World Journal of Agricultural Sciences 5 (5): 597-603, 2009
ISSN 1817-3047

The Projected Cost of Climate Change to Livestock Water Supply and Implications in Kgatleng District, Botswana

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Abstract: Livestock sector is one of the major consumers of water at the national level. Most of the water supplying the livestock sector originates from groundwater. Accessing groundwater is through borehole drilling. This makes water to be the most expensive factor input in the livestock sector. The cost of water supply to livestock sector is influenced by climatic factors particularly temperature and rainfall. These climatic variables influnce per capita daily water demand and livestock drinking behaviour at the boreholes, respectively. Through these linkages, climate change might affect the cost of water supply for the livestock sector. In the study, we assess the impacts of climate change on cost of water supply to the livestock sector. Using a system approach, a model is developed driven by temperature and rainfall. To assess the impacts of climate change, climate scenarios for rainfall and temperature for 2050 were constructed. Results indicate that climate change will lead to increase in cost of water supply by 23%.

Key words: Climate change · Cattle water demand · Water supply · Climate scenarios · GCMs · Variable costs · Temperature · Rainfall · System dynamics model · Diesel · Borehole

INTRODUCTION

In semi-arid environments of Africa, water is ranked as the most costly input in livestock production. This was revealed by farmers interviewed in the eastern and north eastern part of Botswana. The farmers in these regions practise free-grazing where supplementary feeding is extremely low, particularly for the communal livestock sector [1], thus water is their most costly input. Fixed and variable costs are associated with the provision of water for livestock. The fixed costs are borehole drilling and pumps. The variables costs are for diesel to fuel the pumps and and maintance repairs. The variable costs are highly influenced by climatic variability particularly temperature and rainfall. In hot months, variable costs can more than double. Therefore, through the influence of temperature and rainfall, climate change could significantly affect the variable costs and overall total cost of livestock water supply in semi-arid environments. General circulation models (GCMs) indicate that by 2050, rainfall could decline by 10-20% in southern African region while temperatures are expected to increase signficantly [2].

In this paper, we assess the potential climate-related impacts on the cost of supply water for livestock in the Kgatleng District by 2050. A systems dynamic model for cattle water supply and demand was developed with temperature and rainfall as the key drivers. Climate scenarios (rainfall and temperature) were then forced through the developed model. The results reflect the potential impacts of climate change for the cattle water supply and demand system.

Livestock Sector and Water Resources in Botswana: Globally, the livestock sector is an important economic activity, socially and politically [3]. It is the major contributor, accounting for over 40% of agricultural gross domestic product [3,4]. In terms of employment, it represents over 1.3 billion jobs and creates livelihoods for one billion of the world's poor [3]. In Botswana, though its contirbution has declined from 40% to 5%, it is still an important economic sector particularly for the rural economy [1]. The decline of the agricultural sector to GDP could be explained by the fact that the value of the agricultural products could not keep up with the value of mineral products particularly diamonds.

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In most developing countries, particularly in sub-saharan Africa, the livestock forage in a free ranging system [1]. In Botswana, the livestock economy can be categorised as either ‘commercial’ or ‘communal/traditional’. The communal component accounts for over 95% of the cattle population in the country [5]. Cattle reared in the commmunal sector are almost 100% free-ranging and supplementary feeding is rarely practised. As water is the only factor of production (besides labour) that is obtained at a cost, this makes water the most costly factor of production. Most of the water used by the livestock sector is obtained by the drilling of boreholes and pumping. Borehole drilling is therefore highly correlated with the rapid increase in Botswana’s cattle population [6,7]. In 2005, the livestock sector consumed approximately 23% of the nation’s potable water [3]. Though boreholes play a vital role in livestock water supply, pans (natural dams) are also a source of water for cattle in the hardveldt part of the country, particularly during the wet seasons [8,9]. The importance of pans as a source of surface water has prompted the Ministry of Agriculture to construct communal dams [8].

The Current Cost of Water Supply for Cattle in Kgatleng District: Variable costs of water supply for cattle are dependent on factors such as farmer’s borehole and water management strategies, number of cattle and per capita water consumption.These costs can be modelled as follows:

$$VC = f(C_n, S, E, f)$$

Where;
VC = Variable costs;
C_n = Number of cattle a farmer has;
S = Seasonality is defines temperature and rainfall;
f = Forage water content; and,
E = Energy required to lift water from below ground.

