International Journal of Agricultural Science Research Vol. 4(6), pp. 109-116, June 2015
Available online at http://academeresearchjournals.org/journal/ijasr
ISSN 2327-3321 ©2015 Academe Research Journals

Full Length Research Paper

Influence of climate change on smallholder dairy productivity: A case of Kosirai, Kenya, and Namayumba, Uganda

Kirui JW*, Muthama JN, Opere AO and Ngaina JN

Department of Meteorology, University of Nairobi, P.O Box 30197, 00100, Nairobi, Kenya.

Accepted 11 May, 2015

Climate change influences dairy productivity in East Africa through impacts on fodder production and supply, livestock disease outbreak and water availability for livestock. This study assessed the influence of climate change on smallholder dairy farming in Kosirai, Nandi District of Kenya and Namayumba in Wakiso District of Uganda, in support of climate-smart agricultural practices. Observed (1973-2009) and model output (1950-2100) climate data comprising rainfall, minimum and maximum temperature and household survey were used. A simple random sampling technique, time series analysis, and descriptive statistics were used to achieve the objectives of the study. Mean rainfall in the two sites had progressively decreased over the last ten years. Conversely, there was a systematic rise in both the minimum and maximum temperature, both in historical and projected period in the two sites. The weather variables namely rainfall, maximum and the minimum temperature had a positive correlation with fodder production and supply. Likewise, milk production that mainly depended on rain-fed forages also correlated with the supply of feeds. There was increased milk production and supply during the wet season as compared to the dry spells. Climate change was linked to the emergence and rise of both the vector born and viral diseases in the two sites. There was a significant rise in outbreaks of foot and mouth disease and tick-borne diseases in Namayumba area. In Kosirai, there was an increase in outbreaks of tick-borne. The study recommended that dairy farmers be empowered to prepare effectively to climate change through adaptation and mitigation of the effect of extreme climate change. Farmers should also invest in the production and conservation of fodder for their dairy production.

Key words: Climate smart agriculture, smallholder dairy farmers, climate change.

INTRODUCTION

Dairy farming is one of the key sectors in agriculture which contributes to improved nutrition and employment in rural areas. Significant impacts of climate change have been observed in all sectors of the economy in Eastern Africa especially in Agriculture where farmers remain entirely dependent on rainfall (IPCC, 2007). Changes in mean temperatures and rainfall patterns continue to have direct effects on water availability, enhanced frequency and intensity of drought, floods, sea level rises and salinization and perturbations in the ecosystems (Beddington et al., 2012; Thornton et al., 2012). An increase in average global temperature of 2-4°C above pre-industrial levels could reduce crop yields by 15-35% in Africa (FAO, 2004; IPCC, 2007).

Dairy farming is vulnerable to climate change through increased temperatures and changes in rainfall patterns (Kasulo et al., 2009) and thus affect feed and water availability, animal health and in turn milk production. Further, warmer and drier conditions increase the likelihood of heat stress in cattle. There is normally a

*Corresponding author. E-mail: kiruijw@yahoo.com

decrease in milk production for cows under heat stress. Changes in rainfall patterns affect pasture and fodder growth patterns thereby affecting the quality and quantity of feed grains, pasture and fodder produced in dairy areas. Droughts lead to water shortage that in turn leads to a decrease in milk production (Kasulo et al., 2009). Kasulo et al. (2009) indicated that climate change has an impact on the increase or decrease in animal disease risk.

According to the East Africa Dairy Development (EADD) project (TechnoServe Kenya, 2008), milk production is dependent on rain-fed forages production with surplus feed supply during the rainy season. Likewise, there is a corresponding rise in milk production while dry season is characterized by reduction in feed supply and a general deficit in milk production. In Uganda, Lukuyu et al. (2011) indicated although rainfall level in Namayumba was adequate to support cropping activities, its unreliability in both space and time was increasing. In Kenya, climate variability and change has resulted into frequent droughts and emergency of vector-borne parasites that affects milk production due to increased seasonal variability within the year and also a decline in the long rainy season (GOK, 2010).

