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Modelling of Long term Pasture Production and Estimation of Carrying Capacity of Ankole Pastoral Production Systems in South Western Uganda

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Abstract

Ankole cattle pastoral production system in South Western Uganda is based on grazing without supplementary feeding or regular water availability. A stochastic simulation model was developed to determine the dynamics of pastures grazed by Ankole cattle and their Holstein Friesian crosses and to determine the carrying capacity (CC) of the livestock system. The model used the concept of rain use efficiency which relates pasture production to rainfall. The similarity between the results of the simulation rainfall runs and field data are considered to be satisfactory. The lowest CC (6.00 ± 0.57 ha/TLU) occurs in the month of July while the highest CC (1.24 ± 0.09 ha/TLU) occurs in the month of November. Annual carrying capacity ranges between 1.94 ± 0.30 to 2.04 ± 0.37 ha/TLU with an overall mean of 2 ± 0.33 ha/TLU. The overall annual forage production is 3882.15 ± 9.79 kg/ha. The results indicate that CC is dynamic and its variability is more pronounced within the year than between years. In response to seasonal CC, marginal adjustments to actual stocking rates could be done in the month of May shortly before the long dry season. Provision of a range of CC a cattle keeper operates is more appropriate than a single static CC because it ensures social interests (keeping larger herds) as well as economic viability with ecological sustainability.

Key word: Modeling, pasture, carrying capacity, rain use efficiency

Introduction

Ankole cattle production system is highly dependent on the availability of natural pasture, the quantity and quality of which are primarily determined by the amount and distribution of rainfall. In recent times, farmers have started keeping separate herds of both Ankole and Ankole-Friesian for beef and milk production respectively. A wide variation in pasture quality and quantity, as well as cow performance can be observed between seasons (Okello *et al*., 2005).The success of this emerging grazing system will depend on the ability to track availability of forage on the range and being able to relate it to the number of animals that can be grazed on the rangeland. Climate variables, especially rainfall in semiarid and arid areas, have overriding effects on grassland production, and thus affect livestock carrying capacity (Mei *et al*., 2004). Carrying capaity may be altered by both long and short term variations in climate and particularly in precipitation (Phillipson, 1975). The objective of this study was to develop a computer simulation model to predict the dynamics of pastures grazed by Ankole cattle and their Friesian crosses and to quantify herbage productivity and determining the carrying capacity of the pastoral system.

Materials and Methods

A dynamic stochastic compartment model based on difference equations programmed in STELLA 9.0.2 (High Performance Systems, Inc., Hanover, New Hampshire) was developed. The simulations are based on a one-month time step. The results of the simulation are presented as mean and standard deviation values for 50 separate runs of the model. The model simulates the dynamics of standing green forage using the concept of rain use efficiency (RUE, kg DM produced /ha /mm of rainfall /year). Le Hou´erou *et al*., (1988) reported a RUE = 4·0 ± 0·3 for range type, condition and productivity for areas with similar conditions like that of Ankole pastoral production system. Monthly rainfall is generated randomly from a cumulative frequency distribution (Grant *et al*., 1997) for each month, created from real system historical rain fall data of 46 years (from 1961 to 2007) obtained from the Kakoba metrological department, Mbarara.

Equation 1

MRF = RANDOM (cumulative frequency),

Where MRF is the monthly rainfall (mm) and cumulative relative frequency is a value picked randomly from 0-1 for each month. Each randomly picked number has got a corresponding amount of rainfall depending on the month of the year being simulated.

Pasture growth is simulated in monthly time steps using a multiplicative function of rain use efficiency (kg DM/mm/ha) and monthly rainfall (mm). Annual rain fall is modeled as the summation of the individual monthly rainfall within a given year.

