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EFFECT OF CLIMATE CHANGE ON DAIRY PRODUCTION IN BOTSWANA AND ITS SUITABLE MITIGATION STRATEGIES

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ABSTRACT: *This paper explores the effects of climate change on dairy production in Botswana and mitigation strategies are suggested. Dairy farming has not experienced growth over time rendering the country heavily dependent on milk imports. National dairy herd is estimated to be approximately 5000 and per capita consumption of milk about 32.5 litres per person per year. Currently, Botswana is experiencing average high temperatures and low rainfall, frequent droughts and scarcity of both ground and surface water, which all contribute to low livestock and crop productivity. Changes in rainfall patterns, frequent droughts, high incidences of animal diseases (e.g., mastitis and FMD) and parasites, and high environmental temperatures cause significant decrease in livestock productivity. For dairy animals, there is a decline in milk yield and reduced animal weight gain due mainly to high temperatures and inadequate feeds. Mitigation strategies comprise using smaller dairy breeds such as Jersey and Brown Swiss and local Tswana breed, growing fodder crops and utilization of crop residues and constructing cow sheds. Thus, the effects of climate change on dairy cattle production are real and require immediate attention if they are to be minimized or managed properly to attain higher milk production.*

ORIGINAL ARTICLE

Key words: *Botswana, Climate Change, Dairy Production, Greenhouse Gases, Mitigation Strategies*

INTRODUCTION

Climate is an important factor of agricultural production. As a consequence, climate change is expected to affect agricultural and livestock production, hydrologic balances, input supplies and other components of agricultural systems (Aydinalp and Cresser, 2008). The damaging effects of global climate change are increasing and most damages are predicted to occur in developing countries because of their over-reliance on low-input rain-fed agricultural production and their low adaptive capacity (Musemwa et al., 2012). In the opinion of Aydinalp and Cresser (2008), changes in temperature, as well as, changes in rainfall patterns and increased carbon dioxide (CO_2) levels projected to accompany climate change will have important effects on global agriculture, especially in the tropics. Because of erratic rainfall and high incidence of droughts that detrimentally affect crop production, the majority of the rural populace in the developing countries depends on livestock production for their livelihoods (Musemwa et al., 2012). However, the livestock sector is highly vulnerable to climate change. Factors that cause significant losses in livestock are floods, droughts, diseases and poor grazing conditions. Calvosa et al. (2009) stated that many climate change predictions suggest that the African livestock sector will be damaged by 2020.

Botswana's climate is considered subtropical and dry. Rainfall is largely erratic and unreliable resulting in droughts being common. Average daily maximum temperature ranges from 22 ^oC in July to 33 ^oC in January and average daily minimum temperatures from 5 ^oC in July to 19 ^oC in January. Therefore, Botswana's harsh climate supports livestock rearing (including dairy) and wildlife at low densities and dry land cropping in some areas (National Development Plan (NDP) 7 1991). However, ambient temperatures above the thermal neutral zone (>20 ^oC) have detrimental effects on the dairy cows under intensive management (Adin, 2010).

Livestock are known to contribute to greenhouse gas (GHG) emissions. Dairy farming contributes to and is affected by climate change. Dairy production plays a role in GHGs emissions, particularly methane (CH4), which contributes to climate change (Kasulo et al., 2010). The study by Aydinalp and Cresser (2008) showed that most of CH_4 releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (25%). According to Andin (2010), carbon footprints of agriculture and forestry contribute 30% of emission to atmosphere; 5% by all ruminants and 2% by dairy farming. Furthermore, about 50 to 70% of the GHG emission from dairies are originated by CH4 from digestive processes of the cow and manure storage. This paper explores the effects of climate change on dairy production in Botswana. In addition, strategies to be employed to reduce the effect of climate change on dairy production are suggested.

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Effect of climate change on livestock production

The effects of climate change can be direct or indirect. According to Calvosa et al. (2009), the direct effects of climate change include higher temperatures and changing rainfall patterns, which could translate into the increased spread of existing vector-borne diseases and macroparasites, accompanied by the emergence and circulation of new diseases. Climate change could also generate new transmission models in some areas. The indirect effects are attributable to changes in feed resources associated with the carrying capacity of rangelands, the buffering abilities of ecosystems, intensified desertification processes, increased scarcity of water resources and decreased grain production. Other indirect effects are linked to the expected shortage of feed arising from the increasingly competitive demands of food, feed and fuel production, and land use systems (Calvosa et al., 2009). Smit et al. (1996) attributed the indirect effects of climate driven changes in animal performance to mainly alterations in the nutritional environment.

