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# Evaluation of Sahelian livestock production strategies using regression models of cattle performance

**Evaluation des stratégies pastorales sahéliennes moyennant des modèles à régression multiple de l'évolution pondérale des bovins — Les facteurs de la croissance de jeunes taurillons peuls exploitant des pâturages annuels sahéliens à Selibaby (Mauritanie) ont été mesurés sur une période de 21 mois. Simultanément, les conditions climatiques et les ressources fourragères ont été étudiées. Pour chaque saison, l'auteur a calculé des équations de régression multiple reliant entre eux ces paramètres. Les performances de saison sèche (variations quotidiennes de poids mesurées mensuellement) sont fortement influencées par la durée de la saison sèche, la disponibilité en fourrages ligneux et par la distribution d'un complément azoté. La complémentation alimentaire en saison sèche chaude et pendant la période de soudure peut être rentable pour les animaux devant être commercialisés. Cependant, la croissance compensatrice observée pendant la saison des pluies sur les animaux non complémentés réduit l'intérêt de cette pratique.**
**Des simulations par des modèles mathématiques ont montré que les performances de saison sèche ne sont pas améliorées par une diminution de la charge, tant que la biomasse disponible est supérieure à 300 kg de matière sèche par hectare. Les performances de saison humide sont influencées par la disponibilité en fourrages et leur teneur en matière azotée. La croissance de saison des pluies pourrait être améliorée en accroissant la dispersion du bétail, et en diminuant la charge appliquée aux pâturages en fin de saison humide.**
**Les recherches importantes à entreprendre concernent la qualité et la quantité des rations ingérées au pâturage, les relations entre la charge et le taux de disparition du fourrage en saison sèche, et enfin l'importance de la croissance compensatrice en saison des pluies suivante.** *Mots clés :* Bovin Peulh - Taurillon - Alimentation au pâturage - Complément alimentaire - Croissance - Mauritanie - Sahel.

## INTRODUCTION

The Sahelian zone, defined by BREMAN and DE WIT (4) as the zone between the 100 mm and 600 mm isohyets, is an important livestock producing area in West Africa. Local cattle production systems are generally hampered by low per head productivity : 3 to 5 years to first calving, 60 to 75 p. 100 calving rates and 25 to 40 p. 100 calf mortality (6, 13, 15). Poor animal nutrition, due especially to poor forage quality, is generally assumed to be the cause (4, 11). Many techniques have been proposed to improve nutrition of range cattle, including range seeding, supplemental feeding and grazing management (2, 11, 14, 15) but few have been tested on herds in controlled situations (5, 9, 17, 18). A more complete understanding of secondary production is required in order to evaluate the technical and economic feasibility of these proposed improvements.

This article presents 3 seasonal models that predict monthly cattle liveweight change from easily measured indices of feed availability and quality under typical southern Sahelian conditions. The models are based on regression coefficients derived from data collected during a grazing livestock demonstration in Mauritania. These models are then used to examine and rank proposed technical improvements.

## MATERIALS AND METHODS

The data were collected during the 21-month grazing livestock demonstration of the Guidimakha Integrated Rural Development Project. The fenced demonstration site covered 500 ha of upland red clay soils and vertisols derived from schist. The climate was typically sudano-sahelian. Annual rainfall at the site was 421 mm in 1981 and 408 mm in 1982. More detailed information of the Guidimakha region is given by BRADLEY *et al.* (3).

The herbaceous vegetation was composed almost entirely of annual grasses. *Schoenefeldia gracilis* was the dominant grass. On vertisols, *Panicum laetum, Brachiaria lata* and *Echinochloa colona* were present. In areas of organic matter buildup, tall coarse annuals, especially *Andropogon* spp. and *Pennisetum* spp. formed dense stands. The most common legumes were *Sesbania rostrata* (a palatable plant) with *Cassia tora* and *C. mimosoides* (both unpalatable species). Herbaceous cover was less than 50 p. 100. Dominant trees were *Balanites aegyptiaca, Acacia seyal* and *Combretum glutinosum.*

The site was divided by interior fences into 4 blocks, 3 of which were used in the demonstration. Each block

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was further subdivided into 4 pastures, one for the wet season and the others for dry season use. The wet season use was rotated among the pastures. Peulh cattle, local sheep and goats were introduced into the blocks. Herders supervised the movement of the animals within each block.

Initial stocking rates of the blocks varied from 10 to 3.7 ha TLU$^{-1}$ yr$^{-1}$ (1 TLU = bovine of 250 kg). The dry season pastures always provided some dry matter with a minimum of 300 kg DM ha$^{-1}$ remaining at the end of grazing. Demonstration animals were watered once a day and had access to salt blocks. The animals were periodically wormed and treated for external parasites. Animals in several blocks were fed supplements during the late dry season. As part of the demonstration new animals were introduced, while some animals were shifted between blocks or culled. Consequently the blocks were not coherent treatments amenable to analysis of variance, but rather devices that subjected animals to a greater range of nutritional environments than would have been possible with one herd.

