Pasture evaluation under grazing with breeding herds: A methodology for data analysis

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1992.

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Abstract

Pasture evaluation experiments with breeding herds use simple designs; however, efficiency in data manipulation and analysis requires sophisticated and often complex statistical methods. Results from a large grazing experiment, conducted in Carimagua research station, eastern Colombian savannas, for over 6 years, with 325 Zebu x Criollo cows, were used as data source to test different statistical methods for the analysis of reproductive performance. Methodology used for data analysis includes: a) an exploratory data analysis, to determine the minimum acceptable experimental period length for valid statistical inferences; b) the use of MANOVA to analyze continuous variables with repeated measures in time; and c) the use of three statistical procedures to analyze categorical variables: Stratified Analysis using the Cochran-Mantel-Haenszel statistic expressed as a function of the 'traditional' chi-square test (CMH); an Stratified Analysis using the CMH_R, expressed as a function of a 'modified' chi-square test proposed by Brown (1988); and a linear model fit on marginal probabilities. Results of this study suggest that: a) 4 years is the minimum acceptable experimental period length; b) there is a need to accept the use of non-replicated designs for large-scale grazing experiments with breeding herds, thereby using the between-animal variability as a proxy for experimental error; c) the selection of mixed breeding herds provides more generalization capacity to commercial situations although brings complications in data selection, data manipulation and statistical analysis; d) MANOVA is shown as a solid tool of practical use and easy interpretation; e) Stratified Analysis and a linear model fit on marginal probabilities represent a complementary set of tools to make integrated inferences on categorical variables; f) the most sensitive indicators of treatment and site differences were: interval between parturitions calf weaning weight, abortions/cow,

total number of births/cow, total number of weaned calves/cow and the three selected summary parameters.

Evaluación de pasturas con hatos reproductivos bajo pastoreo: Una metodología de análisis estadístico

Resumen

La evaluación de pasturas con hatos reproductivos se basa en diseños experimentales sencillos; sin embargo el manejo y análisis de la información exige del uso de técnicas estadísticas relativamente sofisticadas. Los datos de un experimento reproductivo de más de 6 años de duración, conducido en la estación experimental CIAT-Carimagua, con 325 vacas cebú x criollo, se usó como fuente de información para ofrecer una metodología estadística para el análisis de experimentos reproductivos de gran escala. La metodogía de análisis incluye: a) un análisis exploratorio, para determinar el período experimental mínimo aceptable para lograr inferencias válidas; b) el uso del MANOVA para analizar variables continuas con medidas repetidas en el tiempo; c) el uso del Análisis Estratificado y el ajuste de modelos lineales sobre las probabilidades marginales, para analizar variables categóricas. Los resultados del estudio indican: a) un período experimental de 4 años es suficiente; b) es necesario aceptar el uso de diseños no replicados para este tipo de pruebas de pastoreo a gran escala, lo cual exige utilizar la variabilidad entre animales como una aproximación del error experimental; c) la utilización de hatos de composición heterogénea le brinda mayor capacidad de generalización al experimento; aunque hace más complejo el manejo y análisis de los datos; d) el uso del MANOVA es válido y práctico; e) las técnicas estadísticas seleccionadas en este estudio para analizar variables categóricas se complementan muy bien y brindan la posibilidad de inferencia integral; f) los indicadores más sensibles de diferencias entre tratamientos y sitios fueron: intervalo entre partos, peso de destete de terneros, abortos/vaca, número total de nacimientos/vaca, número de destetos/vaca y los tres parámetros seleccionados de resumen de la producción de carne/vaca.

Authors contribution to the paper:

- Dr. Raúl Vera, present Leader of CIAT's Tropical Pastures Program, was from 1980 to 1990 responsible for pasture evaluation under large-scale beef production systems. He was responsible for the design, implementation and data collection of "Herd Systems Experiment", used as source of information for this study. Dr. Vera read the first draft and made very valuable suggestions to this paper.

- Ms. Maria Cristina Amézquita, Head of CIAT's Biometry Unit, is responsible for this study.

Content

animals; response variables correspond to pasture performance parameters, such as biomass production, pasture quality, pasture persistence, etc. (Mendoza and Lascano 1986). In the second case, the experimental unit is **one** animal or **a group** of experimental animals; response variables correspond to animal production parameters, such as weight gain per animal or per unit area during a given time period, or milk production and milk quality per cow during a given lactation interval (Paladines 1986; Vaccaro 1986). Pasture evaluation experiments under grazing, using beef breeding herds, represent a combination of both categories of grazing trials. Their purpose is to evaluate the **combined** effect of the pasture and pasture/animal management practices required by the pasture, on animal reproductive parameters. The experimental unit is **one cow within a reproductive herd.** Response variables correspond to both, cow performance parameters -such as interval between parturition, weight at conception, calf birth weight, etc.- as well as herd performance parameters -such as conception, abortion and birth rates, weaning rate, calf-mortality rate, etc.-.

The special condition of grazing experiments using breeding herds, needs to be recognized. When compared with classic agricultural research, carried-out with short-cycle crops or with pastures in small-plot cutting experiments, grazing trials with reproductive herds present many differences. In the former, the effect of one or more experimental factors at various levels can be studied under replicated factorial designs, for example; in the latter, given the size of the experimental unit (a breeding herd), non-replicated experiments in space are the norm. In addition, almost inevitably, experimental factors are confounded with management factors whose effects are not the subject of study. For example, the experimental factor "pasture", can produce a change in conception rates, birth rates, and weaning rates, causing then a non pre-determined change --that vary with treatments-- in stocking rate, in its seasonal distribution, and in the animal grazing habits (Houston and Woodward 1966; Lamond 1970; Hennessy and Robinson

Introduction

Since the final products of a pasture are milk, meat or other animal products, the pasture researcher has to recognize that small plot clipping trials and grazing experiments are complementary. It is extremely difficult to assign an economic value to forage except if it is marketed as hay. Therefore, although a given ecotype may be better adapted, persistent and have higher biomass yield than another one, these results are not generalizable until they are confirmed through grazing trials, where a pasture final product is expressed in terms of kg of beef, milk, wool, etc. produced per animal unit or unit area by a given type of animal in a pre-defined time-interval. Pasture evaluation experiments under grazing, using breeding herds as experimental animals represent the most challenging way to evaluate a pasture in terms of its beef production capacity.

Within the scheme used by CIAT's Tropical Pastures Program, pastures evaluation under grazing with breeding herds, designed to measure the effect of an improved pasture in terms of reproductive efficiency in cattle, is only carried-out in a very advanced evaluation stage as it covers several years and is expensive. Pastures that enter this stage are improved grasses, legumes or legume-grass associations that have shown to be adapted to the soil, climatic and biotic conditions, to be resistant to pests and diseases, to posses high level of biomass production under cutting, to be persistent under animal trampling and to have shown a promising performance under weight-gain grazing trials with young steers. (Pizarro and Toledo 1986).

According to 't Mannetje et al (1976), grazing trials can be classified in two main types: a) those which evaluate the effect of management practices on the pasture (studies of grazing systems, stocking rates, grazing pressures), and b) those which evaluate the effect of the pasture on animal production parameters. In the first case, the experimental unit is a paddock with its associated

1979). If all these factors are to be controlled, the experimental design would result in high-level factorials, impossible to implement under grazing. For this reason, pasture evaluation experiments with breeding herds, study not the pasture effect alone, but the effect of "beef production systems", in which there is an **intentional** confounding between experimental factors with pasture/animal management practices associated with the pasture technology being tested (Vera 1982).

It has been recognized that pasture evaluation experiments with breeding systems tend to be of simple design, such as randomized blocks or completely randomized designs, and oriented towards a direct adoption by producers; however efficiency in data manipulation and analysis requires the use of sophisticated and often complex statistical methods (O'Rourke, 1986). Breeding systems have reproduction, survival and growth as interactive components, each expressed by a set of response variables that need to be carefully selected and estimated; therefore, extreme care in data depuration and clear rules for parameter estimation are required (Amézquita 1982). For statistical analysis purposes, response variables can be grouped in three classes that require different statistical treatment: a) continuous variables with repeated measurements in time, such as cow weight at conception; b) summary parameters of continuous nature, with one value per animal during the experimental period, such as total beef production per cow; and c) summary parameters of categorical nature, such as total number of births per cow.

