



Vulnerability and adaptation strategies to climate variability of the Bos-taurusdairy genotypes in Nandi South and Rongai Counties in Kenya

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Vulnerability and adaptation strategies to climate variability of the Bos-taurusdairy genotypes in Nandi South and Rongai Counties in Kenya

Kiplangat Ngeno

Animal Breeding and Genetics Group,
Department of Animal Sciences,
Egerton University, Egerton, Kenya.

Bockline O. Bebe

Livestock Production Systems Group,
Department of Animal Science, Egerton
University, Egerton, Kenya.



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Abstract

The study assessed the vulnerability and adaptation strategies of the Bos-taurus dairy breed/genotypes (DBG) to climate variability of in two diverse production environments (PEDs) namely Rongai and Nandi South counties. Long-term climatic data analysis presents a declining rainfall trend and ascending trend in temperature in both production environments. Through farmers' perception ranking, the impacts of climate change and variability (CCV) on dairy breed/genotype ranged from low (2.60) to high (3.96) in the production environments. Impacts were high for seasonal heat stress (3.74), droughts (3.96), flooding (3.57) and feed resource shortage (3.80) and moderate for disease epidemic (3.39) and water resource decline (3.26) in Nandi South County. On the other hand, impacts in Rongai County were high for frequent droughts (3.60), disease epidemic (3.87) and feed shortage (3.60) and moderate for heat stress (3.30), flooding (2.60) and water resource decline (3.10). The current and earlier production systems in the two PEDs as well as response strategies to impacts of CCV were different in the two counties. The results from the study indicate that the DBGs are vulnerable to impacts of CCV. Production systems in different PEDs have evolved in response to effects of climate variability. Different response strategies have been adopted and used by farmers depending on the PEDs to mitigate the Climate change and variability.

1. Introduction

1.1 Background information

Climate change and variability (CCV) in Sub-Saharan Africa is already impacting negatively on rain-fed agriculture and livestock systems. The CCV are caused by both natural and human related activities. There are many complex and interrelated issues that contribute to this state of affairs. Probably more than 90% of the activities of humankind are largely responsible for the current day CCV. Climate change and variability complexities are exacerbated by increasing human population and demand for more agricultural land for food production, resulting in the destruction of the vegetation cover and subsequently rampant environmental degradation (Gordon et al., 2010). The demand for food, fuel wood (charcoal and firewood) and other forest products (including timber and poles for building and construction) increase this problem.

Kenya is already experiencing a number of hazards resulting from CCV including more frequent droughts, prolonged dry spells, intense rainfall and flush floods, increased heat stress and disease outbreaks (IPCC, 2007). These climatic hazards are accompanied by more changes in the productivity of rain-fed crops and forage, reduced water availability and more widespread water shortages, changing severity and distribution of important human, livestock and crop diseases.

The Fourth Assessment Report (4AR) of Intergovernmental Panel on Climate Change (IPCC, 2007; Morton, 2007) demonstrates the relationship among heat stress, declines in physical activity and the associated direct and indirect declines in animal feed intake. High ambient temperature and reduced feed intake put a limitation on milk yield and this can reach a third to half of the potential yield of a dairy cow. In the United state of America, maintenance energy requirement of dairy cow can increase by 22% at 32oC compared to maintenance requirement at 16oC which is much lower (Chase, 2009). When temperature increases from 16 to 32oC, dry matter intake decreases by 18% and subsequently milk yield decreases by 32%.

Dairy farming is a key component of livestock industry in Kenya and is dominated by *Bos-taurus* dairy breeds/genotypes (DBG) comprising Friesian, Ayrshire, Guernsey, Jersey and crosses among themselves (Muriuki et al., 2004). The industry is a major source of livelihood to a large majority of Kenyans and it contributes approximately 4% of Kenya's Gross Domestic Product (GDP) (though recent studies indicate 8%), acts as a source of income and employment to over 1.5 million smallholder dairy farmers in addition to 500,000 direct jobs in milk transportation, processing and distribution, and a further 750,000 in related support services (Kenya Dairy Board, 2012).

The DBGs are raised in different agro-ecological zones under diverse production environments (PEDs) and are classified as vulnerable to poor feeding, heat load and disease incidences, which are projected to increase in frequency, intensity and magnitude with the increasing climate variability and change. The PEDs thus has both direct and indirect climate effects on DBG, which will adversely impact on their performance and therefore limit their potential for providing food, nutrition, income and job securities to the Kenyans (Muriuki et al., 2004). The direct effects on dairy include impacts on animal health, welfare, growth and reproduction, while the indirect effects are due to the impact of climate change on the productivity of pastures

and forage crops (DEFRA, 2009). Ambient temperature has the greatest direct effect while feed intake has the greatest indirect effect on dairy cattle performance (Lingington, 1990; McManus et al., 2005). These climatic hazards are accompanied with more changes in quantity and quality of feeds.

The quality and quantity of the forage component of dairy cattle diet is likely to be affected by impact of CCV due to changes in forage growth and dry matter (DM) yield. If mean rainfall declines this would lead to soil moisture deficits which reduces DM yield and affect also the stage of maturity for forage. The stage of maturity at which the crop is cut is a major determinant of quality and in any altered climatic scenario the interplay between increasing quantity and declining quality would continue to be of major importance although the alterations in climate may be favourable to conservation and reduce losses during either ensilage or hay-making (Rowlinson, 2008). There is also a possibility that climate change will lead to a shift in the forage species grown and indirectly affects DBG performance.