Variability in climate coupled with high poverty index (52%) affect dairy production that is predominantly practiced by smallholder farmers in East Africa (Salami et al., 2010). Moreover, rainfall seasonality affects forage availability, livestock production and ultimately the livelihoods of these people (Galvin et al., 2003). Although the direct impact of climate change to dairy production will be minimal, the indirect impacts brought about by a change in feed and fodder supply may severely alter the existing livestock production system (FAO, 2004). The low dairy herd productivity in East Africa is attributed to the limited use of production technologies and inadequate exploitation of the existing environmental influences. Mapiye et al. (2006) alluded that the low quantity and quality of feed resources affected the productivity of dairy animals in sub-Saharan Africa.

Milk production grew steadily in East Africa in the 1980s and 1990s. The pace of growth has since accelerated following recent high rates of income growth and urbanization though exact figures are not easy to verify (Place et al., 2009). Ngigi (2004) reports that milk production increased during the 1990s at an annual rate of 4.1% in Kenya and 2.6% in Uganda due to high rates of domestic consumption among other reasons. The smallholder farming systems in Kaptumo, Kenya are characterized by lowland and livestock productivity due to unreliable and inadequate rainfall, infertile soils, poor agronomic practices, undeveloped marketing channels and lack of agricultural inputs (Wambugu and Franzel, 2012). Farmers experience frequent droughts, excessive rains in the wet season and subsequent crop failures and decline in livestock productivity which increases their vulnerability to food insecurity and poverty (Zagst, 2011).

This study sought to investigate the perception and knowledge of smallholder farmers on climate change and their current coping methods aimed at determining the effects of past, present and future climate change on fodder production. These will provide the basis for development and adoption of climate smart fodder production practices by smallholder dairy farmers in the region and thus sustainably increase productivity, resilience of agricultural sector, adaptation and mitigation strategies to climate change and enhance achievement of national food security (Chaudhury et al., 2012) and reduce rural poverty in the region.

Scope of the study

The study was carried out in Kosirai, Nandi County in Kenya and Namayumba sub-county of Wakiso district in Uganda (Figure 1). The two sites are covered by the East Africa Dairy Development (EADD) project on dairy production that intends to incorporate climate-smart agricultural practices. The two sites mainly rely on rain-fed fodder production resulting variation between the wet and dry seasons thereby leading to fluctuation in available fodder and thus milk productions.

In Kosirai, farmers keep cross breed of Ayrshires and Friesian under grazing and stall feeding production system. Dairy farmers grow forage crops such as Napier grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), and Nandi Setaria (*Setaria sphacelata*) (Lukuyu et al., 2011). About 4000 dairy farmers in Kosirai came together to form a producer organization called Lelchego dairies that assist farmers to bulk and market their milk. The area receives a mean rainfall of between 1200 and 2000 mm per year. The rainfall is bimodal with dry spells experienced between December and March. The distribution of rainfall is affected by topography and the south-westerly winds from Lake Victoria (Waithaka et al., 2000).

In Namayumba, farmers practice intensive and semi-intensive dairy farming. The most common fodder crops grown by dairy farmers are Napier grass (*Pennisetum purpureum*), Nandi Setaria (*Setaria sphacelata*) and Rhodes grass (*Chloris gayana*) while a few farmers plant legumes such as Lablab purpureus, Mucuna pruriens and fodder trees. On average, each household has two to three cows with 80% keeping Nganda type of cattle that is characterized by low milk yield potential. Only 30% have cross breed of Friesian, Jersey with the local Nganda breed (Lukuyu et al., 2011).

