THE USE OF COMPUTER MODELS TO PREDICT SUSTAINABILITY

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ABSTRACT

Livestock restocking is very expensive, both financially and in terms of time. Many efforts are put into the planning and implementation of such projects. The long-term sustainability of production often makes the difference between a success and a failure. Therefore, a method of predicting sustainability could prove very valuable. One possible method to achieve this is through computer modelling.

THE USE OF COMPUTER MODELS IN SMALL RUMINANT PRODUCTION RESEARCH

Models are representations of real systems that show the relationships between the variables or components of the system (Vaz, unpublished). The type of model to be constructed depends on the purpose of it: the model should represent those facets of the real system relevant to the model-uses (Dent and Blackie, 1979). According to Spedding (1988) models try to simplify reality, showing only those features that are important for the objectives they pretend to serve. The purpose for building a model sets the criteria for deciding what is essential to include in the model and what is not.

At present, models are widely used in all fields of research Models in animal science include models for animal processes like the rumen model for digestion, and animal product models, like lactation models (France and Thornley, 1984). Stochastic models are also frequently used for epidemic disease control and predictions of eradication (Short, pers. comm.).

Some of the arguments for using models in research are pointed out by Dent and Blackie (1979):

- The possibility to study systems where real life experimentation be either impossible, costly or disruptive; hence, intervention can be assessed at a lower cost and risk level;
- The complete control over all factors by the researchers;
- The possibility to study long-term effects;
- The testing of mutually exclusive policies; and
- Model building forces an objective examination of the system and a critical review of existing knowledge.

Some of the arguments for using models in research are pointed out by Dent and Blackie (1979):

- The actual construction of a model can be very time consuming;
- If a system is not understood, a misleading model can be produced;
- Simplified assumptions about the system structure will nearly always have to be made. Sometimes the development of a model may also require the estimation of parameters that cannot be measured and the use of incorrect values can lead to wrong conclusions;
- It is difficult to validate a model; and
- False results can be produced if a model ignores risk and probability of occurrence.

GOATFLOCK: AN EXAMPLE

The Goatflock model described here is an example to illustrate how simple computer models can be applied, to predict possible sustainability, in the planning phase of a project. This model is used because it was constructed to study the environment of market-oriented goat production systems and sustainable land use in semi-arid conditions. Hence, environmentally it resembles parts of the environments in Namibia and also the extensive, small-scale livestock farming system as can be expected in Namibia.

It is important to note that most models use empirical data specific to the climatic and environmental conditions of a particular area as well as the production data of a specific breed in that environment. Therefore, extrapolating these data to another breed, or other climatic or management conditions, is not advisable. Furthermore, great care must be taken to treat the results from such a program only as predictions. Biological systems are far too complex to include all the variables in one model. Hence, results represent only a possible outcome for specific fixed variables and inputs.

Background

This model was constructed at the University of Reading as part of a research project on the environment of market-oriented goat production systems and sustainable land use in semi-arid conditions. Socio-economic surveys on selected villages in Zambia and Zimbabwe, and monitoring of goat flocks over a year in selected areas (Matebele goats in Zimbabwe and Small East African Goats in Zambia) and surveys on local, rural and urban marketing structures were carried out. Use was also made of data from a PhD thesis (Sibanda, 1992) on Matebele goats in Zimbabwe. One objective of the project was to define management regimes of goat production systems for each area within the whole family complex. There are many publications available on goat production parameters in southern Africa, but the majority of them are on disease. For this project there were not sufficient data available, and time did not allow it, to construct a full biological model.

This model was constructed as an initial aid for advisors to small goat farmers, to enter their own local data, relying on their experience of the circumstances supporting their data, to predict the flock sizes for the following years. They would enter their data from the survey on the monitoring flock with the idea that the environment and management parameters could apply to goat flocks throughout the region or to small individual farmers. The program and its outputs are explicit so that the user can appreciate the interactions in the model. Many of the parameters are correlated to each other, to the climate of the survey year and often a result of more than one year s climate. At present, there are only data for two years from the PhD thesis and one year s data from monitoring surveys in Zambia and Zimbabwe. For the latter, the goat flocks are being restocked after severe drought years and it is best to consider management practises in this light (Neal, pers. comm.).