As temperature and carbon dioxide (CO₂) levels change due to climate change, optimal growth rates for different species also change; species alter their competition dynamics, and the composition of mixed grasslands changes (Thornton et al., 2007). Rowlinson (2008) reported that, an elevation of temperatures may lead to an increase in the hectareage of maize grown for silage and of alfalfa for hay. Rising temperatures increase lignification of plant tissues, reducing the digestibility and the rates of degradation of plant species (IFAD, 2009). This condition may consequently leading to reduced nutrient availability for animals and ultimately to a reduction in livestock production (Thornton et al., 2007). This does raise concerns of securing livelihoods for the poor, creating the necessity to identify options and strategies for climate variability (CCV) adaptation by poor dairy farmers. Intervention measures are needed to contribute towards building adaptive capacity and resilience to climate variability in the short-term and climate change in the long-term.

1.2 Rationale

Comprehensive information on the PEDs of the DBG will; (a) facilitate better understanding of the potential impacts and consequences of CCV, (b) increase industry capability to manage the implications of CCV, (c) inform and engage industry stakeholders to improve understanding of CCV issues, (d) facilitate better understanding of the likely impacts and opportunities associated with reducing and/or offsetting CCV for the dairy industry and (e) enhance understanding needed on the likely impacts of CCV on the vulnerability of the DBG, (f) facilitate understanding of the resilience to current CCV as well as to the risks associated with longer-term CCV to be gauged, and appropriate actions set in place to increase or restore resilience where this is threatened. All these action combined contribute to securing livelihood assets for the poor.

The objective of the study was to assess the vulnerability and adaptation strategies of DBGs to CCV under PEDs inguiding the identification of appropriate breeding strategies that can help dairy farmers mitigate CCV and improve productivity and adaptation for secured livelihoods to the poor. Both natural and human induced CCV are considered in this study.

Specific objectives of the study include:

- To characterize the diverse production environments (PED) for dairy production by degree of vulnerability to CCV.
- To assess impact of climate variability and change based on farmer's perception in the different production environments.
- To rank vulnerability and general performance of the dairy breeds/genotypes (DBG) to CCV in the identified PEDs based on farmer's perception and experience.
- To examine diversity and dynamics of dairy production systems in the identified PEDs and adaptation strategies in response to CCV.

2. Literature Review

Kenya has 17,467,774 million dairy cattle population (KNBS, 2009) of which 3,355,407 and 14,112,367 are exotic and indigenous respectively. Eighty percent of these cattle are owned by smallholder farmers (Bebe et al., 2002). Most of the smallholder farmers are found in the highlands due to the favourable agro-ecology in these areas for dairy and crop production. The main dairy production systems in the country are zero-, semi-zero- and free-grazing systems. Zero-grazing dominates in the highlands where landholdings are declining and it is mostly a way of intensifying dairying (Bebe et al., 2003b). The most preferred DBG is the Friesian followed by the Ayrshire. Other dairy breeds like the Jersey and Guernsey, and the dual-purpose breeds like the Sahiwal, Brown Swiss, Red Poll, Small East African Zebu, Zebu and Boran (for the pastoralists) are also reared. Bebe et al. (2003a) quantified the breed preference for high milk production as 78%, 59%, 47% and 22% for Friesian, Ayrshire, Guernsey, and Jersey and the indigenous breeds, respectively. The exotic DBGs were introduced in 1902 by the European settlers (Kenya Dairy Board, 2012).

Smallholder dairy farmers produce milk in diverse production environments where productivity of dairy breeds is increasingly challenged directly and indirectly with the impacts of variable and changing climate. Increasing ambient temperatures directly impact heat load stress on the animals while feed resource base worsens with more frequent droughts and climate change induced outbreaks of transboundary animal diseases (Bebe et al., 2010). These stresses are expected to increase in magnitude with the projected changing and variable climate, which will further depress dairy productivity levels.

In their choice of dairy breeds, smallholder dairy farmers hardly pay attention to breed tolerance and adaptability to the climate related stresses (Bebe et al., 2003a; King et al., 2006). They utilize Friesian, Ayrshire, Guernsey or Jersey breeds in production environments already classified as hotspots of CCV, which include highlands, Semi-arid rangelands, Coastal and Great-lakes ecosystems where Thornton et al. (2006) projects an increased severity of climate variability and change. Dairy cattle performance is best at temperatures between 4 to 24°C, but temperatures frequently rise above this thermal comfort zone in the smallholder dairy production environments (King et al., 2006; Thornton et al., 2009) due to CCV. Under high temperature and high rates of solar radiation, dairy cows decrease their feed intake to reduce their digestive heat production and they also avoid grazing during the hot mid-day hours, consequently resulting to lesser grazing time which translates to overall poor productivity. However, smallholder dairy farmers may face a feed resources constraint which worsens with frequent droughts and flooding associated with the changing climate. This change is associated with reduction in herbage growth rate, quality, species composition and DM yield. This leads to reduced nutrient available to the animals and ultimately leads to a reduction in their productivity (Thornton et al., 2007). Heat and nutritional stresses in dairy cows reduce herd productivity and profitability through mortality, reduced growth and reproduction, which can be of substantial economic loss to producers utilising less adaptable breeds. Heat stress has a variety of detrimental effects on livestock with significant effects on milk production and reproduction in dairy cows (Fuquay, 1981; Johnson, 1987; Valtorta, 1996b). In Kenya, heat and nutritional effects on DBGs under PEDs have not yet been studied. In addition, the DBGs bred with imported semen could be less adaptable to more frequent outbreaks of CCV induced diseases, especially the Rift Valley Fever, Foot and

Mouth Disease and East Coast Fever, further impacting adversely on productivity of the DBGs. The outbreaks can cause increased production losses as well as lowering product quality and raising safety issues and consequently translating into reduced opportunities for the dairy products in the domestic and export markets.

Attaining sustainable dairy productivity requires utilizing breeds adaptable to the variable and changing climate in order not to enter state of insecurities in food, nutrition, income and health of smallholder dairy farmers and their livestock assets. When adaptable dairy breeds are identified, they can be promoted in appropriate environments together with appropriate management interventions that effectively reduce animal stresses to changing climate to enable smallholder dairy farmers mitigate and adapt to effects of changing climate to maintain and sustain their livelihood assets.

