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Full Length Research Paper

Susceptibility of conventional beef sector to drought and the problems of climate change: The case of Kgatleng District, Botswana

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Cattle's rearing in Botswana is undertaken in two sectors: the communal and commercial. The communal sector is exclusively free range and therefore depends on biomass production. This makes the systems highly susceptible to drought. One strategy that has been devised by farmers to adapt to drought has been to overstock. However, this strategy may not be the best adaptation strategy as it leads to overgrazing and quick depletion of scarce biomass during the drought years. Climate change may increase the vulnerability of the communal cattle sector in the country mostly through changes and variability of rainfall. In the article, we determine the reliability of the rainfall in the Khurutshe area, Botswana. Vulnerability of the cattle sector to system severe failure is also determined. Lastly, the effects of climate change on return period of drought are investigated. Results indicate that the reliability index of rainfall in the Kgatleng District is 0.5. The vulnerability index of the cattle is estimated at 8000 per year. Lastly, using SimCLIM computer model climate change will shorten the return period of mild drought from 2 years to 1.6 years by 2050. These findings have serious implications on the recovery period of the cattle to withstand the next drought period.

Key words: Cattle sector, climate change, climate scenarios, drought, reliability, return period, vulnerability index, adaptation measures.

INTRODUCTION

Botswana has a long history of cattle rearing with the livestock sector acting as the backbone of the economy prior to the discovery of diamonds at Jwaneng and Orapa (BIDPA, 2005; Harvey and Lewis, 1995). Although cattle rearing's contribution to GNP has slipped below 5%, it is still important at a microeconomic (BIDPA, 2005). Many rural households dependent upon it as a source of income and employment. Over time, those rearing cattle have adapted to recurrent and sometimes severe drought. Drought is further influenced by phenomenon such as the *El Nino* southern oscillations. Drought can fluctuate in intensity from mild to harsh droughts. Yet regardless of the intensity drought can have a significant effect on cattle production and hence rural welfare and food security. To enhance resilience cattle rearers often have as many cattle as possible so that with drought a percentage can survive. However, this has failed as the high stocking rates exacerbate the impact of drought and leads to heavy losses (CSO, 2000).

Greenhouse gas -induce climate change may alter two important features of drought in Botswana. Firstly, the return period of drought may be shortened. Secondly, the magnitude and intensity of drought may increase (IPCC, 2001b; Meadows, 2006). It is already evident that climate change will lead to a decline in precipitation in southern Africa thereby affecting drought (Hulme, 1996; IPCC, 2001, 2007; Mukheibir and Sparks, 2003; UNPE, 2005). Thus, climate change poises a serious threat to food security especially for small-scale agriculturalists that lack economic resilience owing to a lack of alternative sources of income and a dependence on cattle.

In this article we attempt to determine a vulnerability index to drought for Botswana's traditional cattle; an estimate of the cattle sector's exposure to drought tempo

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Table1. Comparative performance of the commercial and traditional cattle sectors

	Commercial	Traditional
Annual calving rates	70%	50%
Annual off take rate	17%	8%
Annual mortality	5%	11%

Source: CSO (2000)

rally; and, to determine the potential impact of climate change on the return period and magnitude of drought by 2050 for the Kgatleng District of Botswana.

METHODOLOGY AND DATA COLLECTION

In order to achieve the objectives of this paper, interviews were conducted on farmers focusing on farmers' sources of income, off-takes rates, purchases of supplementary feeds, and daily cattle intake rates in the communal sector. Data was collected on a total of 34 farmers which were randomly selected. Data was also collected on cattle numbers from 1980 - 2005 from secondary sources. Baseline climate data (1960 - 1990) was obtained from Department of Meteorology and this was used to construct climate scenarios for year 2050. A SimCLIM software programme is used to generate climate scenarios with inputs from HadCM3 and CSIRO mk2 and the SRES emission scenarios. Vulnerability index, return periods of drought and exposure of cattle to drought are estimated based on these data.

