measured (Table 3) in Friesian cows in the two climate analogue sites, those in Shawa had higher heart rates (*P* = 0.0001), respiration rates (*P* = 0.0004) and sweating rates (*P* = 0.0009) in the afternoon, regardless of age group, but rectal temperatures did not differ (*P* = 0.0863). These observations are in harmony with the moderately high THI in the afternoon that was recorded for Shawa (Table 1).

Table 3 Physiological response measures of Friesian cattle in the climate analogue sites for time of day and cattle age groups

Physiological measures	Climate analogue sites	Time of the day		Age group	
		07:00	14:00	4 ± 1 years	7 ± 1 years
Rectal temperature	Njoro	37.9 ± 0.53	38.9 ± 0.32	38.5 ± 0.63	38.3 ± 0.68
(°C)	Shawa	37.9 ± 0.41	38.8 ± 0.43	38.4 ± 0.64	38.2 ± 0.55
Sweating rate	Njoro	227.3^a ± 70.11	408.2^a ± 84.86	284.4^a ± 124.19	305.2^a ± 142.03
(g m^{-2}h^{-1})	Shawa	183.1^b ± 60.64	413.0^b ± 107.89	320.1^b ± 129.96	320.2^b ± 130.81
Respiration rate	Njoro	32.2^a ± 5.67	43.5^a ± 5.40	38.4^a ± 8.52	37.5^a ± 7.43
(Breaths per minute)	Shawa	28.4^b ± 4.55	51.9^b ± 11.27	40.3^b ± 13.77	39.9^b ± 15.87
Heart rate	Njoro	58.3^a ± 6.01	63.4^a ± 7.90	60.3^a ± 7.71	61.3^a ± 7.28
(Beats per minute)	Shawa	62.5^b ± 4.59	73.1^b ± 5.83	68.2^b ± 7.85	67.1^b ± 6.78

[ab] Means with different letter superscripts for each variable in a column differ (*P* <0.05*)* between the analogue sites

For the haematological and haematimetric measures obtained in Friesian cows (Table 4), the differences between the two climate analogue sites were higher for Plt (*P* = 0.0087) and lower for PCV (*P* = 0.0001*),* Hg (*P* = 0.0001), MCH (*P* = 0.0001), MCV (*P* = 0.0048), and MCHC (*P* = 0.0001) in Shawa, regardless of time of day and age group.

Table 4 Friesian cattle haematological measures between climate analogue sites for time of day and cattle age groups

Haematological Parameters	Climate analogue sites	Time of the day		Age group	
		07:00	14:00	4 ± 1 years	7 ± 2 years
PCV (%)	Njoro	31.6^a ± 3.47	32.0^a ± 3.44	30.9^a ± 3.14	32.5^a ± 3.54
	Shawa	26.6^b ± 3.61	26.7^b ± 3.39	26.2^b ± 3.64	27.5^b ± 3.05
RBC (x10^6 cells/µl)	Njoro	6.9 ± 0.85	6.7 ± 0.68	6.7 ± 0.59	6.9 ± 0.88
	Shawa	7.0 ± 0.69	6.6 ± 0.61	6.7 ± 0.76	6.9 ± 0.45
Plt (x10^3 cells/µl)	Njoro	213.4^a ± 94.62	198.3^a ± 108.83	191.2^a ± 116.22	216.5^a ± 89.31
	Shawa	273.9^b ± 134.42	289.9^b ± 149.70	322.6^b ± 134.16	213.4^b ± 128.92
Hg (g/dl)	Njoro	10.9^a ± 1.36	10.7^a ± 1.24	10.6^a ± 1.16	11.0^a ± 1.37
	Shawa	8.9^b ± 1.23	8.6^b ± 1.06	8.6^b ± 1.26	9.0^b ± 0.90
MCV	Njoro	46.1^a ± 3.77	48.1^a ± 3.20	46.3^a ± 3.54	47.7^a ± 3.58
	Shawa	38.2^b ± 3.56	40.3^b ± 3.84	39.0^b ± 3.89	39.8^b ± 3.71
MCH	Njoro	15.8^a ± 1.11	16.1^a ± 1.08	15.8^a ± 1.21	16.1^a ± 0.99
	Shawa	12.8^b ± 1.10	13.0^b ± 1.14	12.8^b ± 1.22	13.0^b ± 0.94
MCHC	Njoro	34.5^a ± 1.20	33.5^a ± 0.72	34.2^a ± 1.08	33.8^a ± 1.12
	Shawa	33.1^b ± 2.55	32.3^b ± 1.82	33.0^b ± 1.88	32.2^b ± 2.68

[ab] Means with different letter superscripts for each variable within a column differ (*P* <0.05) between the analogue sites; PCV- Packed cell volume; RBC- Red blood cells; Plt- Platelets; Hg- Heamoglobin; MCV- Mean corpuscular volume; MCH- Mean corpuscular haemoglobin; MCHC- Mean corpuscular haemoglobin concentration

However, the haematological measures, including all leucocytes, were not different between the two climate site analogues, but in Shawa lymphocytes and neutrophils were the most numerous, while basophils

were missing in the differential counts and the N/L ratio was higher. These results are therefore not presented.