3. Methodology

3.1 The study area

The criterion for the selection was guided by the need to have many trainees and develop pThe study was carried out in Rongai county which lies in the latitude and longitude of 0° 10' 0" S and 35° 51' 0" and Nandi South County within latitudes 0° and 0°34" North and longitudes 34° 44" and 35° 25" East administrative counties of Kenya. The PED's were selected from lowland (Rongai County) and highland (Nandi South County) which represent varying degree of climatic conditions in Kenya. Nandi south County altitude ranges from 1,400m-2,400m above sea level, with average temperatures of 18-25°C and annual rainfall between 1,200mm-2000mm. On the other hand, Rongai County receives annual precipitation of 927mm and average temperatures ranging from 25-37°C.

3.2 Data collection

In each county, one location and all sub-locations per location were chosen in consultation with officers from the ministry of livestock and development, ministry of agriculture, local community based organization, and the local provincial administration (chiefs and their assistants) for the survey. One location per county prominent in dairy production were selected on the basis that they have the highest populations of the DBGs. The sub-location included Boito, Lengenet and Mogotio sub-locations in Rongai and Mosombor, Toretmoi, and Kimolwo sub-locations in Nandi South County. Two pairs of major landmarks were selected in each sub-locations and transect lines were drawn between each pair. Simple random sampling procedure was then used to select households for interviews by randomly picking the 5th households.

The following measures were undertaken to test for reliability and validity of the research instruments:

- Assessment of the presentation and relevance of the questionnaire to ensure that the questions were relevant, reasonable, unambiguous and clear.
- To ensure that the content and format of the instrument was consistent with the objectives of the research and the sample of subjects measured, pretesting of the questionnaire with ten (10) people from the target population was done in Nakuru County.
-

3.3. Measurements of Variables

Quantitative research approach was employed in this study. Quantitative data were obtained by interviews. A total of 100 smallholder farmers per location who rely on rain-fed agriculture under natural production environment were interviewed. A pretested structured questionnaire was used to gather information. Interviews were done in all the households. During pre-visits, local enumerators were recruited in each location and trained by the researchers. Local enumerators were employed for ease of acceptability and communication within the communities.

The questionnaire was used to explore the farmers' available knowledge on general information, cattle breeds, cattle performance, production systems, vulnerability of the DBG based on farming experience, constraints to production and response strategies. Research methods embraced a participatory approach, following the guidelines presented by FAO/WAAP (2008). Scoring, ranking, seasonal calendar analysis, seasonal trend analysis techniques were used. The questionnaire captured climate change effects of heat load, feed

resource shortage, water shortage, disease incidence, vector incidence and flooding levels under normal weather, before change in normal weather and after change in normal weather in three different degree of climate induced stress (high, medium and low) throughout the wet, normal and dry seasons.

The data collected was analyzed descriptively using frequencies, percentages, means and cross tabulation using the SPSS (Version 17) computer programme.

4. Results and Discussion

4.1 Characterization of the diverse production environments

Figure 1 and 2 show rainfall trends in the two PEDs of Nandi South County and Rongai County respectively. Climatic data analysis from the study reveals a declining rainfall trend and ascending trend in temperature, which agrees with reports from literatures that CCV are taking place (IPCC, 2007). Total annual precipitation range from 821.1mm-1647.70mm, with average minimum temperatures of 8.340C and maximum of 24.010C (Figure 3). Annual rainfall between 407.01mm-1407.52 mm (Figure 2) were recorded in Rongai County with the average temperature ranging from 16.660C- 36.400C (Figure 4).