To determine the current variable costs of supplying water to cattle and the influence of climate to costs of water supply, data was collected on a total of 70 farmers, 24 in the Kgatleng and 46 farmers in the North East. All the farmers indicate that temperature and rainfall affect the pumping rate of groundwater given a constant number of cattle. Farmers indicated that during summer months (December, January, February) 200 litres of diesel is required per month to pump water for 500 cattle. In winter months (May, June, July) the same amount of fuel will last for three months. This finding corresponds well with observations from other semi-arid countries where water demand peaks in summer months [10-14].

A strong and positive correlation of 0.97 was estimated between the amount of diesel used and abstraction of groundwater. The following table shows the relationship between water pumped and diesel used.

To estimate the cost of water supply, data was collected on the amount of diesel and price of diesel required to abstract one cubic meter of groundwater. Ignoring drawdown, the following equation was used to estimate the cost of groundwater abstraction.

$$Vc = (W_d * D) * P$$

Where:
Vc = Variable cost of diesel
Wd = Daily water requirement
D = Diesel required to abstract water required by cattle
P = Price of diesel per liter

The equation for diesel required to abstract one cubic meter of water was fitted by a polynomial.

$$D = 0.213W - 0.00001W^2 + 24.74$$

$$R^2 = 0.97$$

Where:
D = Amount of diesel in litres
W = Amount of water in cubic meters

Figure 1 shows relationship between diesel used and water abstracted and the polynomial fitted line.

The daily water requirement for cattle is a function of various factors such as: size of animal, the condition of the animal, lactation, forage water content, and temperature [12-14]. In this study, other factors were assumed constant and only temperature was used as the driver of the cattle’s daily water requirement. This is based on numerous studies and observation that above 27°C water demand for cattle doubles (Smart Undated). Water consumption was fitted using the following equation:

$$W_c = 59.3 \ln(temp) - 161.35$$
$$R^2 = 0.62$$

W_c is water consumption in liters
Temp is temperature is degrees celcius

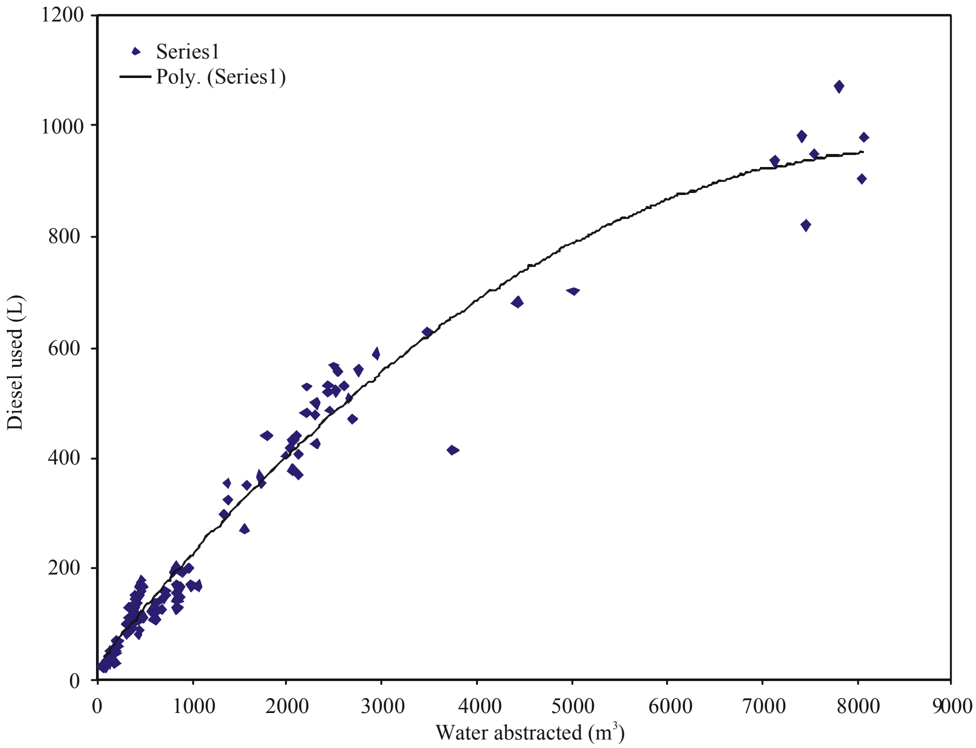

Fig. 1: Relationship between water abstracted and diesel used

Current Cost and Impacts of Climate Change to Cattle Water Supply: To assess the impacts of climate change on cost of water supply, a systems dynamic model was constructed using STELLA software Fig. 2. climate scenarios were constructed. A scenario is described by IPCC (2001) is a coherent, internally consistent and plausible description of a possible future state of the world [15]. In this study, climate scenarios were constructed using the SIMCLIM software system with HadCM 3 and CSIRO mk2 GCM. By 2050, both GCMs indicate an increase in temperature with more increases, of up to 3°C in the winter months. The GCMs also indicate a decline in rainfall by as much as 10% annually. With climate scenarios for rainfall and temperature, the cost of water was simulated for current conditions and 2050 years. The baseline curve depicts current cost while curves HadCM3 A to CISRO B depict future cost (2050) depending on the emission scenario.

