Computer experimentation with an energy-based simulation model of animal production in the eastern savannas of Colombia

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Results of preliminary experimentation with a computer based simulation model of beef production in the Eastern Savannas of Colombia are reported The energetic consequences of various uses of sown pastures are examined with reference to their long term biological feasibility The quality of grass legume mixtures currently under evaluation at the International Centre for Tropical Agriculture is such that the availability of energy in the extensive animal production systems is limiting during the dry season as it is for traditional savanna based production systems A number of options are identified which appear to ameliorate this constraint Dual purpose beef and milk systems based on the use of sown pastures are viable and productive owing to the increased availability of energy in the wet season

Keywords Computer simulation Animal production Colombia

The extensive animal production systems in the Eastern plains of Colombia are orientated towards breeding and fattening for meat production Production levels on native savanna are of the order of 45 kg animal^{-1} year^{-1} The region falls within the mandate area of the International Centre for Tropical Agriculture (CIAT) The Tropical Pastures Program (TPP) in CIAT is concerned with the identification testing and dissemination of introduced genetic material that is capable of raising production levels under low input conditions and of withstanding a four month dry season and acid infertile soils (mainly Oxisols pH 4 5 80% Al saturation) Altogether there are some 3 × 10^{6} ha of acid infertile soils in Latin America within the Program s mandate region Problems associated with the near zero opportunity cost of low quality native savanna forage species coupled with its abundance and poor infrastructure and low capital availability limit any use of pasture sown to small areas for most producers

One objective of the TPP is the identification of management methods which make efficient use of small areas of well adapted grass legume pastures whose quality is higher than that of the surrounding native savanna A simulation project was set up with the aim of attempting to identify alternative uses of sown pasture that could then be tested on farm This Paper describes a series of simulations carried out with a computer model whose *modus operandi* is the flow of energy in the system some promising production alternatives are identified

Methods

The model used was that of Kahn (Kahn and Spedding 1983 1984 Kahn and Lehrer 1984) with modifications for savanna production systems (Thornton 1988) The model operates around the flow of energy that is material of a certain quality and quantity is ingested by the animal and the energy is partitioned among various requirements for example growth reproduction lactation and activity expenditure Required inputs include genetic potential parameters such as maximum animal liveweight and milk yield and environmental parameters such as standard energy expenditure and forage quality and availability The model underwent extensive validation when it was originally built (Kahn and Spedding 1984 Kahn and Lehrer *ibid*) and validation to test the modifications made for Colombian conditions is described in detail elsewhere (Thornton *ibid*) Simulated results were in general agreement with the production levels typically observed in the Eastern plains With regard to sensitivity analysis the model reacted sensibly to small changes in important input parameters it was concluded that the model was capable of simulating increases in the energy status of the herd brought about by the feeding of forage of medium quality as opposed to the native savanna species of low inherent quality

Energy has been identified (Lascano and Spain 1986) as the primary limiting resource in the extant production systems Other limitations of less general importance include mineral and protein deficiencies under certain conditions the incidence and severity of animal disease do not constitute a major constraint to production An energy based model is thus well suited to the investigation of possible use to which improved pasture might be put in such systems While the emphasis on energy is not misplaced it does put a considerable burden on the provision of dependable information relating to the quality and quantity of forage available to the animal The approach taken was to assume that savan

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na acts as the buffer between the ingestion of improved pasture if any and starvation its availability *per se* is rarely limiting whilst its quality usually is The inter face between the animal and the pasture has received some attention through the construction of a conceptual pasture growth model but it must be admitted that pending rigorous validation it is currently unknown how suitable the model built for grass legume mixtures is in terms of general predictive power and flexibility Monthly values of forage digestibility were used which were unchanging from year to year The native savanna treated as a homogeneous resource (a gross but necessary simplification) exhibited a mean annual digestibility of 44% while the grass and legume components of the sown pasture had digestibilities of 48% and 58% respectively A simple growth model was used to ascertain forage availability at any time (see Thornton 1988) Ration rules were imposed such that if availability animal unit^{-1} day^{-1} fell below a certain fixed level all animal mobs having access to improved pasture were moved onto savanna until sufficient biomass became available Animal effects on pasture were assumed to be limited to its removal which is not an unreasonable simplification in view of observed sustainable stocking rates of 0 2 and 1 0 stock units ha^{-1} for the savanna and a grass legume pasture such as *Andropogon gayanus* Kunth var bisquamulatus cv Carimagua 1 and *Stylosanthes capitata* Vog cv Capica (CIAT 1985) respectively