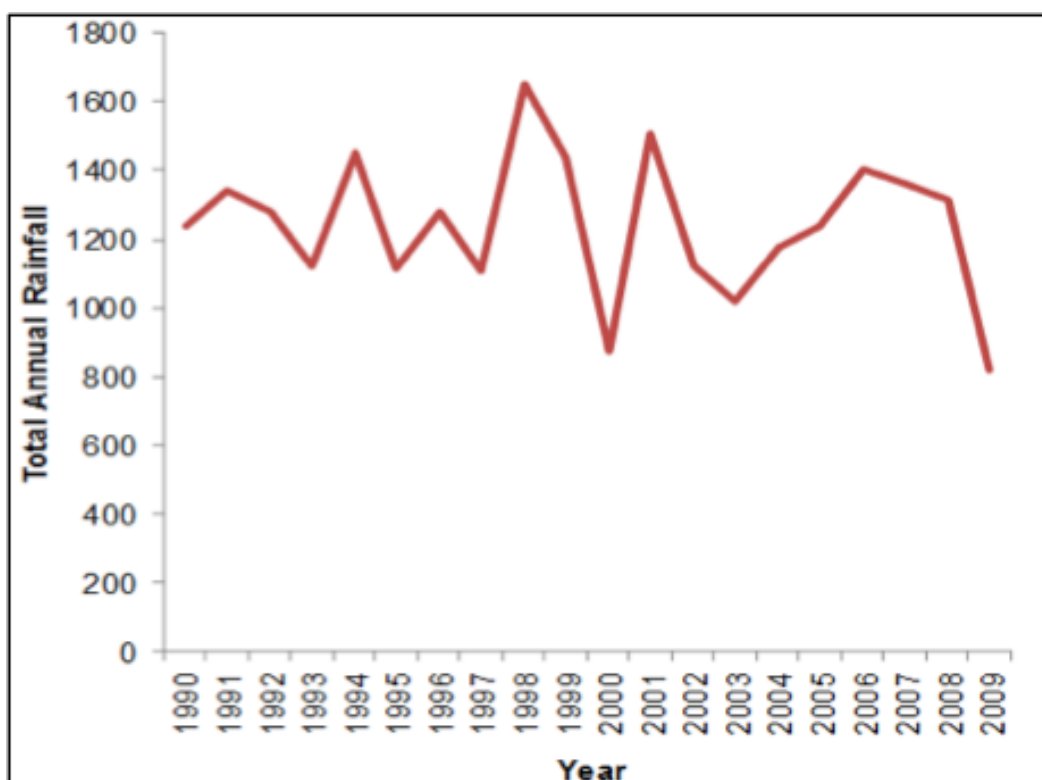


Figure 1: Rainfall trend in Nandi South County

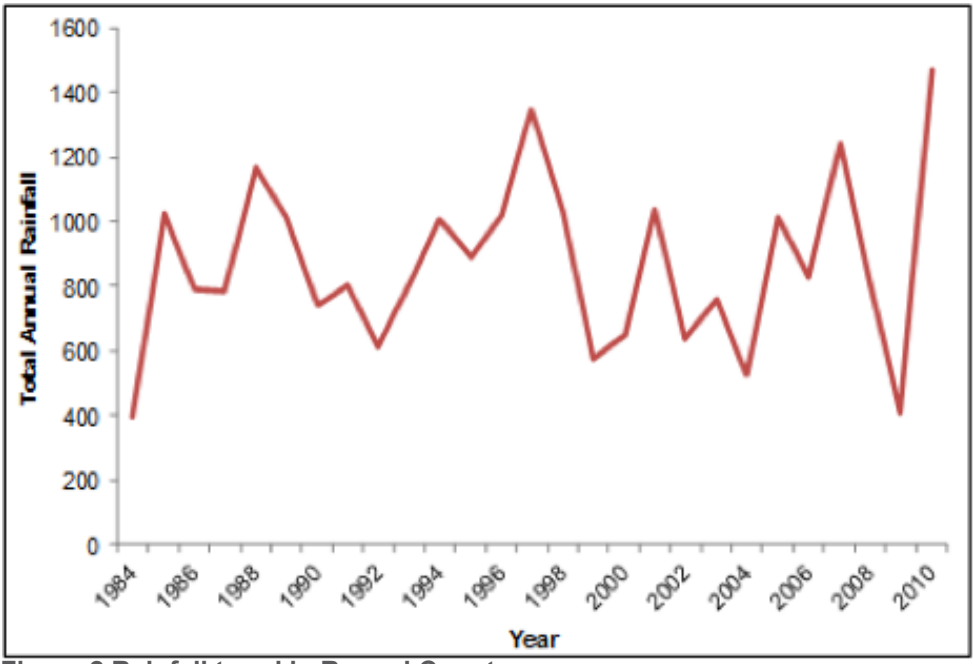


Figure 2 Rainfall trend in Rongai County

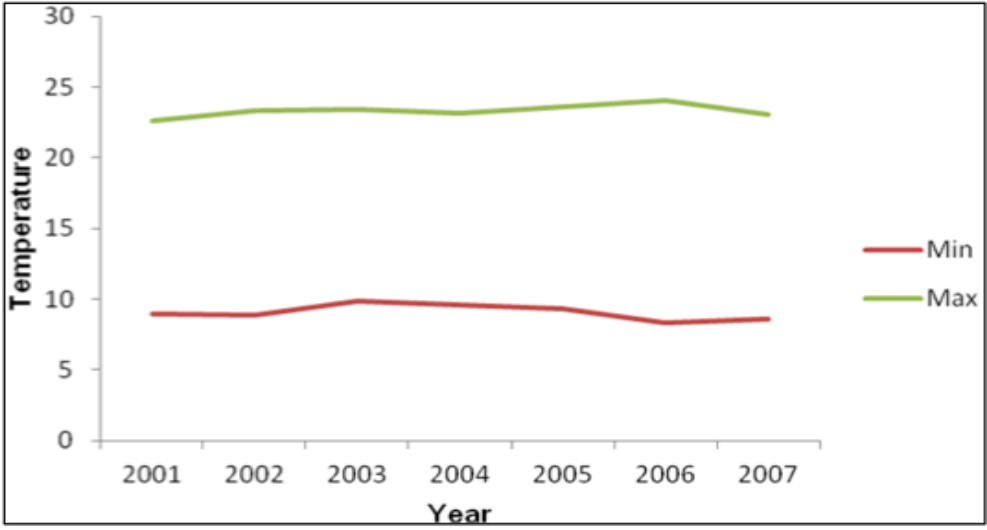


Figure 3: Maximum and minimum temperature for Nandi South County

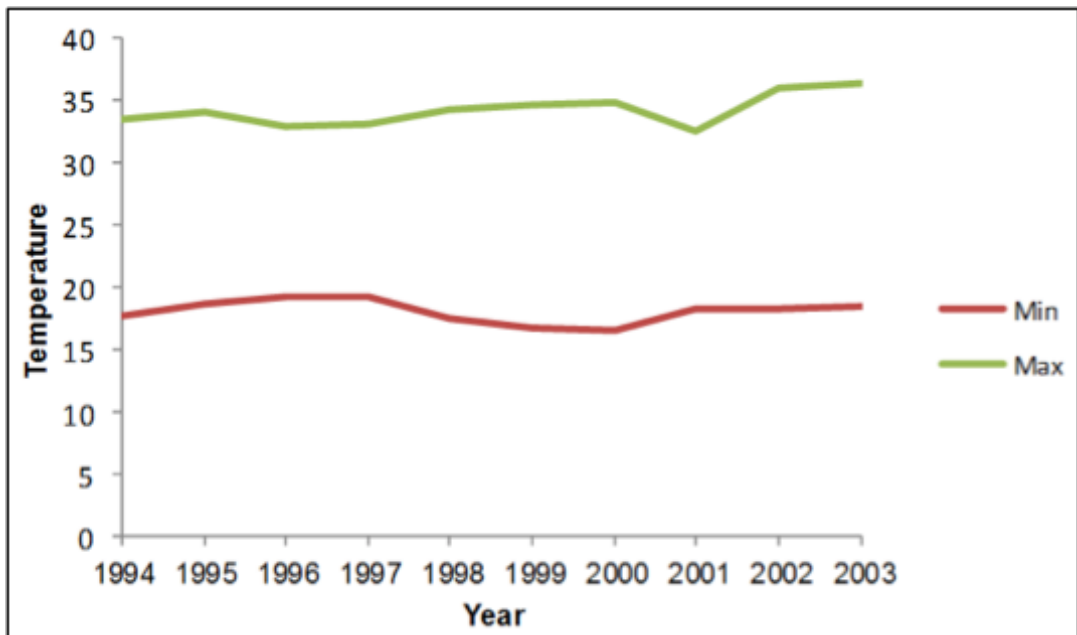


Figure 4 Maximum and minimum temperature for Rongai County

In Kenya, temperatures have risen by 1°C over the past 50 years (GoK, 2009) and warming is expected to accelerate with temperatures rising by nearly 3°C by 2050 (IPCC, 2007). This increase has been higher from March to May. According to Kenya meteorological department report (2008), the prolonged and severe droughts in Kenya are widely perceived to be symptomatic of the changing climate.

4.2 Perception of climate variability and change impact

Table 1 shows the farmers perception on CCV impacts in the different production environment. A scale of 1 to 4 (1 = No, 2 = mild, 3 = moderate, 4 = high) were used to assess the impact of seasonal heat, drought, flooding, disease epidemic, feed resource shortage and water decline stress induced by CCV. The impacts were low (2.60) to high (3.96) (Table 1). Impacts were high for seasonal heat stress (3.74), droughts (3.96), flooding (3.57) and feed resource shortage (3.80) and moderate for disease epidemic (3.39) and water resource decline (3.26) in Nandi South County. On the other hand, impacts in Rongai County were high for frequent droughts (3.60), disease epidemic (3.87) and feed shortage (3.60), moderate for heat stress (3.30) and water resource decline (3.10) and low for flooding (2.60). The impacts affect DBGs both directly and indirectly. Heat stress affects animals directly whereas drought, flooding, disease epidemic, feed resource shortage and water decline affects indirectly. Hot dry conditions during the grazing period can reduce the quality and consistency of the feed, which may lead to animal welfare and productivity problems (DEFRA, 2009). Furthermore, ambient temperatures above 5–25°C thermal comfort zone are often experienced in smallholder production environments in Kenya and depress productivity (King et al., 2006). This is through depressed feed intake and reduced grazing time in order to reduce digestive heat produced (McManus et al, 2009). From farmers' points of view, drought is the main cause for low feed quantity and the little available are poor quality. According to Thornton et al. (2006), CCV is associated with changes in herbage growth, quality and dry matter yield which is agreement with the findings of this study. Changes in rainfall and humidity are often considered as the key necessary parameters which modulate the emergence of various animal diseases and this is confirmed by moderate to high impacts in the two PEDs. Baker et al. (1998) reported that, changes in rainfall and temperature regimes influence the abundance and distribution of disease vectors, causing an increased incidence of disease, often contributing to reduction

in animal productivity and possibly increase animal mortality. The moderate (Nandi south County) to high (Rongai) impact of diseases may be attributed to widespread diseases and/or “exotic” diseases becoming more apparent in the PEDs. The low (2.60) to high (3.96) impacts of climate change in these regions are negatively influencing on the dairy production systems which are consistent with the IPCC report (2007) which suggested that CCV impacts are possible factors which contributed to a shift in the dairy production system in the PEDs.