The rural population and cattle management

Cattle's grazing is the dominant land use in Botswana as oppose to other land uses such as crop production, contributing about 80% in agricultural GDP (BIDPA, 2005). 52.7% of the land in Botswana is used for grazing (Centre for Applied Research, 2005). According to McDonald (2000) this situation owes itself to periodic and severe droughts that privileges livestock over arable farming as crops are highly vulnerable to droughts. There are two systems for raising cattle in Botswana: commercial and communal/traditional. The traditional sector is practised on the tribal land whereas the commercial enterprises are situated on freehold land. As the name implies, the commercial sector is a production system designed to maximise profits. However, ninety-seven percent of the nation's cattle population is raised on communal land and therefore is reared under the traditional system (CSO, 2000). In the traditional sector households are not concerned with profits. Rather livestock are reared:

- As a 'bank' and for payment of school fees. Given as dowry (token of appreciation to the bridegroom at weddings).As a form of draught power, however, this is declining as a majority of farmers are now using tractors and on rare occasions donkeys. In addition, the number of households that plough has declined with changes in rainfall amount and patterns. As a sign of prestige. For slaughter at weddings and other ceremonial activities.
- Occasionally for cash sale to buy food and essentials. Compared to the commercial sector, the traditional sector is inefficient with low offtake rates, high mortality and low calving rates. Table 1 compares the performance of the two sectors. A majority of rural dwellers are dependent on the livestock sector for their household income where alternative and formal economic activities are scant. However, the cattle economy generates considerable informal eco-economic activity and is thought to employ directly and indirectly up to 50% of the rural population (BIDPA, 2005).

The number of cattle in Botswana has risen from 1 million in 1920 reaching a peak of 3 million in 1975 and then stabilises and fluctuates around 2.2 million by the 2000. The factors responsible for this increase include adequate rain, new borehole drilling technology and government incentives that encouraged investment in the cattle industry (Durraippah and Perkins, 1999; Fidzane, 1996; Harvey and Lewis, 1996). In addition, the eradication of the tsetse fly in the country's northwest and increased government expenditure on veterinary services reduced death rates and fostered growth in cattle numbers. However, the most important factor was borehole development which greatly expanded access to groundwater. Boreholes enabled farmers to keep larger herds of cattle and for ranching to expand into the hitherto inhospitable Kgalagadi District.

Traditional cattle's rearing is based around free-ranging and therefore depends on aboveground net primary production (ANPP). There is very low supplementary feeding (BIDPA, 2005; Centre for Applied Research, 2005). Generally the only cost incurred is for extraction of water (diesel for the pump and maintenance of the borehole) and labour (herders) associated with looking after the cattle. Traditional cattle management is characterised by high stocking rates which commonly exceed recommended carrying capacity (CSO, 2000). Thus, in the traditional sector management is lacking in terms of controlling stocking rates. In the traditional sector cattle frequently roam free (not fenced) and are typically only kraaled during the government imposed vaccination period. It is recognised that the high stocking rates adopted by the traditional cattle sector are considered by them to be an adaptation strategy against drought. Many cattle are considered insurance against drought such that when drought occurs the probability of all cattle being lost is remote.

Impacts of drought to cattle sector

Drought in Botswana is recurrent yet highly variable in intensity (CSO, 2000; Bhalotra, 1985; 1987). In Botswana drought is defined as annual precipitation falling below long-term mean rainfall (Tsheko, 2003). However, Burgess (2005) defines drought and its impacts on the livestock sector as annual rainfall is 40 less than the long term mean. When the Burgess definition is applied it does not categorise the 1983 drought as a livestock drought yet the impacts of the Tsheko-defined drought of 1983 on livestock sector were significant (CSO, 2000; Centre for Applied Research, 2005). We consider drought to basically mean that a deficiency in rainfall, at any particular point in time, results in failure of biomass for cattle. Bhalotra (1985) on the other hand defines drought as a meagre and highly variable rainfall, both in time and space, combined with high evapotranspiration rates. On the other hand IPCC (2001) defines drought as persistent below-average rainfall.

There can be two distinct impacts of drought on the cattle sector that are dependent on the magnitude of the drought. Firstly, mild drought results in cattle losing weight and this affects revenue and household income. Secondly, harsh droughts results in cattle perishing from a lack of feed. Regardless of a drought's severity subsistence farmers who derive other flow benefits from cattle such as milking and draught power suffer important losses. More recently the droughts of 1983 extending to 1987, 1992 and 2003 droughts had devastating impacts on cattle (CSO, 2000; BIDPA, 2005; Masike, 2008). Figure 1 depicts the influence of drought on cattle numbers in Kgatleng district.