DATA AND METHODOLOGY

Household survey and climate data were used in this study. Household survey using a structured questionnaire, captured trend of fodder production and availability, level of smallholder dairy farmer’s awareness to climate change impact on dairy production and their

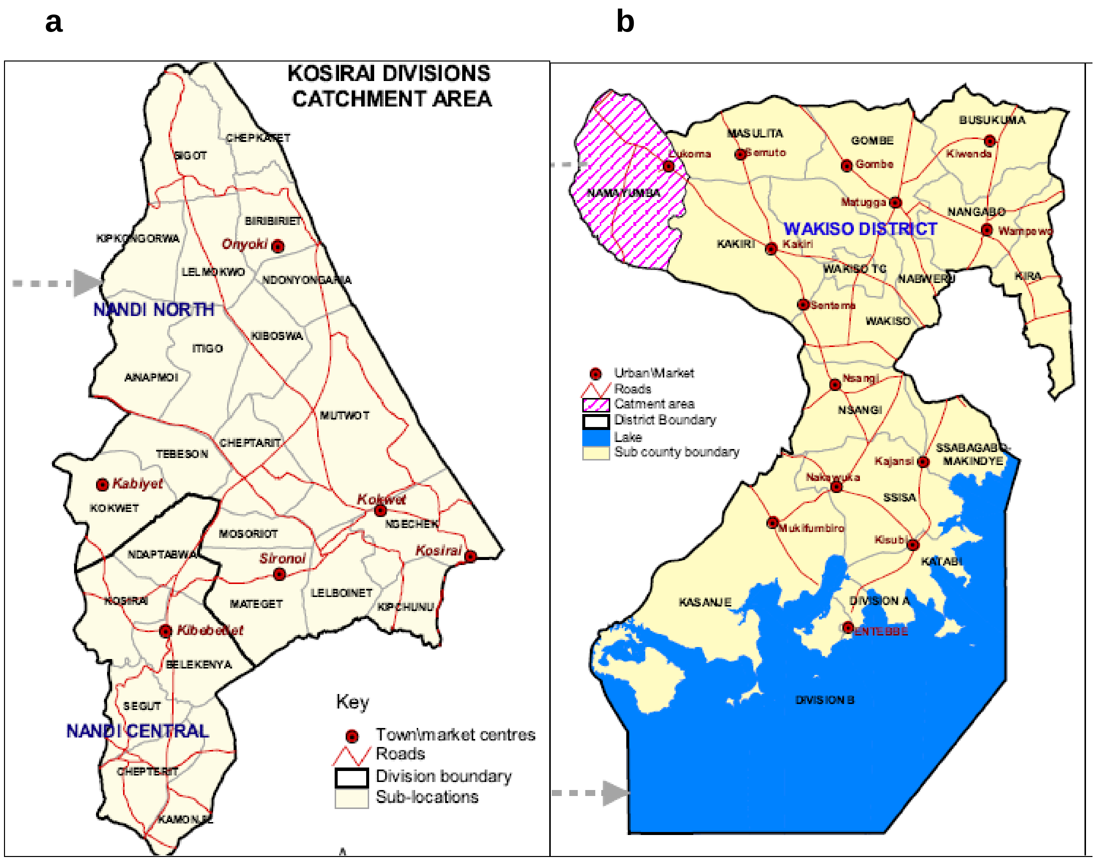

Figure 1. Area of study: (a) Kosirai, Nandi North County of Kenya, and (b) Namayumba sub-county, Wakiso in Uganda.