Table 1: Perception of climate change impacts in the production environments

County	Climate change impacts					
	Seasonal heat stress	Droughts	flooding	Disease epidemic	Feed resource shortage	Water resource decline
Nandi South	3.74	3.96	3.57	3.39	3.80	3.26
Rongai	3.30	3.60	2.60	3.87	3.60	3.10

4.3 Impacts of climate vulnerability and change (CCV) in general performance (production and reproduction) of various DBGs

A scale of 1 to 5 (1=low, 2 = fair, 3 = good, 4 = very good, 5 = excellent) was used to assess the impacts of CCV on general performance of various DBGs based on farmer’s perception. General performance included production (milk and growth rate) and reproduction (fertility in general for cows and bulls, calving rate, calving interval and conception rate). In Nandi South County during the period of ‘medium heat load’ in the past (20 years ago), Friesian (3.52), Ayrshire (3.55), Guernsey (3.00), Jersey (3.00), dairy crosses (3.27) and dairy-zebu crosses (3.00) had good to very good performance (Table 2). For the same region under ‘medium heat load after’ (20 years from now and beyond), DBGs are expected to perform differently between fair to good (Friesian (2.40), Ayrshire (3.17), Guernsey (3.00), Jersey (3.00), dairy crosses (3.02) and dairy-zebu crosses (2.50) as shown in Table 2. In the past (20 years ago) during ‘medium heat load, general performance in Rongai County were fair to good; Friesian (2.08), Ayrshire (2.25), Guernsey (2.50), Jersey (2.25), dairy crosses (1.82), dairy-zebu crosses (2.40) and zebu (2.60) (Table 2). The DBG in the same Rongai region 20 years from now and beyond (‘medium heat after’) under medium heat load are expected to perform between low to fair is expected; Friesian (1.85), Ayrshire (1.75), Guernsey (2.50), Jersey (1.75), dairy crosses (1.73), dairy-zebu crosses (1.78) and zebu (2.25) as shown in Table 2. The findings from the study revealed that CCV may impact both direct and indirectly on DBG general performance. According to DEFRA, (2009), the direct effects may include impacts on animal health, welfare, growth and reproduction, and indirectly on the productivity of pastures and forage crops which are in agreement with the findings of this study. In the two Counties, high heat load is expected to reduce DBGs performance from good to poor (Table 2). The study proofed the detrimental effects of heat stress on animals. Johnson (1987) and Valtorta (1996b) reported that heat stress have significant effects on milk production and reproduction in dairy cows. Dairy cattle show signs of heat stress when the temperature humidity index (THI) is higher than 72 (Armstrong, 1994). The comfort limit depends on the level of production. Animals with higher level of production are more sensitive to heat stress (Johnson, 1987) which is consistent with the findings of this study. Impacts of heat stress were higher in Rongai. Rongai is hot (36.40C) and dry (annual precipitation as low as 407mm). Hot dry conditions during the grazing period can reduce the quality and consistency of the feed, which may lead to productivity problems (DEFRA, 2009). Rowlinson (2008) revealed that extreme high temperatures may subject the dairy cow with thermal stress and this may result to reduced feed intake and performance.