The purpose of this paper is to contribute to the understanding of the inner complexity of grazing trials with breeding herds, by presenting a methodology for its statistical analysis. Source of information for this study corresponds to data recorded by a 6.25-year reproductive experiment, the "Herd Systems Experiment" conducted at the CIAT's Carimagua Experimental Station, eastern Colombian savannas, between April 1982 and December 1988 (Vera

1982; CIAT Tropical Pastures Program Annual Reports 1983-1990). This experiment evaluates in two contrasting sites of the experimental station, two savanna-based beef production systems in which improved grass-legume associations are incorporated, comparing them with the local beef production system.

Methodology

Source of information

The "Herd Systems" experimental design corresponds to a non-replicated factorial with two factors: **production system** (at 3 levels: 1) savanna-based; 2) savanna-based plus 800m^2 per animal unit of an improved grass-legume association; and 3) savanna-based plus 1600m^2 per animal unit of an improved grass-legume association); and **site** (at 2 levels: 1) Yopare, loamy soil and 2) La Alegria, sandy soil) (Vera 1982).

The initial number of experimental cows was 325, Zebu x Criollo crosses typical from the region, grouped in six herds, one per treatment within each site, with variable number of cows per herd (table 1). Herds were made-up by adult cows of variable age (table 2) and of different physiological status (table 3), in order to represent the composition of a typical commercial herd of the region. Their initial weight is shown in table 4. Cow culling was performed when a cow presented reproductive problems, not caused by the treatment, or when reached 12 years of age. Continuous joining was selected for all herds.

Periodic measures recorded on the animals include:

- Liveweight of all animals every 2-3 months.
- Cow reproductive status (diagnosed through rectal palpation), every 2-3 months.
- Dates of calf abortion, birth, death and death cause.
- Cow culling weight.

- Calf birth weight.

Statistical analysis methodology

Definition of animal performance parameters. Reproductive data from grazing experiments have a wide range of potential response variables. Calf mortality, weaning rate, weaning weight and growth rate of progeny are of most consequences to the producer; however, earlier and more sensitive indicators are conception and birth, with conception rate among lactating animals been recognized as providing the best early indication of response to a treatment (O'Rourke and Howitt, 1986). Unfortunately, in our "Herd Systems Experiment", conception among lactating animals did not occur. Therefore, the following response variables were selected to represent useful indicators to the researcher and the producer.

Cow performance parameters:

- **Cow weight adjusted to "non lactating-non pregnant" (CWA)**, in kg.

  $CWA_{ij} = W_i - \lambda_i + \lambda_j$, where

  CWA_{ij} = cow weight adjusted from physiological state i (present state) to physiological state j (non-lactating non pregnant, the most frequently observed state)

  W_i = observed cow weight at its present state (state i)

  λ_i = effect of state i within a given site, treatment and season, estimated as (mean weight at state i)-(overall mean weight) for cows in that given site, treatment and season.

  λ_j = effect of state j within a given site treatment and season, estimated as: (mean weight at state j)-(overall mean weight) for cows in that given site, treatment and season.

- *Cow weight at conception (CWCONC)*, in kg: the nearest cow weight to the estimated conception date (that is, parturition date - 283 days).

- *Interval between parturitions (IBP),* in days, estimated as the difference between two contiguous parturition dates, or the difference between the expected calving date and the previous parturition date.
- *Cow culling weight (CCW)*, in kg: recorded at the time of event.

Calf performance parameters:

- *Calf birth weight (CALFBW)*, in kg.
- *Calf weaning weight (CALFWW)*, in kg: adjusted to 9 months of age through regression of calf weight vs calf age.
- *Calf growth rate from birth to weaning (CALFGR)*, in kg/day: estimated, for each calf, as the slope of the linear regression of weight vs age.

Summary parameters:

- *Total production of weaned calves/cow (TPWCC)*, in kg.
- *Total production of calves/cow (TPCC)*, in kg
  TPCC = TPWCC + last weight of lactating calf
- *Total beef production/cow (TBEEFPC)*, in kg
  TBEFFPC = TPCC + cow culling weight (or cow weight at the end of the experiment).
- *Total number of births/cow (0,1,2,3...6);* categorical variable
- *Total number of abortions/cow (0,1,2...);* categorical variable (*)
- *Total number of calf deaths/cow (0,1,2...);* categorical variables (*)
- *Total number of weaned calves/cow (0,1,2,..7);* categorical variable

Sources of variation on animal performance parameters. Three types of sources of variation affect animal performance parameters in this type of long-term reproductive experiment. a) **Experimental factors**, imposed by the researcher, in our case "soil type" (at 2 levels) and "beef production system" (at 3 levels). b) **Environmental factors**, as

(*) *These two variables, as defined, were not submitted to statistical analysis due to small cell frequencies. However, when expressed as binary variables (yes, no), the statistical analysis was possible.*

"season", not imposed by the researcher but whose effect needs to be taken into consideration in the analysis (at 2 levels: dry season, from January to April, and rainy season, from July to November). In statistical terminology, "season" can be considered a repeated-measurement factor and it will be treated as such for data analysis purposes. c) **Animal factors**, such as "cow age", "cow physiological stage" in terms of pregnancy and lactation, "calf weaning age", or "calf sex". As the distribution of cows according to their age at the beginning of the experiment (table 1) shows that all are **adult** cows, older than 4 years, "cow age" was not considered a source of variation in the analysis. **"Cow lactating state"** was not considered a source of variation for cow weight at conception nor for calving interval. The reason is that in these extensive systems, calving intervals are long (> 18 months), implying that very few cows conceive while lactating, and those that do so, become pregnant at advanced stages of lactation (table 3). This is confirmed by previous experiences, in which weight at conception and calving intervals are similar in lactating and dry cows (Amézquita, 1986). Periodic cow weights, however, were adjusted by the cow physiological stage. As calf weaning age varied between 8.0 and 9.5 months across treatments, calf weaning weight was adjusted at 9 months of age. "Calf sex" was not considered a source of variation for calf birth weight nor for calf weaning weight because, under low-nutrition conditions as in the present case, sexual differences are not expressed.

Exploratory data analysis. Reproductive experiments typically extend over at least three breeding cycles to sample a range of seasons. As some treatments only exhibit their superiority under adverse seasonal conditions, long term experiments are required. As the experimental unit is **one cow within a breeding herd observed through the experimental period**, it is highly desirable to concentrate the analysis on those cows with complete reproductive evaluations during the experimental period considered. However, in our case, only 97 out of the initial 325 cows completed the 6.25 years of experiment; the rest were discarded at different times for health reasons (not related to the experiment) or due to age. Therefore, in order to keep a balance between the value of long-term reproductive records and sufficient number of cows per treatment, an exploratory data analysis was carried-out, to determine the minimum acceptable experimental period length for valid statistical inferences, based on two criteria: a) stability of observed trends in animal production parameters, and b) representability of the sub-sample of cows considered for data analysis.

Inferential statistical analysis. The methodology for inferential analysis considers the nature of the experimental design as well as the nature of animal performance parameters. As the experiment was a (2x3) factorial, non-replicated in space, the error term used was the variability between cows within a given production system and site. Although this error term permits ANOVA and MANOVA calculations, the generalization capacity of the experimental results is restricted to the specific site conditions and beef production systems considered.

Analysis of continuous variables with repeated measures in time. A multivariate analysis of variance (MANOVA) was performed for each parameter, using a 2-dimensional response vector Y, where

Y = [dry season performance, rainy season performance]

under the model:

$$Y = \mu + S_i + T_j + (SxT)_{ij} + e_{ijk}$$

where,

Y = response vector

μ = overall means vector

S_i = site i effects vector

T_j = treatment j effects vector

$(SxT)_{ij}$ = site i x treatment j interaction vector

e_{ijk} = error vector (variability between cows 1,..,k within site i and treatment j)

The Wilks Lambda Statistic, Λ, was used to compare site and treatment vectors. The decision to use MANOVA with seasonal performance values as the response vector, instead of a traditional ANOVA model including "season" as a source of variation, obeys to various reasons: a) individual animal responses during subsequent musters throughout the year are not independent; so the use of an split-plot ANOVA model including "season" and "muster (season)" as repeated measurement factors would be inappropriate; b) additionally, animal performance parameters under Carimagua conditions exhibit a high heterogeneity of variance between dry and wet season (Amézquita, 1986). This would also make inappropriate the inclusion of "season" as a source of variation in an ANOVA model.

Analysis of summary parameters of continuous nature. The same model described above was utilized under a univariate mode using standard ANOVA.