Based on the developed model, the cost of cattle water supply are highly influenced by temperature and rainfall. During summer months, the amount of diesel required to supply a constant number of cattle doubles. This is in line with observation by the farmers. Figure 3 depicts the simulated variable cost of water supply between the current year and 2050. At 350 days, the total variable cost rise signficantly, this is a result of cost of mantaince incurred annually. While Fig. 4 depicts daily diesel required to abstract groundwater for a constant number of cattle between the baseline and 2050. The model projects that climate change will lead to an increase in the use of diesel for groundwater abstraction. The increase in diesel use is greater in winter months than summer. This is because climate scenarios indicate that there will be a substantial increase in temperature in the winter months compared with the summer months.

Table 1: Statistic of diesel required to abstract m3 of groundwater

Mean	0.35
Median	0.35
Standard deviation	1.041
Variance	4.2

Table 2: Total variable cost of water supply between baseline and 2050

GCM	Total cost of water supply	Cost of climate change
Baseline	16018.20	-
HadCM3 A2	19851.25	3833.05
HadCM3 B2	19463.00	3444.80
CSIRO A2	18991.90	2973.70
CSIRO B2	18358.98	2340.78

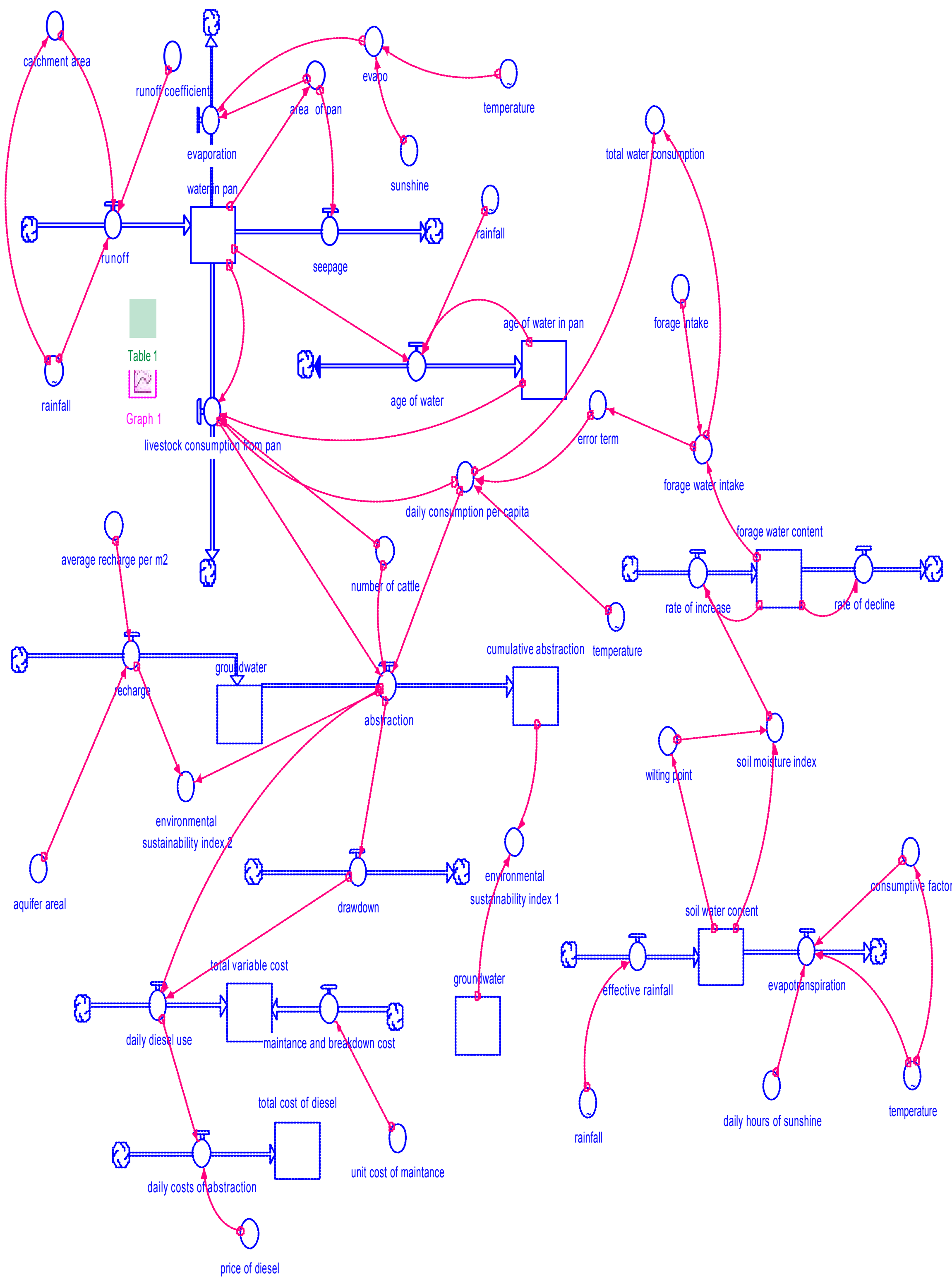

Fig. 2: Qualitative cattle water demand and supply system

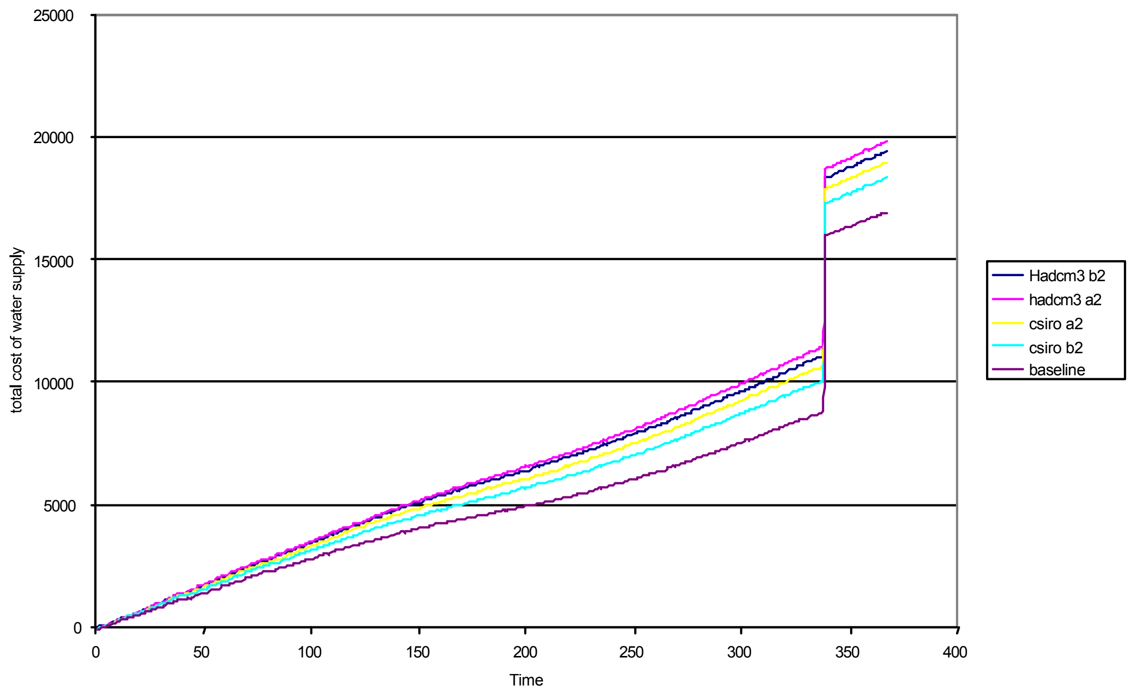

Fig. 3: Total variable costs between baseline and 2050

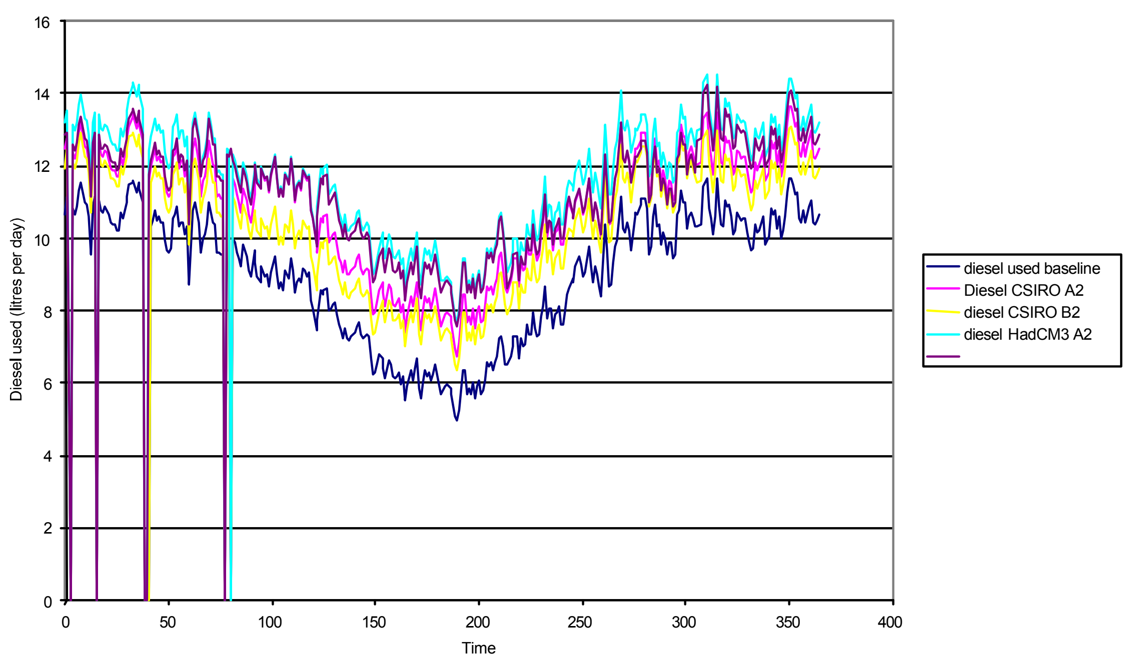

Fig. 4: Daily diesel required between baseline and 2050

