Vulnerability and adaptation strategies to climate variability and change of the Bos-taurus dairy genotypes under diverse production environments in Kenya

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Vulnerability and adaptation strategies to climate variability and change of the Bos-taurus dairy genotypes under diverse production environments in Kenya

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Abstract

The study assessed the vulnerability and adaptation strategies to climate variability and change (CVC) of the Bos-taurus dairy genotypes (DBG) under three diverse production environments (PEDs); Rongai (lowland), Kipkelion (moderate altitude) and Nandi South (highland) districts. The PED's were selected from lowland to highland to represent varying degree of CVC in Kenya. The changes observed in the study area are declining rainfall trend and ascending trend in temperature. In terms of vulnerability of DBG to CVC impacts, Friesian was the most vulnerable breed for all climatic stress types and to different levels (medium to high stress) under all circumstances in the identified PEDs. For instance, vulnerabilities to heat stress were from moderate to high for Friesian (2.79-3.70) as compared to Ayrshire (1.15-2.0), Guernsey (1.0-2.0), and Jersey (1.13-2.0) in Nandi South district. Under low heat stress, Friesians were not vulnerable (1.00) in highland (Nandi south district) and under moderate altitude of Kipkelion district (1.08) but different in Rongai district (3.08). Across the three PEDs, Friesian was also the most vulnerable breed to feed stress and disease infection under medium and high stress levels. Vulnerability levels to high feed stress were; high for Friesian (3.88-4.00) as compared to Ayrshire (2.38-3.88), Guernsey (3.00-3.75), Jersey (3.00-3.75) and Dairy crosses (2.08-3.75). Susceptibility levels to high disease stress were high for Friesian (3.74-4.00), Ayrshire (2.12-3.88), Guernsey (3.25-3.75), Jersey (2.00-4.00) and Dairy crosses (2.17-3.92). Information based on performance history was the most frequently used during selection of breeding stock; Nandi South (3.14), Kipkelion (3.17) and Rongai (3.15). The results from the study indicate that the DBGs are vulnerable to impacts of CVC and a susceptibility level varies with both DBG and PEDs. Inferences generated from this study can provide a strong basis for mitigating CVC and improving productivity by designing breeding and adaptation strategies for specific production environment.

1. Introduction

1.1 Background information

Climate change in Sub-Saharan Africa is already impacting negatively on rain-fed agriculture and livestock systems. Kenya is already experiencing a number of hazards of climate change and climate variability (CVC) 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 with 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.

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 amongst themselves (Muriuki et al., 2004). The DBG 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 the DBG performance and therefore limit their potential for providing food, nutrition, and income and job securities to the farmer (Muriuki et al., 2004). This does raise concerns of securing livelihoods for the farmer, creating the necessity to identify options and strategies for CVC 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, but are currently deficient in Kenya.

One approach to this problem is to characterize the PEDs in which a breed has been kept over time. Several technology practices and strategies have been suggested for mitigation and adaptation to CVC stress. However, breeding strategies targeted at improving their productivity have been applied uniformly disregarding the adaptability level of DBG. There is an urgent need for detailed performance assessment of DBGs under PEDs to guide the identification of appropriate breeding strategies that can help dairy farmers mitigate CVC and improve productivity and adaptation for secured livelihoods to the poor.

1.2 Cause and Effects

Increasing hazards of CVC are already being experienced and the increased scientific evidence for CVC has significantly raised the level of uncertainty about future climate conditions. The DBG are vulnerable to increasing hazards of CVC already being experienced in Kenya. The CVC hazards are accompanied with changes in disease outbreaks, forage productivity and, reduced water quantity and quality. These changes are projected to increase and DBG raised in diverse PEDs will likely suffer some impacts of increasing CVC since they are the most vulnerable to climate stresses and yet least adapted compared to Bos-indicus. These impacts of climatic stress on DBG performance have not been assessed and adaptations to offset these impacts have not been assessed in detail. Nevertheless, appropriate breeding strategies that can help dairy farmers stabilize production under changing CVC are unknown.

1.3 Objectives

1. To characterize the diverse production environments (PED) for dairy production by degree of vulnerability to climate variability (CVC).

2. To rank vulnerability of the dairy breeds/genotypes (DBG) to CVC in the identified PEDs based on farmers' experience.
3. To identify adaptive traits of importance to stresses of CVC in the specific PEDS.
4. To identify breeding strategies for DBG to CVC for improved productivity and adaptation.

1.4 Rationale

Comprehensive information on the PEDs of the DBG will; (a) facilitate better understanding of the potential impacts and consequences of CVC, (b) Increase industry capability to manage the implications of CVC, (c) Inform and engage industry stakeholders to improve understanding of CVC issues, (d) Facilitate better understanding of the likely impacts and opportunities associated with reducing and/or offsetting CVC for the dairy industry (e) enhance understanding needed of the likely impacts of CVC on the vulnerability of the DBG and (f) facilitate understanding of the resilience to current CVC and (g) enables the risks associated with longer-term CVC 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.

2. Literature Review

2.1 Impacts associated with climate variability and changes

2.1.1 Changes in quantity and quality of feeds

The most important environmental constraint to improved dairy productivity is nutrition. Nutritional stress in dairy cows reduces herd productivity and profitability through mortality, reduced growth and reproduction, which can be of substantial economic loss to producers utilising less adaptable breeds. The quantity and quality of the forage component of dairy cattle diet is likely to be affected by CVC. The CVC changes are associated with changes in herbage growth, quality and dry matter (DM) yield. Decline in rainfall accompanied with greater variability in rainfall patterns (IPCC, 2007; Thornton et al., 2006, 2008) is likely to increase the risk that DBGs will suffer lengthy periods of nutritional stress. If mean rainfall decreases, 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 forage is cut is a major determinant of the quality (Rowlinson, 2008).

Changes in temperature also compromise the quantity and quality of forage. It has been known that increased temperatures, increases lignification of plant tissues and therefore reduces the digestibility and the rates of degradation (Pilling and Hoffmann, 2011). An increase in temperature tends to favour C4 forage plants (which generally produce huge amounts of low-quality DM with low nutritive value as compared to C3 plants (Christensen et al., 2004; Morgan et al., 2007; Pilling and Hoffmann, 2011). The C4 forage plants are plants that produce the 4-carbon compound oxalocethanoic acid as the first stage of photosynthesis. A C3 is a plant that utilizes the C3 carbon fixation pathway as the sole mechanism to convert CO2 into an organic compound (Biology dictionary, 2008). A C3 plant must however be in areas where CO2 concentration is high, temperature and light intensity are moderate, and ground water is abundant. A C4 plant is better adapted than a C3 plant in an environment with high daytime temperatures, intense sunlight, drought, or nitrogen or CO2 limitation (Biology dictionary, 2008). Consequently, an increase in C4 forage might lead to decline on DBGs performance because of poor quality. Conversely, Christensen et al. (2004) and Morgan et al. (2007) reported that CVC may increase shrub cover and such shrub encroachment will reduce the quantity of forage available. Although the browses from shrubs are of superior quality in terms of protein content than the grasses, their digestibilities are lower than that of grasses due to the presence of secondary metabolites (Illius, 1997). This leads to reduced nutrient availability for DBG and ultimately to a reduction in dairy production.