As in other parts of the world livestock farming in Botswana is an important source of income at individual, household and national levels (Nsoso et al., 2009). In addition, livestock are a source of liquid asset, inputs to crop production (draught power and manure), diversification of risk/ buffer to crop production, cultural value (livestock may be sacrificed at the time of a certain festival) and source of food (Conroy, 2005). Dairy farming is an important activity in the lives of Batswana (nationals). Climate change is expected to greatly impact dairy farmers. For instance, crop yields will change due to variations in climate, thus affecting feed costs to farmers. Climatic events such as rising temperatures and atmospheric CO_2 concentrations will change the prices of dairy farms' inputs, including feed, fuel, and electricity. In addition, higher temperatures expose dairy cows to heat stress resulting in a decline in milk yield (Calil et al., 2012). Climate change could affect the costs and returns of livestock production by altering the thermal environment of animals thereby affecting animal health, reproduction, and the efficiency by which livestock convert feed into retained products, especially meat and milk (Key and Sneeringer, 2011). In addition, exposure of livestock to elevated ambient temperature decreases fertility in cattle and pigs especially but also in poultry, rabbits and horses (Nardone et al., (2010). According to Smit et al. (1996), climate change affects animal production in four ways: (a) the impact of changes in livestock feed-grain availability and price; (b) impacts on livestock pastures and forage crop production and quality; (c) changes in the distribution of livestock diseases and pests; and (d) the direct effects of weather and extreme events on animal health, growth and reproduction.

Table 1 - Predicted climate changes in Botswana for period 2008-2037 based on SCENGEN Programme

Variable	Location		Season of the year *				Annual
			Summer	Autumn	Winter	Spring	
Mean Temperature (ºC)	Entire country	Value	1.2	1.4	1.3	1.3	1.3
		Range	0.1 to 1.2	0.2 to 1.5	0.3 to 1.4	0.3 to 1.4	0.3 to 1.3
Rainfall (%)	South Western	Value	-0.9	-4.2	-27.5	3.4	10.5
	Eastern	Value	-0.9	-7.3	32.5	-1.1	6.3
	Western	Value	-0.9	-7.3	51.5	-1.1	10.5
		Range	-11.4 to 32.5	-14.2 to 15.7	-11.1 to 54.4	-14.5 to 18.9	-7.7 to 14.2
Cloud cover (%)	Western	Value	0.6	-1.4	2.1	0.2	0.4
		Range	-2.8 to 4.6	-1.8 to 1.2	-3.6 to 3.0	-3.9 to 3.3	-2.5 to 2.4
	Northern and Eastern	Value	-0.1	-1.4	2.1	-0.5	-0.2
		Range	-2.8 to 4.6	-1.8 to 1.2	-3.6 to 3.0	-3.9 to 3.3	-2.5 to 2.4
Wind speed (%)	South Western	Value	1.7	-1.3	1.1	1.3	1.5
		Range	-4.1 to 3.5	-1.4 to 3.2	-1.2 to 2.2	-1.0 to 3.4	-0.9 to 2.7
	Eastern	Value	1.7	2.1	1.1	1.3	1.5
		Range	-4.1 to 3.5	-1.4 to 3.2	-1.2 to 2.2	-1.0 to 3.4	-0.9 to 2.7
Minimum Temperature (ºC)	Rest of the country	Value	1.2	1.4	1.5	1.3	1.3
		Range	0.1 to 1.2	0.2 to 1.4	0.3 to 1.5	0.3 to 1.3	0.3 to 1.3
	Northern Botswana	Value	1.2	1.4	1.5	1.3	–
		Range	0.1 to 1.2	0.2 to 1.4	0.3 to 1.5	0.3 to 1.3	
Maximum Temperature (ºC)	Western	Value	1.2	1.6	1.1	1.4	1.3
	Eastern and South Western	Value	1.2	1.4	1.1	1.4	–
	Northern	Value	1.2	1.4	1.1	1.5	
		Range	0.2 to 1.2	0.2 to 1.6	0.3 to 1.2	0.3 to 1.5	0.3 to 1.3
Vapour Pressure (hPa)	South Western	Value	0.7	0.5	0.7	0.7	0.7
		Range	0.3-1.7	0.4 to 1.8	0.4 to 1.6	0.3 to 1.6	0.4 to 1.6
	Rest of the country	Value	0.9	0.5	0.7	0.7	0.7
		Range	0.3-1.7	0.4 to 1.8	0.4 to 1.6	0.3 to 1.6	0.4 to 1.6
Diurnal Temperature (ºC)	Rest of the country	Value	0.1	0.2	-0.3	0.1	0.0
		Range	-0.6 to 0.1	-0.4 to 0.2	-0.4 to 0.0	-0.1 to 0.2	-0.3 to 0.0
	South western	Value	0.1	0.2	-0.3	0.0	0.0
		Range	-0.6 to 0.1	-0.4 to 0.2	-0.4 to 0.0	-0.1 to 0.2	-0.3 to 0.0