Thorax perimeters of demonstration bullcalves were measured monthly for the first eight months. Thereafter, the bulls were weighed every month. A regression line ($R^2 = 0.93$ ; $P < 0.001$) developed from simultaneous mensuration and weighing of the animals was used to estimated liveweights for the first eight months.

The liveweights of bulls initially weighing 100 to 200 kg were the basis for 3 of the variables used in the regression analysis. First, daily weight change of every animal between weighings (DWTCHG) was calculated for every period. The liveweight at the start of every period (STWT) divided by the previous maximum weight of the animal was defined as the condition of the animal (CONDITN). This index equalled 1 when the animals attained their maximum weights during the cool season. The index dropped below 1 during the hot season and exceeded 1 during the subsequent wet season.

To explain variation in DWTCHG, data were collected on the nutritional environment encountered by the animals. Herbaceous forage samples were collected during each grazing period. Two transects in each pasture used by the animals were systematically sampled using 0.1 m$^2$ quadrats. The species present in each quadrat were noted and all above-ground biomass clipped. Easily prehended litter was also gathered. Initially, 60 quadrats were clipped in each pasture. After five months the number of quadrats was increased to 90 per pasture to provide more precise estimates of the forage on offer. Wet season samples were dried 48 hours at 70 °C. All samples were weighed and the dry matter from a pasture combined, mixed and subsampled for proximate forage analysis. Thus, the quality of forage on offer during any period in any pasture was characterized by its crude protein content (CPF) and its energy content expressed in *Unités Fourragères* (UFF). The availability of forage at the start of any period was expressed as herbage allowance (HERBALL, kg DM kg$^{-1}$ LWT and as its reciprocal, grazing pressure (RHERBAL, kg LWT kg$^{-1}$ DM).

Browse is acknowledged to be an important component of dry season diets (7). The relative abundance of browse was incorporated in the analysis by the creation of a browse allowance (BROWSALL). Fruit and leaf production of Sahelian trees has been shown to be proportional to the trunk diameter of the tree (10). It was hypothesized that the contribution of browse to the diet would be proportional to the sum of the diameters of all trees producing forage in a pasture during a given period and inversely proportional to the weight of animals competing for that forage. The browse allowance was thus defined as cm trunk diameter kg$^{-1}$ LWT, with its reciprocal, browsing pressure (BROWSALL) expressed as kg LWT cm$^{-1}$ trunk diameter.

Point-centered quarter sampling along permanent transects was used to estimate the density and species distribution of trees in each pasture. The following trees were considered to produce palatable browse: *B. aegyptiaca, A. seyal, A. senegal, Grewia bicolor, Feretia apodanthera, Combretum acculeatum* and *Ziziphus mauritiaca*. At the start of each grazing period the trees sampled on the PCQ transects were evaluated as either providing or not providing browse. The trunk diameters of those trees providing browse were used to calculate the browse allowance for that pasture for that period.

When animals received sorghum residues or concentrates as supplements the quantities of feed offered and the amount remaining 24 hours later were recorded. Samples of each were taken for proximate feed analysis. The amounts of supplemental crude protein (CPS) and supplemental energy (UFS) ingested per 100 kg of liveweight per day were calculated. The product of supplemental crude protein and the herbage allowance (CPSXHERB) was included to investigate interaction.

The number of months elapsed in the season (MONTHSEA) and the number of months that a pasture had been in use (MONTHPAS) were included as variables. Initial analysis (8) indicated that animal performance in the dry season responded as a decay function with respect to both of the above variables. Therefore, the natural logarithms of each variable (LNMNSEA and LNMNPAS) was included in the analysis.

Since nutritional conditions and animal performance vary greatly from one season to another, the data were

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stratified by season. The working hypothesis was that for a given season, monthly animal performance, expressed as DWTCHG, was a function of the animal's status (liveweight and condition), the forage and browse on offer (quantity and quality), the amount of supplemental food and the time elapsed in the season and in the use of the pasture.

All possible subsets of independent variables were considered in a multiple regression analysis of the data. The regression models thus produced tested the hypothesis and indicated the relative importance of each independent variable as a predictor of daily weight change. For each season one regression model was selected as the most accurate. The regressions residuals were then examined to determine if the residual variation could be attributed to blocks, animals or periods. The regression equations were then used to simulate liveweight changes over an annual cycle in monthly time steps under various management strategies.

# RESULTS

The selection among hundreds of equations for the most appropriate regression model for a given season proceeded from several criteria. First, the model chosen would have a relatively high $R^2$ and a low Cp criterion (which measures the relative efficiency of the predictor variables in each model). Next, each regression coefficient would be significantly different from zero. Parameters for several models for each season are presented in table I. The models selected for each season will be considered in more detail.