Discussion

Based on the temperature and rainfall patterns observed in Shawa, an increasing trend in temperature is likely, but the trend in rainfall is uncertain in Njoro in the 2050s. This is in agreement with other studies in the region, which show increasing trends in temperature (Washington & Pearce, 2012; Daron, 2014; Musau *et al.*, 2015; Gichangi *et al.*, 2016;). However, studies in Kenya recorded mixed observations on projected trends for rainfall. McSweeney *et al.* (2010) reported a projection of 1% to 13% increase in Kenyan rainfall by the 2090s, Ngeno *et al.* (2014) observed a decreasing trend in rainfall for Rongai and Nandi South sub-counties, while Washington & Pearce (2012) and Gichangi (2016) indicated no clear trend for rainfall in Kenya. This uncertainty in rainfall trends can be attributed to heterogeneous topography, altitude, influence of sizable water bodies and atmospheric forces (Herrero *et al.*, 2010; Owiti & Zhu, 2012; Washington & Pearce, 2012; Daron, 2014) resulting in greater interannual and diannual variability in rainfall amounts and distribution (King'uyu *et al.*, 2009; Huho *et al.*, 2012; Huho & Kosonei, 2013; Musau *et al.*, 2015).The THI in the two climate analogue sites reflected weather changes during the study period and revealed that Friesian cattle in Njoro were within thermal comfort zones, while those in Shawa experienced mild thermal stress in the afternoon. Using Shawa THI to construe thermal conditions for Njoro in the 2050s suggests that Friesian cattle will experience thermal comfort in the morning and mild thermal stress in the afternoon during dry seasons.

Rectal temperature did not turn out to be a differentiating indicator of thermal stress in Friesian cattle between the climate analogue sites, though it had a high correlation with body core temperatures (Gebremedhin *et al.*, 2008; McManus *et al.*, 2009; Ganaie *et al.*, 2013). Friesian cows had rectal temperature within the normal ranges, suggesting thermal stress conditions in Njoro in the 2050s will not be notable from changes in rectal temperature. An above-normal rectal temperature range signifies overwhelmed thermal regulation mechanisms when THI exceeds 75 in dairy cattle (Kucevic *et al.*, 2013). In the thermal comfort zone, the normal rectal temperature for dairy cattle can range between 38.4 °C and 39.1 °C, with an average of 38.6 °C (Gantner *et al.*, 2011; Kucevic *et al.*, 2013).

Other physiological measures that are indicators of thermal stress, such as sweating rates and heart rates, were higher in Shawa relative to Njoro. Heightened sweating rate is the initial response for heat dissipation in cattle and varies among breeds. With the mild thermal stress of Friesian cattle suggested to be likely during dry seasons in the 2050s in Njoro, utilization of upgraded Friesians to pedigree level should be discouraged because of the likelihood of increased vulnerability to thermal stress. Sweating rate accounts for between 70% to 80% of evaporative heat loss, with the remainder being through the respiratory routes (Hansen, 2004). Friesian cattle experience limitations in their sweating rate, coupled with high metabolic rates to maintain the large body sizes and high production levels (McManus *et al.*, 2009; Chan *et al.*, 2010). There are breed differences in sweating efficiency, which suggests that alternative breeds for adaptability to thermal stress are possible. *Bos indicus* demonstrate more efficiency in sweating than *B. taurus* owing to a high number of well-developed sweat glands in the skin (Jian *et al.*, 2013). As well as breed differences, skin colour affects sweating rate, with black having higher rates (Gebremedhin *et al.*, 2008). The sweating rates observed in this study were higher than those reported by other researchers (Mc Manus *et al.*, 2009; Gomes *et al.*, 2011), but were within the observed margins (Gebremedhin *et al.*, 2008; Chen *et al.*, 2015) for the Friesian breed and its crosses in near similar climatic conditions.

Heat dissipation through the respiratory avenue is observed through heightened respiratory rates, which graduate into panting with an increase in thermal stress from mild to severe (Moran, 2012). Projections in this study show the likelihood of respiratory rates slightly above normal ranges in the afternoon (14:00), which corresponds to elevated ambient temperatures and THI (Ganaie *et al.*, 2013). Changes in physiological responses to heat stress cause alterations in the haematological profile, making it a complement indicator of thermal stress. The study observed differences in haematological and haematimetric parameters except for RBC between Friesian cows in Njoro and those in Shawa. The RBC were highest for Friesian cows in Shawa at 07:00 and lowest at 14:00 compared with those in Njoro. Conversely, haemoglobin concentration and haematimetric parameters (MCV, MCH, and MCHC) were higher for Friesian cows in Njoro than for those in Shawa. The mild thermal stress observed in Shawa caused erythrolysis to reduce oxygen supply to the cells to suppress metabolic heat production (Das *et al.*, 2016) and hence the observed changes in RBC, HC, and haematimetric parameters.

The leukograms for the study animals in both sites were within the normal ranges for cattle (Jackson & Cockcroft, 2002; Roland *et al.*, 2014), except for the WBC, which were overly exaggerated. The WBC anomaly resulted from erroneous configuration of correction values for WBC in the Coulter hematogical analyzer and did not affect other parameters. Nonetheless, PCV was lower in Friesian cows in Shawa

relative to Njoro. The observed PCV for Friesian cows in Shawa could be attributed to haemoconcentration resulting from electrolytes loss under elevated evaporative heat loss through heightened sweating and respiration rates (McManus *et al.*, 2009).

Conclusion

The study revealed that Friesian cattle currently in Njoro were within their thermal comfort zone, but would experience mild thermal stress in the afternoons during the dry seasons in the 2050s with the projected magnitude of climate change that is likely to occur. Their physiological and haematological responses will be elevated, but will probably remain within the normal margins.

Authors' Contributions

JCW and BOO did the layout and the first draft of the manuscript. JOO and SOO edited the content of the manuscript.

Conflict of Interest Declaration

Authors declare no conflict of interest.

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