coping mechanisms. Climate data included rainfall, minimum and maximum temperature for both observed (1973-2009) and climate model output (1950-2100). Observed data for two Synoptic Meteorological stations (Eldoret in Kosirai and Kampala in Namayumba) were sourced from Kenya and Uganda National Meteorological and Hydrological Centers (NMHCs) respectively. Commonwealth Scientific and Industrial Research Organization (CSIRO Mk3.6) model data were sourced from the European Climate Assessment Data and KNMI Climate Explorer Coupled Model Intercomparison Project Phase 5 (CMIP5) (http://climexp.knmi.nl/get_index.cgi). The Mk3 version of the CSIRO model contains a comprehensive representation of the four major components of the climate system: atmosphere, land surface, ocean, and sea-ice. The model resolution is 1.875°EW × (approx.) 0.9375°NS (sometimes referred to as "T63_2" resolution) (Gordon et al., 2010). CSIRO Mk3.6 model output included historical and projected data based on baseline (1950-2005) and Representative Concentrations Pathways (RCPs) 2.6Wm2, 4.5Wm2 6.0Wm2 and 8.5Wm2 scenarios (2006-2100). The RCPs describe a wide range of potential futures for the main drivers of climate change: greenhouse gas and air pollutant emissions and land use. Trend of past, present, and future climate was investigated through time series analysis. The household survey was guided by a cross-sectional survey research design (Wiersma, 1986). A purposeful simple random sampling technique was used to select the farmers from the two sites with a total of 253 farmers being sampled comprising 129 from Kosirai site in Kenya and 124 from Namayumba in Uganda. The study instrument underwent pretesting to ascertain its reliability in Molo District of Kenya which has smallholder dairy farmers experiencing similar socio-economic and climatic characteristic to the two study sites. Improve clarity and ambiguity, pre-testing was done with 15 smallholder dairy farmers and responses and analysis used to review the data capture tool. Pre-testing enables the summary and focused questions that improve clarity and ambiguity.

The household survey data were analyzed by Statistical Package for Social Sciences (SPSS) version 21.0 and descriptive analysis such as proportions, percentages, frequency distributions and measures of central tendency mean and median being used. Data summary and classification were done and presented using tables and graphs. An assessment of the effects of climate change on milk and fodder production was developed from observed rainfall and farmer's awareness. Major wet and dry seasons were identified based on observed rainfall as extreme values and computed based on moving average method. The Autoregressive Moving Average (ARMA) method (equation 1) implemented by a macro program identified three highest values (extremes) in the first block where each block had a length of three years. It also computes the relative frequency of the highest values in the first block of the whole data set. It then shifts by one step and repeats the whole procedure. As it moves, it checked on how the extreme values in each block related to other values in the whole dataset series. The resulting time series of perturbations of monthly rainfall totals were then compared to identify how extremes were changing and then compared to fodder and milk production data from the household survey using bar graphs. Details of ARMA model can be found in Biging and Gill (1997).

RESULTS AND DISCUSSION

Trend of past and future climate

The observed mean annual rainfall at Kosirai and Namayumba was 1062.8 and 1165.2 mm, while the average observed maximum temperature was 28.5 and 26.5°C respectively. Future projections showed that mean annual rainfall would range between 648.2 and 823.2 mm in Kosirai and between 930.4 and 1063.0 mm in Namayumba, an indication that Namayumba in Wakiso district of Uganda received higher amounts of annual rainfall compared to Kosirai in Nandi North District of Kenya. Maximum temperature ranged between 27 and 31°C, while minimum temperature ranged between 16 and 21°C with RCP of 8.5 Wm2 showing the highest standard deviation of between 1 and 2°C. The study showed that only 4.8% ($R2 \sim 0.048$) and 3.4% ($R2 \sim 0.034$) of data in the trend line of baseline rainfall from both observed and model data lied along the line of best fit in Namayumba and Kosirai that fitted the linear regression line. Further, the study indicated that the trend of both maximum and minimum temperature was increasing with a coefficient of determination value of less than 0.02 over the two sites.

Future projections indicated that the trend of annual precipitation under the different representative concentration pathways was increasing with only RCP 2.6 scenario in Namayumba (Figure 2a) showing a decreasing trend in annual precipitation, while highest increase was noted in Kosirai (Figure 2b) observed under the RCP 8.5 scenario. These showed that annual precipitation was expected to increase in most scenarios with the RCP 8.5 likely to show a higher increase compared to other RCP scenarios. These changes in rainfall pattern over time are expected to influence fodder production and supply, especially in East Africa where smallholder dairy production is dependent on rain-fed forage production. The study showed that both maximum and minimum temperature increased in Namayumba and Kosirai areas. Increasing trend in maximum and minimum temperature for RCP 4.5, RCP 6.0 and RCP 8.5 could be explained by R2 values of more than 0.5 (50%). These meant that projected temperature would most likely increase over the two sites. Notably, Food and Agriculture Organization (FAO, 2004) indicates that an increase in average global temperatures of just two to four degrees Celsius above pre-industrial levels could reduce crop yields by up to 15-35% in Africa.