*TABLE I Characteristics of selected models of daily weight change during three seasons.*

| Model characteristics | n | k | $R^2$ | Cp |
|---|---|---|---|---|
| Dry season | 273 | 5 | .279 | 30.26 |
| | 273 | 7 | .338 | 17.27 |
| | *273 | 10 | .370 | 9.69 |
| | 273 | 14 | .377 | 15.00 |
| July (transition) | 49 | 2 | .299 | 7.62 |
| | *49 | 4 | .408 | 3.72 |
| | 49 | 6 | .418 | 7.00 |
| Wet season | 105 | 2 | .636 | 10.92 |
| | *105 | 4 | .668 | 5.33 |
| | 105 | 9 | .685 | 10.00 |

** : models selected to predict animal performance ; n : number of observations ; k : number of predictor variables : $R^2$ : squared multiple correlation coefficient ; Cp : MALLOW's criterion.*

## Dry season

The regression coefficients, standardized regression coefficients and the multiple correlation coefficients for each variable in the 10 variable dry season model appear in table II *a*. The model has a low but very significant $R^2$ of 37 p. 100 ($P < 0.0001$). The month of the season and its natural logarithm were the two most important predictor variables. They were strongly autocorrelated but were not independent. Together they created a non-linear function with respect to time with an overall negative effect of DWTCHG. Supplemental crude protein was the next most important factor and had a positive effect. Both herbage allowance and grazing pressure had negative coefficients. Since the two were related but not highly correlated, their simultaneous inclusion created a non-linear function with respect to herbage allowance. This function indicated the optimum level of herbage allowance to be 3-4 kg DM $kg^{-1}$ LWT. Though both animal and forage densities varied in the demonstration, variation in total available forage was the major source of variation in the herbage allowance. The low optimal herbage

*TABLE IIa Predictor variables, standardized regression coefficients, multiple correlation coefficients and regression coefficients for the 10 variable dry season model of daily weight change.*

| Predictor variable | Standardized regression coefficient | Multiple correlation coefficient | Regression coefficient |
|---|---|---|---|
| Ln (month of season) | – 1.376 | .9574 | – 1.23041 |
| Month of season | .936 | .9552 | .22739 |
| Supplemental crude protein | .636 | .9133 | .01388 |
| Herbage allowance | – .499 | .9262 | – .09438 |
| Browse allowance | .417 | .7776 | .07309 |
| Interaction (CPSXHERBALL) | – .402 | .8908 | – .00145 |
| Condition index | – .337 | .6848 | – .82906 |
| Starting liveweight | – .313 | .5124 | – .00324 |
| Grazing pressure | – .313 | .8530 | – 1.20462 |
| Forage crude protein | – .158 | .4972 | – .07757 |
| Intercept | — | — | 2.94558 |

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allowance may reflect greater nutrient dilution in areas of dense forage growth or greater energy expenditures in search behavior in larger pastures. Browse allowance had a positive coefficient, confirming the role of browse during the dry season. The negative interaction coefficient indicated that the interaction was the opposite of that supposed. There was no obvious explanation for this result. Both animal condition and starting weight had negative influences on daily weight change during the dry season. Crude protein in the forage also had a negative influence. This result conflicts with the accepted hypothesis of protein limitations to dry season animal performance in the Sahel (4). Crude protein levels in the dry season forage were generally unchanging through the dry season, except for several determinations which showed increases in crude protein for all pastures during the month of May in one year of the demonstration. Since no herbaceous growth occurred in May, the increase was probably an artifact of the forage analysis. These data were responsible for the negative influence of CPF.

Four variables had high multiple correlation coefficients. MONTHSEA and LNMNSEAS were highly correlated but were not independent and in fact can be represented as a single function. Consequently, their simultaneous inclusion does not threaten the predictive power of the model. Supplemental crude protein (CPS) and herbage allowance (HERBALL) had high multiple correlation coefficients which indicated that their estimated regression coefficients might be unstable. For this reason the 7 variable dry season model (table II *b*) in which all independent variables had acceptable

***TABLE IIb Predictor variables, standardized regression coefficients, multiple correlation coefficients and regression coefficients for the 7 variable dry season model of daily weight change.***

| Predictor variable | Standardized regression coefficient | Multiple correlation coefficient | Regression coefficient |
|---|---|---|---|
| Ln (month of season) | – 1.608 | .9499 | – 1.43803 |
| Month of season | 1.267 | .9458 | .30792 |
| Starting liveweight | – .291 | .4306 | – .00301 |
| Condition index | – .289 | .6531 | – .71194 |
| Forage crude protein | – .249 | .3388 | – .12207 |
| Browse allowance | .228 | .4721 | .03987 |
| Supplemental crude protein | .206 | .4861 | .00450 |
| Intercept | — | — | 2.09184 |

multiple correlation coefficients was used occasionally to check on the predictions of the 10 variable model.