Analysis of categorical variables. Methods of analysis for categorical variables range from use of individual contingency tables to ANOVA and log-linear modelling (Mayer, 1986). Reviews of available analytical methods and comparisons between these are not common, although Cox (1970) gives a theoretical overview. For simpler experimental designs, chi-square and some non-parametric tests have been used, although results tend to be similar to those from the more widely used ANOVA (Haseman and Kupper, 1979). For more complex designs, such as factorials, chi-square tests are not sufficient and other techniques have been applied Mayer (1986) reports the use of ANOVA on the raw data (RAW. ANOVA), ANOVA using arcsine transformation on cell proportions when the experiment is replicated (ARCSINE. ANOVA), and linear model fit using LOGIT (a ratio of the logs of cell proportions) (Grizzle, Starmer and Koch, 1969), finding a close agreement between LOGIT and RAW.ANOVA for the analysis of binary data, although LOGIT is the preferred technique.

In this study, three methods were used for the analysis of categorical response variables:

a) Stratified Analysis, using the Cochran-Mantel-Haenszel Statistic (CMH) (Mantel and Haenszel, 1959) to test the homogeneity of distribution for the response variable between treatments across multiple strata (sites, in this case). This method was used for the analysis of binary response variables as well as for k-level categorical response variables. If a CMH statistic is significant, then there is heterogeneity in the distribution of the response variable between treatments in at least one stratum. An advantage of the CMH statistic is that it does not require a large sample size in each stratum: it requires only a large overall sample size.

b) The second method applied was an Stratified Analysis using a CMH_R statistic, based on a 'modified' chi-square statistic, X^2_R, proposed by Brown (1988). This X^2_R is used to compare rates (birth rates, weaning rates, abortion rates, calf mortality rates) among treatments. The CMH_R statistic, calculated as the sum of the X^2_R on each site, tests the homogeneity of the response rate between treatment across sites. X^2_R, is calculated as described in Brown's paper (1988), as follows:

$$X^2_R = T_2 - T^2_1/T_0 \quad \text{, distributed as } X^2_{g-1}$$

where,

g = number of treatments whose response rates (R_i) are being compared.

R_i = overall response rate for treatment i (birth rate, for example).

W_i = inverse of the estimated sampling variance of R_i, calculated as:

$$W_i = (n_i-1)/(R_i(1-R_i)+\sum_{j=0}^{k}{}_j(j-1)p_j),$$

where, n_i = number of cows in treatment i
k = maximum number of births per cow
p_j = proportion of cows with j births

T_0 = sum of the W_i values across treatments whose response rates are being compared.

T_1 = Sum of the R_iW_i products across treatments.

T_2 = Sum of the $R^2{}_iW_i$ products across treatments.

c) The third method used was a linear model fit on marginal probabilities (or cell proportions) instead of on the logits as used by the LOGIT model. Although both methods provide the same results, the use of cell proportions is easier to interpret. The model used was:

$$[p_1, p_2, \ldots p_{k-1}] = \mu + S_i + T_j + (SxT)_{ij}$$

cell proportions for a k-level categorical variable; overall mean; site effect; treatment effect; site x treatment interaction effect

Results and Discussion

"Herd Systems Experiment" has been a rich source of data for testing and applying alternative statistical techniques for the analysis of reproductive performance of beef cattle in a long-term set-out. Results, product of the analysis, are of methodological and practical nature and have important implications concerning the design of this type of research, its recommended experimental period length, type of response variables to be submitted to statistical analysis, and statistical methods found useful and of practical application in the analysis of animal reproductive parameters, either of continuous or categorical nature.

Results will be discussed around four main issues:

- Implications related to the Experimental design.
- Exploratory data analysis results.
- Methodology and practical results from the analysis of continuous variables with repeated measures in time.
- Methodology and practical results from the analysis of categorical response variables.

Implications related to the Experimental design

An outcome of interest from both a practical and a methodology point of view, is the detection of statistically significant differences between experimental sites and a significant site x treatment interaction in many of the animal performance parameters considered (it is recalled that the two sites represent contrasting environmental conditions within the same experimental station). From a practical point of view, these results have confirmed the anecdotal evidence of differences in animal productivity in savanna-based systems located in "loamy" vs. "sandy" soils, with distinct pasture performance in terms of animal productivity. From a methodological point of view, it calls the attention of researchers to the very real possibility of finding significant interaction between pasture treatments and intended replicates (sites, in this case) in large-scale grazing experiments, thereby forcing the use of non-replicated experiments, utilizing the between-animal variability as a proxy for experimental error. This issue has been largely discussed in the literature (Martinez Garza, 1991), but upon which there is no generalized agreement.

Methods used for selection and initial allocation of experimental animals to treatments were compatible with the objectives of the research project. In this case, a mixed composition of the experimental herds, both in terms of age of cows as in its physiological state, relate very well to commercial practice, giving results of wide generality with little added cost. We have to accept that data manipulation, statistical analysis and interpretation is more complex and demands a very well-thought strategy when compared to the case where homogeneous groups of experimental animals are chosen.

Cow replacement policy in "Herd Systems Experiment" is adequate for maintaining stocking rates and herd composition; however it is important to point-out that for data analysis purposes, the benefit of using cows with complete reproductive records through the experimental period considered, implies a high percentage of data loss.

Exploratory data analysis results

This analysis was performed to determine the minimum acceptable length for the experimental period in terms of stability of observed trends in animal production parameters and representativity of data sample for inferential analysis purposes. Trends in animal performance parameters estimates (figures 1, 2, 3a, 3b, 4 and 5) show consistency in stabilizing from the 4th year onwards. Also, the sub-sample of 178 experimental cows included in the 4-years period (table 5) maintains the same herd composition in terms of age, physiological stage and initial weight when compared with the original experimental population (tables 6, 7, 8 as compared with tables 2, 3, 4). This guarantees valid statistical inferences. As a result, a 4-year experimental period (April 1982-April 1986) is considered sufficient to study the effect of experimental and non-experimental factors on animal production parameters in this long-term set-out. Tables 9a and 9b show overall descriptive statistics for animal production parameters during the 4-year experimental period analyzed. Overall means for animal production parameters reflect the low nutrition condition of beef cattle in the eastern Colombian savannas in general.

Results from the analysis of continuous variables with repeated measures in time

The use of MANOVA for the analysis of continuous variables measured during the dry season as well as in the rainy season, utilizing as response vector the seasonal performance of each animal, solves many problems related to the violation of statistical assumptions when an ANOVA is utilized. This assumptions are: a) independence of repeated measures --which is not held in long-term reproductive experiments--, and b) homogeneity of variance across sources of variation considered in the ANOVA --which is not true when "season" is included as an additional source of variation in an Anova model. Therefore, the use of MANOVA to analyze animal performance parameters, of continuous nature and with repeated measures in time, represents a solid and valid statistical technique, of relatively easy interpretation and practical use.

The MANOVA performed on cow performance parameters, such as cow weight adjusted by physiological state, cow weight at conception and interval between parturitions (tables 10a, 10b, 10c) shows that cow weight was not affected by treatment nor by site, remaining rather constant around a value of 322 kg during the dry season and 330 kg during the rainy season. Cow weight at conception was not affected by treatment, although there was a significant difference between sites. However, the interval between parturitions did show a significant reduction due to the improved beef production systems (treatments 2 and 3), when compared with the control (treatment 1), both for cows conceiving during the dry season as well as for those conceiving during the rainy season. The calving interval was significantly different between sites, but there was no treatment x site interaction.

MANOVA results for calf performance parameters (birth weight and weaning weight) show that statistically significant differences between sites exist for both parameters. Although the effect of treatment is not reflected on calf birth weight, it does significantly increase calf weaning weight.

Growth rate for calves was not statistically analyzed due to the small number of observations available. As this parameter was estimated by the slope of the regression of calf weight vs calf age, calves with less than 3 weight values were not included; additionally, as MANOVA requires complete pairs of values for any cow entering the analysis, in this case pairs of values for dry season calf growth rate and rainy season calf growth rate, then the total number of cows available for the MANOVA was only 10.

Results from the analysis of categorical variables

Results show that the three methods applied to analyze categorical variables complement each other, offering the researchers a complete set of statistical tools for their decision-making.