2.1.2 Changes in forage species composition

Different forage species may have different capacities in responds to CVC. There is a possibility that CVC will lead to a shift in the forage species grown and these will indirectly affects DBG performance. As temperature and CO2 levels change due to CVC, optimal growth range for different forage species also changes which will alter their competition dynamics, and the composition (Thornton et al., 2007). For example, the proportion of browse in rangelands will increase in the future as a result of increased growth and competition of browse species due to increased CO2 levels (Morgan et al., 2007). Rowlinson (2008) reported that, an elevation of temperatures may lead to an increase in the hectarage of maize grown for silage and of alfalfa for hay. It is also predicted that CVC will induce a shift from C3 to C4 plants as well as grasses to shrubs (Christensen et al., 2004; Morgan et al., 2007) and these have implications on forage supply. Pilling and Hoffmann (2011) observed that there is a possibility of new regions being invaded by weeds which are generalist or colonizing species because they may take advantage of CVC to expand their ranges. The forage species dynamics can be related to the CVC hazards which often interact with those of other physical aspects of the environment such as soil characteristics to influence the distribution of other various biological components of the agro-ecosystem such as pests, diseases, herbivorous animals, pollinators, soil micro-organisms, which in turn will influence plant communities (Pilling and Hoffmann, 2011). The interactions may favour or disadvantage some forage plant species in specific environments depending on the climate-related agro-ecosystem changes (Foden et al., 2008).

2.1.3 Changes in quantity and quality of water

Climate variability and change is expected to increase the number of extreme meteorological events. The frequency and severity of both droughts and floods is already high and is expected to increase in future (Ojwang et al., 2010) and is expected to impact negatively on smallholder dairy farmer's activities due to their dependence on the availability of rainfall.

2.1.4 Changes in temperatures

Temperature is predicted to increase globally (FAO, 2007; IPCC, 2007) and it is expected to impact negatively on the levels of livestock production. Direct effects involve heat exchanges between the animal and the surrounding environment that are related to radiation, temperature, humidity and wind speed. Dairy cattle performance is best at temperatures between 4 to 24 ^{0}C, however, temperatures frequently rise above this thermal comfort zone in the smallholder dairy production environments (King et al., 2006; Thornton et al., 2009) due to CVC. Dairy cattle show signs of heat stress when temperature humidity index (THI) is higher than 72 (Armstrong, 1994). The comfort limit depends on the level of production. Animals presenting higher level of production like exotic DBGs are more sensitive to heat stress (Hahn, 1989).

High ambient temperature, relative humidity and radiant energy compromise the ability of animals to dissipate heat and provoke heat stress. Heat stress has a variety of detrimental effects on feed intake, mortality, growth, maintenance, milk production and reproduction in dairy cows (Johnson, 1987; Valtorta, 1996b). Hot dry conditions during the grazing period can reduce the quality and consistency of the feeds and feeding, which may lead to animal welfare and productivity problems (DEFRA, 2009). Under high temperature and solar radiation, dairy cows feed intake decreases in order to reduce digestive heat production and avoid grazing in hot mid-day hours, consequently reducing grazing time which translate to poor productivity. High temperatures and humidity put an upper bound on milk production, regardless of feed intake and also may affect conception rates.

2.1.5 Changes in livestock diseases and disease vectors

Climatic restrictions on vectors, environmental habitats and disease causing agents are important for keeping many animal diseases in check (Stem et al., 1989). Alterations of temperature and precipitation regimes may result to spread of diseases and parasites into new region or produce increased incidences of diseases, which, in turn, would reduce animal productivity and possibly increase animal mortality (Baker et al., 1998). The link between CVC and disease risks from various pathogens has been increasingly recognized. Diseases currently thought of as "exotic" may become of importance (Lancelot, 2008) whilst existing diseases may become more widespread with increased costs of control and risks of immunity developing (Skuce et al., 2008). Climate change has effects on; (a) Pathogens; Higher temperatures increases the development rate of pathogens whereas changes in winds may affect the spread of certain pathogens and vectors, (b) Epidemiology; By altering transmission rates between hosts, survival of the pathogen or parasite or intermediate vector is likely to be affected, (c) Hosts; CVC changes might suppress cellular immunity of the host, conversely affecting genetic resistance to diseases, (d) Disease distribution; Substantial shifts in disease distribution, and outbreaks of severe disease could occur in previously unexposed animal populations.

Climate variability and changes generally affect distribution and abundance of predators, competitors, disease vectors and parasites of vectors themselves. The effects influence diseases patterns, causing the emergence of new diseases through exposure of hosts to new and/or mixture pathogens and vectors. The ability of some insect vectors to become or remain infected with viruses (such as blue tongue) varies with temperature. The feeding frequency of arthropod vectors is known to increase with the rise in temperature. In the country of Mali, Diarra (2008) noted a significant drop in the spread of glossines linked to drought, the drying up of permanent rivers and the intensive land clearing. In Sudan and in Sudan-Guinea regions, a progressive decline of tsetse flies and their prevalence rates has been reported by Gouro et al. (2008). Lacaux and Tourre, (2008) has also reported geographical extension of Lyme disease (Borrelia crocidurae) within the Sahara and Sahel since the vector Alectorobius sonrai has found a 'good environment' attributed by the West African drought experienced in the last three decades. In Rongai (lowland), Kipkelion (moderate altitude) and Nandi South (highland) districts of Kenya, an increase of houseflies, ticks, crabs and frogs has been observed by farmers. Furthermore, rainfall and humidity are often considered as the necessary key parameters which modulate the emergence of various human, animal and plant diseases. For example, mosquitoes and other 'vectors' that facilitate the transmission and diffusion of diseases such as Rift Valley Fever (RVF), Blue Tongue, Malaria, Dengue Fever and Chikungunya among others, responds to the spatio-temporal distribution of seasonal rainfall (Lacaux and Tourre, 2008).