Examination of the residuals of the 10 variable model showed a random scatter of residuals when compared to predicted values. Analysis of variance of the residuals could attribute no more variation to either period, block or individual animal. However, two of the 21 animals did appear to differ from the others.

## July

The parameters for the 4 variable model of the July transition period appear in table III. The model had a low but significant $R^2$ of 41 p. 100 ($P < 0.0001$). Supplemental energy measured in UF 100 $kg^{-1}$ LWT $day^{-1}$ had a strong positive influence as did browse allowance and crude protein in the forage. Animal condition had a negative influence.

All 4 variables had acceptable multiple correlation coefficients. Examination of residuals showed random scatter around predicted values and no effect of either block, period or individual animal. However, 6 of the 21 animals responded consistently differently than the others, with 2 of them being the 2 previously noted during the dry season.

***TABLE III Predictor variables, standardized regression coefficients, multiple correlation coefficients and regression coefficients for the 4 variable July model of daily weight change.***

| Predictor variable | Standardized regression coefficient | Multiple correlation coefficient | Regression coefficient |
|---|---|---|---|
| Supplemental energy | .832 | .6023 | 2.35924 |
| Browse allowance | .588 | .2670 | 1.83428 |
| Condition index | – .345 | .5121 | – .95202 |
| Forage crude protein | .317 | .2882 | .41154 |
| Intercept | — | — | – 2.12701 |

## Wet season

The regression coefficients, standardized regression coefficients and multiple correlation coefficients for the 4 variable wet season model appear in table IV. The model had an $R^2$ of 67 p. 100 ($P < 0.0001$). Crude protein in the forage and herbage allowance had strong positive influences. Browsing pressure had a positive

*TABLE IV Predictor variables, standardized regression coefficients, multiple correlation coefficients and regression coefficients for the 4 variable wet season model of daily weight change.*

| Predictor variable | Standardized regression coefficient | Multiple correlation coefficient | Regression coefficient |
|---|---|---|---|
| Forage crude protein | 1.245 | .7835 | .39372 |
| Herbage allowance | 1.016 | .7600 | .66374 |
| Browsing pressure | .311 | .7450 | 1.94097 |
| Condition index | − .305 | .6916 | − .74418 |
| Intercept | — | — | − 2.95247 |

effect, a result with no obvious explanation. The coefficient may indicate better forage conditions in less woody areas or less grazing time available to animals in bushy areas. Animal condition had a negative effect on daily weight change, modelling compensatory growth.

The multiple correlation coefficients were all acceptable, and examination of the residuals showed a random scatter, and no influence of block, period or individual animal. Only one animal responded differently from the others.

## Baseline annual animal performance

Since these models predicted daily weight change for a monthly time step, it was necessary to integrate the models over an annual cycle to predict the annual evolution of an animal's weight. Monthly baseline values for the predictor variables were drawn from the data and used in the models to calculate iteratively the monthly liveweight changes and consequently the monthly weights of the animals. Values of certain predictor variables were then changed to simulate different management strategies. The resulting liveweight predictions were then compared to those of the baseline.

Baseline conditions were defined as no supplemental feeding with grazing at moderate herbage allowances. The iterative nature of the liveweight change calculation required monthly herbage and browse allowances which changed as the season progressed. The dry season herbage allowance used for the baseline started at 10 kg DM $kg^{-1}$ LWT in October and decreased linearly to 3 kg DM $kg^{-1}$ LWT in May. This rate of dry matter disappearance was equivalent to 3.3 p. 100 of liveweight per day and corresponded well with the data. A dry season pasture with 1,000 kg DM $ha^{-1}$ in October and an herbage allowance of 10 would have had a stocking density of 0.4 TLU $ha^{-1}$ for the 8 months of the season, or 3.7 ha $TLU^{-1}$ $yr^{-1}$. These herbage allowances, moderate within the demonstration, reflected heavy stocking densities for the zone [6 ha $TLU^{-1}$ $yr^{-1}$ is recommended by BOUDET (2)].

Wet season herbage allowances were taken directly from the data, starting at 0.5 kg DM $kg^{-1}$ LWT in July and rising to 3 kg DM $kg^{-1}$ LWT in September. Crude protein in the forage was set at 3 p. 100 for October and 1.8 p. 100 for all other dry season months. During the wet season it was set at 9 p. 100 in July, 6 p. 100 in August and 3 p. 100 in September.

The predicted liveweight and condition over an annual cycle for an animal weighing 100 kg in October is shown in Fig. 1. The animal gains weight until January, maintains its weight until June, loses considerable weight from June to July, then gains weight rapidly to reach 191 kg in October, 91 kg heavier than in the previous October. Liveweights predicted from the 7 variable dry season model are also shown in Fig. 1. With this model the final predicted liveweight is within 3.6 kg of that predicted by the 10 variable model. While not a definitive test, this close accord indicates that predictions of the 10 variable model are not grossly unrealistic because of collinearity among certain predictor variables.