How does it work?

Goatflock is a mechanistic, dynamic population model constructed to predict the final flock structure after a number of years from an original flock structure, acted upon by climatic, environmental and also management effects. All the data must be provided by the user. The information required about the user flock is entered on four input screens:

- *Run initiation,*
- *Production parameters,*
- *Initial flock structure,* and
- *Management parameters.*

In places, data to be entered are very detailed. The opportunity exists for advisors to examine the result of reducing losses, particularly due to disease. However, in the case where data regarding losses are not broken down, totals can be entered.

The *run initiation* screen is used to enter an identification name (runname). A choice can be made to either recall a previous run and edit the recorded data for a comparison run, or to enter a fresh set of data. For a new run, four items of data are required:

- the type of goat (Small East African or Matebele),
- the number of years for which the program is to be run,
- the number of different climate years (maximum 5), and
- the pattern of climate years.

When there are no data for different degrees of drought, the pattern of climate years will be the same for each year. However, if different management takes place over a period of years, this could be simulated by keeping the production data the same while the management data varies. The number of climate years will then be the number of different management screens.

The *production parameter* screen requires all the production data of the flock. There are two versions for this screen, one for each breed. Data are entered for each climate year. The following data are used:

- Immature animals - Seasonal birth weights (male and female), and
  Seasonal live weight changes up to maturity (male and female);
- Mature animals - Seasonal live weight change for does, bucks and castrates aged 25-36 months, and
  Seasonal live weight for does, bucks and castrates over 3 years;
- Reproduction - Seasonal distribution of does in the flock that will produce surviving kids, and
  Number of kids per doe that kids in each season;
- Losses and livestock units - Losses are classified into two groups: pre-weaning and disease or predator, theft and missing. Livestock units are entered as a mythical maximum level for sustainability of rangeland per season.

In the *initial flock structure* screen the number of each class and sex group at the beginning of the run is entered.

For each climate year the following *management seasonal parameters* are entered:

- Purchases and gifts in,
- Sales and gifts out, and
- Slaughter and castrated.

There are also four output screens:

- *Calculation of flock structure,*
- *Comparison display,*
- *Seasonal flock structure,* and
- *Numbers and liveweight display.*

The *calculation of flock structure* screen displays the flock number at the end of the run and also the total goat movements, in and out, at the end of every year. The *comparison display* gives a comparison between different runs of your choice. The flock structure in terms of class and sex groups for each season of the first three years can be displayed using the *seasonal flock structure* screen. The *numbers and liveweight display* screen show the numbers and average live weight of females, males and castrates in three month age groups for each season of the final year.

Two types of flock simulations are possible. The first includes the whole flock or survey data. The production, management and initial flock data are those of the whole district herd. Different climate years can be constructed to predict the flock structure in future years or under different management conditions. Once the original data has been entered, re-runs can be done by calling back the original climate years and editing the data. The second type of flock simulation that can be done is that of a sub-flock or individual farmer flock. The data for the whole district herd should be entered as in a whole flock run. In the re-run the data of the initial flock is edited to that of the farmer.

EXAMPLES AND RESULTS

Six example runs were done. For clarity, run 1 is described below while runs 2-6 are summarised in Table 1. The results for the last year are summarised in Tables 2 and 3.

RUN 1: The initial run was done to set up the scenario for the following runs. The production data were according to the data from the PhD thesis (Sibanda, 1992). Management changes were made to allow for a general restocking project where no other purchases or gifts would be received and sales and gifts out would also be zero. The number of animals slaughtered was kept as in the original data since it can be expected that some slaughterings would occur.