In addition, the DBGs bred with imported semen are geographically restricted and thus could be less adaptable to outbreaks of CVC induced diseases, especially the Rift Valley Fever, Foot and Mouth Disease and East Coast Fever. The outbreaks can cause increasing productivity losses as well as low product qualities and raise safety concerns on the health of the DBGs. Consequently these may translate into barriers to trading opportunities for the dairy products in the domestic and export markets. Despite the fact that some diseases are accelerated by climate change and variability, the impacts of the diseases on livestock and farmers' income is widely un-documented. Therefore, understanding how CVC affects the transmission of these diseases will lead to enhanced preparedness for early and effective interventions.

2.2 Adaptation strategies

Adaptation and mitigation are inextricably linked; mitigation policies can affect the range of adaptation options available to practitioners, whilst adaptation has the potential to "buy time" until effective mitigation responses can be implemented. Adaptation is concerned with coping with the unavoidable changes that will occur, even if mitigation is successful at minimising or avoiding the worst impacts (DEFRA, 2009). According to IPCC (2001), adaptation is the 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. Adaptation may therefore be used to inform both the magnitude and timing of mitigation (World Bank, 2008). Identifying and evaluating various adaptation strategies as well as mitigation options is of fundamental value to determining a set of dynamic climate policy options (World Bank, 2008). Farm level analyses have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn and Dinar, 1999). Numerous adaptation strategies in the livestock sector have been identified by several experts. These include;

2.2.1 Breeding

There are many ways in which producers can adapt to CVC. Producers can either modify their animals' genetics to the changed environment or modify the production environment to suit the genetics (Hoffmann, 2008 Climate change and variability has effects on cattle genetic diversity by determining the cattle breed most adapted to each agro-ecological zone. Many local breeds are already adapted to their harsh conditions. Adaptation include not only their tolerance to heat, but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann, 2008). Zebu (indigenous cattle breed) has been reported not only capable of utilizing poor quality feeds but they are more resilient to climatic stress, and are more resistant to local parasites and diseases. When animals are genetically adapted to specific/extreme conditions, they will be more productive (Simm et al., 2004). To increase productivity, farmers have been advised to adapt their dairy genetics to the changed PEDs through; (a) Increasing gene flow and introduction of breeds more adapted to the environment (Hoffmann, 2008)., (b) breeding for improved adaptation to heat, disease and harsh conditions using tropically adapted breeds/genes or insert specific genes via strategic crossbreeding or biotechnology, and (c) use adaptive traits of indigenous animal genetic resources (Thornton et al., 2007).

2.2.2 Structural Interventions

Structural interventions aim at the rehabilitation of sustainable productive assets through the improvement of processes, institutions or policies that have a direct influence on a target population's assets/liabilities. The interventions which have been suggested are; (a) Enabling dairy farmers to participate in decision-making at policy level. Farmers should have key roles in determining what adaptation strategies they support, (b) development of collaborative learning processes to support the adaptation of livestock systems to better cope with the impacts of CVC, and (c) Introduction and integration of adaptation and mitigation concepts into regular development activity.

2.2.3 Technology Integration

Successful adaptation is about the quality of both scientific and indigenous knowledge, local social capital and willingness to act. Science and technology development will aid in better understanding of the causes and impacts of CVC on livestock. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of CVC adaptation strategies (MacOpiyo et al., 2008). Access to technologies will determine the ability of producers to adapt their herds to the physiological stress of CVC. If CVC exceeds the adaptive capacity of local breeds in extensive or pastoral systems, where the rate of technology adoption is generally low, the risk of breed displacement or loss might increase. Intensive livestock production systems have more potential for adaptation through the adoption of technological changes and may sustain the high-output breeds (Hoffmann, 2008). A variety of technologies which have been proposed in animal husbandry include; (a) Development of new breeds and genetic types (Thornton, et al., 2008; Sidahmed et al., 2008), and (b) improved animal health technology (Kurukulasuriya and Rosenthal, 2003).

2.2.4 Cattle re-distribution

It is an adopted coping mechanism which consists of displacement of livestock into areas where natural resources are available. Consequently, affecting the distribution of reared animal species in different agro-ecological zones. There has been a displacement of flocks from arid and semi-arid zones, mainly to the sub-humid zones. This in fact explains the upward trend in the number of animals to humid zones where the environment is still unfavourable for livestock farming (Gouro et al., 2008). These changes have been observed in Niger and in the arid country of Mauritania.

2.2.5 Feeding approaches

New feeding approaches, supplementary feeding and adoption of either new feeds or other forms of rangeland management have been adopted as is the case in Senegal (Gouro, et al., 2008). Highly digestible feeds are recommended because poor quality roughage generates a lot more heat than highly digestible rations (Stewart, 2005). To minimize exposure of cattle to heat stress, Stewart (2005) suggested feeding under the shade if feeding is done in midday.

2.2.6 Livestock management systems

Efficient and affordable adaptation practices which have been developed for rural poor who are not able to buy expensive adaptation technologies include; (a) shading, sprinkling and ventilation to reduce heat stress from increased temperature. It involves setting up an irrigation line in the pasture, and run it for sometimes until all the cows have enjoyed a cool off (Stewart, 2005), (b) modification of the grazing times. Mostly, farmers in CVC hotspots are encouraged 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 at night (Stewart, 2005), (c) changing herd composition such as shifting from large animal to small animal, etc., (d) improve management of water resources through the introduction of simple techniques for localized irrigation (e.g. drip and sprinkler irrigation), accompanied with 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; Thornton, et al., 2008; Sidahmed 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 herd 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 (Stewart, 2005). In addition, lactating cows need enough rest before milking to enable them cool down and farmers are advised to bring the cows early in the afternoon.

3. Methodology

3.1 Study areas

The study was carried out in Rongai district which lies in the latitude and longitude of 0° 10' 0" S and 35° 51' 0", Kipkelion district which lies in the latitude and longitude 0° 13' 45" S and 35° 27' 23" and Nandi South District with latitudes 0° and 0°34 North and longitudes 34° 44″ and 35° 25″ East. These are administrative districts in Kenya. The PED's were selected from lowland (Rongai district), moderate altitude (Kipkelion district) and highland (Nandi South district) to represent varying degrees of CVC in Kenya. Nandi South district altitude ranges from 1,400m-2,400m above sea level, with average temperatures of 18-25^{o}C and annual rainfall between 1,200mm-2000mm. Kipkelion district lies at an altitude range of 1700m-2000m above sea level, with an average temperature of 17-25^{o}C .and annual rainfall between 900mm-1300mm. Rongai district receives annual precipitation of 927mm and average temperatures ranging from 25-37^{o}C.