The traditional sector is more exposed to the impacts of drought for the following reasons: Firstly, there are high stocking rates in the communal area as offtake rates are low. Thus, during a drought year an already over-grazed forage/biomass is quickly depleted through trampling and further consumption. This increases the severity and prolongs the drought period. Secondly, there is limited capacity for supplementary feeding in the traditional sector in com-

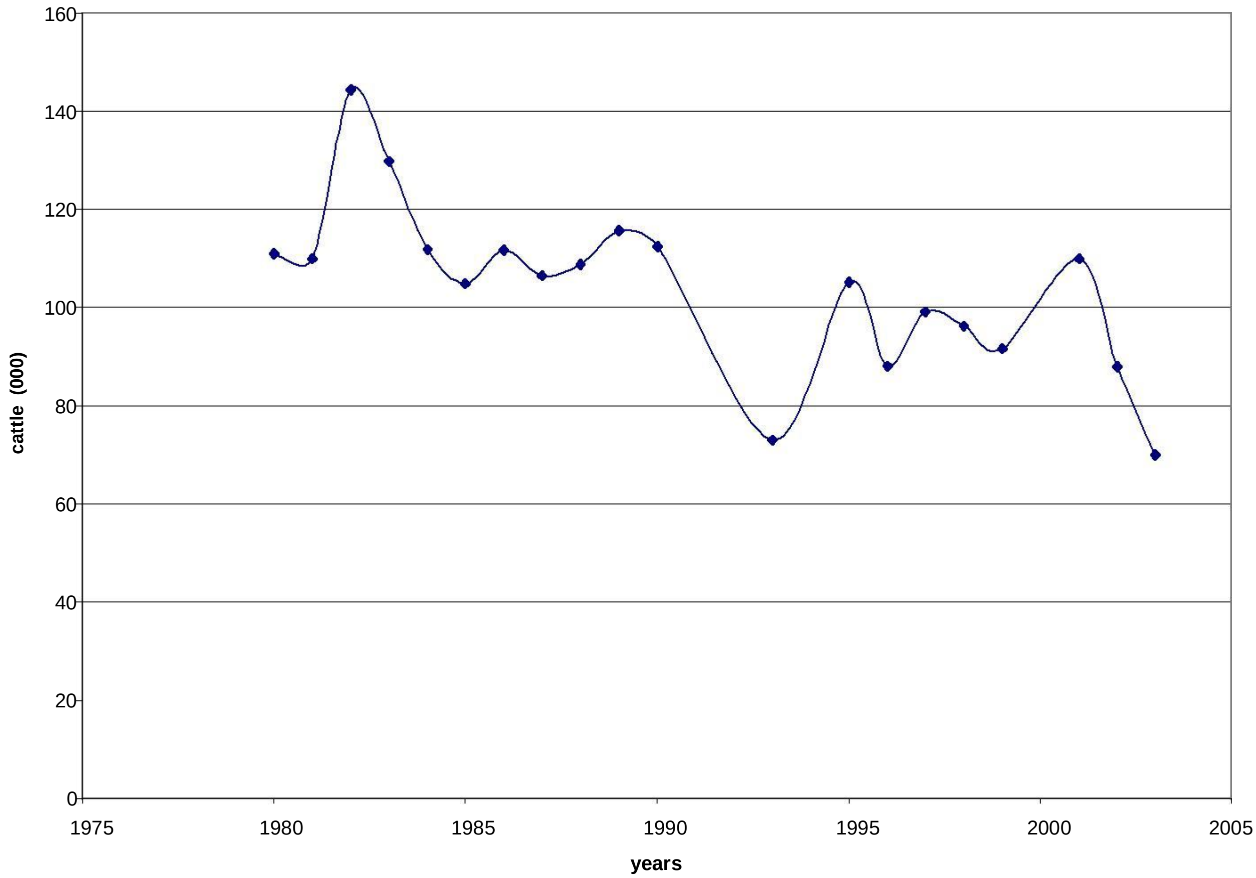

Figure 1. Cattle numbers in the Kgatleng District (1979 - 2004).

comparison with the commercial sector. This discrepancy in capacity is owing to annual sales in the traditional sector that are extremely low thus effectively eliminating their capacity to purchase supplementary feeding.