The Stratified Analysis, offers the possibility of making inferences across multiple contingency tables (or across strata), which is more efficient than the traditional use of individual chi-square tests for each contingency table. As it was pointed-out by Brown (1988), while the traditional chi-square test may detect differences among treatments in terms of the **distribution** of the response variable, it is possible that his 'modified' chi-square test shows no significant differences among treatments overall response rate. Results of the Stratified Analysis performed on "number of births per cow" (table 11c) and on "number of weaned calves per cow" (table 11d) confirm Brown's remark. Improved beef production systems (treatments 2 and 3) exhibit higher percentages of cows with 3 or 4 calves during the 4-years of experimental treatment than the control treatment (treatment 1); however, observed differences in calving rate among treatments are not statistically significant. The same results apply to "number of weaned calves per cow" (table 11d). In the case of binary response variables, such as 'abortion/cow (yes, no)' or 'perinatal death/cow (yes, no), the CMH or the CMH_R statistics test the same hypothesis, ie. the homogeneity of "success" rates between treatments across sites. A significant effect of treatment on the reduction of abortion rates across sites was found (table 11a); however this was not the case in perinatal death rates (table 11b), implying that although improved beef production systems reduced the abortion percentage, therefore increasing calving percentages, they could not significantly reduce the incidence of calf death soon after birth.

The use of a linear model fit to study treatment, site and interaction effects on the marginal probabilities, provides a model as powerful as LOGIT but of easier interpretation. Results of this analysis (tables 13a and 13b) reinforce the Stratified Analysis results when using the CMH statistic. That is, improved beef production systems significantly increase the proportion of cows with 4 calves and decrease the proportion of cows with 2 calves, when compared with the local production system. Similarly, there was a significant increase in the proportion of cows with 3 weaned calves and a reduction (higher in site 1 than in site 2) in the proportion of cows with only one weaned calf, when compared with the control treatment.

Conclusions

This study permits methodological and practical conclusions regarding the design, data analysis methodology and interpretation of pasture evaluation trials under grazing with breeding herds.

From a methodological point of view, the following conclusions may be drawn:

1. Pasture evaluation trials under grazing with breeding herds, although of simple design, require sophisticated and often complex procedures for data manipulation and statistical analysis. Extreme care should be given to selection and estimation of animal performance parameters to be analyzed, selection of appropriate data set for analysis purposes, determination of sound statistical methodology and extrapolation of results.
2. The detection of statistically significant differences between sites (intended replicates within the experimental station) and significant site x treatment interaction in some of the animal performance parameters analyzed calls the attention of researchers to the need of accepting non-replicated designs for large-scale grazing experiments, thereby forcing the use of between-animal variability as a proxy for experimental error.
3. The selection of experimental herds of mixed composition, both in terms of cow age as in terms of their lactating/pregnancy status, provides the experiment with more generalization capacity to commercial situations, although brings complications in data selection, data manipulation and statistical analysis. Also the benefit of using experimental animals with complete reproductive history for statistical analysis purposes, implies a certain amount of data loss when mixed herds are contemplated.
4. This study suggests that an experimental period of 4 years is considered the minimum acceptable length for large-scale grazing experiments with breeding herds.
5. The use of MANOVA statistics to analyze continuous animal production variables with repeated measurements in time was found statistically valid, of practical implementation and of easy interpretation.

6. The use of Stratified Analysis together with linear model fitting on marginal probabilities for the analysis of categorical responses is methodologically innovative for this type of experiments. These techniques represent a complementary set of statistical tools, of relatively easy application and interpretation, and offer the researcher the possibility of making integrated inferences.
7. The use of summary production parameters helps in the transference of results to researchers and producers.

From a point of view of pasture evaluation research with breeding herds, the following conclusions may be drawn:

1. Important differences in animal productivity were detected and quantified in savanna-based beef production systems located on loamy vs sandy soils.
2. Animal production parameters found as more sensitive indicators of treatment and site differences were:
   - Interval between parturitions (days)
   - Calf weaning weight (kg)
   - Abortions/cow (yes, no)
   - Total number of births/cow (0,1,2,3,4...)
   - Total number of weaned calves/cow (0,1,2,...)
   - Total production of weaned calves/cow (kg)
   - Total production of calves/cow (kg)
   - Total beef production per cow (kg)
3. The following animal production parameters were found as non-sensitive indicators of treatment differences, although they did detect site differences.
   - Cow weight at conception (kg)
   - Calf birth weight (kg)
4. The following animal production parameters were found relatively insensitive response indices for research.
   - Cow weight, adjusted by physiological state (kg)
   - Perinatal deaths/cow (yes, no)

Acknowledgements

To Mr. Germán Lema, from CIAT Biometry Unit, for his very valuable support in handling and maintaining the "Herds System Experiment" database.

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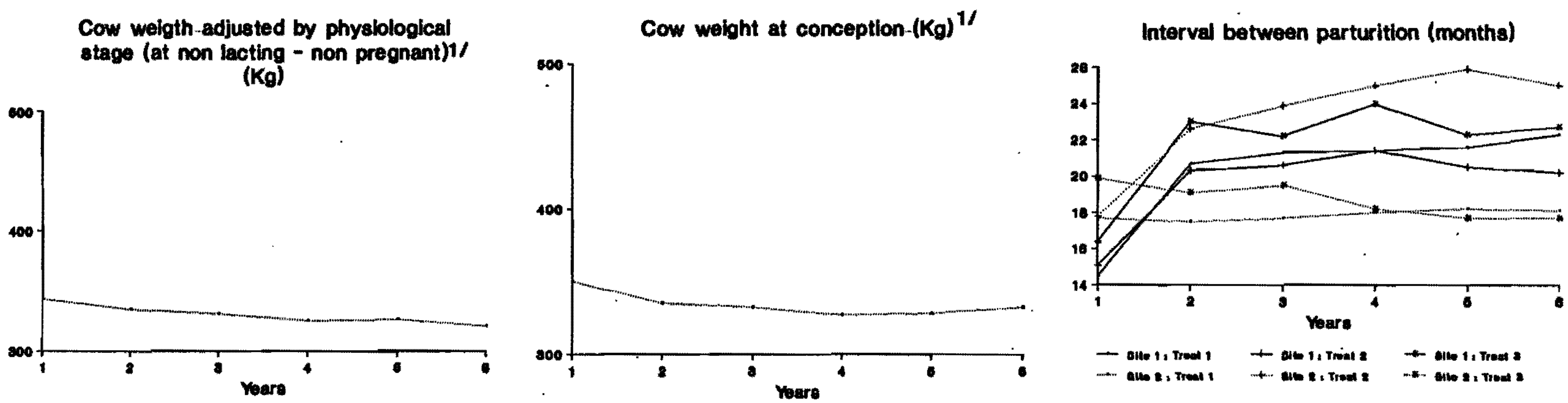
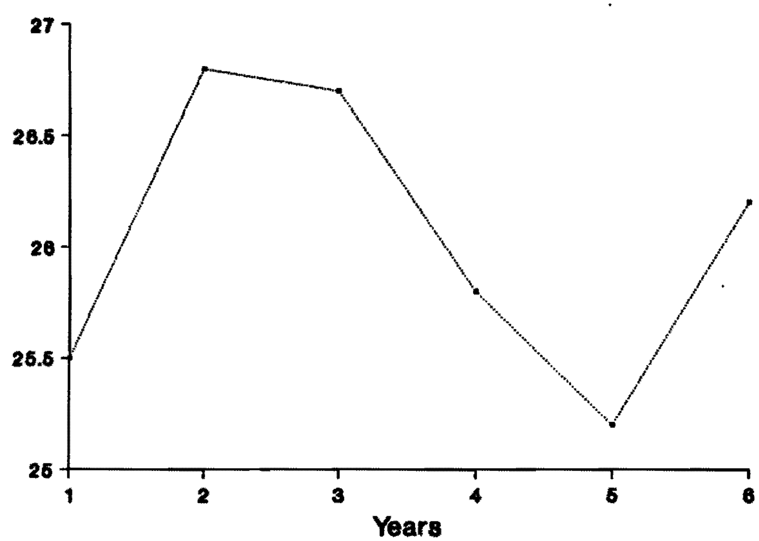
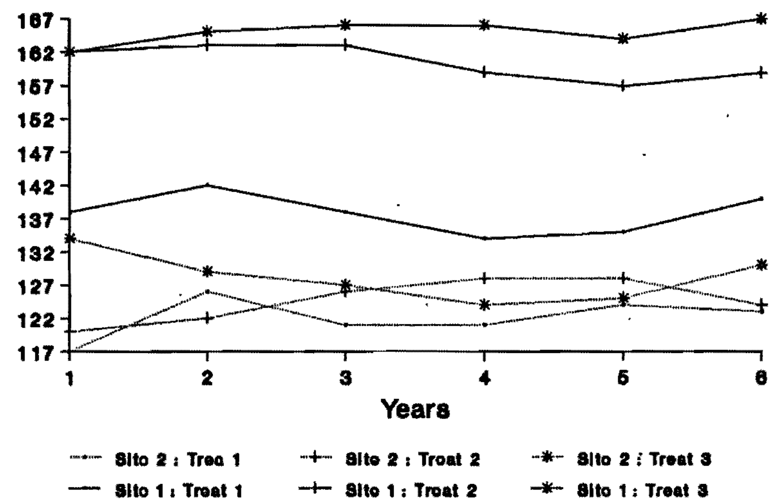
Figure 1: Cow performance parameters estimated after n years of experimental treatment. (n=1,2,3,...,6.25 years)



1/ plotted values correspond to overall means, as the difference between treatment means is negligible.