3.2 Data Collection Procedure

Quantitative research approach was employed in this study. Quantitative data was obtained through interviews. A pretested structured questionnaire was used to gather information. 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 objectives of the survey and the benefits were explained to the farmers during visits. At each household, interviews were done using the questionnaire. The specific objective of the questionnaire was 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 dairy production and response strategies. Research methods embraced a participatory approach, following the guidelines presented by FAO/WAAP (2008). Scoring, ranking, seasonal calendar analysis and seasonal trend analysis techniques were used.

3.3 Sampling Method

In each district, one location with three sub-locations was chosen in consultation with officers from the ministry of agriculture, local community based organizations, and the local provincial administration (chiefs and their assistants) for the survey. Three sub-locations per district prominent in dairy production were selected on the basis that they have the highest populations of the DBGs. Two pairs of major landmarks were selected in each sub-location and transect lines were drawn between each pair. Interviewed households were selected using simple random sampling technique by randomly picking the 5th households. These regions included Boito, Lengenet and Mogotio sub-locations in Rongai, Mosombor, Toretmoi, and Kimolwo sub-locations in Nandi South district and Kipsirichet, Kedowa and Chakoror sub-locations in Kipkelion district. Data were analyzed using the SPSS (Version 17) computer software.

3.4 Data analysis

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

4. Results and Findings

4.1. Characterization of the diverse production environments (PEDs)
Generally, rainfall trend is on decline with a high variability as shown by the zigzag pattern in figure 1 to 3. Total annual precipitation for Nandi South district ranged from 821.1mm-1647.7mm (figure1), 407.0mm-1407.5 mm (figure 2) was recorded in Rongai district and 685.2mm -1458.8mm (figure 3) in Kipkelion. Findings of this study are in agreement to IPCC report, (2007) which noted that the Kenyan arid and semi-arid lands (ASAL) are expected to experience an overall decrease in precipitation due to CVC. According to Ojwang et al. (2010), declining rainfall trend is caused by rising temperature levels which inevitably lead to higher rates of evapo-transpiration. Fluctuation in rainfall pattern was prominent among the studied PEDs.

Although the variability of rainfall pattern and intensity is a common feature in Kenya due to variations in topography, the spatial and temporal changes in recent years point to the general CVC (Ojwang et al., 2010). In the last five decades, Kenya has experienced serious droughts more than thirteen times including the worst episodes witnessed in 1971, 1975, 1977, 1980, 1983/1984, 1991/1992, 1995/1996, 1999/2000, 2007/2008 (Kenya Meteorological Department, 2008; Ojwang et al., 2010). On the other hand, serious periodical flooding have been observed such as 1982, 1985, 1997/1998 (El-Nino), 2002, 2003, 2004/2005, 2007 and 2012 incidences. More flooding is expected in future as the mean annual temperatures in the country are expected to increase (IPCC, 2007). Expected temperature increase of 1.3-4.0°C by the year 2100 is likely to be accompanied by an increase in mean annual rainfall of up to 48 percent, with the increase in the total rainfall greatest from October to December while the proportional change is largest in January and February (Ojwang et al., 2010). The magnitude and frequency of CVC impacts have increased for the last four decades with more than 103 weather-related disasters observed of which more than half occurred after the year 2000. Trend increased sharply in the last one decade for drought and from the beginning of 2009 for flooding (Ojwang et al., 2010). According to UNEP/GoK, (2005), drought frequency used to be every nine to ten years. However, the pattern seemed to have changed to five years (GoK, 2009) and currently to every two to three years (The Economist on East Africa Drought, 2009).

Temperature trend in the Nandi south and Rongai districts are shown in figure 4 and 5. The trend was slightly on an ascending trend with average temperatures ranging between 8.34^{0}C and 24.01^{0}C for Nandi South district (figure 4), and between 16.66^{0}C and 36.4^{0}C for Rongai district (figure 5). Constant increase in temperatures reported in this study are consistent with GoK report (2009), the IPCC report (2007) and FAO report (2007), all of which predict that by the year 2100 the increase in global average surface temperature may be between 1.5 and 4.0°C. An increase by 1°C over the last five decades have been recorded in Kenya (GoK, 2009) and a further 1-2.5^{0}C is expected by 2030 (IPCC, 2007). The phenomenon and direction of trends in temperature has become increasingly deviant from normal, with more hot and fewer cold days and nights, also warmer and more frequent hot days and nights over most land areas (IPCC, 2007). This increase has been observed to be higher from March to May and expected to lead to an overall increase of around 7 % in annual rainfall over the same period, although this change will not be experienced uniformly across the region or throughout the year (Ojwang et al., 2010). The impact of the temperature change has manifested through detrimental effects associated with changes in; quantity and quality of feeds, quantity of water, forage species composition, livestock diseases and disease vectors and other effects. The recent rise in temperature and prolonged and severe droughts in Kenya are widely perceived to be symptomatic of the changing climate (Kenya Meteorological Department, 2008). Rainfall and temperature changes observed in the study suggest the three studied PEDs are hotspots of CVC.