Figure 1 also continues the evolution through a second cycle, somewhat beyond the range of the data used to derive the models. In this second cycle the animal attains a maximum weight earlier in the cool season and loses 33 kg through the dry season, 19 kg of which are lost in July alone. Annual weight gain over the second cycle is 43 kg. Because values of the predictor

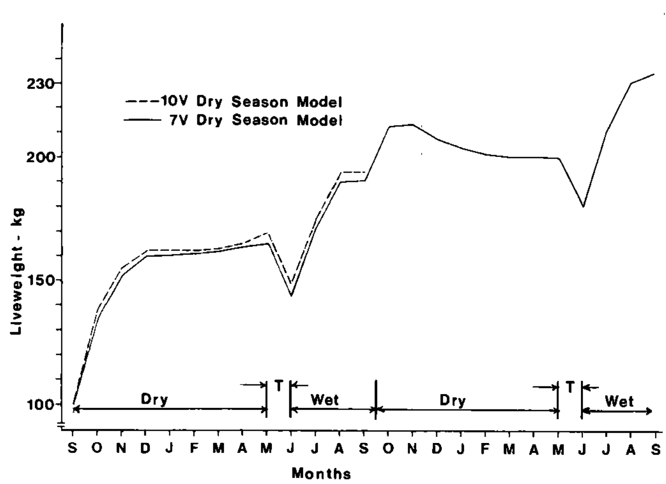


*Fig. 1 : Stimulated evolution of liveweight under baseline conditions.*

variables are drawn from the data, this baseline constitutes a summary description of animal performance under the average monthly conditions of the demonstration.

Validation of the models was difficult since comparable data sets for southern Sahelian cattle did not exist in the literature. However, the evolution of liveweight under baseline conditions was similar to that reported by DENIS *et al.* (5), and KLEIN (9). The baseline weight gains over the year were considerably less than those reported by KLEIN (9). This difference may have been due to the lower precipitation and consequent higher forage quality at the Ekrafane ranch.

## Evaluation of different strategies

October liveweights for animals weighing 100 kg in the previous October and raised under different strategies appear in table V. More available dry season forage can be simulated by doubling the herbage allowance in October. Data from this demonstration and from other experiments (1, 18) show that rates of dry matter disappearance per head increase with herbage allowance. Therefore, herbage allowances have been set to include monthly losses of 3 kg DM $kg^{-1}$ LWT from October to December, 2 kg DM $kg^{-1}$ LWT in January and 1 kg DM $kg^{-1}$ LWT thereafter, with 6 kg DM $kg^{-1}$ LWT remaining in June.

This strategy produces animals weighing 168.5 kg in October, 22.6 kg less than under lower herbage allowances. Since herbage allowances in this demonstration varied largely with differences in forage density

*TABLE V Simulated annual liveweight gains of a 100 kg animal under different management strategies.*

| Strategy | Weight gain (kg) | Gain over baseline (kg) |
|---|---|---|
| Doubling wet season herbage allowance | 166.0 | 75.0 |
| Higher late wet season forage quality | 126.5 | 35.5 |
| Supplemental feeding March to July | 105.0 | 14.0 |
| Supplemental feeding June to July | 100.0 | 9.0 |
| Baseline (no supplement with moderate herbage allowance) | 91.0 | .0 |
| Deferred dry season use | 71.0 | – 20.0 |
| Doubling dry season herbage allowance | 68.5 | – 22.5 |

and pasture area, this poorer performance would be due to greater energy expenditures for movement in larger pastures and poorer forage quality in areas of high forage density. The data do not indicate that for a given dry season pasture area and forage quality, higher stocking rates would increase weight gains.

Deferred dry season use divides the dry season range into several pastures that are used successively. The division of the baseline range into smaller pastures gives herbage allowances of 3, 2 and 1 kg DM $kg^{-1}$ LWT, respectively for the 3 months of grazing use in each pasture. Though the lower herbage allowances tend to increase weight gain, the lower browse allowances lead to a 20 kg loss when compared to the baseline performance. If herbage allowances for the period of use are set near the apparent optimum herbage allowance, the simulation shows only a 6 kg increase over baseline liveweight gain. These results conflict with those reported by WYLIE *et al.* (17) which show some increase in weight gain and diminution of weight loss during the dry season by the use of deferred grazing in Niger. Again, this difference may be due to higher quality forage in pastures that grew with half the rainfall received in Selibaby.