*Summer (December, January, February), autumn (March, April, May), winter (June, July, August) and spring (September, October and November); Source: Nsoso et al. (2009).

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In Botswana, Aganga et al. (2010a) investigated the impact of climate change on water availability and rangeland conditions on animal production and reported that global warming will result in a drier environment that will accelerate the rate of retrogression on rangelands and shift composition to less desirable plants with low nutritional values. Together with lack of grazing management control and overstocking, global warming will also discourage prolificacy and sustenance of the desirable plant species. The dominance of undesirable plant species which are not preferred by livestock will contribute to a decline in livestock productivity.

The SCENGEN Programme was used by Nsoso et al. (2009) to predict climate changes in Botswana for 2008-2037 period. Tables 1 shows that minimum and maximum temperatures will rise over time and across the seasons. Aydinalp and Cresser (2008) reported that higher temperatures in warm regions would likely result in a decline in dairy production, reduced animal weight gain and reproduction and lower feed conversion efficiency. Climate change is also likely to affect the incidence of diseases of livestock and other animals since most diseases are transmitted by vectors such as ticks and flies, the development stages of which are often heavily dependent on temperature. Frequent outbreaks of foot and mouth (FMD) disease in Botswana in recent years could be attributable to climate change. It is argued (Aydinalp and Cresser, 2008) that increasing temperature may also bring beneficial effects in some areas of the world where agricultural production is limited due to low average temperatures by extending the growing season available for plants and by reducing the growing period required by these crops to reach maturity.

Table 1 shows that rainfall in Botswana will decrease from 2008 to 2037, indicating scarcity of grazing resources and stover that is usually used as a feed resource during the dry season. Low rainfall affects crop production and leads to prices of livestock feeds becoming prohibitively expensive. In a study conducted in Botswana, Ethiopia, Ghana and Malawi, Simelton et al. (2011) observed that rainfall was erratic, rains came late or not at all, rainy season was short and ended earlier. The authors ascribed the erratic pattern of rainfall to changes in temperature, wind and wind speed. It is predicted in Table 1 that cloud cover and wind speed will decrease over time.

Dairy production in Botswana

The economy of Botswana is mineral-based with agriculture contributing 1.7% to the gross domestic product (GDP) (NDP 10, 2009). At independence in 1966, the contribution of agriculture to GDP was 40%. Despite its current low contribution to GDP agriculture still plays an important role in the rural economy as a source of employment, food, draught power, animal products and income. About 70% of the rural households derive part of their livelihoods from agriculture. Currently, Botswana is a large importer of agricultural products in the form of fruits, grain, vegetables and products of animal origin such as pork and dairy products.

The dairy industry in Botswana can be categorized into commercial and subsistence sectors. The commercial sector is further sub-divided into small-scale dairy farms that keep 1 to 50 milking dairy cows; medium-scale (51 to 100 milking dairy cows) and large-scale (>100 milking dairy cows). Dairy animals are either kept under intensive, semi-intensive or extensive systems (Ministry of Agriculture, 2013). Mahabile (1997) reported that semi-intensive system predominated with the Friesian being the most popular breed. A recent study by Mahabile and de Waal (2010) in Gaborone Agricultural Region (Botswana) also reported that semi-intensive system is practised by both small-scale and large-scale dairy farmers.

Cattle population in Botswana is estimated to be 2.5 million and dairy cattle account for less than one percent. Department of Animal Production Annual Report (2011/12) estimated the population of dairy cattle to be 4600. Dairy breeds in Botswana include Friesian, Ayrshire, Guernsey, jersey, dairy shorthorn and the dairy Swiss (commonly referred to as Brown Swiss) (Moreki et al., 2011). According to TAHAL Consulting Engineers LTD. (2000), Friesians constitute 47.8% of dairy cattle kept in Botswana followed by Brown Swiss (37%) and others (*e.g.*, Ayrshire, dairy shorthorn, Guernsey and jersey) 5%. Furthermore, Mahabile and de Waal (2010) found the main dairy breeds to be Friesian-Holstein, Jersey, Brown Swiss and crosses. Due to its large size, Friesian requires large amounts of feed in comparison to smaller breeds such as Jersey and Brown Swiss. In addition, Friesian is vulnerable to heat stress which will contribute to reduced feed intake resulting in a decline in milk production. These attributes render Friesian unsuitable for the harsh climatic conditions of Botswana.