Simulation runs were carried out over 18 years with a self replacing herd of 30 breeding animals whose age structure and physiological status at the start followed closely those observed in savanna systems (Vera and Sere 1986) Simulation routines were written mainly in FORTRAN 77 Animals were weaned 270 days after birth and the culling of breeding stock took place every August and December on the basis of age or infertility At each of these dates the herd of recently weaned animals was disposed of unless the treatment concerned modified such decision rules The total area of land available to the herd was 150 ha Conception (the occurrence of oestrus and the occurrence of conception following oestrus) animal death and calf sex at birth were defined to be stochastic events so replication was carried out The levels of variability thus introduced were small but in the absence of experimental data it is essentially unknown how these levels relate to real life levels of system variability over long periods of time

Results

Model output for nine selected treatments was assembled and tabulated (Table 1) The first of these treatments represented a savanna production system whilst for all the others the herd had access to areas of sown grass legume pasture

Provision of 30 ha of improved pasture in conjunction with an unchanging set of decision rules (Treatment B) resulted in clear increases in production levels over the savanna system (Treatment A) Death rates the average conception interval and the age of first calving were reduced whilst conception percentage weaning weight and sales increased by factors of 1 85 1 11 and 2 38 respectively Comparison of the distribution of conceptions throughout the year for these two systems (Figure 1) showed that the provision of improved pasture tended to induce marked seasonality into that system a lagged response due primarily to the flush of higher quality pasture that became available to the herd at the commencement of the wet season (March–April)

Table 1 Model results for nine selected treatments showing the means and standard errors for 21 replicates SU = stock unit

Treatment	Average number stock units in herd	Age at first calving years	Conception interval days	Production kg SU^{-1} yr^{-1}	Conception percentage	Weaning weight kg	Adult mortality %	Sales kg SU^{-1} yr^{-1}	Internal rate of return %
A 150 ha savanna	32 03	40 001	626 41	40 03	47 02	133 03	11 02	34 05	30 083
B 30 ha improved pasture (IP)	42 02	31 001	389 08	74 03	83 05	148 03	8 02	81 05	133 217
C IP + harsher culling	41 01	30 001	396 09	71 03	84 04	148 03	5 02	86 06	144 150
D IP + seasonal breeding months 5–7 (SB1)	39 01	33 002	431 19	74 05	72 05	148 03	7 02	81 07	96 239
E IP + seasonal breeding months 6–2 (SB2)	43 01	31 001	389 08	71 03	84 05	144 03	7 02	85 06	149 135
F IP + early weaning at 7 months (FW)	45 02	30 001	385 08	66 03	85 06	131 03	7 02	79 07	145 183
G IP + milk offtake proportion of 0 333 (MO1)	40 01	31 001	382 08	67 04	85 06	129 03	7 02	73 06	245 328
H IP + milk offtake proportion of 0 333 during wet season only (MO2)	41 01	31 001	388 08	71 03	84 05	133 03	7 02	79 07	232 229
I IP + MO2 + SB2	42 02	31 001	390 09	65 03	85 04	131 03	5 02	85 06	255 228

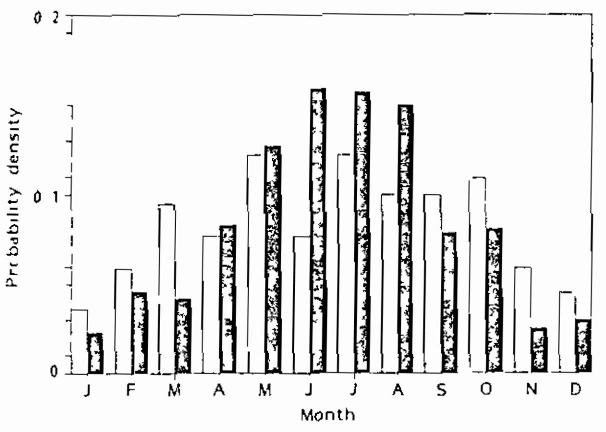

Figure 1 Monthly occurrence of conceptions over eighteen years for herds of breeding cows on diets of ☐ native savanna ◘ improved pasture

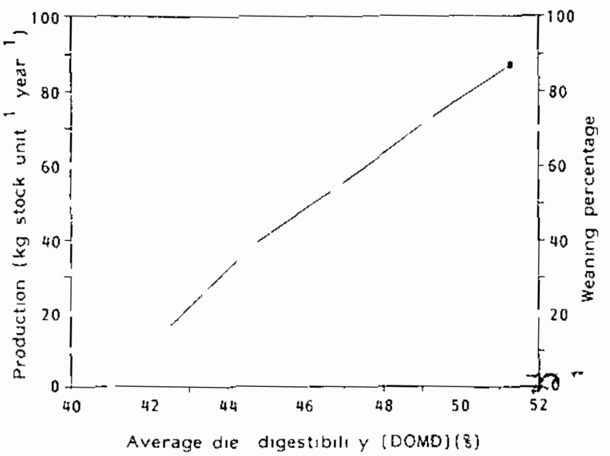

Figure 2 Response of the beef model to increases in mean diet digestibility ◘ production (kg stock unit^{-1} year^{-1}) + weaning percentage