Table 2 The DBG general performance levels under normal weather, before change in normal weather, and after change in normal weather in Nandi South and Rongai counties

CCV effects	Heat load	Before			After		
		high	medium	low	high	medium	low
Friesian	Nandi	2.52	3.52	4.64	1.86	2.40	4.00
	Rongai	2.23	2.08	2.50	1.69	1.85	2.50
Ayrshire	Nandi	2.47	3.55	4.90	2.41	3.17	4.34
	Rongai	2.13	2.25	3.00	1.75	1.75	2.29
Guernsey	Nandi	2.00	3.00	4.00	2.00	3.00	4.00
	Rongai	2.25	2.50	3.00	2.25	2.50	2.75
Jersey	Nandi	1.40	3.00	4.00	1.60	3.00	4.00
	Rongai	2.25	2.25	2.75	2.00	1.75	2.50
Dairy crosses	Nandi	2.46	3.27	4.98	2.02	3.02	4.06
	Rongai	1.50	1.82	2.60	1.50	1.73	2.10
Dairy Zebu crosses	Nandi	3.00	3.00	4.00	1.50	2.50	4.00
	Rongai	2.30	2.40	2.70	1.56	1.78	2.29
Zebu	Nandi	-	-	-	-	-	-
	Rongai	2.00	2.60	3.25	2.00	2.25	2.50

4.4 The diversity of dairy production system utilised in PEDs

Several livestock production systems exist and farmers practice the most suitable depending on the magnitude of the resource, production environment, major outputs and a set of productivity indices. To identify the dairy production systems and if they are changing with time, farmers were asked the type of the system they were using currently and what they have been using in the past (20 years ago). Nandi South County in the past and the percentage of farmers who adopted were; crop-livestock (15.6%), agro-forestry-livestock (35.4%) and scavenger (49%) systems. Due to the effects of CCV, dairy production systems have changed. The current production systems with the percentages of farmers practicing were; pastoralism (9%), crop-livestock (68%), agro-forestry-livestock (1%) and scavenging (5.2%) systems whereas 16.8% stopped dairy farming in Nandi South County (Figure 5). In Rongai County, 6%, 26%, 39%, 16% and 13% of farmers practiced ranching, pastoralism, crop-livestock, agro-pastoralist and scavenger systems respectively earlier (Figure 6). These systems in Rongai have shifted to 6%, 24.9%, 36.8%, 11% and 21.3% of farmers practicing ranching, pastoralism, crop-livestock, agro-pastoralist and scavenging systems.