Equation 2

FG = RUE * MRF, where FG is the monthly forage growth (kg DM/month/ ha)

A basic technique for determining carrying capacity is to calculate the total amount of forage at the end of the growing season, multiply this by a correction factor and then divide by the average yearly feed requirements of a livestock unit (Hocking and Mattick, 1993). In this study, a year long proper use factor of 30% (Guevara *et al*., 1996) was used as consumable forage. The model uses the tropical livestock unit (TLU) to calculate the carrying capacity (CC) of the range. Daily feed intake per TLU was taken at 2.5% of body weight (Hocking and Mattick, 1993).

Results and Discussion

The similarity between the results of the simulation rainfall runs and field data are considered to be satisfactory (Figure 1). The mean long-term annual forage productivity was predicted to be 3898 ± 76.6 kg/ha over a 30 year period which is close to 3900 Kg/ha reported by Mugerwa (1992) and considerably lower than 4560 Kg/ha estimated by Byenkya (2004). In this study, the minimum and maximum forage produced were 3610 Kg/ha and 3998 kg/ha respectively. The overall annual dry matter yield is relatively high though its high variability within the year may lead inadequate forage during the course of the year. The difference between the current study and previous ones could be due to that fact that earlier studies were based on one-year rainfall whereas the current study is based on 30 year rainfall data. The overall carrying capacity predicted in this study was 2.01 ha/TLU which is higher than 2.27ha/TLU (Byenkya, 2004) and lower than 1.52 ha/TLU reported by Mugerwa (1992). Hocking and Mattick (1993) reported a carrying capacity in the range 2.5 - 3.5 ha/TLU for wooded grasslands of Tanzania receiving 875-1000 mm of annual rainfall. Carrying capacity variability is more pronounced within year than between years (Table1 and 2). The lowest carrying capacity occurs in the month of July (6 ± 0.57 ha/TLU) while the highest occurs in the month of November (1.24 ± 0.09 ha /TLU). The dynamic nature and seasonal changes are dramatically visible though variability of annual CC was negligible ranging between 1.88 ± 0.23 ha/TLU to 2.07 ± 0.37 ha/TLU. This means that carrying capacity is a dynamic concept requiring active monitoring and rapid adjustments of stoking rates. The policy implication of this is a move towards more flexible and short-term responses to environmental variation. Farmers need to make marginal adjustments to actual stocking rates in response to seasonal carrying capacity and the best months to reduce stocking rates in May shortly before the long dry season. Now that the extreme CC (6 – 1.25 ha/TLU) values have been determined, there is need to evaluate stocking rates that fall within the above range for economic viability and ecological sustainability. Findings of the above study would then provide a range of CC within a cattle keeper could operate other than recommending a single static carrying capacity because a range ensures social interests (keeping larger herds) as well as economic viability with ecological sustainability. Supplementation of cattle with hay especially in the dry season needs to be encouraged.