Trend of fodder production and availability

Trend of fodder and pasture was determined based on the type and changes over the ten-year period and the results are presented in Table 1.

Table 1 shows that most respondents in Kosirai and Namayumaba currently depend on Natural pasture (82.8%) and Napier (68.9%) respectively. In Kosirai, farmers were noted to plant napier (53.3%) and rhodes (40.5%), while those in Namayumba were noted to plant napier (68.9%), natural pasture (52.1%) and fodder trees (41.0%). Compared to ten years ago, pastures grown had similar trends with slight variations and natural pasture was still noted to contribute greatly to the dairy cow.

Further, the study noted that most respondents had a total land holding of less than 3 acres and that most of the respondents in Kosirai land tenure system were either secured and had title deed (49.1%) or categorized as family land (48.4%). Conversely, the land tenure system for most respondents in Namayumba was categorized squatters with an increase of 36% and 30% in the number of farmers with less than 1 acre of land currently planting napier and natural pasture in the ten year period while natural pasture grown on more than 1 acre land was noted to decline over the same period. In Namayumba, an increase of 14% in the number of farmers growing fodder was noted with declining trend of natural pasture of the same period. In general, there was a decline in land under pasture fodder with acreage per type decreasing. A large proportion of farmers (35.2%) in Kosirai indicated that they bought fodder/pasture from neighbors, while 45.8% of farmers in Namayumba used preserved crop residue in case of a shortage. Notably, most farmers used manure with direct spreading of manure on the farm being preferred as opposed to compost making. Out of the total respondents, 33.8 and 48.5% in Kosirai and Namayumba had introduced intercropping while 24.7 and 20.6% in Kosirai and Namayumba practiced double digging for water retention and to improve soil fertility. Furthermore, 35.7 and 19.1% of farmers in Kosirai and Namayumba had stopped burning of crop residue.

Trend of dairy animals and diseases

The study established that most farmers presently owned

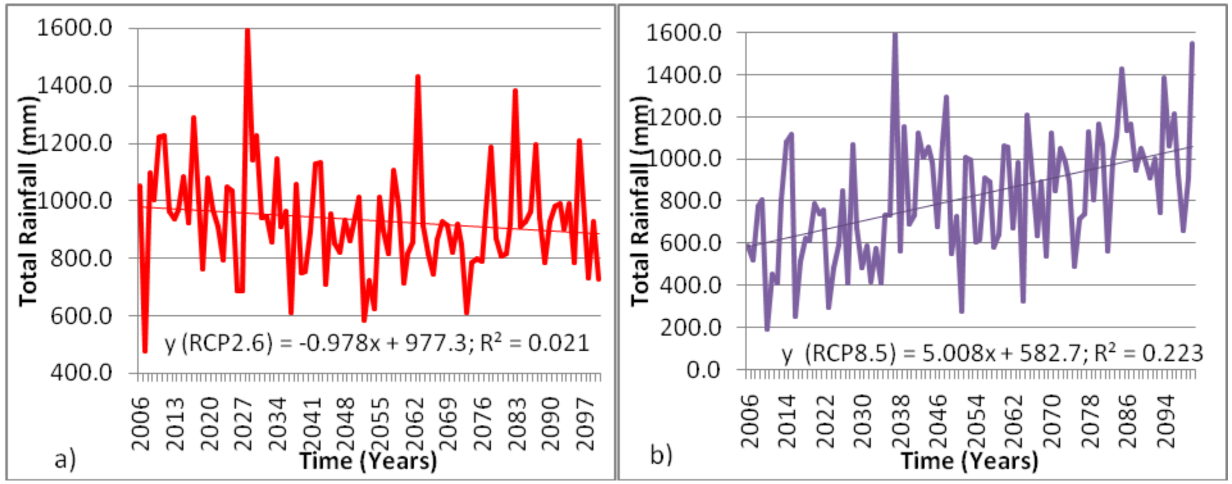

Figure 2. Trend of annual rainfall based on: (a) 2.6 Wm^2 scenarios in Namayumba, and (b) 8.5 Wm^2 scenarios in Kosirai.