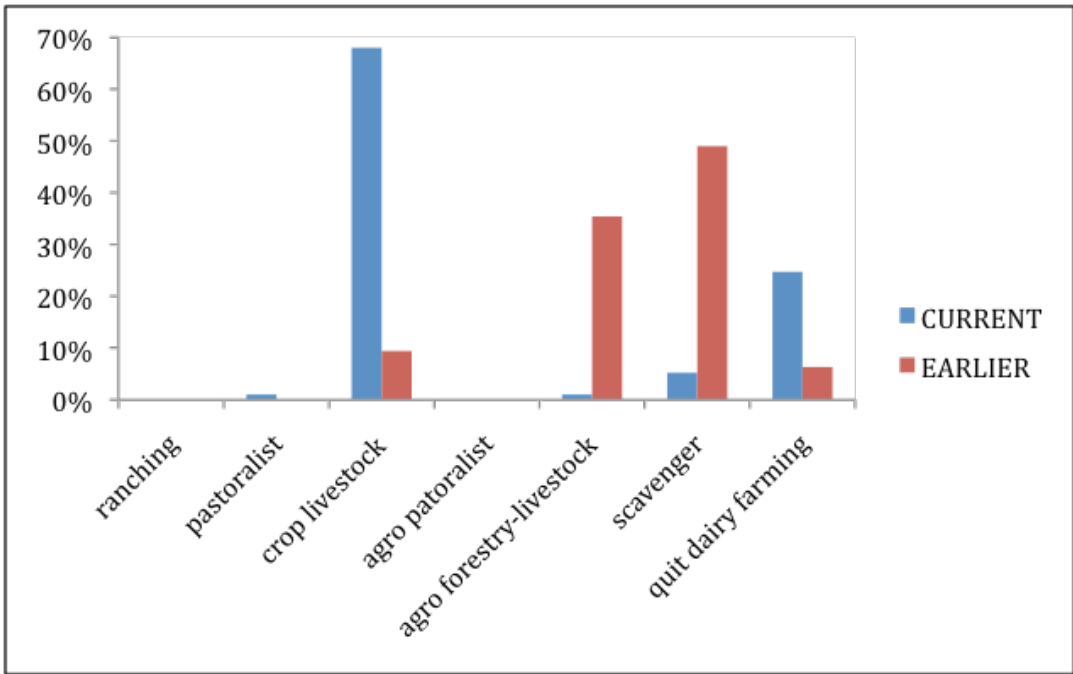


Figure 5: Earlier and current dairy production system in Nandi South County

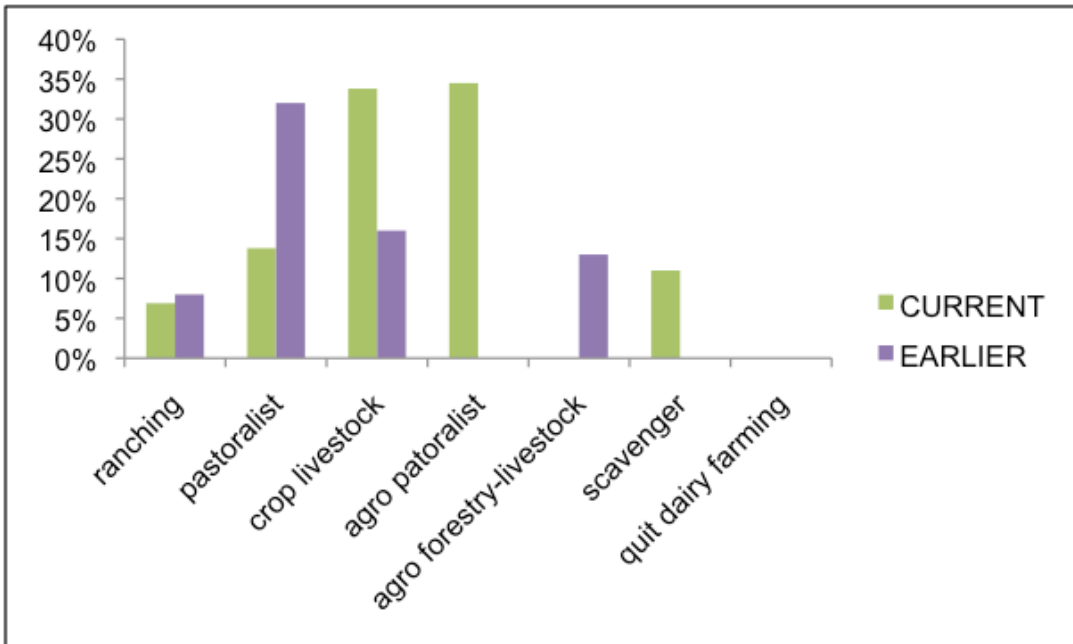


Figure 6: Earlier and current dairy production system in Rongai County

4.5 Vulnerability of the various DBG to climate variability and change

Current relative vulnerability ranking of DBG to CCV impacts in the PEDs was done in a four scale ranking order; 1= not vulnerable; 2= mild vulnerable; 3= moderately vulnerable and 4= highly vulnerable. Friesian was the most vulnerable genotype under all levels of heat stress as compared to other genotypes in Nandi South County (Table 3). Vulnerabilities were moderate to high for Friesian (3.08-3.92), Ayrshire (3.13-3.75), Guernsey (2.75-3.50), Jersey (2.75-3.50), dairy crosses (2.82-3.83), and dairy-zebu crosses (2.67-2.90) and mild for zebu genotype (1.75-2.25) in Rongai county. In the face of climate challenges, adaptation of different dairy genotypes to tropical conditions might become highly imperative. Climate determines the type of livestock most adapted to different agro-ecological zones and therefore the genotypes that are able to sustain rural communities. For instance, under low heat stress, in Nandi South County, Friesians were not vulnerable (1.00) and can do better than the same Friesian under low heat stress (3.08) in Rongai (Table3). Vulnerability of Friesians to heat stress more than other DBGs could be attributed to lack of genes relevant to tropical heat stress. Certain major genes have been found to be relevant in tropical production environment characterised by high heat load (Horst, 1989). Friesian high susceptibility than other DBGs is because of its poor heat regulatory capacity, due to differences in metabolic rate, feed and water consumption, sweating rate, and coat characteristics and colour. Friesian breed have a higher heat loading at the skin, which have to evaporate substantially more sweat than other DBGs to maintain normal body temperatures. In addition, exotic breeds like Friesian under tropical conditions, might show impaired productivity since genotype x environment (G x E) interactions could lead to a reduction in the biological and economic efficiency. Therefore, Rongai region which is currently characterised by high temperatures and low rainfall might shift towards more adaptive genotypes such as dairy-zebu crosses and zebu. Indigenous cattle breeds such as Zebu and its crosses are highly adapted to the harsh conditions, poor nutrition and disease and parasite challenges. Their adaptation is attributed to different hereditary characteristics that have resulted in differences in reactions to environmental stimuli. These reactions are intimately associated with anatomical-physiological characteristics, which have developed as a result of natural selection. Conversely, indigenous cattle breeds possess genes and alleles that are pertinent to their adaptation to the local production environments.

Table 3: Vulnerability ranking of DBG to CCV impacts now in the production environment

DBG	County	Heat load		
		High	Medium	Low
Friesian	Nandi	3.72	2.79	1
	Rongai	3.92	3.38	3.08
Ayrshire	Nandi	2.07	1.15	1
	Rongai	3.75	3.5	3.13
Guernsey	Nandi	2	1	1
	Rongai	3.5	3.25	2.75
Jersey	Nandi	2	1	1
	Rongai	3.75	3.25	2.5
Dairy Crosses	Nandi	2.08	1.13	1.02
	Rongai	3.83	3.33	2.82
Dairy Zebu Crosses	Nandi	-	-	-

	Rongai	2.9	2.67	2.67
Zebu	Nandi	-	-	-
	Rongai	2.25	2	1.75

4.6 Adaptation strategies

Table 4: Response strategies for high heat load before normal weather change and high heat load now for Friesian