NAME:	Original	
FLOCK:	Whole flock	
NUMBER OF YEARS:	3	
NUMBER OF CLIMATE YEARS:	1	
GOAT TYPE:	Matebele	
INITIAL FLOCK STRUCTURE:	Suckling females (SF)	= 82
	Rearing females (RF)	= 126
	Breeding females (BF)	= 288
	Suckling males (SM)	= 78
	Rearing males (RM)	= 96
	Breeding males (BM)	= 13
	Castrate males (CM)	= 10
	Total flock size	= 693
MANAGEMENT:	Purchases	= 0
	Gifts in	= 0
	Sales	= 0
	Gifts out	= 0
	Number slaughtered	= 40
	Proportion castrated	= 0.6

RUN 2 (Flock 10): In the second run, a restocking project was simulated where 10 breeding females and 1 breeding male was given to each farmer. The management was kept exactly as in the previous run. The number of slaughterings for all the following runs is in the same proportion as that in the original run.

RUN 3 (Flock 100): For this run, the management was still the same but a flock of 100 breeding females and 4 breeding males were given to each farmer.

RUN 4 (Flock 150): A flock of 150 breeding females and 4 breeding males was distributed to each farmer. No management changes were made.

RUN 5 (Flock 15m): For a similar flock size (154) the proportion of rearing males castrated were lowered to 0.4.

RUN 6 (Flock 5): In the last run only 5 breeding females and 1 breeding male were given to each farmer. No rearing males were castrated.

Table 1. A summary of the structure of the different runs

	Original	Flock 10	Flock 100	Flock 150	Flock 15m	Flock 5
Flock	Whole	Sub	Sub	Sub	Sub	Sub
Years	3	3	3	3	3	3
Climate Years	1	1	1	1	1	1
Goat type	Matebele	Matebele	Matebele	Matebele	Matebele	Matebele
SF	82	0	0	0	0	0
RF	126	0	0	0	0	0
BF	288	10	100	150	150	5
SM	78	0	0	0	0	0
RM	96	0	0	0	0	0
BM	13	1	4	4	4	1
CM	10	0	0	0	0	0
Total flock	693	11	104	154	154	6
Purchases	0	0	0	0	0	0
Gifts in	0	0	0	0	0	0
Sales	0	0	0	0	0	0
Gifts out	0	0	0	0	0	0
Slaughtered/proportion slaughtered	40	0.06	0.06	0.06	0.06	0.06
Proportion castrated	0.6	0.6	0.6	0.6	0.4	0

Table 2. A comparison of the production structures and flock management for the final year

	Flock	Kids	Bought	Gifts in	Sales	Carcasses	Gifts out	Losses
Original	600	328	0	0	0	40	0	316
Flock 10	42	13	0	0	0	0	0	15
F 100	240	99	0	0	0	0	0	46
F 150	345	142	0	0	0	9	0	72
F 15m	350	142	0	0	0	7	0	72
Flock 5	25	7	0	0	0	0	0	8

Table 3. A comparison of the flock structures for the final year

	Female			Male			
	Kids	Rearing	Breeding	Kids	Rearing	Breeding	Castrated
Original	45	36	324	50	76	21	48
Flock 10	4	7	15	4	7	2	3
F 100	23	31	110	23	39	6	8
F 150	31	47	156	32	53	10	16
F 15m	31	47	156	32	54	18	12
Flock 5	2	5	8	2	4	4	0

Table 4.The number of kids born per season for Flock 150

Year	Nov - Jan	Feb - Apr	May - Jul	Aug - Oct
1	15	48	51	26
2	14	45	48	24
3	14	46	54	28

USING THE RESULTS IN THE DECISION MAKING PROCESS

The first important point to realise is that the number of losses is extremely high. In the thesis survey (Sibanda, 1992), 37% of the existing 805 goats were 'missing', 21% were sold or slaughtered and 16% died as a result of disease. The flock size at the beginning of the survey was 670 goats. It can be expected that in an arid environment where vegetation is sparse and under very extensive rearing conditions, losses will be high. This must be included in any estimation for sustainability.

Looking at Flock 5 it can be concluded that giving only five breeding females and one breeding male is not a sustainable herd. After three years there will still only be eight breeding females and the total herd size will be between 17 and 25 (25-8 possible losses). With an average of only six kids born per year, no more than two could eventually be sold. It is doubtful whether any family can sustain their livelihood on the sales of two animals per year.