Table 1. Types of fodders and pastures currently planted as compared to those planted ten years ago in Kosirai and Namayumba.

Station	View	Natural (%)		Improved pasture (%)		Napier (%)		Rhodes (%)		Fodder trees (%)		Mucuna/Lab (%)		Others (%)	
		Now	Ten years ago	Now	Ten years ago	Now	Ten years ago	Now	Ten years ago	Now	Ten years ago	Now	Ten years ago	Now	Ten years ago
Kosirai	Yes	82.8	73	3.3	3.3	53.3	35.2	40.5	20.7	2.5	1.7	0	0.8	4.9	0.8
	No	17.2	27	96.7	96.7	46.7	64.8	59.5	79.3	97.5	98.3	100	99.2	95.1	99.2
Namayumba	Yes	52.1	50	4.9	5.7	68.9	52.5	2.5	0.8	41	18	12.3	10.7	10.7	4.1
	No	47.9	50	95.1	94.3	31.1	47.5	97.5	99.2	59	82	87.7	89.3	89.3	95.9

less than five dairy animals and accounted for more than 79% of total dairy animals in both Kosirai and Namayumba areas. Compared to ten years ago where most of the dairy farmers (46.7%) owned less than two dairy animals in Namayumba and 30.7% owned two to five animals in Kosirai, it thus indicated an increase in the number of dairy animals owned by farmers in the ten year period as affirmed by a change of 52.8 and 32.3% of farmers in Kosirai and Namayumba areas. In terms of animal diseases, the tick born and pneumonia diseases had increased by 16.6%, while the foot and mouth disease had decreased by 30.9% in the last ten years in Kosirai area while slight changes were noted in Namyumba area with the tick born disease accounting for the most cases of animal disease affirmed by more than 67% of the farmers' responses. In general, the tick born disease was noted as the most dominant animal disease over the two sites.

Trend of water source and manure management

It was noted that most people (more than 60%) in both Kosirai and Namayumba areas used boreholes or shallow wells as their main source of water for their dairy animals. In Kosirai, 81.4 and 54.3% of farmers watered their animals 3 times a