Vulnerability of the traditional cattle system to drought

Vulnerability is the significance of failure (Hashimoto et al., 1982). IPCC (2007) defines vulnerability to climate change as "the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects". That is, it deals with the extent or, the magnitude of the likely impacts to the system if failure does occur. In order to measure a system's vulnerability to drought, it is imperative that the system's reliability be assessed. Reliability of the (cattle grazing) system is defined by Hashimoto et al. (1982) as being a function of how often the system fails. As the traditional sector is dependent on annual rainfall, it makes sense to determine the reliability of rainfall. We assume that rainfall is random and denoted by X_t and t is time and is discrete. According to Hashimoto et al (1982) rainfall events can be divided into two sets: success (S) and failure (F) . Therefore, the reliability of a system is measured by the probability of the

$$\alpha = \Pr ob[X_t \in S]$$

Using the climatic baseline period (1960 - 1990), for the Khurutshe area in Kgatleng District the probability of the rainfall being a success is 0.5 based on the mean rainfall of 377 mm per year. The estimated reliability for the study area is in agreement with other's findings (Tsheko, 2003). This probability measures the chance when rainfall in any year is above a long- term mean. Vulnerability is estimated based on the reliability of the system. To assess this, a set of failure events is further divided into two sets, failure and severe failure, s. Vulnerability is commonly affiliated with severe failure (Hashimoto et al., 1982). System vulnerability is thus estimated from severe failure as follows (Hashimoto et al., 1982)

$$v = \sum_{j \in F} s_j e_j$$

Where,

v is the vulnerability index
s_j is the indicator of severity in the set of failure variables
e_j is the probability of severe outcome from a set of failure

The probability of a severe outcome from the failure subset the during baseline period is 0.2 This is based on the number of failures only. On average, a severe failure of the system resulted in a loss of close to 30% of the total cattle population, that is approximately 40 000 cattle lost when severe failure occurs. Thus, in any year a vulnerability index is estimated at 8000 cattle.

Adaptation strategy as a measure of vulnerability

Vulnerability of the cattle grazing system to drought is a combination of various socioeconomic and physical attributes such as the

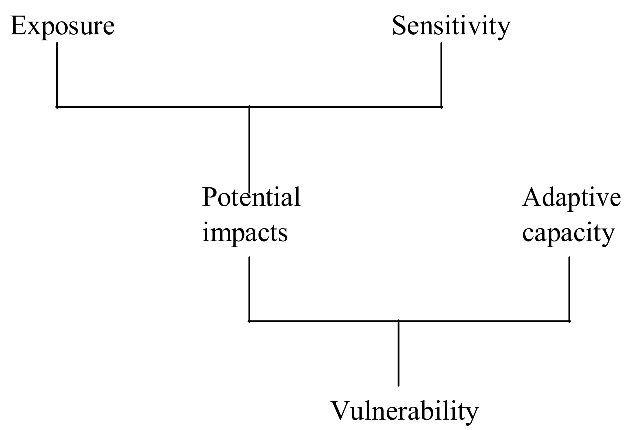

Figure 2. Vulnerability of the sector to impacts.

drought monitoring systems. The monitoring system determines the preparedness of a household to drought. The socioeconomic variables determine the extent of adaptation to drought. Schroter and ATEAM Consortium (2004) depict vulnerability of sectors or systems to failure as in Figure 2.

Exposure and sensitivity of the system to a failure is a function of management while adaptive capacity is a determinant of income. Cattle management deals with the stocking rates and the dependency on rangeland biomass for feed. Thus, these two factors define the exposure of the traditional sector to severe failure. As noted, the traditional sector is characterised by high stocking rates. This exposes the cattle to failure. Responses to drought warnings are also slow and this exposes the cattle system. Some of the factors that influence slow responses to drought are the following: due to the public nature of the communal grazing lands, farmers fear that as soon as they sell their stock, someone will increase their stocking rates and therefore take up their grazing space. This argument is linked to the free-riding and tragedy of the commons theory (Vink and Kaisser, 1987; Boonzaier et al., 1990). Secondly, most of the farmers in the Kgatleng District especially in the east and southeast part of the district are small farmers and therefore they cannot further reduce their cattle numbers due to existing low numbers. Other factors include lost weight during the pre-drought period and the low prices cattle will attain on the market. Lastly, many rush to sell and therefore the supply exceeds demand leading to further reductions in prices. Moreover, the market cannot absorb the number of cattle that farmers are wishing to sell. It has been argued that low prices for cattle are one of the disincentives for farmers to sell (CSO, 2000). Thus, high stocking rates persists through droughts.