National milk production remains very low indicating that the dairy industry is one of the under-performing sectors in Botswana's agriculture. Generally, milk production has not increased over time due to *inter alia* feed shortages (Boitumelo and Mahabile, 1991; Pelaelo-Grand et al., 2010) and use of inappropriate dairy breeds such as Friesian (Ministry of Agriculture, 2013) resulting in a linear increase in imports of fresh raw milk (Table 2). Milk and other milk products are imported from the Republic of South Africa (RSA). On average milk production declined by 110 000 litres per year from 2001 to 2011 while dairy herd increased by 65.5 cows per year. Mahabile (1997) also observed a downward trend in milk production. In 2011, the national dairy herd was estimated to be approximately 4600 while milking cows were slightly over 1000. The decline in the national dairy herd and milking cows over time has resulted in a concomitant decline in milk production, thus rendering the country heavily dependent on imports.

Table 2 shows that milk imports are greater than local milk production, thus providing an opportunity for the dairy sector to either expand or for new projects to be established in order to increase milk yield. The similar sharp increases in milk imports (Table 2) and consumption (Figure 1) in 2006 could possibly be attributed to surplus milk production in RSA that was imported at a lower price. Based on the human population of 2 million (The United Nations Children's Fund, 2012) and milk consumption of 65 008 000 million litres in 2011 (Department of Animal

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Production Annual Report, 2011/12), the *per capita* consumption of milk in Botswana is estimated to be 32.5 litres per person per year.

According to Figure 1, milk consumption increased over time with the highest increase observed in 2006. From 2001 to 2011 milk consumption increased by an average of 1.1 million litres per year, whereas milk production declined by about 110 000 litres per year during the same period. A sharp decline in milk production of 4 800 000 litres (representing 61%) occurred from 2010 to 2011 milk rendering the country heavily reliant on imports.

Table 2 - Dairy cow population, milking cows and milk production and imports from 2001 to 2011

Year	National Dairy Herd	Milking cow	Local milk production (litres)	% Change	Fresh raw milk imports (litres)	% Change
2001	3 936	2 552	4 200 000	36.7	49 518 485	12.3
2002	4 478	1 838	4 700 000	11.9	38 942 493	21.4
2003	5 304	1 763	5700 000	21.3	72 000 000	84.9
2004	5 694	1 779	5 900 000	3.5	35 620 003	-50.53
2005	4 953	1 641	6 300 000	6.8	71 347 909	100.3
2006	5 138	1 707	5 400 000	-14.3	124 047 500	73.86
2007	6 475	1 989	7 700 000	42.6	40 016 570	-67.74
2008	5 348	1 810	7 700 000	0	48 513 732	21.23
2009	6 000	2 000	8 300 000	7.8	40 000 000	-17.55
2010	6 204	1 670	7 900 000	-4.8	38 600 000	-3.5
2011	4 591	1 241	3 100 000	-60.8	61 908 000 est.	60.38

Department of Animal Production Annual Report (2011/12)