Figure 2: Calf perfomance parameters estimated after n years of experimental treatment (n=1,2,3,....,6.25 years)





1/ plotted values correspond to overall means, as the difference between treatment means is negligible.

Figure 3a: Accumulated beef production after n years of experimental treatment (n= 1,2,3,...6.25 years)

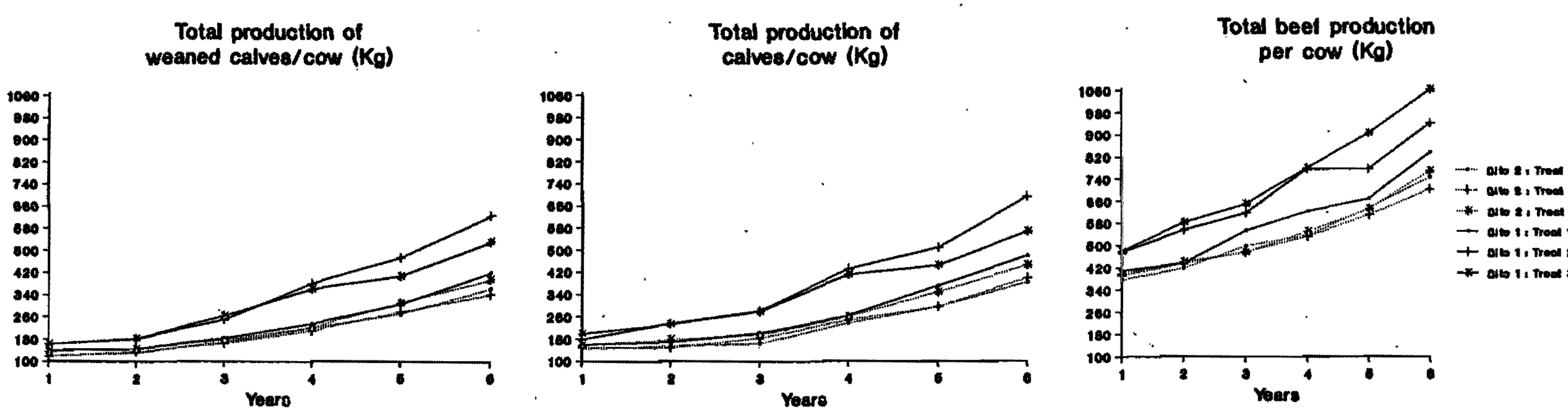
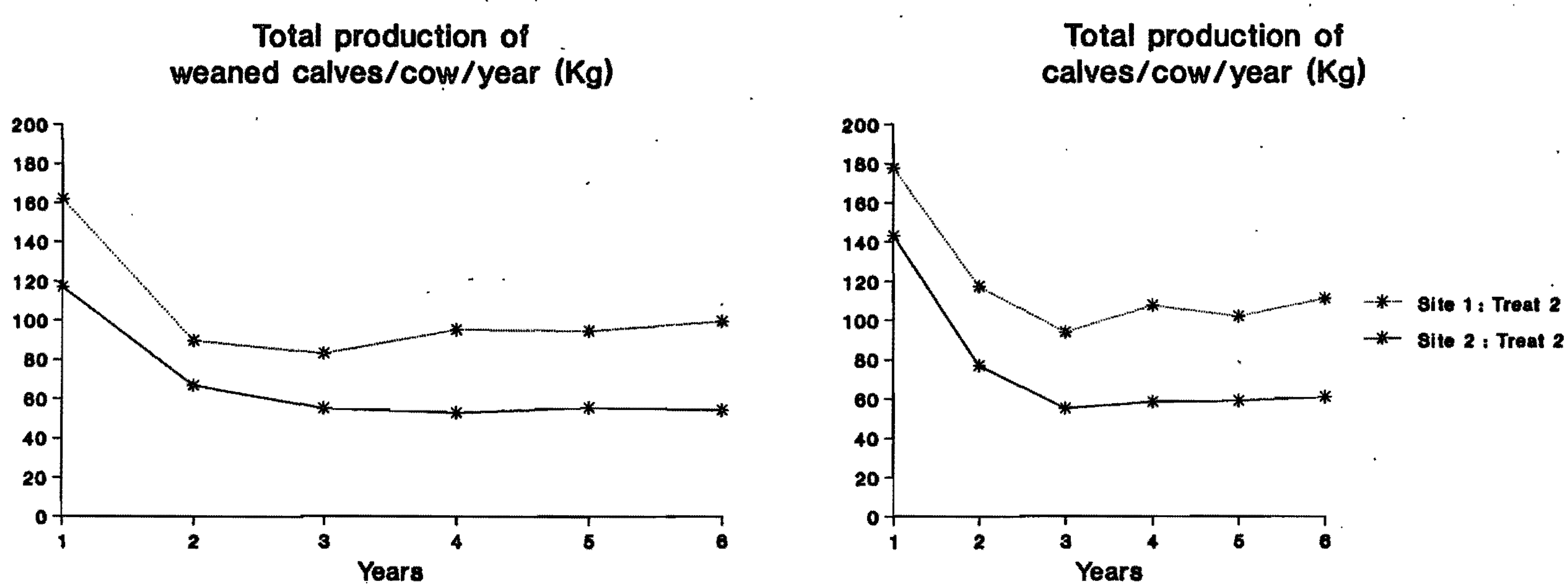


Figure 3b: Beef production/year estimated after n years of experimental treatment (n= 1,2,....,6.5 years)[1/]



1/ only treatment 2 is plotted for both experimental sites. The other two treatments were not plotted as their trend is similar to that of treatment 2.

Figure 4: Annual birth rate estimated after n years of experimental treatment (n= 1,2,3,....,6.25 years)