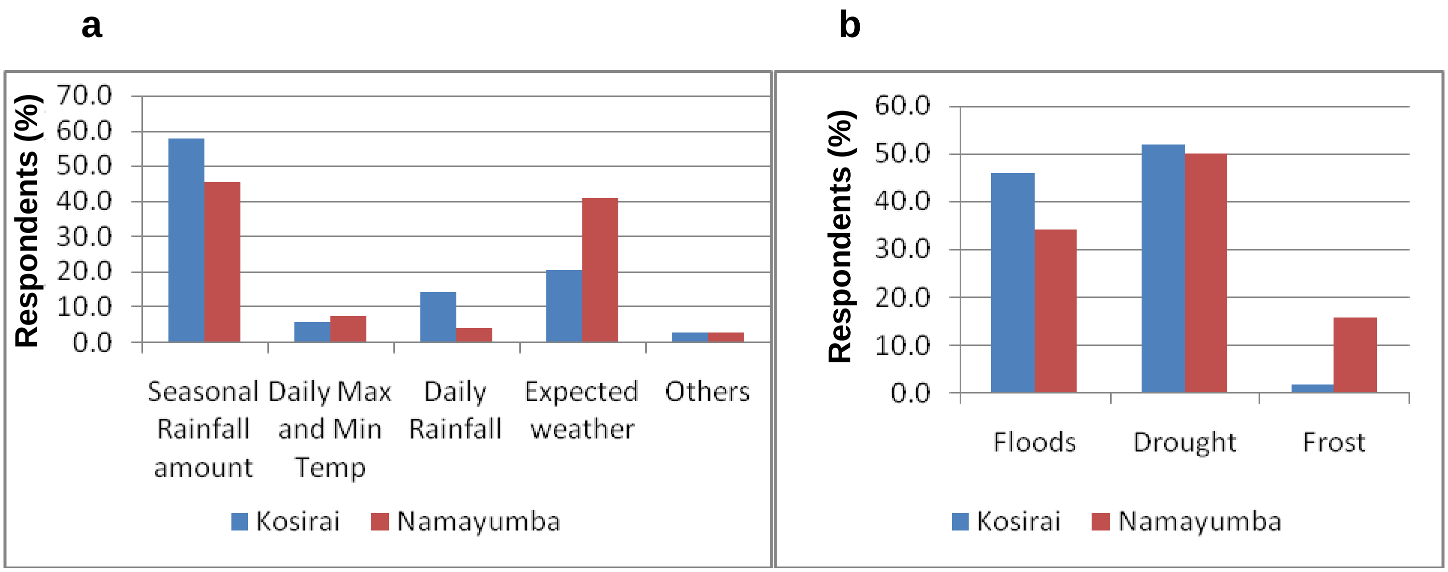

Figure 3. Farmers awareness on (a) type of weather information they want to receive, and (b) climate risk in Kosirai and Namayumba.

day during dry season and twice daily during wet season respectively, while 45.3 and 53.4% of farmers in Namayumba area watered their animals twice daily during dry season and once a day during wet season. During both wet and dry season, the main source of water was from a shallow well in Kosirai and Namayumba areas. However, in Kosirai, the dependence of these shallow wells decreased from 66.4% ten years ago to 58.5% now during the wet season while it increased from 50.9 to 55.9% during the dry season. In Namayumba, the dependence on shallow well increased from 38.5 to 42.2% during the wet season and decreased from 62.5 to 56.9% during the dry season. Most of these water sources were located less than 200 m from the farm in both sites and were noted to decrease over time.

Farmer's awareness to climate change

The study shows that radio is the main source of weather information for over 80% of the farmers in Kosirai and Namayumba. Further, 57.5 and 45.5% of farmers were noted to be interested in the information on the seasonal rainfall amount while 20.4% and 40.9% preferred to receive the expected weather conditions in Kosirai and Namayumba areas respectively (Figure 3a). Drought was observed as the main climatic risk condition by 51.9% and 50.0% of respondents in Kosirai and Namayumba in the last 10 years, while 46.2% of the respondents in Kosirai noted floods as the main climate risk compared to 34.1% in Namayumba (Figure 3b). The farmers acknowledged that there is occurrence of climatic risks with 51.9% and 50.0% reporting that climate risk in Kosirai and Namayumba had occurred two to three times in the last ten years.

Relationship between rainfall and milk/fodder production

This study showed that in both sites, dairy production was dependent on rain-fed forages. There was increasing fodder option like Napier grass, Rhodes grass, and fodder trees in the two study sites. Development of improved fodders especially Napier grass and fodder trees were, however, more significant in Namayumba than Kosirai. The size of land allocated to fodder development was however decreasing both in Kosirai and Namayumba. Respondents in both Kosirai and Namayumba estimated the decreased changes in production of fodders and improved pasture over the last ten years (Figure 4) to be 43.9% and 59.6% respectively. Moreover, the study noted that during the wet season, the average milk production per cow ranged from 5-8 L that were comparatively higher than the average production per cow of 2-5 L during the dry season. The changes in milk and fodder production positively correlated with changes in rainfall amounts in both sites; these changes could be attributed to the increasing trend of extreme periods between the year 2002 and 2010 (Figure 5).