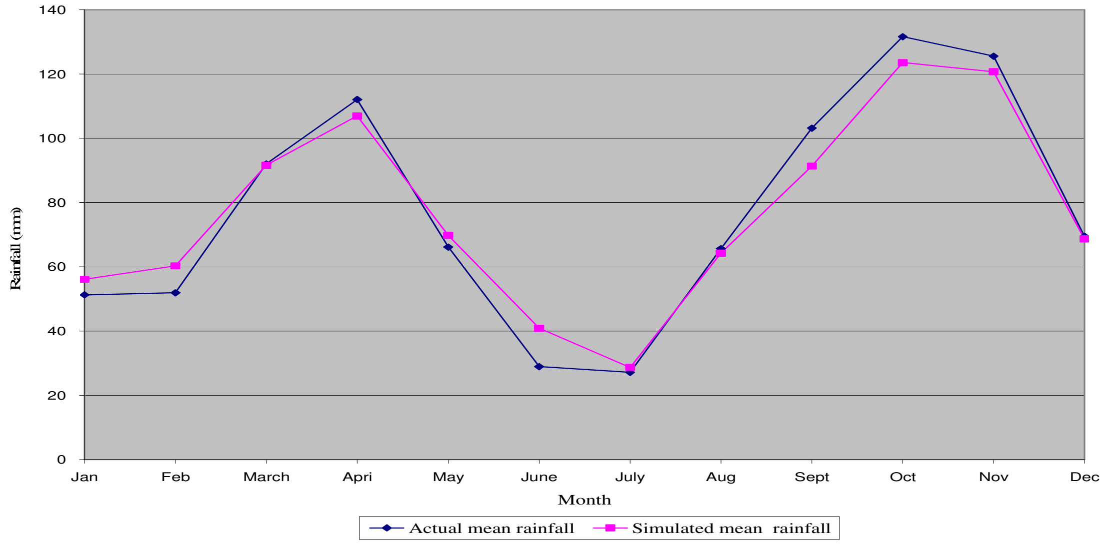

Figure 1. Actual and simulated monthly rainfall

Table 1. Pasture production, rainfall and carrying capacity in Ankole pastoral production

Year	Mean forage production (Kg DM/ha/year)	Mean annual rainfall (mm)	Carrying capacity (ha/TLU)
1	3819.28	954.82 ± 167	2.06 ± 0.37
2	3863.92	965.98 ± 150	2.01 ± 0.32
3	3967.04	991.76 ± 152	1.97 ± 0.29
4	3788.64	947.16 ± 150	2.06 ± 0.36
5	3866.24	966.56 ± 161	2.03 ± 0.35
6	3886.56	971.64 ± 178	2.03 ± 0.39
7	3843.36	960.84 ± 188	2.07 ± 0.37
8	3833.12	958.28 ± 167	2.05 ± 0.38
9	4100.72	1025.18 ± 129	1.88 ± 0.23
10	3917.04	979.26 ± 162	1.99 ± 0.34
12	4037.44	1009.36 ± 150	1.93 ± 0.28
13	3932.48	983.12 ± 163	1.97 ± 0.32
14	3827.52	956.88 ± 117	2.02 ± 0.25
15	3996.08	999.02 ± 162	1.93 ± 0.33
16	3853.84	963.46 ± 169	2.03 ± 0.40
17	3806.96	951.74 ± 171	2.04 ± 0.40
18	3856.48	964.12 ± 151	2.04 ± 0.38
19	3984.56	996.14 ± 141	1.94 ± 0.30
20	3927.52	981.88 ± 149	1.98 ± 0.31
21	4015.20	1003.8 ± 168	1.97 ± 0.34
22	3955.44	988.86 ± 168	1.97 ± 0.35
23	3848.56	962.14 ± 169	2.04 ± 0.38
24	3892.00	973.00 ± 128	2.00 ± 0.28
25	3836.48	959.12 ± 126	2.02 ± 0.29
26	3882.48	970.62 ± 130	2.01 ± 0.25
27	3913.36	978.34 ± 126	1.98 ± 0.28
27	3847.20	961.8 ± 164	2.03 ± 0.35
28	3847.12	961.78 ± 134	2.01 ± 0.28

Table 2. Monthly carrying capacity for Ankole cattle production system

Month	Carrying capacity (ha/TLU)
January	3.18 ± 0.37
February	2.86 ± 0.24
March	1.73 ± 0.12
April	1.36 ± 0.08
May	1.53 ± 0.10
June	4.96 ± 0.69
July	6.00 ± 0.57
August	2.38 ± 0.27
September	1.59 ± 0.13
October	1.25 ± 0.06
November	1.24 ± 0.09
December	2.20 ± 0.15

(TLU = 250 kg)

Conclusion

Carrying capacity (CC) is dynamic and its variability is more pronounced within the year than between years. Although big short term changes to stocking rates may not be possible, marginal adjustments to actual stocking rates must be done in the month of May, shortly before the long dry season. Basing on the results of this study, for the Ankole pastoral system to be sustainable, the stocking rate should not go below 1.24 ha/TLU.

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