Supplemental feeding is simulated by specifying different levels of supplemental crude protein and energy consumption. Feeding 15 gm of crude protein $day^{-1}$ 100 $kg^{-1}$ LWT from mid-March to mid-June and 0.2 UF $day^{-1}$ 100 $kg^{-1}$ LWT from mid-June to mid-July gives a gain of 14 kg over baseline. The weight gain to June (8.7 kg) is equivalent to 3.89 gm of gain $gm^{-1}$ of crude protein consumed. This high conversion efficiency may indicate higher digestibilities of forage because of supplementation or a release due to another limiting factor contained in the supplement but not measured in the feed analysis, such as vitamin A in green sorghum fodder. With liveweight valued at 34,5 UM $kg^{-1}$ in the local market (8) and a supplement of 12 p. 100 crude protein and 0.5 UF $kg^{-1}$, supplemental feeding would break even at a cost of 12 UM $kg^{-1}$ supplement. Supplemental feeding of 0.2 UF $day^{-1}$ 100 $kg^{-1}$ LWT from mid-June to mid-July alone produced a gain of 9 kg over baseline. With the same type of supplement, the break-even cost of this operation is 15.5 UM $kg^{-1}$ supplement.

The forage analyses show that crude protein levels exceeded 5 p. 100 only for the first half of the wet season, as is normal for the Sahel (4). It may be possible to extend the period of high forage quality by seeding native range with forage legumes, such as *Stylosanthes humilis.* Simulation of seeding is accomplished by holding the CPF at 6 p. 100 rather than 3 p. 100 during the third month of the wet season. Seeding results in the project area were encouraging but not conclusive (8), so it cannot be asserted that seeding will in fact produce such a forage quality.

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However, the simulated increase does not seem unduly optimistic.

The extension of the high forage quality period resulted in a 35.5 kg gain over the baseline. The seasonal stocking rates assumed in this simulation correspond to approximately 1.5 simulated animals per hectare during the 3 month period. Therefore, the liveweight increase corresponds to 53 kg $ha^{-1}$ or 1,837 UM $ha^{-1}$ $yr^{-1}$. Initial costs of seeding are estimated at 3,700 UM $ha^{-1}$ (8). With capital costing 10 p. 100 $yr^{-1}$, the operation would begin to show a profit in the third year of operation, assuming that the pasture could be used every year, and that the benefit accrued uniquely to the investor.

Lighter wet season stocking rates were simulated by doubling the baseline wet season herbage allowances. Such higher wet season herbage allowances were at the upper limit of those encountered in the demonstration, corresponding to approximately 6 ha $TLU^{-1}$ $yr^{-1}$. Simulation of this strategy predicted a gain of 75 kg over the baseline. At herbage allowances lower than those of the baseline, the model does not predict any decline in per head performance. This result corroborates initial analysis of the data which found that very high stocking rates were the most productive of liveweight gain per hectare.

# DISCUSSION

## Dry season model

The preponderant influence of time in the model indicates that if nutrition determines animal weight change, some factors other than those measured in the demonstration but which nonetheless correlate with time are the major determinants of dry season animal performance. Three candidates are temperature, intake and digestibility. As temperatures increase during the hot season, greater energy use for thermoregulation could increase weight loss. Lower intake due to lower rates of both passage and digestion would also increase weight loss. A higher fraction of stem in hot season diets could certainly lower rates of passage, yet would not necessarily be detected by the sampling and forage analysis used in the demonstration. Decreasing rates of digestion could result from an exhaustion of the animal's internally cycling nitrogen pool in late hot season. The great liveweight response to supplemental crude protein and the positive influence of browse indicate that such might be the case. Indeed all of these factors require much greater study.

The negative influence of liveweight and condition may be due to the increasing energy content of liveweight gain as liveweight or condition increase (16). It may also indicate that during the dry season heavier or fatter animals find it more adaptive to live off reserves than to forage extensively to obtain an intake of sufficient quality. Smaller or leaner animals would not have this option. This hypothesis would suggest that daily activity patterns should differ between younger, lighter animals and older, fatter animals. It also implies that dry season weight losses are not strictly caused by low forage quality, but may also be a reasonable component of the animal's energetic strategy.

The analysis of variance of the regression residuals indicates that differences between blocks, such as might arise from different herders, peculiarities of the block, etc., did not produce different responses. The lack of differences attributable to weighing data indicates that errors associated with particular dates, such as might arise from weighing the animals after rather than before watering, did not effect the results. Finally, very few of the animals involved deviated systematically from the predicted liveweight change. Those that did deviate in a positive direction, however, might have traits worthy of inclusion in a selective breeding program.

Thus, the large residual variation of 67 p. 100 appears to be noise, inherent in the weighing process or in the methods used to estimate the independent variables. Confidence intervals about estimations of DWTCHG correspond to a range of +/− 1 to 3 kg per month, indicating that errors in the weighing procedure could contribute a large part of the variation embodied in the 95 p. 100 confidence interval of the model. Future research should concentrate on improving the precision of measurement of both animal and vegetation parameters.