CONCLUSIONS AND RECOMMENDATIONS

Historical data on observed rainfall and model output indicated a declining trend in the amount of rainfall experienced in both study sites. Similarly, there was a progressive increase in both the minimum and maximum temperature within the two sites. Changes in climatic patterns especially the increasing dry spell contributed to increased livestock diseases incidences, shortage of feed

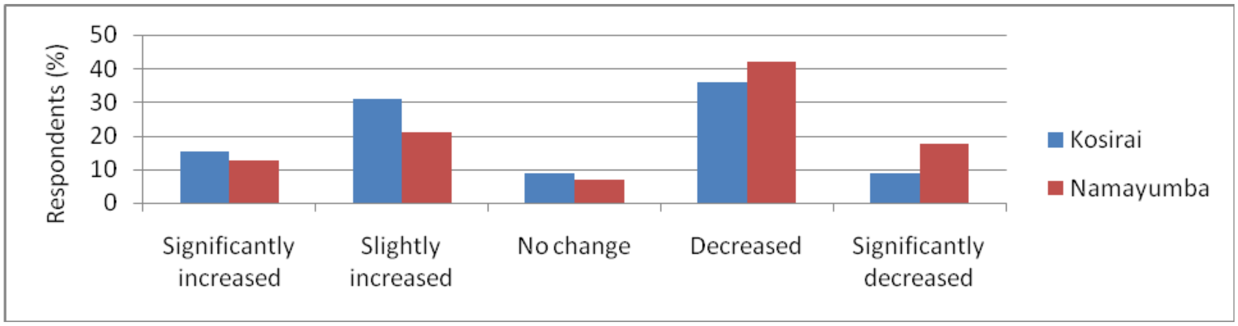

Figure 4. Changes in fodders and pastures production over the last ten years (2000 to 2010).

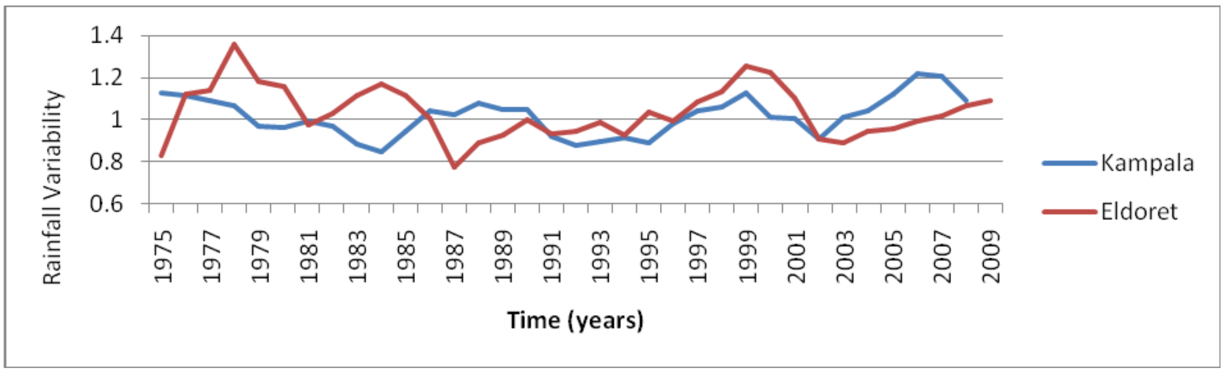

Figure 5. Variability of observed extreme values based on monthly rainfall in Eldoret (Kosirai) and Kampala (Namayumba).

resources and overall reduction of milk production in Kosirai and Namayumba. There existed a relationship between the changing climatic patterns and dairy herd productivity in the two study sites. Further, projected changes based on CSIRO Mk3.6 model output RCPs scenarios and observed variables indicated an increasing trend in both minimum and maximum temperature in Kosirai and Nyamayumba. These changes are expected to have adverse impacts on livestock productivity.

As a response to the effects of climate variability and change, dairy farmers should invest in fodder development and conservation in order to sustain their dairy herd productivity. Adequate mechanisms should be put to minimize losses and damages of the dairy herd and dairy herd productivity occasioned by increased frequency of extremely wet and dry spells over the two sites. Notably, dairy farmers should be empowered to adapt and mitigate against the effects of drought and emergence of new vectors and livestock diseases occasioned by extreme weather variability.

ACKNOWLEDGEMENTS

This paper is part of the M.Sc. Thesis presented to the University of Nairobi by Kirui JW. The authors would like to thank Kenya Meteorology Department for providing rainfall data and the team in Kosirai and Namayumba for their support in data collection.

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