These factors increase exposure of the cattle sector to drought in Kgatleng District. The problem is exacerbated by the cattle sector's dependence on rainfall biomass production. All of the 34 farmers interviewed in the Kgatleng District indicate that they do not buy supplementary feed for their cattle, even during drought years. 10 farmers indicate that they occasional buy salt licks for the cattle as it is affordable. Obviously, as farmers' income dependent on sales of cattle, it means that farmers' livelihood are dependent on rangeland productivity. Household income determines the ability of the farmers to purchase supplementary feed especially hay and bone meal to compensate for the decline in grass productivity.

Approximately 7.5 kg of forage would be required each day given that a cow's average consumption is approximately 2.5% of its average body weight (300 kg). During severe droughts this is the amount that a farmer would need to supply each stock unit per day to maintain production. Based on the cost of hay and household income which is assumed to be a function of offtake rates, Figure 3 depicts the cost of supplementary feed and the farmers' ability to pay on a monthly basis. The difference between the cost of feed and the household income is the measures of the exposure of the cattle sector to drought.

High supplementary feed costs combined with the low income (from low offtake rates) leads to adaptive management that is totally dependent on rangeland biomass. At present it is economical for subsistence farmers to practise low-cost farming even though it is highly vulnerable to drought. The management system of not undertaking any adaptation measure may not be unusual. Hashimoto et al., (1982) argue that it is important to realise that efforts to maximise system efficiency and reliability can actually increase a system's vulnerability to costly failure, should failure occur. That is, if much resources are allocated in reducing the system's vulnerability to a failure, the costs (total cost incurred in reducing vulnerability and costs incurred during and after) can be too high compared to if the system fails with fewer resources employed (Figure 3).

Climate scenarios and drought for the study area

Climate scenarios for the study area were generated using the SimCLIM software (Warrick et al., 2005). SimCLIM software uses the global circulation models as inputs and SRES emission scenarios to generate local climate scenarios. In this study, HadCM3 and CSIRO Mk2 GCMs were used to develop climate scenarios for the study area. In addition, the A1B, A1FT and A1T SRES emission scenarios were selected. Table 2 depicts the percentage change between the baseline data (1960 - 1990) and 2050 for temperature based on GCM results with different emission scenarios.

Table 3 shows the percentage change for rainfall between baseline and 2050. 0verall the annual average change in precipitation is a decline of between 3 to 9%. Under the CSIRO Mk2 GCM and A1FT emission scenario by 2050 average annual precipitation could be reduced from the current (1960 - 1990) average of 377 mm year^{-1} to 337 mm year^{-1}, an decline of 11% (Table 3).

By 2050, the frequency of drought occurrence could increase. For instance, for the baseline, the return period of drought was two years and, by 2050 the return period could be between 1.6 and 1.75 years depending on the GCMs used and SRES emission sce-narios as shown in Table 4. Another emerging issue is the fact that the intensity of drought could also be altered, as mild droughts that were experienced during the baseline could become severe in future. Drought intensity can be estimated by the difference between annual recorded precipitation and the long-term average, as precipitation could decline with climate change, it means that the intensity of drought could concomittantly increase with climate change (Table 3).

Implications of shifts in droughts for the cattle sector of the Kgatleng district

Climate change will challenge the livestock sector which supports a majority of Botswana's rural population. For the cattle sector to survive potential alterations in drought frequency and magnitude, effective range management will be needed in unison with clear policies from government. As seen, by 2050, the return period of drought could be shorter than the baseline return period (1960 - 1990). Thus, the frequency of drought will increase. In addition, the magnitude of drought may also increase owing to a decline in future precipitation coinciding with increased in evapotranspiration as a result of higher temperatures. The exposure of the cattle sector to drought means the rural population is highly vulnerable to drought and related climate change. As drought are cyclical in the country, the 1983/87 and 1990 type droughts may in future be magnified by climate change.