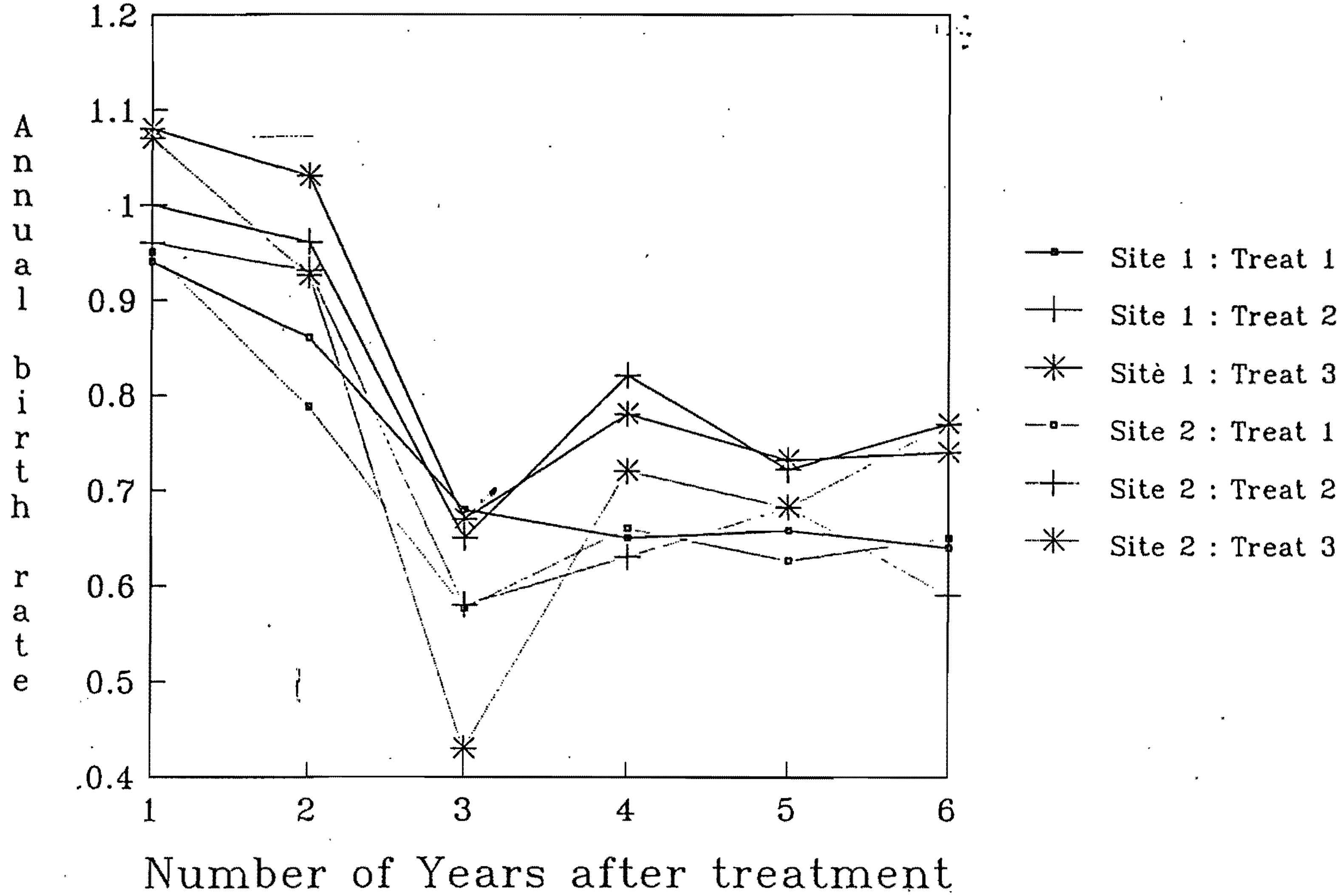


Figure 5: Annual weaning rate estimated after n years of experimental treatment (n= 1,2,3,.....,6.25 years)

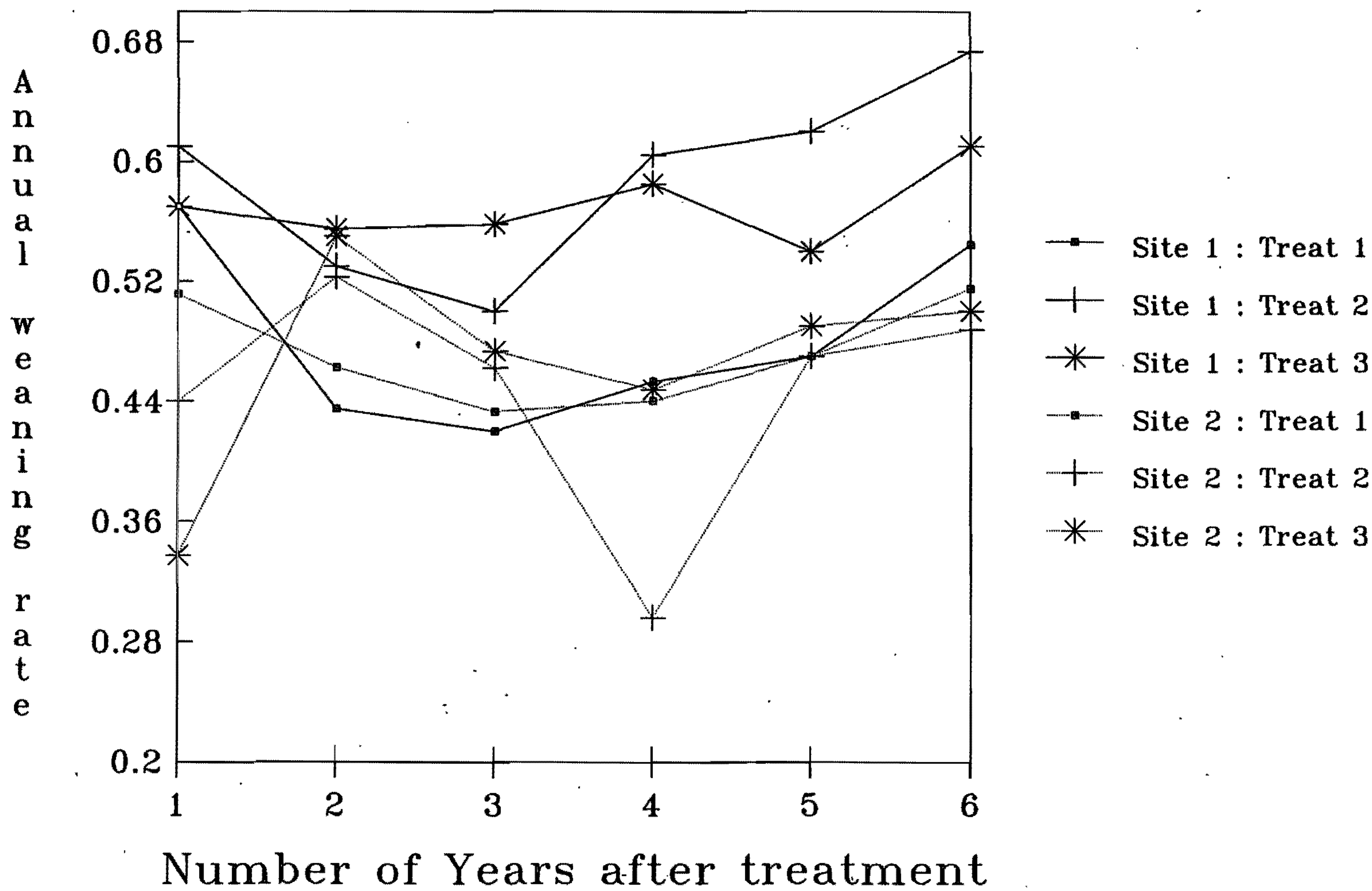


Table 1.: Initial number of experimental cows - "Herd Systems Experiment", Carimagua (April 1982-December 1988).

Treatment	Site 1	Site 2	Total
1	53	51	104
2	52	64	116
3	49	56	105
Total	154	171	325

Table 2.: Distribution of cows by their age at the beginning of the experiment (April 1982)

Age (years)	Site 1			Site 2			Total	
	Treat 1	Treat 2	Treat 3	Treat 1	Treat 2	Treat 3	N	%
4	6	7	8	10	15	13	59	18.2
5	11	6	7	9	14	8	55	17.1
6	7	11	9	4	9	9	49	15.0
7	12	12	10	13	9	13	69	21.1
8	7	6	6	13	10	9	51	15.7
9	5	8	5	2	6	4	30	9.2
10	5	2	4	-	1	-	12	3.7
Total	53	52	49	51	64	56	325	100%

Table 3.: Distribution of cows by their physiological state at the beginning of the experiment (April 1982)

Physiological State	Site 1						Site 2						Total	
	Treat 1		Treat 2		Treat 3		Treat 1		Treat 2		Treat 3			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1. Non lactating/ non pregnant	15		13		12		24		29		21		114	35.1
2. Non lactating, <4.5 months pregnancy	1		3		2		-		2		2		10	3.1
3. Non lactating ≥4.5 months pregnancy	12		8		14		16		19		23		92	28.3
4. Lactating non pregnant	25		28		21		11		14		10		109	33.5
Total	53		52		49		51		64		56		325	100.0

Table 4.: Cow weight (kg) at the beginning of the experiment (April 82)

Site/ Treatment		N	Non adjusted weight (kg)			Weight adjusted by physiological stage (at "non lactating - non pregnant")		
			Mean (Kg)	SD (kg)	CV (%)	Mean (kg)	SD (kg)	CV (%)
Site 1	Treat 1	53	309.6	45.0	14.6	307.6	42.8	13.9
	Treat 2	52	314.2	42.9	13.7	311.9	35.2	11.4
	Treat 3	49	324.0	47.0	14.5	316.4	42.4	13.8
Site 2	Treat 1	51	326.9	51.1	15.6	328.7	45.4	14.8
	Treat 2	64	324.4	46.0	14.2	326.1	37.9	12.3
	Treat 3	56	321.0	44.5	13.9	323.0	37.1	12.0
	Total	325	320.1	46.1	14.4	319.0	40.1	13.0

Table 5.: Number of cows with complete reproductive history after n years of experimental treatment. (n=1,2,...,6.25 years)

Experimental period (years, staring on April 82)	Site 1			Site 2			Total No. of cows	Culling %	
	Treat 1	Treat 2	Treat 3	Treat 1	Treat 2	Treat 3		Based on previous year	Based on initial number of cows
1	49	51	49	43	45	45	282	0.13	0.13
2	45	49	44	40	43	40	261	0.07	0.20
3	38	42	43	30	31	31	215	0.18	0.34
4	32	34	35	25	28	24	178	0.17	0.45
5	24	26	29	15	24	17	135	0.24	0.59
6.25	15	25	18	11	17	11	97	0.28	0.70

Table 6.: Distribution of cows by their age at the beginning of the experiment. Sub-Sample: 178 cows with 4-years reproductive history.