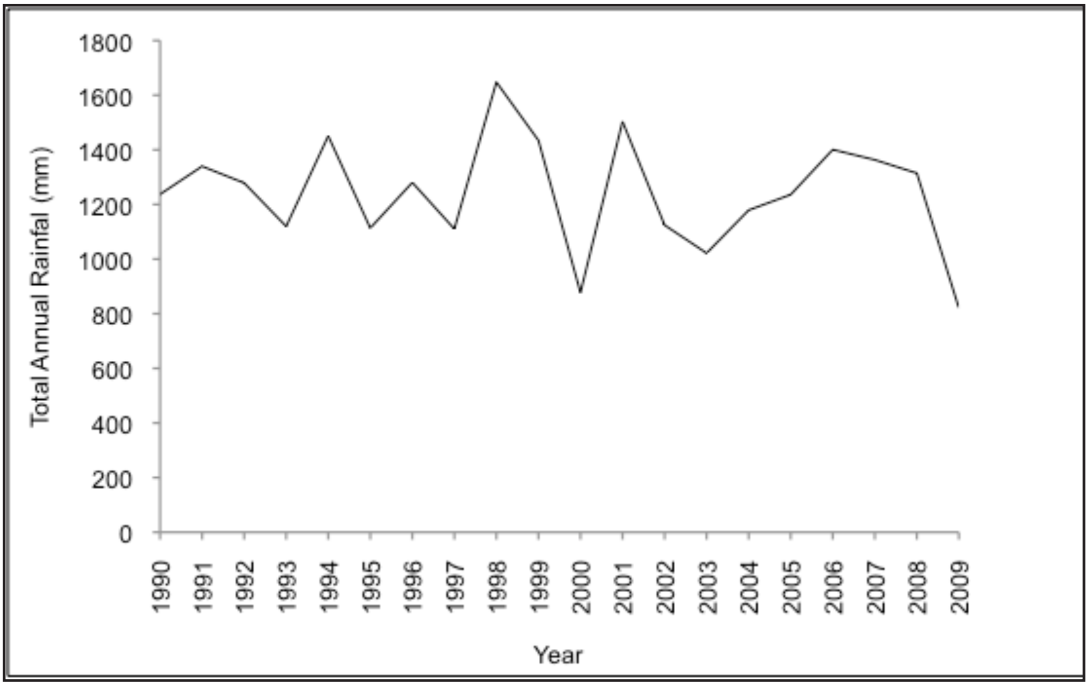

Figure 1: Rainfall trend in Nandi South district

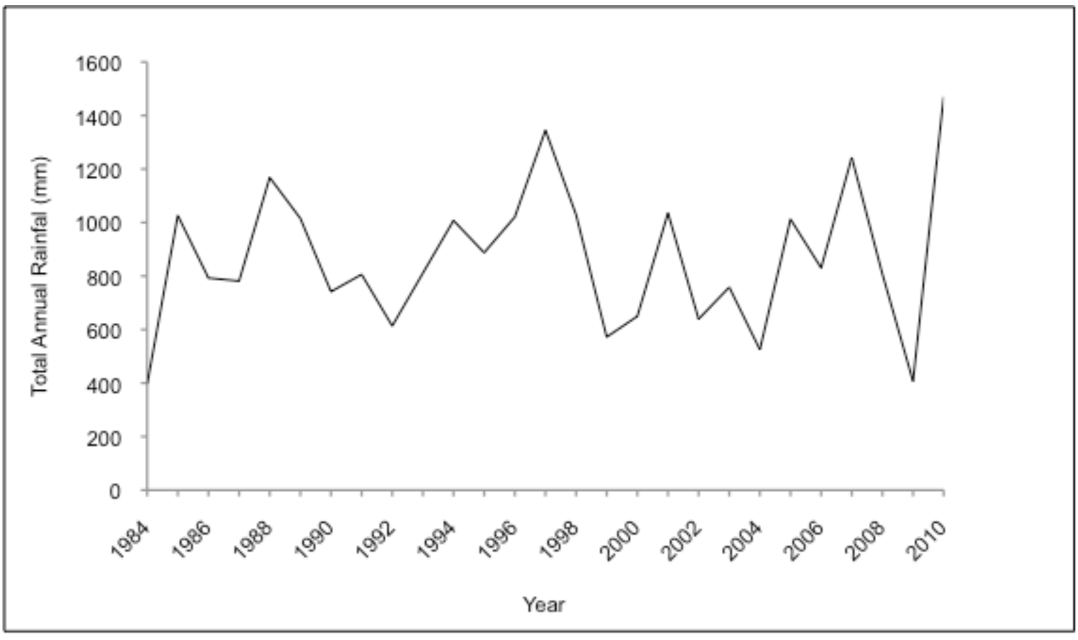

Figure 2: Rainfall trend in Rongai district

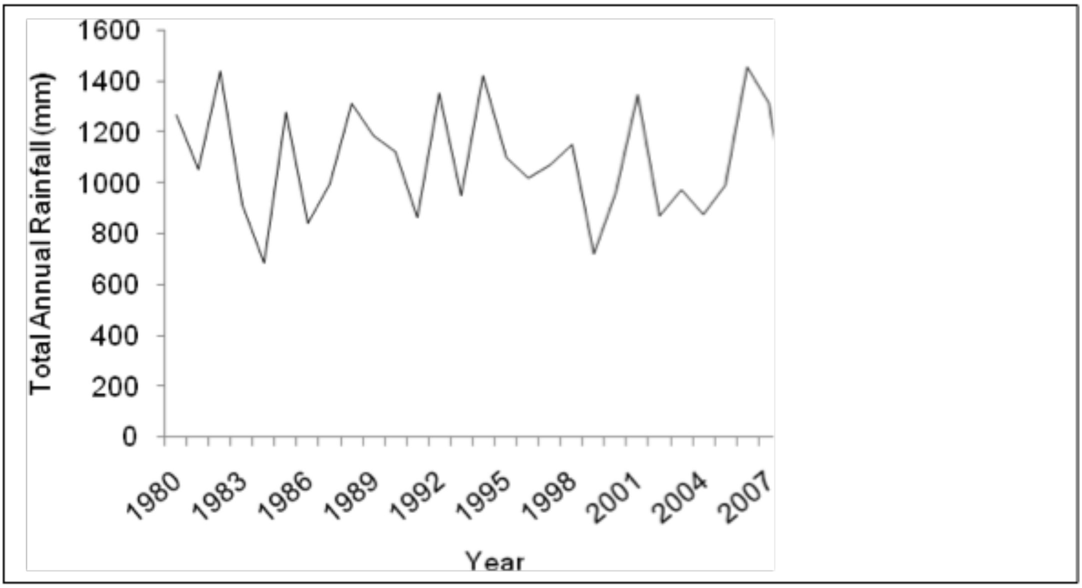

Figure 3: Rainfall trend in Kipkelion district

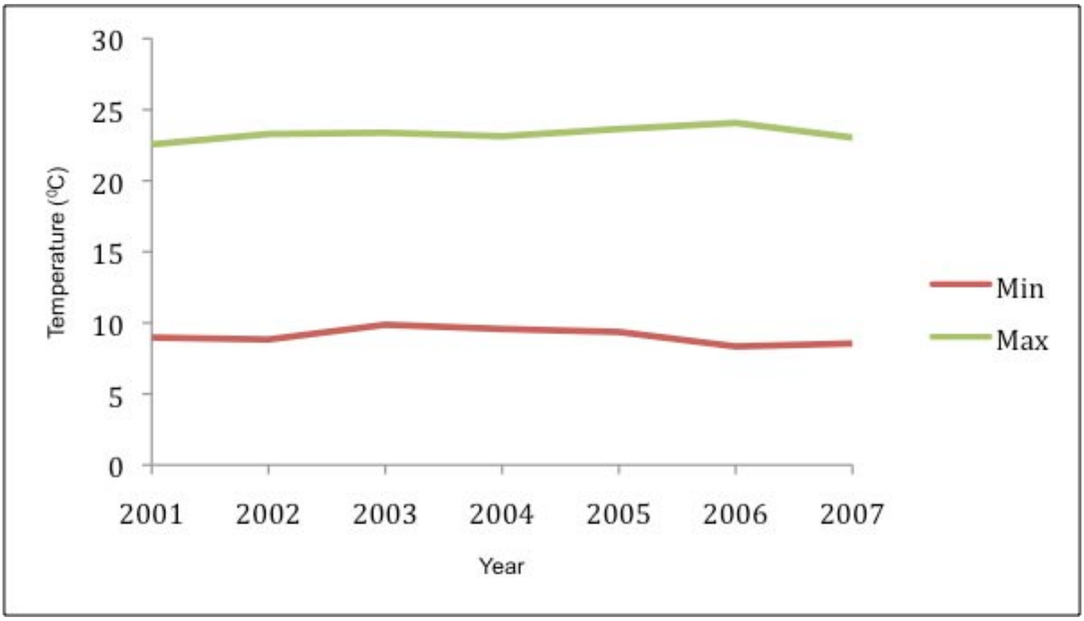

Figure 4: Maximum and minimum temperature for Nandi South district

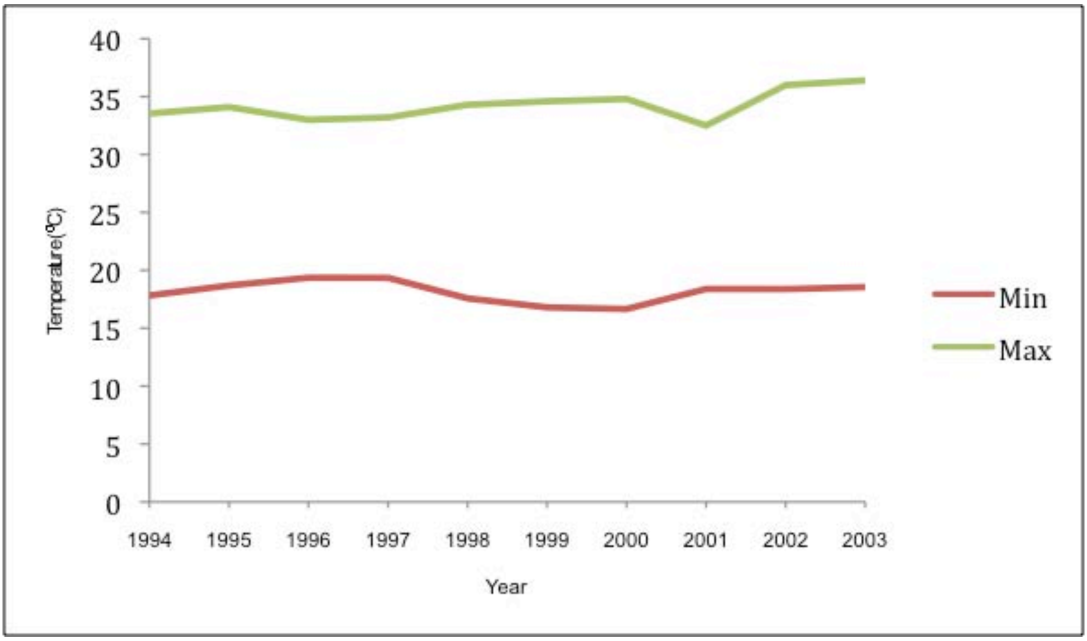

Figure 5: Maximum and minimum temperature for Rongai District

4.2. Vulnerability ranking of the dairy breeds/genotypes (DBG) to CVC in the identified PEDs based on farming experience

A relative vulnerability ranking of DBGs to CVC impacts in the diverse production environments were done in a four scale ranking order; 1 = not vulnerable; 2 = mild vulnerable; 3 = moderately vulnerable and 4 = highly vulnerable. The DBGs were ranked under three varying levels of CVC stress (low, medium and high stress levels). Friesian was the most vulnerable breed under both medium and high climatic stress under all circumstances in the three PEDs compared to other DBGs (Table 1). Under high heat stress, vulnerabilities were moderate to high for Friesian (2.79-3.70) whereas Ayrshire (1.15-2.0), Guernsey (1.0-2.0), and Jersey (1.13-2.0) were less affected. Under low heat stress, Friesians were not vulnerable (1.00) in Nandi south district and can do better than the same Friesian under low heat stress in moderate altitude of Kipkelion district (1.08) but different in Rongai district (3.08) (Table 1). Across the three districts, Friesian was also the most vulnerable breed to feed stress and disease infection under medium and high stress levels. Vulnerability levels to high feed stress were; high for Friesian (3.88-4.00) as compared to Ayrshire (2.38-3.88), Guernsey (3.00-3.75), Jersey (3.00-3.75) and Dairy crosses (2.08-3.75) (Table 1). Susceptibility levels to high disease stress were high for Friesian (3.74-4.00), Ayrshire (2.12-3.88), Guernsey (3.25-3.75), Jersey (2.00-4.00) and Dairy crosses (2.17-3.92).