A flock size of 10 breeding females and one breeding male seems to be more sustainable. The addition of only five breeding females almost doubles the flock size after three years and also the number of kids born. The flock size will rise to 42 (between 29 and 42 if the losses are included), with 15 breeding females, two breeding males and three castrated males that can be sold. Kids born average 10 for the first two years and 12 for the last year. Possible sales from these kids will be between four and five, leaving six for replacement purposes. In the case where animals were given on a loan basis, more than three years will be needed to build flocks up to viable sizes before repayments can be expected.

Even when the flock sizes reach 100 and 150 animals, the possibility of sustaining a family only on the income of animal products after three years, seems doubtful. Even though 46 and 63 kids are born in the final year for these flock sizes respectively, the losses are extremely high. Low survival rates result in the low proportion of males that eventually reach the slaughtering age. The arid environment and limited production resources may account for the problems faced. If goat production could be integrated with crop production or intensified, the viability of the whole system could be increased. However, in Namibia none of these will easily be achieved.

In order to simulate the influence of a management change on the flock structure, castration levels were lowered. Lowering the proportion of castrated males does not seem to have a big impact on total flock size. The number of kids born per year stays the same. Whether castration should be practised at all will depend on the market and the age at which male kids are slaughtered. Depending on the specific circumstances of the project, different possible management regimes can be simulated and the effects evaluated in order to introduce the most profitable one.

According to the results in Table 4, for Flock 150 there is a big difference in the number of kids born in different seasons. Using these results, the planning of the project, as well as the management later on, can be adapted to increase kid survival and flock growth.

The effect of a drought on the production and flock structure can be simulated by decreasing the live weight, increasing the number of losses and decreasing the kidding rate. If real numbers are not available, a 10% change, or any other percentage range, can be simulated. Including the possibility of drought in the planning of the project will increase the reliability of the results produced.

It is also possible to develop an economic model where all the potential costs of the project are included. For example, Shaw (1990) developed a spreadsheet model for the analysis of economic benefits in cattle production attained by tsetse control programmes. Different scenarios can be simulated to see how variation in parameters would influence the budget of the project, e.g. to match goats ready for sale with market requirements. Using the grazing potentials as summarised by Brown (1994), it can be calculated that to sustain 100 goats in the very low potential areas of the country, 480ha are needed, and in the high potential areas, 200ha. Hence, it is possible to calculate the area of land needed for resettlement, and by including this in a model, calculate the optimum flock size and area that needs to be obtained with the available funds.

CONCLUSIONS

The use of computer models provides a way of simulating real life scenarios for project decision making without actually implementing the project. Through computer models the best possible way to increase sustainability can be chosen and the use of available funds can be optimised. However, it is important to remember that models are only predictions based on all the available information and cannot be taken as the only possible outcomes. The Goatflock model (even though it is just an example) suggested that in an arid environment where the production system is extensive with a low level of management, restocking with goats would be very hard to achieve and sustain.

REFERENCES

BROWN, C.J. 1993. Land as a factor in poverty alleviation in Namibia: Environmental considerations. In: *Land as a factor in poverty alleviation in Namibia*, Published by the Ministry of Lands, Resettlement and rehabilitation of the Republic of Namibia, Windhoek. 72-100.

DENT, J.B. and M.J. BLACKIE. 1979. *Systems Simulation in Agricultural.* Applied Science Publishers Ltd. England.

FRANCE, J. and J.H.M. THORNLEY. 1984. *Mathematical Models in Agricultural.* Butterworth & Co. Publishers Ltd., London.

SHAW, A.P.M. 1990. A spreadsheet model for the economic analysis of tse-tse control operations benefiting cattle production. *Insect Science and its Applications,* 11,449-453

SIBANDA, L.M. 1992. Studies on the production and nutrition of Matebele goat. Ph.D. thesis, University of Reading, Reading, UK.

SPEDDING, C.R.W. 1988. *An Introduction to Agricultural Systems.* Elsevier applied Science Publishers Ltd., England.

VAZ, Y. (Unpublished). Models - Concepts and applications in small ruminants production system research.