Age (years)	Site 1			Site 2			Total	
	Treat 1	Treat 2	Treat 3	Treat 1	Treat 2	Treat 3	N	%
4	3	6	8	5	9	5	36	20.2
5	10	6	7	6	8	3	40	22.5
6	5	8	6	1	6	6	32	18.0
7	8	9	9	9	5	7	47	26.4
8	4	2	4	4	0	3	17	9.6
9	2	3	1	-	-	-	6	3.3
Total	32	34	35	25	28	24	178	100.%

<u>Table 7</u>.: Distribution of cows by their physiological status at the beginning of the experiment. Sub-sample: 178 cows with 4-years reproductive history.

Physiological State	Site 1						Site 2						Total	
	Treat 1		Treat 2		Treat 3		Treat 1		Treat 2		Treat 3			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1. Non lactating/ non pregnant	12		9		7		12		14		9		63	35.4
2. Non lactating, <4.5 months pregnancy	-		1		1		-		2		1		5	2.8
3. Non lactating ≥4.5 months pregnancy	7		6		9		7		6		8		43	24.2
4. Lactating non pregnant	13		18		18		6		6		6		178	37.6
Total	32		34		35		25		28		24		178	100.0

Table 8.: Initial weight of cows. Sub-sample: 178 cows with 4-years reproductive history

Site/ Treatment		N	Non adjusted weight (kg)			Adjusted by physiological stage (at non lactating - non pregnant)		
			Mean	SD	CV	Mean	SD	CV
Site 1	Treat 1	32	310.7	46.9	15.1	297.3	42.1	14.2
	Treat 2	34	313.9	46.4	14.8	295.3	40.7	13.8
	Treat 3	35	320.1	49.5	15.5	313.9	43.5	13.9
Site 2	Treat 1	25	321.9	57.6	17.9	336.7	49.3	14.6
	Treat 2	28	311.9	45.8	14.7	326.7	38.8	11.9
	Treat 3	24	309.7	42.8	13.8	325.3	26.9	8.3
	Total	178	314.8	48.3	15.3	314.2	41.0	13.1

Table 9a.: Overall Descriptive Statistics for continuous variables
Sub-sample: 178 cows with 4-years reproductive history.

Parameter		N	Mean	Minimum	Maximum	CV [1] (%)	Pure CV [2] (%)
On Cows							
. Initial liveweight, adjusted at "non-lactating/non-pregnant"	(kg)	178	314.2	210.2	459.9	13.8	13.0
. Cow liveweight at conception	(kg)	320	327.4	229.0	456.0	13.1	12.7
. Interval between parturition	(months)	330	20.7	10.2	40.4	30.0	27.0
. Culling weight	(kg)	15	299.3	215.0	400.0	17.2	12.8
On Calves [3]							
. Birth liveweight	(kg)	275	26.1	18.0	38.0	14.2	13.1
. Weaning liveweight	(kg)	343	143.3	75.0	227.0	20.4	16.0
. Weaning age	(days)	347	261.5	181.0	285.0	13.5	13.6

1/ CV calculated from row data ($CV = \frac{\text{S. Deviation}}{\text{Mean}} \times 100$)

2/ CV calculated from the ANOVA ($CV = \sqrt{\overline{\text{MSError}}} \times 100$)

3/ Although the total number of calves born was 416, not all have records on birth liveweight, weaning age and weaning weight.

Table 9b.: Overall Descriptive Statistics for summary parameters.
Sub-sample: 178 cows with 4-years reproductive history.

Parameter	N	Mean	Minimum	Maximum	CV [1/] (%)	Pure CV [2/] (%)
. Total production of weaned calves/cow (kg)	178	280.9	88.0	557.0	41.5	33.0
. Total production of calves/cow (kg)	178	317.4	100.0	692.0	42.4	33.7
. Total beef production/cow (kg)	178	640.7	353.0	1067.0	23.3	17.3
. Total beef production/cow/year (kg)	178	162.2	89.4	270.1	23.2	17.3

1/ CV calculated from row data ($CV = \frac{\text{S. Deviation}}{\text{Mean}} \times 100$)

2/ CV calculated from the ANOVA ($CV = \sqrt{\text{MSError}} \times 100$)

Table 10a: MANOVA Results, using as response vector Y
Y = [dry season response, rainy season response]

Response Variable: Cow weight adjusted to "non-lactating/non-pregnant"

Source of variation	df	Dry Season F	(prob) 1/	Rainy Season F	(prob)	Wilk's Lambda Statistic	F	(prob)
Site(S)	1	0.04	(0.85)	0.02	(0.88)	0.99	0.84	(0.43)
Pasture(P)	2	0.01	(0.99)	0.00	(0.99)	1.00	0.16	(0.96)
S x P	2	0.08	(0.93)	0.00	(0.97)	0.97	1.42	(0.23)
Error	172							

Mean Vector: Overall = [321.6, 329.5]
Site 1 = [321.2, 329.8]
Site 2 = [322.0, 329.1]
Treat 1 = [321.0, 329.6]
Treat 2 = [321.6, 329.6]
Treat 3 = [322.1, 329.3]

1/ Prob of significance of the F statistic

Table 10b.: MANOVA Results, using as response vector Y
Y = [dry season response, rainy season response]

Response Variable: Cow weight at conception

Source of variation	df	Dry Season F	Dry Season (prob) 1/	Rainy Season F	Rainy Season (prob)	Wilk's Lambda Statistic	F	(prob)
Site(S)	1	2.82	(0.09)	4.64	(0.04)	0.93	2.35	(0.10)
Pasture(P)	2	0.93	(0.40)	0.03	(0.97)	0.94	0.97ns	(0.43)
S x P	2	0.04	(0.96)	0.35	(0.71)	0.99	0.20ns	(0.94)
Error	62							

Mean Vector: Overall = [323.7, 329.2]
Site 1 = [335.3, 335.2]
Site 2 = [309.6, 314.0]
Treat 1 = [316.3, 345.5]
Treat 2 = [328.1, 324.7]
Treat 3 = [325.3, 321.7]

1/ Prob of significance of the F statistic

Table 10c.: MANOVA Results, using as response vector Y
Y = [dry season response, rainy season response]

Response Variable: Intervals between parturitions

Source of variation	df	Dry Season F	(prob) 1/	Rainy Season F	(prob)	Wilk's Lambda Statistic	F	(prob)
Site(S)	1	9.03	(0.004)	7.14	(0.001)	0.80	8.1	(0.007)
Pasture(P)	2	2.28	(0.11)	1.17	(0.32)	0.90	1.7	(0.15)
S x P	2	2.50	(0.09)	0.56	(0.58)	0.91	1.5ns	(0.21)
Error	66							

Mean Vector: Overall = [655.0, 624.8]
Site 1 = [584.9, 592.0]
Site 2 = [737.3, 702.6]
Treat 1 = [714.8, 654.7]
Treat 2 = [651.0, 632.4]
Treat 3 = [599.9, 602.2]

1/ Prob of significance of the F statistic

Table 10d.: 'MANOVA Results, using as response vector Y
Y = [dry season response, rainy season response]

Response Variable: Calf birth weight

Source of variation	df	Dry Season F	Dry Season (prob) 1/	Rainy Season F	Rainy Season (prob)	Wilk's Lambda Statistic	F	(prob)
Site(S)	1	2.40	(0.13)	21.4	(0.0001)	0.64	11.1	(0.002)
Pasture(P)	1	0.81	(0.45)	1.0	(0.36)	0.91	0.9	(0.49)
S x P	2	0.45	(0.64)	0.5	(0.64)	0.95	0.5	(0.75)
Error	40							

Mean Vector: Overall = [25.6 , 27.0]
Site 1 = [26.7 , 27.9]
Site 2 = [24.5 , 23.9]
Treat 1 = [24.6 , 26.3]
Treat 2 = [25.9 , 26.6]
Treat 3 = [26.3 , 27.8]

1/ Prob of significance of the F statistic

Table 10e..: MANOVA Results, using as response vector Y
Y = [dry season response, rainy season response]