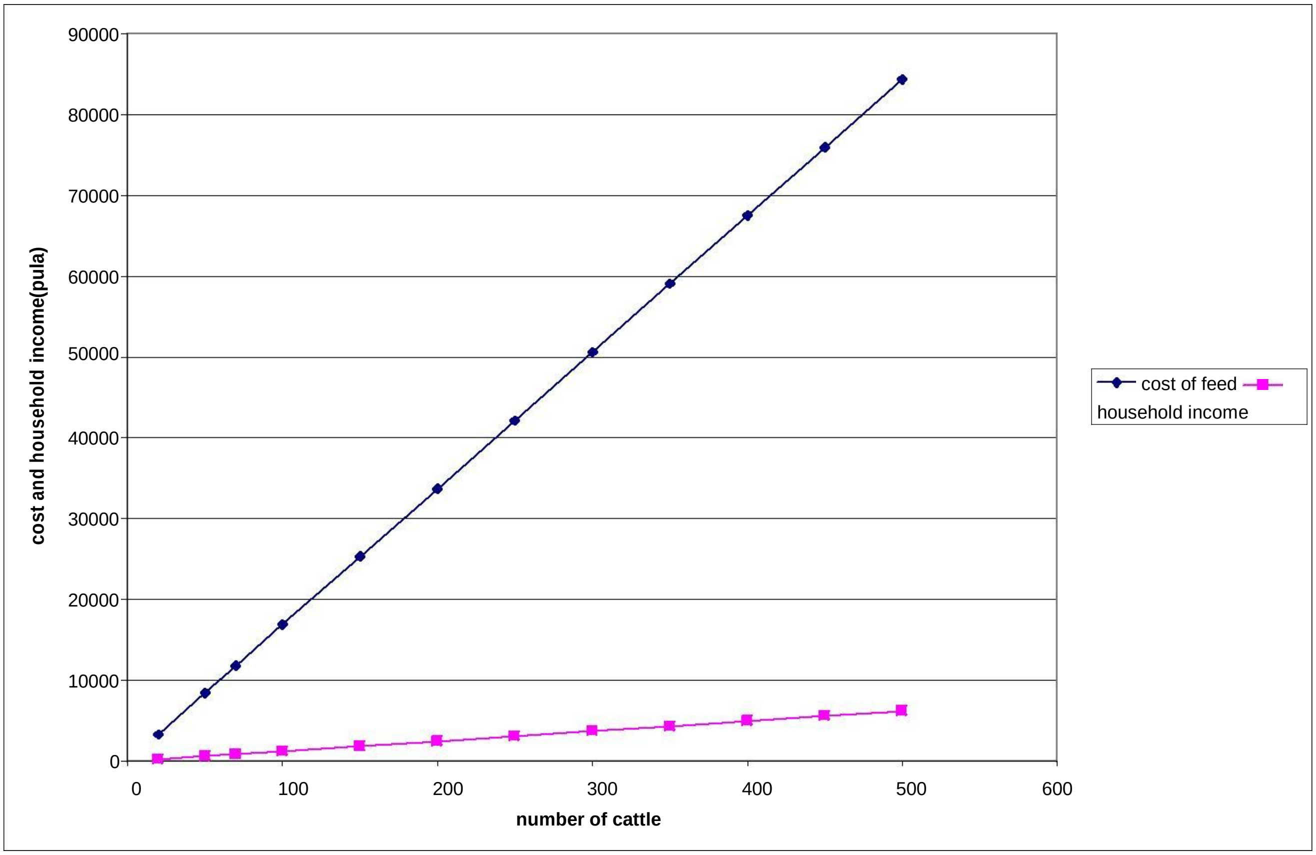

Figure 3. Relationship between cost of supplementary feeding and household income.

Table 2. Temperature increase in ^{o}C by 2050.

Months	CSIRO Mk2 A1T	CSIRO Mk2 A1B	CSIRO Mk2 A1FT	HadCM3 A1B	HadCM3 A1FT	HadCM3 A1T
1	1.31	1.09	1.39	1.49	1.90	1.73
2	1.10	0.92	1.16	1.50	1.92	1.78
3	1.09	0.90	1.15	1.51	1.93	1.84
4	1.09	0.90	1.15	2.11	2.70	2.54
5	1.35	1.12	1.43	2.71	3.46	3.28
6	1.59	1.32	1.69	2.42	3.10	2.90
7	2.00	1.65	2.12	2.32	2.97	2.45
8	1.71	1.41	1.81	2.11	2.70	2.52
9	1.22	1.17	1.49	1.99	2.54	2.40
10	1.54	1.30	1.68	1.74	2.23	2.10
11	1.39	1.15	1.47	1.66	2.11	2.00
12	1.42	1.18	1.50	1.66	2.13	2.01