## July

The great response of liveweight to supplemental feeding indicates that the supplemental feeding acts to remove some limiting factor to energy digestion rather than to replace forage intake. Whether the important component is energy or protein is difficult to determine from the data. Supplemental crude protein is highly correlated with supplemental energy and can be used in place of UFS without a great loss of explanation. The response to forage crude protein however indicates that nitrogen may be the critical factor.

## Wet season

Unlike during other seasons, both quantity and quality of forage in the wet season are important determinants of animal performance. The negative influence of condition during the wet season reflects compensatory growth. Compensatory growth during the wet season reduces the profitability of supplemental feeding during the dry season. When calculations of liveweights are continued until maximum liveweights are attained, the difference in liveweight between an animal fed during the hot season and July and one receiving no supplement shrinks from 21.1 kg in July immediately after feeding to 7.8 kg in November (Fig. 2).

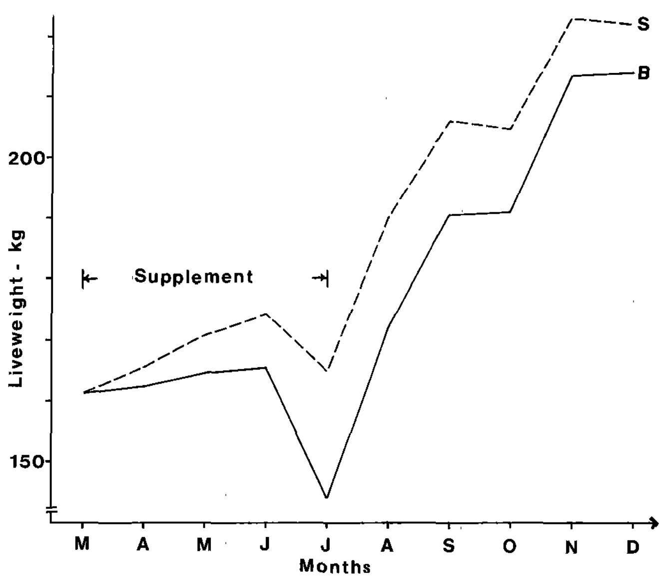


*Fig. 2 : Stimulated liveweight change of supplemented vs baseline animals.*

## Evaluation of different strategies

The ranking of annual liveweight gains in table V suggests that none of the alternate dry season grazing strategies tested improved overall annual animal production. Herbage allowance appeared in the 10 variable dry season model but was not included in the 7 variable model with little decrease in $R^2$. Thus, the provision of at least 300 kg DM ha$^{-1}$ until the end of hot season, daily watering and basic veterinary care compose a very cost-effective strategy of animal production. The provision of this minimum amount of dry matter may, however, be very difficult to achieve, particularly for sedentary herds. Since conservation of a maximum number of animals on a limited amount of forage until the arrival of the rains is the herder's goal, research should concentrate on dry season grazing systems that optimize the use of dry forage for animal survival. Data from this demonstration suggest that at high herbage allowances, daily dry matter losses are also high, often several times greater than consumption estimated as a percentage of liveweight (Fig. 3). If it is impossible to conserve dry matter, it would be useful to understand the interaction between submaintenance intakes during the dry season and compensatory growth during the succeeding wet season.

The profitability of supplemental feeding for meat production depends on the local cost of supplemental feed and the increment of gain attributable to supplemental feeding at the time of sale. Because of compensatory growth this increment decreases over the succeeding growth period. An interesting economic enterprise might be supplemental feeding during the hot season expressly for sale during the wet season when animal prices are generally quite high. For reproductive females supplementation during the hot season may be much more profitable than for meat animals because the supplement can be converted to greater lactation, lower calf mortality and higher weaning weights. The feasibility of this operation deserves study.

The greatest increases in per head production occurred with higher wet season herbage allowances and higher late wet season forage quality. Many Sahelian production systems already employ great dispersal of animals during the wet season. Development projects should identify and alleviate constraints to dispersal. These constraints may be such things as a lack of surface water, but may also include other aspects of household economy such as inadequate herding labor or access to milk markets. At some overall stocking rate it may become advantageous to split herds with sale animals being crowded into smaller pastures to maximize production per hectare while reproductive animals enjoy higher herbage allowances with greater per head

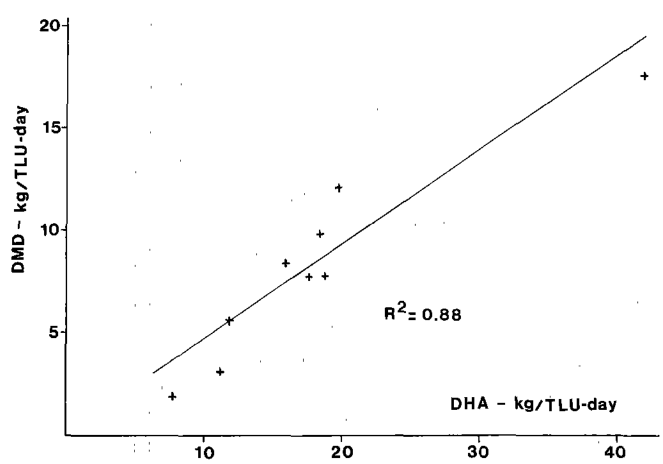


*Fig. 3 : Dry matter disappearance vs daily herbage allowance.*

productivity as measured by calving rate and calf survival.