Findings of this study indicated that the zebu breed (indigenous cattle breed) and its crosses were the most adapted breed to climatic conditions in all the PEDs than exotic counterparts, which is in agreement with the report by McManus et al. (2009) on heat tolerance of local breeds. Zebu breed and its crosses like most local breeds in the tropics and subtropics are comparatively well adapted to high temperatures. 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. According to Romanov et al. (1996), locally adapted breeds possess genes and alleles that are pertinent to their adaptation to the local environments. Genes that confer thermo-tolerance at the physiological and cellular levels were acquired during the evolution and natural selection process. Superiority of zebu breed and their crosses over other DBGs in ability to regulate body temperature during heat stress is the result of lower metabolic rates and larger sweat glands which increased sweating capacity for heat loss. Furthermore, Zebu posses lower tissue resistance to heat flow from the body core to the skin compared to exotic breeds (Hansen, 2004).

In general, the high-output exotic DBGs are not well adapted to heat stress. For example, milk production, fertility and longevity in Holstein-Friesian cattle decline as temperature increases (St-Pierre et al. 2003; West 2003). Therefore, Rongai district which are currently characterised by high temperatures and low rainfall may be expected to lead to a shift towards more highly adaptive species such as dairy-zebu crosses and zebu breeds. In such hot and dry environment of Rongai district, selecting DBGs adapted to this PED or incorporation of tolerance genes from zebu breed into Bos-taurus while avoiding undesirable genes may be an alternative scheme. The zebu genotype has been utilized in crossbreeding systems to develop cattle for dairy production systems in hot climates. For example, mapping of specific genes responsible for thermo-tolerance in zebu can be explored through breeding strategies such as marker-assisted selection and transgenics (Hansen, 2004).