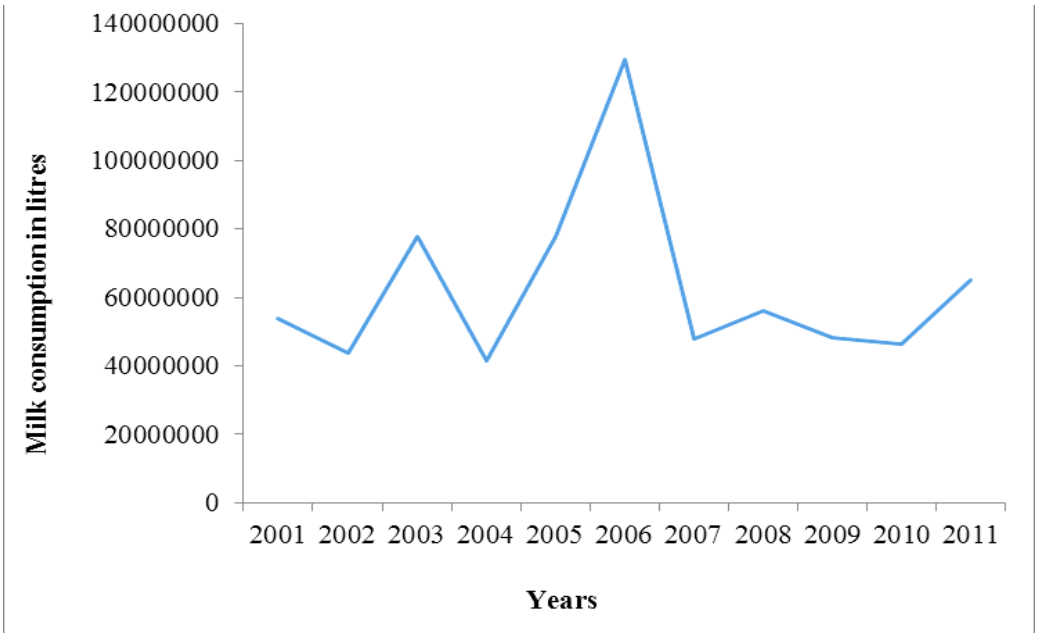

Figure 1 - Milk consumption in Botswana from 2001 to 2011;
Source: Department of Animal Production Annual Report (2011/12)

Mitigation strategies

Climate change necessitates employing strategies that will alleviate the impacts of heat stress on animal performance. Beede and Collier (1986) suggested three basic management options for reducing the effect of heat stress and these are (a) physical modification of the environment; (b) genetic development of less sensitive breeds and (c) improved nutritional management schemes.

Physical modification of the environment

- Prevention or reduction of solar radiation by providing shade and painting the roof white (Adin, 2010; Frank et al., 2005).
- Showering / wetting, ventilation, combination of showering and ventilation will help to cool dairy cows during heat stress.
- Fogging or misting, using fans or air conditioners will help cool cows during high temperatures. Sprinklers may also be used (Frank et al., 2005).
- Provision of cold water to cattle during hot days (Singh et al., 2012). Similarly, cows should be provided bedding and warmth to protect them from extreme cold. Other mitigation strategies include diversifying farming

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practices and changing planting dates (Singh et al., 2012). The use of heat tolerant crop varieties such as sorghum and millet is another mitigation strategy. As the rainy season is short and ends earlier (Simelton et al., 2011) early maturing plant/crop varieties could also be used as a mitigation strategy.

Improved nutritional management schemes

- Dairy feeding regime in Botswana should emphasize producing more fodder and less concentrates. Producing own feeds will be cost effective since 60-80% of production costs come from feeding (Madibela, 2013). Kalaugher et al. (2012) suggested that pasture production is the driving force in the New Zealand dairy system, resulting in small differences in pasture productivity reflecting proportionally larger differences in profit.
- Creating dairy belts in Botswana's traditionally arable producing areas such as Borolong in the south, the eastern side of the country and Pandamatenga farms in the north, which have relatively higher rainfall for fodder production (Madibela, 2013) appears to be appropriate. Crop residues produced from arable fields in these areas will provide a valuable feed resource for dairy animals.
- Conservation and storage of feed from the time of its availability to the time of its use could be a useful strategy of making feeds available to dairy animals during the dry season (Aganga et al., 2010b).

Genetic development of less sensitive breeds

Utilizing small frame dairy cattle such as Jersey and Brown Swiss which have higher volume/ weight index, making them easier to get rid of heat of metabolism (Madibela, 2013) appears to be a better option for Botswana. Smaller dairy breeds require less feed and do not suffer from heat stress as much as Friesian making them ideal for the local climate.

Lack of herd health programme and nutritional management skills are the major challenges in dairy production in Botswana. In order to raise the knowledge levels of farmers, Kumar (2012) suggested that there is a need for farmers to be equipped with management practices that are suitable to the conditions resulting from climate change.

CONCLUSION

Climate change affects livestock productivity in Botswana, especially the dairy sector which is currently performing poorly. There have been changes in rainfall patterns with rains coming late and inadequate amounts resulting in low crop yields and inadequate forages available for grazing. Unusually, high ambient temperatures occur requiring dairy cows to be provided with cow sheds in order to protect them from heat stress. Frequent droughts also call for farmers to grow fodder crops under irrigation, as well as, for harvesting and conservation of crop residues for later use. Furthermore, there is a need to consider using local *Tswana* cattle breed and smaller dairy breeds such as Jersey and Brown Swiss *in lieau* of Frisians which require large quantities of feeds and do not tolerate hot climatic conditions.

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