Increasing late wet season forage quality by the creation of annual legume-grass pastures could be an important improvement. Many local ecological, economic and political considerations govern the feasibility of such range improvements. In some areas it may be easier simply to feed supplemental protein in the late wet season. At that time the animals are physiologically set for production and, in the presence of abundant dry matter, supplemental protein could dramatically increase liveweights or improve rates of conceptions, particularly for cows that calved relatively early in the hot season.

## CONCLUSIONS

The models presented in this paper are only first approximations. Considerably more attention must be given to isolating better predictor variables, particularly for dry season animal responses. Intake and diet quality will certainly be important. The models do, however, permit an evaluation of development alternatives. The models suggest that development efforts should concentrate on providing a minimum amount of dry matter, water and veterinary care during the dry season. Optimizing the use of dry season forage and quantifying the interaction of submaintenance dry season diets with wet season compensatory growth are important research topics. Development efforts should also attempt to increase production by maximizing animal dispersal during the wet season and by improving late wet season diet quality. The profitability of supplemental feeding of meat animals depends on the cost of supplement and the time of sale. Supplemental feeding of reproductive animals before the start of, and possibly during the latter part of the wet season deserves more study. Range improvements should concentrate on improving late wet season quality, and possibly extending the green feed period on more favorable sites. ■

**GREENWOOD (G.).** Evaluation of Sahelian livestock production strategies using regression models of cattle performance. *Rev. Elev. Méd. vét. Pays trop.*, 1986, **39** (1) : 41-50.
**Nutritional, environmental and endogenous factors contributing to young Peulh bull performance on Sahelian annual grass range were studied over a 21-month period at Selibaby, Mauritania. Multiple regression equations estimated animal daily weight change on a monthly basis within seasons. Dry season performance was strongly influenced by the time elapsed in the season, supplemental protein and browse allowance. Transition period performance was strongly influenced by supplemental feeding and browse allowance. Wet season performance was influenced by forage crude protein and herbage allowance. Simulation of changes in the management of cattle showed that no grazing strategy increased per head performance during the dry season beyond that produced with the provision of at least 300 kg DM ha$^{-1}$. Supplemental feeding during the hot season and during the transition period could be profitable for sale animals, though compensatory growth reduces its benefit over time. Wet season growth could be maximized by increasing dispersal of animals and by increasing late wet season forage quality. Important research topics include diet intake and quality, the relation of dry season dry matter disappearence to herbage allowance, and the magnitude of compensatory growth.** *Key words :* Peulh cattle - Bull calf - Grazing - Supplemental feed - Growing - Mauritania - Sahel.

**GREENWOOD (G.).** Evaluación de estrategias de producción de ganado saheliano mediante el uso de modelos de regresión de comportamiento bovino. *Rev. Elev. Méd. vét. Pays trop.*, 1986, **39** (1) : 41-50.
**Durante un periodo de 21 meses se estudió el efecto de los factores nutricionales, ambientales y endógenos sobre el comportamiento de toritos Peulh en una pradera natural anual en Selibaby, Mauritania. Los cambios de peso diario dentro de cada estación fueron estimados por ecuaciones de regresión múltiple en una base mensual. Los factores que más influyeron en el comportamiento variaron de acuerdo a la estación del año, siendo los más importantes, duración de la estación seca, suplementatión, y contenido de proteína cruda del forrage para la estación seca, de transición y húmeda, respectivamente. Simulaciones en el manejo del ganado demostraron que ninguna estrategia de pastoreo mejoró el comportamiento por cabeza más alla de lo producido con la provisión al menos de 300 kg MS ha$^{-1}$. Alimentación suplementaria durante la estación cálida y durante el periodo de transición podría ser ventajosa económicamente en los animales para la venta, aunque el crecimiento compensatorio reduce sus beneficios con el tiempo. El crecimiento en la estación húmeda podria ser maximizado por el aumento en la dispersión de los animales y por la mejoría de la calidad del forraje producido a fines de esta estación. Tópicos importantes de investigación incluyen dieta consumida y calidad, la relación entre la desaparición de la materia seca en la estación seca, la disponibilidad de pasto y la magnitud del crecimiento compensatorio.** *Palabras claves :* Bovino Peulh - Torito - Pastoreo - Complemento alimenticio - Aumento de peso - Mauritania - Sahel.

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