Table 1: Relative vulnerability ranking of DBG to climate change impacts now in the production environment

		Heat stress			Feed stress			Water stress			Disease stress			Vector stress			Flooding stress		
DBG	**District**	**High**	**Medium**	**Low**	**High**	**Me-dium**	**Low**	**High**	**Medium**	**Low**	**High**	**Medium**	**Low**	**High**	**Medium**	**Low**	**High**	**Me-di-um**	**Low**
Friesian	Nandi South	3.72	2.79	1.00	3.88	3.65	1.16	3.67	3.40	1.00	3.74	3.53	1.05	3.67	2.84	1.14	3.52	2.90	1.10
	Kipkelion	3.73	2.76	1.08	3.89	3.59	1.16	3.73	3.43	1.08	3.81	3.54	1.16	3.73	2.78	1.22	3.57	2.86	1.15
	Rongai	3.92	3.38	3.08	4.00	3.23	2.92	3.92	3.54	2.77	4.00	3.38	3.17	3.85	3.62	3.08	3.54	3.31	2.62
Ayrshire	Nandi South	2.07	1.15	1.00	2.38	1.50	1.00	2.13	2.13	1.03	2.12	1.90	1.30	2.65	1.95	1.03	2.47	1.53	1.03
	Kipkelion	2.07	1.19	1.00	2.30	1.42	1.00	2.14	2.28	1.05	2.19	1.93	1.35	2.77	1.98	1.07	2.70	1.70	1.07
	Rongai	3.75	3.50	3.13	3.88	3.38	2.88	3.88	3.63	3.25	3.88	3.38	3.14	3.50	3.13	3.13	3.38	2.88	2.38
Guernsey	Nandi South	2.00	1.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	2.00	1.20	1.00	2.00	1.00	1.00	2.00	1.00	1.00
	Kipkelion	2.00	1.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	2.00	1.50	1.00	2.00	1.00	1.00	2.00	1.00	1.00
	Rongai	3.50	3.25	2.75	3.75	3.00	3.00	3.75	4.00	3.75	3.75	3.25	3.25	3.75	3.25	3.25	2.75	3.25	2.75
Jersey	Nandi South	2.00	1.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00
	Kipkelion	2.00	1.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	2.00
	Rongai	3.75	3.25	2.50	3.75	2.75	3.25	3.75	3.75	3.00	4.00	3.25	3.25	3.50	2.75	2.75	3.00	3.00	2.25
Dairy crosses	Nandi South	2.08	1.13	1.02	2.08	1.40	1.00	2.15	1.58	1.02	2.17	1.98	1.38	2.62	1.90	1.04	2.41	1.41	1.06
	Kipkelion	2.05	1.14	1.08	2.14	1.43	1.03	2.19	1.59	1.08	2.27	2.00	1.51	2.73	1.97	1.14	2.38	1.54	1.13
	Rongai	3.83	3.33	2.82	3.75	3.08	3.18	3.58	3.17	3.00	3.92	3.42	3.25	3.67	2.91	2.73	3.27	2.91	2.40
Dairy-zebu crosses	Nandi South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kipkelion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rongai	2.90	2.67	2.67	3.00	3.00	2.89	3.40	2.78	2.60	3.50	2.80	2.70	3.60	2.80	2.30	2.89	2.44	2.11
Zebu	Nandi South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kipkelion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rongai	2.25	2.00	1.75	2.75	2.25	2.00	3.00	2.25	2.50	3.25	2.50	2.25	3.00	2.25	2.25	2.25	2.50	1.75

4.3. Adaptive traits to stresses of CVC in the specific PEDS

A range of traits ranked in terms of their relevance to animal adaptability to environmental stress as perceived by the farmers across the three districts are presented in Table 2. A ranking scale of 5= very important, 4= moderately important, 3 = (averagely important), 2 = mildly important and 1 = least important) were used. Body condition, survival, rehydration, coat colour and foraging ability traits were considered most relevant to animal adaptability to CVC stress ($P<0.05$) whereas fertility, calving interval and calf survival were not (Table 2). The fact that some traits were critical indicates that selection for these traits had an impact in that environment. Body condition may be useful to assess in relation to climate variation. Body condition is an assessment of weight in relation to length and is a commonly used indicator of the overall fitness of individuals (Lowe, 2003). Efficient dairy production is dependent on the management of the cows' energy reserves. Monitoring body condition is a useful management tool to assess these energy reserves Cow's body condition is positively correlated with the ability to reproduce (Reading, 1986), and declines in body condition have been directly linked to declines in annual survivorship (Jørgensen 1986). Ward and Tiffin (1975) observed that body condition is important at the time of breeding. For example, to obtain a reasonable compromise between milk yield and fertility, a target condition score of 3 at calving, and a target score of 2 at service is needed (Merwe, 2005). It is expected that CVC stresses, would result in a poor body condition and, investigating DBG's body condition in relation to climate variables will increase our understanding of how CVC variation might indirectly affect their population over multiple years by directly affecting energy stores. In addition, if survival is predicted by body condition, it would provide a response variable that reacts to climate variables and may be indicative of survival. Therefore, most farmers are likely to prefer DBGs that maintain body condition under stressful periods. Coat colour is an important trait across the three PEDs. Bright coloured or shiny coats have been reported to reflect sunlight thus reduce too much heat stress. Brown coat colour is adaptive trait that may well suit harsh environment conditions with greater climate variability. For example in Zebu, their hair coat enhances conductive and convective heat loss and reduces absorption of solar radiation.

Fertility in cattle is affected by environmental, genetic, disease and management factors. Fertility may be defined as the ability to conceive and produce a viable calf. Under harsh environmental conditions, generally, most cows develop important strategies to modulate the timing of conception to take advantage of resource abundance. Fertility is generally highest in the cold-dry season compared to hot-wet season and hot-dry season. Therefore, as rainfall declines accompanied by rise in temperature, fertility is likely to be affected negatively. The CVC may impact bulls' fertility in several ways, including delayed puberty due to feed associated stress, depressed immune system under heat stress (Chakravarty et al., 2012), and poor quantity and quality of the sperm produced. Under the CVC stress, fertility is expected to vary with DBGs depending on individual and breed coping mechanisms. Fertility rates are generally high in Bos-taurus compared to Bos-indicus, particularly under ideal management (Mugerwa, 1989.). However, the trend might become reversible under stressful conditions. It has been observed that, the hot-wet season, characterized by high humidity, high temperatures and low wind speed, seem to exert some stress on the Holstein Friesian cows. Effect of stress normally varies and calving interval probably reflects the adaptation levels. The long calving interval of the cattle probably reflects lack of adaptation to the environment (Mugerwa, 1989). In studies conducted by Jochle (1972) and Mugerwa (1989), they also found direct linear correlations between conception rate in cows and precipitation, pressure and temperature. Good foraging ability under seasonal fluctuations in fodder availability and quality are important in the context of CVC as it will make DBGs less vulnerable to CVC. The ability of some organisms to survive extreme dehydration conditions has been reported by many authors. In the last 5 decades, it has been known that many animal species seem to possess this remarkable ability to overcome dehydration. They are able to withstand removal of essentially all their intracellular water without suffering irreversible structural and functional damage (Crowe et al. 1987). Their adaptations include morphological changes and a reduction in metabolic rate (Womersley, 1981a; Freckman and Womersley, 1983). This ability to withstand dehydration and rehydrate is increasingly becoming important in PEDs where rainfall is declining accompanied with increasing temperature.