Response strategies	High heat load before (20 years ago)		High heat load now	
	Nandi South	Rongai	Nandi South	Rongai
More housing	0.0%	11.1%	2.3%	20.0%
Provide shade	53.5%	44.4%	4.7%	10.0%
Adopt housed system	0.0%	22.3%	0.0%	30.0%
Monitoring and disease surveillance	0.0%	11.1%	0.0%	10.0%
Improve building insulation	0.0%	11.1%	0.0%	30.0%
Multiple strategies	46.5%	0.0%	93.0%	0.0%

Table 4 shows the most common response strategies to heat stress. Farmers (indicated in percentage) indicated that the most preferred methods in both counties were provision of shade, more housing, use of shelter systems, monitoring and disease surveillance, improved building insulation or combination of multiple strategies. Response strategies for 'high heat load before' (high level of heat stress 20 years ago) normal weather change and 'high heat load now (high level of heat stress currently-2011)' varied between the two counties. The main strategies for 'high heat load before' in Nandi South County were provision of shade (53.5%), and multiple strategies (46.5%). Multiple strategies combines two or more strategies and combined strategies in the PEDs included shade, housing, housed system, monitoring and surveillance and/or improve building insulation etc. In Rongai county, main strategies used were; more housing (11.1%), provision of shade (44.4%), adoption of housed system (22.3%), monitoring and disease surveillance (11.1%) and improved building insulation (11.1%) as shown in Table 4. Response strategies to heat stress 20 years ago and now were different. During the period of 'high heat load now', 93.0% of farmers adopted multiple adaptation strategies in Nandi South County. For Rongai County, more housing (20%), housed system (30%) and improved building insulation (30%) were used. Zero-grazing was not common in the two production environments. From the study, it was revealed that response strategies may vary with production environments (as is the case with Rongai and Nandi South County). Variation in response strategies could be because of diversified characteristics of the two PEDs. Rongai district which lies in the latitude and longitude of 0° 10' 0" S and 35° 51' 0" is a lowland area and receives annual precipitation of 927mm and average temperatures ranging from 25-37°C. On the other hand, Nandi South district with latitudes 0° and 0°34 North and longitudes 34° 44" and 35° 25" East is an highland region with altitude ranging from 1,400m-2,400m above sea level, average temperatures of 18-25°C and annual rainfall between 1,200mm-2000mm.

5. Conclusions and Recommendations

The paper presents the vulnerabilities and adaptation strategies of *Bos-taurus* dairy genotypes to CCV in Nandi South and Rongai Counties. The results from the study indicate that the DBGs are vulnerable to impacts of CCV. Production systems in different PEDs have evolved in response to effects of climatic variations. Different response strategies have been adopted and used by farmers depending on the PEDs to mitigate the impact of CCV. Inferences generated from this study can provide a strong basis for mitigating CCV and improving productivity through either genetic manipulation of their DBGs to the specific PED or modification of production environment to suit the DBGs.

Genetic approach need to be developed and applied to help dairy industries mitigate impacts of CVC using genetic tools. Broader breeding goals have become the norm in the dairy, usually incorporating production and “fitness”(health, fertility, longevity) traits in developed world. However, exotic cattle produced from such breeding programmes faces challenges of genotype by environment interactions, hence there is a need to develop local breeding programme for specific production environment. Therefore, an economic evaluation of the different DBGs imported and across PEDs is necessary to identify the most suitable breed (s) for the different production environments. The assessment of the presence and magnitude of DBGs by environment interaction is needed, which will enable the achievement of optimum performance across the different environments. In the presence of breed by environment interactions, particular genotypes will be sought for particular environments in order to optimize total merit of production. Increased training to farmers on how to handle the DBGs is also necessary.

Selection for breeds with effective thermoregulatory control may be exploited. Some opportunities exist to improve DBG adaptation through manipulation of genetic mechanisms at cellular level. Inclusion of traits associated with body condition, survival, rehydration, coat colour and foraging ability traits which are considered most relevant to animal adaptability to CVC stress as well as temperature, disease and parasite tolerance in breeding indices for species/breeds under threat e.g. genetics of CVC stress and G*E interactions are of paramount. For example, selection for heat tolerance based on rectal temperature measurements and inclusion of a temperature-humidity-index in the genetic evaluation models can be a promising option.

Efficient and affordable adaptation strategies which have been developed for farmers in the PEDs were expensive adaptation technologies. Other practices to counter CVC impacts which need to be promoted include; (a) sprinkling and ventilation to reduce heat stress from increased temperature, (b) modification of the grazing times. Mostly, farmers in CVC hotspots need to maximise on night grazing. Cattle tend to graze two thirds of their intake during the day and a third at night, but in hot weather this need to be changed to half during the day and half night (Stewart, 2005), (c) changing herd composition such as shifting from Friesian to Zebu in Rongai district, etc., (d) improvement of water resources management infrastructure to harvest and store rainwater, such as small superficial and underground dams, tanks connected to the roofs of houses, etc. (Kurukulasuriya and Rosenthal, 2003; FAO, 2008; Sidahmed, 2008; Thornton et al.,2008), (e) matching stocking rates with pasture production, altering the rotation of pastures, altering forage and animal species/breeds, altering the integration within mixed livestock and crop systems including the use of adapted

forage crops (Howden, et al., 2007; World Bank, 2008), and (f) early milking so that the DBG can get out to graze while the day is still cool and milk early in the afternoon so that the cows can cool down when the day is still very hot.

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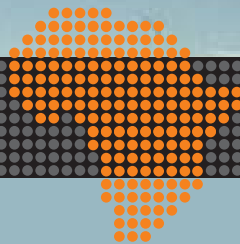
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Contact the Executive Director at
The Chancery, 3rd Floor, Valley Rd.
P O Box 10081, 00100-Nairobi, Kenya
Tel: (254 020) 2714092, 2714168,
2714498, 2723800
Fax: (254 020) 2714028

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