Table 2 shows the total variable cost for both the baseline and 2050. The model projects that by 2050 for a constant number of cattle, the increase in total cost will be between P2973.7-P3833.05.

RESULTS AND DISCUSSION

Climate change will affect livestock water demand and supply in semi-arid environments of Africa [9]. These effects will lead to increases in the cost of water supply to cattle. In this study, the findings are that climate change will result in an increases in cost of water supply by 23% depending on the emission scenario and GCM used. It is important to note that, the costs estimated in this paper are those that are associated with an increase in the hours of pumping. Hence, this paper only estimated the partial cost of climate change. There are other costs that will be incurred such as costs associated with depletion and drawdown. In summer months, farmers already experience a decline in borehole yield due to drawdown as observed by Calow *et al*. [16] with more pumping being required to meet demand as a result of climate change, drawdown might increase leading to more energy required to abstract water. Hanemannen *et al.* [16] observed that as groundwater levels fall the cost of pumping increases. Thus, the total cost of climate change includes the increase demand for diesel to meet water demand and increase in energy required to lift water due to drawdown. Therefore, climate change will make it more expensive to supply water to livestock. In addition, there are farmers in the country who rely on shallow hand-dug wells and basins to water their cattle [8,9]. The implication of climate change is that these farmers maybe forced to install modern boreholes as their shallow wells dry up due to a reduction in rainfall and increased incidence of drought. Already, farmers in the country are vulnerable to costs associated with climatic variability such as drought. Thus, increases in the cost of water due to climate change will put more strain on their livelihood. Therefore, the rising socio-economic costs related to climatic variability will have serious impacts on rural livelihood (IPCC, 2001) [2]. In addition, to the increases in the world prices of oil products (diesel and petrol), climate change will significantly affect the cost of water supply to the livestock sector to Botswana.

CONCLUSIONS

The cost of water supply are relatively higher than other input costs in Botswana. The cost of water supppy to cattle is affected by seasonality such that in hot months they double. This is due to the influence of rainfall and temperature which affects the drinking pattern and behaviour of cattle. Climate change might affect the cost of water supply. Using a system dynamic model, the simulation result shows that the cost will increase by as much as 23% by 2050. However, these are partial cost, as the cost of drawdown is not included. In addition, climate change could increase the challenges of water scarcity and depletion in semi-arid environments [2, 17] by increasing the cost of water supply. These impacts have implications as far as international competitiveness of beef and cattle products are concerned for local farmers.

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