The model was highly sensitive to changes in overall system quality The response curve relating average diet digestibility to production (Figure 2) exhibited diminishing marginal production returns to increases in diet quality The shape of the curve at its base suggests that a self replacing herd on a diet consisting solely of native savanna was not far removed from being the worst production system that could still retain its biological viability in the long run

Harsher culling policies where breeding animals were sold off in response to earlier signs of infertility and where the maximum age of breeders was reduced (Treatment C) resulted in a beneficial marginal effect through a lowering of the death rate for adult animals Such animals otherwise lost to the system contributed to increased sales The removal of older less fertile animals and their replacement with younger more fertile animals might be expected to have a beneficial effect through herd rejuvenation although there is no clear evidence of this from Table 1

Imposition of a three month breeding season had a detrimental effect on production levels when compared with year round breeding (Treatments D and B) Short breeding seasons may be expected to be beneficial in situations where the conception interval is less than one year this was not achieved in any of the treatments considered In view of the 11% increase in conception interval for Treatment D it was concluded that the plane of nutrition was not high enough to support a short breeding season However a nine month breeding season (Treatment E) led to increased sales despite lower weaning weights By precluding the possibility of calvings during the dry season when animals were under considerable stress energy that would have been used for milk production could go to maintain body weight instead

The effects of weaning at seven months of age rather than at nine (Treatment F) were equivocal The conception interval decreased slightly but sales and production suffered Early weaning in systems of low to medium productivity have been shown to have beneficial effects (CIAT 1986) but it may be that any benefits are due to factors to which the model is simply not sensitive

Dual purpose beef and milk systems were feasible even for maximum milk yields of only 5 kg day^{-1} for a range of offtake proportions (Table 2)

Table 2 Milk offtake proportion and its effect on weaning weight and annual production

Milk offtake proportion	Weaning weight kg	Production kg stock unit^{-1} year^{-1}
0 000	148	74
0 250	133	69
0 330	129	67
0 375	126	59
0 500	(not feasible)	

Production suffered when milk was removed all year round (Treatment G) but stopping offtake during the dry season (Treatment H) restored production to levels approaching those of Treatment B The transition from year round to seasonal milk offtake reduced the probability of calf death due to insufficient energy intake during the dry season

When seasonal milk offtake and the nine month breeding system strategies were combined sales and reproductive performance were restored to levels comparable with Treatment C despite lower weaning weights (Treatment I) Each of these energetic effects were thus additive to a degree there was an excess of energy in the system during the wet season when it could be safely removed in the form of milk for profit Energy was limiting during the dry season and improved biological performance was obtained if energy (as milk) was removed from the cow neither by suckling nor by offtake for human consumption

An indication of the economic performance of improved pasture systems is given in Table 1 in terms of the internal rate of return of each treatment The superiority of the dual purpose systems is apparent although such analysis fails to take account of the levels of expertise necessary for the successful operation of such a system In addition ranchers may be more interested in the effects of various production alternatives to their cash flow *per se* rather than on the overall profitability of such investments The financial feasibility of small investments in sown pasture has been documented elsewhere (CIAT 1986)

Conclusion

The results of this analysis indicated that the quality of improved pasture sown at the present time in the savannas of Colombia appeared to be insufficiently high to support short breeding seasons since in adequate numbers of animals were able to build up body weight to the point where re conception with in one year was probable No benefits could be found to early weaning although it is possible that any advantages demonstrated in the field are due to hormonal rather than to energetic effects Dual purpose systems were biologically viable for a range of milk offtake rates Energy was limiting during the dry season but detrimental effects on long term herd stability and productivity could be avoided to some extent by a nine month breeding season such that no calves were suckled during this time and by removing milk from the herd during the wet season only There are a number of implications of chang ing to dual purpose systems not least the increase in the level of management input required to oper ate such systems Stricter culling of the breeding herd was one improvement identified that would involve little extra management input

The options identified above involve relatively gross changes in system quality brought about by the use of sown pastures of higher inherent digesti bility than that of the native savanna species The identification of other less profound changes to the extant production systems that are still beneficial could be expected to be facilitated by improvements to the empirical specification of the model used The pasture component is awaiting rigorous validation and field trial data suitable for this purpose are in the process of being generated The model would also benefit from a fuller treatment of the interface between the animal and its pasture Such measures could be expected to enhance the resolution and hence the usefulness of the model

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