These findings are in agreement with, report by Hoffmann (2008), who suggested that producers can either adapt their animals' genetics to the changed environment or modify the production environment to suit the genetics. Genetic make-up influences fitness and adaptation and determines an animal's tolerance to shocks from temperature extremes, drought, flooding, pest and disease challenges. A number of commentators, such as Yarwood and Evans (2002), noted that many Bos-indicus genotypes are more resilient to CVC stress and host unique traits which may be useful for improving health and performance traits in future. In Kenya, local breeds such as zebu are already adapted to their harsh conditions. However, neglect of adaptive traits and lack of technology in cattle breeding programmes which might help to speed the adaptation have not been addressed.

Table 2: Traits ranking in terms of their relevance to animal adaptability to environmental stress

District	Fertility	Calving interval	Body condition	Survival	Rehydration	Coat colour	Calf survival	Foraging ability
Nandi South	4.59	4.57	4.86	4.99	3.28	3.49	4.32	4.95
Kipkelion	4.52	4.51	4.85	4.90	3.24	3.48	4.32	4.94
Rongai	4.50	4.60	3.77	3.80	3.90	3.13	4.63	3.90
Sig (p=0.05)	.567	.611	.000	.000	.000	.050	.215	.000

[Scale: 5=very important, 4=moderately important, 3 = (averagely important), 2 = mildly important, 1 = least important)]

4.4. Breeding strategies for DBGs under diverse production environments

A relative ranking of farmers' indigenous knowledge in animal breeding across the three districts were scaled in order of; 1= No, 2= occasionally, 3=always and 4= frequently. Information on selection criteria of breeding animal including use of individual merit, family history, performance history and external sourcing of breeding stock were captured. Information based on performance history was the most frequently used when selection for breeding or replacement purposes in the three districts; Nandi South (3.14), Kipkelion (3.17) and Rongai (3.15). Information based on individual merit was always practiced; Nandi South (2.21), Kipkelion (2.28) and Rongai (2.45) (Table 3). Few farmers outsourced breeding stock; Nandi South (1.78), Kipkelion (1.61) and Rongai (1.90). From the results, it is clear that most farmers across the three districts did selection based on the information that they know about the family and the performance history. Indigenous livestock management practices under natural selection through social and rational breeding mechanisms contributed to breed adaptation and fitness to harsh environments (Sansthan and Rollefson, 2005; CGRFA, 2009). Such traditional knowledge can contribute to solving serious global problems through practices such as sustainable use of DBGs to address issues such as CVC impacts. Farmers in different PEDs have clear-cut breeding objectives which are multi-faceted, and include the DBG's ability to survive. Understanding indigenous practices and processes among farmers are essential for the design of intervention strategies for adaptation. Their traditional knowledge however, provides a key for successful local level adaptation and advice on sustainable mitigation activities.

Table 3: Indigenous knowledge in animal breeding

District	Individual merit	Family history	Performance history	External sourcing of breeding stock
Nandi South	2.21	2.68	3.14	1.78
Kipkelion	2.28	2.74	3.17	1.61
Rongai	2.45	1.93	2.70	3.14

5. Conclusions and Recommendations

The paper presented the vulnerabilities and adaptation strategies to CVC of the Bos-taurus dairy genotypes under diverse production environments. The results from the study indicate that the DBGs are vulnerable to impacts of CVC and their susceptibility levels vary with both DBG and PEDs. Inferences generated from this study can provide a strong basis for mitigating CVC and improving productivity by designing breeding and adaptation strategies for specific production environment. For DBGs, developing the traits needed to cope with CVC is promising. Bos-indicus genotypes such as Zebu breed contain a wide genetic diversity of tolerance traits which can be exploited. Though largely neglected in modern breeding, such Bos-indicus genotypes could play a vital role in helping farmers adapt to CVC, despite the challenges of compromising the yield.

Traits and tools 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 to address the adaptation challenges. Selection for breeds such as zebu breed with effective thermoregulatory control may be exploited and incorporated into DBGs to boost their heat tolerance levels. 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. However, in dairy cattle, it may be difficult to combine the desirable traits of heat tolerance with high reproduction and production potential.

In spite, lack of scientifically back up information, indigenous knowledge about cattle genetic diversity has been revealed to offer an important knowledge base for selective breeding. Indigenous knowledge on animal breeding is a valuable resource about the existence of cattle breeds and their adaptive traits. . Integrating indigenous knowledge into selective breeding programmes can be an opportunity for the development of low-cost, locally-appropriate CVC adaption strategies.

Therefore, attaining sustainable dairy productivity requires utilizing DBGs adapted to the variable and changing climate. In all of the areas discussed above, greater benefits could likely be achieved through identification of adaptive DBGs and strengthen their adaptive capacity. In all of the areas discussed above, greater benefits could likely be achieved through identification of adaptive DBGs and strengthen their adaptive capacity. Dairy breeds genotypes that are already well-adapted and can survive the changing climatic conditions need to be promoted in the suitable production environments together with appropriate management interventions. This will effectively reduce animal stresses and enable smallholder dairy farmers mitigate and adapt to effects of changing climate thus promote and sustain their livelihood assets.

Recommendations

- More interaction is required at all levels among breeders, farmers, climatologists, traders and consumers to develop robust breeding program to curb the CVC threats.
- In the presence of breed by environment interactions, specific DBG need to be sought for particular environments in order to optimize performance total merit of production. Therefore, frequent assessment of the magnitude of G*E interaction is needed.
- Increased training to farmers on how to handle the DBGs is also necessary.
- Frequent documentation of the farmer's indigenous knowledge about PEDs, DBGs and breeding. It can be a source of information that scientists have overlooked and which may have unrecognised advantages and potential.

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