Response Variable: Calf weaning weight

Source of variation	df	Dry Season F	Dry Season (prob) 1/	Rainy Season F	Rainy Season (prob)	Wilk's Lambda Statistic	F	(prob)
Site(S)	1	20.9	(0.01)	37.4	(0.0001)	0.53	23.2	(0.001)
Pasture(P)	2	3.2	(0.05)	4.0	(0.02)	0.82	2.7	(0.03)
S x P	2	3.1	(0.06)	14.3	(0.0001)	0.62	6.9	(0.001)
Error	54							

Mean Vector: Overall = [135.1, 144.3]
Site 1 = [149.1, 157.2]
Site 2 = [114.8, 126.7]
Treat 1 = [125.6, 132.3]
Treat 2 = [143.4, 148.3]
Treat 3 = [134.9, 150.1]

1/ Prob of significance of the F statistic

Table 11a: Stratified Analysis results

Response Variable: Abortion/cow (Yes, No)

Site 1

Treat	No	Yes	
1	18 (56.2)	14 (43.8)	32
2	24 (70.6)	10 (29.4)	34
3	31 (88.6)	4 (11.4)	35
	73 (83.3)	28 (27.7)	101

$X^2 = 8.79$ (prob = 0.012)

Site 2

Treat	No	Yes	
1	21 (84.0)	4 (16.0)	25
2	27 (96.5)	1 (3.5)	28
3	23 (95.9)	1 (4.1)	24
	71 (93.2)	6 (7.8)	77

$X^2 = 3.48$ (prob= 0.18)

CMH Statistic = 11.15 (prob = 0.004)

Table 11b.: Stratified Analysis results

Response variable: Perinathal death/cow (Yes, No)

Site 1

Treat	No	Yes	
1	21 65.7)	11 (34.3)	32
2	24 (70.6)	10 (29.4)	34
3	24 (68.6)	11 (31.4)	35
	69 (68.3)	32 (31.7)	101

X^2 = 0.19 (prob = 0.91)

Site 2

Treat	No	Yes	
1	22 (88)	3 (12)	25
2	28 (100)	0 (0)	28
3	17 (70.8)	7 (29.2)	24
	67 (87.0)	10 (13.0)	77

X^2 = 9.76 (prob = 0.008)

CMH Statistic = 3.25 (prob = 0.197)

Table 11c.: Stratified Analysis results

Response variable: Number of births/cow (2,3 or 4)[1/]

Site 1

Treat	2	3	4	N	R_t	R_a
1	13 (43.3)	13 (43.3)	4 (13.4)	30	2.7	0.68
2	3 (9.1)	19 (57.6)	11 (33.3)	33	3.2	0.81
3	4 (11.4)	23 (65.7)	8 (22.9)	35	3.1	0.78
	20 (20.4)	55 (56.1)	23 (23.5)	98	3.01	0.75

$X^2 = 15.2$ (prob = 0.004)
$X^2_R = 0.72$ (prob = 0.71)

Site 2

Treat	2	3	4	N	R_t	R_a
1	9 (37.5)	13 (54.2)	2 (8.3)	24	2.7	0.68
2	13 (46.5)	14 (50.0)	1 (3.5)	28	2.6	0.65
3	8 (33.3)	11 (45.8)	5 (20.9)	24	2.9	0.73
	30 (39.5)	38 (50.0)	8 (10.5)	76	2.73	0.68

$X^2 = 7.26$ (prob = 0.12)
$X^2_R = 0.19$ (prob = 0.91)

CMH = 6.47 (prob = 0.015)
$CMH_R = 0.91$ (prob = 0.86)

1/ 4 cows were deleted from the analysis: one with 5 births (in treat 2, site 1), and three with 1 birth (2 in treat 1 site 1, and 1 in treat 1 site 2)
2/ R_t = 4-year period birth rate (expressed as births/cow in 4 years)
3/ R_a = Mean annual birth rate (expressed as mean births/cow/year)

Table 11d.: Stratified Analysis results

Response variable: Number of weaned calves/cow (1,2 or 3) 1/

Site 1

Treat	1	2	3	N	R_t	R_a
1	7 (24.1)	19 (65.5)	3 (10.4)	29	1.9	0.47
2	1 (2.9)	18 (53.0)	15 (44.1)	34	2.4	0.60
3	3 (8.5)	17 (48.6)	15 (42.9)	35	2.3	0.60
	11 (11.2)	54 (55.1)	33 (33.7)	98	2.22	0.55

X^2 = 14.1 (prob = 0.007)
X^2_R = 0.61 (prob = 0.74)

Site 2

Treat	1	2	3	N	R_t	R_a
1	6 (24.0)	18 (72.0)	1 (4.0)	25	1.8	0.45
2	7 (25.0)	19 (67.9)	2 (7.1)	28	1.8	0.45
3	7 (29.2)	15 (62.5)	2 (8.3)	24	1.8	0.45
	20 (26.0)	52 (67.5)	5 (6.5)	77	1.8	0.45

X^2 = 2.4 (prob = 0.66)
X^2_R = 0.001 (prob = 0.99)

CMH = 13.01 (prob = 0.011)
CMH_R = 0.611 (prob = 0.89)

1/ 1 cow (from trat 2 site 1), with 4 weaned calves, was deleted from the analysis.

Table 12.: ANOVA results for summary parameters

Source of variation	df	Total production of weaned calves/cow F	prob [1/]	Total production of calves/cow F	prob	Total beef production per cow F	prob
Site	1	57.1	(0.0001)	55.4	(0.0001)	109.1	(0.0001)
Pasture	2	9.2	(0.0002)	10.2	(0.0001)	8.0	(0.0005)
Site x Pasture	2	10.6	(0.0001)	10.7	(0.0001)	7.7	(0.0006)
N		175		176		177	
Means: Overall:		280.9		317.4		640.7	
Site 1 :		330.3 a		372.8 a		718.7 a	
Site 2 :		218.1 b		246.1 b		539.4 b	
Treat 1:		229.0 b		255.4 b		584.5 b	
Treat 2:		304.2 a		342.1 a		667.6 a	
Treat 3:		303.8 a		349.1 a		665.7 a	

1/ Probability of significance of the F statistic

Table 13c.: Linear model fit using marginal probabilities, for the analysis of "number of births/cow".

a) - Response frequencies and response probabilities for each population

Population	Response: No. of births/cow 2	3	4	Total
1: Site 1 Treat 1	13 (43.3)	13 (43.3)	4 (13.4)	30
2: Site 1 Treat 2	3 (9.1)	19 (57.6)	11 (33.3)	33
3: Site 1 Treat 3	4 (11.4)	23 (65.7)	8 (22.9)	35
4: Site 2 Treat 1	9 (37.5)	13 (54.2)	2 (8.3)	24
5: Site 2 Treat 2	13 (46.5)	14 (50.0)	1 (3.5)	28
6: Site 2 Treat 3	8 (33.3)	11 (45.8)	5 (20.9)	24

Response functions/population: two marginal probabilities p_1, p_2,

where, p_1 = proportion of cows with 2 calves

p_2 = proportion of cows with 4 calves

Table 13b.: Linear Model fit, using marginal probabilities for the analysis of "number of births/cow"

- Results -

Source	df	Chi-Square	Prob 1/
Intercept	2	170.05	0.00002
Site (S)	2	10.37	0.0056
Treatment (T)	4	5.08	0.0793
S x T	4	12.24	0.0157

1/ Probability of significance of the Chi-square test

Table 14a.: Linear model fit using marginal probabilities for the analysis of "number of weaned calves/cow"

a) Response frequencies and response probabilities for each population

Response: No. of weaned calves/cow

Population	1	2	3	Total
1: Site 1 Treat 1	7 (24.1)	19 (65.5)	3 (10.4)	29
2: Site 1 Treat 2	1 (2.9)	18 (53.0)	15 (44.1)	33
3: Site 1 Treat 3	3 (8.5)	17 (48.6)	15 (42.9)	35
4: Site 2 Treat 1	6 (24.0)	18 (72.0)	1 (4.0)	25
5: Site 2 Treat 2	7 (25.0)	19 (67.9)	2 (7.1)	28
6: Site 2 Treat 3	7 (29.2)	15 (62.5)	2 (8.3)	24

Response functions/population: two marginal probabilities p_1, p_2,

where, p_1 = proportion of cows with 1 weaned calf.

p_2 = proportion of cows with 3 weaned calves.

Table 14b.: Linear Model fit, using marginal probabilities for the analysis of "number of weaned calves/cow"

- Results -

Source	df	Chi-Square	Prob 1/
Intercept	2	981.15	0.0000
Site (S)	2	27.48	0.0000
Treatment (T)	4	17.87	0.0013
S x T	4	8.09	0.0983

1/ Probability of significance of the Chi-Square test.