As rural household income is intricately linked to cattle sales, it means that drought could threaten the income of rural communities. By the year 2050, the return period of drought could be shorter and those that do occur could be more intense. The frequency of drought has serious implications for post-drought recovery of th e cattle population. Over the years, cattle populations have recovered in both numbers and weight in preparation for subsequent droughts. However, with potentially shorter return periods, the cattle sector may have little time or no time to recover as was evident in the drought of 1982-1987. Due to the recurrence of the 1982 - 1987 droughts, livestock did not recover from the previous drought. In fact, it is during these droughts events, where, the national herd was heavily impacted. Thus, it is possible that in future, farmers' income will decline precipitously owing to lower prices for lean cat-

Table 3. Precipitation scenario for 2050.

GCM	Emission scenario	Average %change	Max % Change	Min %change
HadCM3	A1B	-3.17	2.14	-8.09
	A1FT	-4.09	2.66	-10.50
	A1T	-3.86	2.50	-10.00
CSIRO Mk2	A1B	-7.53	0.50	-8.09
	A1FT	-9.60	0.58	-11.00
	A1T	-9.09	0.58	-14.10

Table 4. Extreme event analysis for drought.

GCM	Emission Scenario	Return period
Baseline	1990	2.00
HadCM3	A1B	1.75
	A1FT	1.75
	A1T	1.75
CSIRO Mk2	A1B	1.66
	A1FT	1.66
	A1T	1.66

cattle. Secondly and, more seriously, the losses from drought in terms of cattle perishing may be devastating. For farmers with small herds, the frequency of drought may put them out of business. The shorter return period may be too short for the animal to have gained weight and be strong to resist the next drought as noted by Mati et al. (2006) in Kenya.

Potential mitigation and adaptation measures against climate change impacts

As demonstrated in this paper, heavy reliance on ANPP increases vulnerability of traditional livestock sector to climatic variability particularly drought. Obviously, reducing reliance on ANPP is an adaptation measure to mitigate the impacts of drought and climate change to cattle sector. This can be done through changing the current livestock production regime from traditional to commercial production practises. As indicated, farmers' incomes are low because of low offtake rates. Through commercialisation of the sector, farmers will be able to afford buying livestock feeds during drought years. However, for commercialisation to take place there is a need to improve the market structures for livestock in the country. Linked to the commercialisation of the livestock is improvements in the early warming systems for drought, this measure can reduce the impact of drought by warming farmers to sell early and buy feed for the remaining livestock. Diversification or mixture of small stocks (goats and sheep) is one of the possible and most attractive adaptation measures against drought. It has been found that goats do better than cattle during dry seasons and drought (Lebbie and Kagwini, 1996). Lastly, farmers should be encouraged to stock -pile crop residues during normal and above normal rainy years and use for supplementary feeding during drought years.

Conclusions

Botswana's cattle sector is highly exposed to drought as was evident in the 1983/1987 and 1990 when farmers incurred heavy losses. There are various factors that make cattle farming highly vulnerable: the sector is totally dependent on rangeland biomass which in turn is determined by annual rainfall. Secondly, stocking rates are high leading to overgrazing. Thus, during drought, already limited forage is quickly depleted leading to prolonged period of drought-stress than would have been the case with lower stocking rates. Lastly, farmers' in-comes are generally too low to enable them to afford supplementary feed during drought. The adaptation cost-income ratio to estimate shows that the cattle sector of the Kgatleng District is highly exposed to drought and future vulnerability is likely to increase. Very few farmers have adapted to drought other than to keep stocking rates high so that the probability of at least some cattle surviving the drought increases. This drought management strategy actually increases the negative effects of drought. Climate scenarios for the Khurutshe area indicate that by 2050, there could be an increase in temperature of as much as 2^{o}C and a decline in rainfall by as much as 11%, the declines differ considerably depending on the seasons. In addition, the return period of drought may be shortening by 2050 from two years to 1.6 years by 2050. These changes will have a profound impact of the livestock sector. Firstly, it is possible that a shorter return period is too short for cattle to recover and withstand another drought. Secondly, droughts may in-tensify due to a decline in rainfall. The overall impact on the rural population will be leaner cattle fetching lower prices thus reducing household incomes. Moreover, households may also experience heavy losses in terms of cattle that perish. Climate change seriously threatens future food security (and economic sustainability for subsistence farmers) in rural Botswana through its influence on drought.

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