PRODUCTIVITY ASSESSMENTS IN SMALL RUMINANT IMPROVEMENT PROGRAMMES. A CASE STUDY OF THE WEST AFRICAN DWARF GOAT

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PRODUCTIVITY ASSESSMENTS IN SMALL RUMINANT IMPROVEMENT PROGRAMMES. A CASE STUDY OF THE WEST AFRICAN DWARF GOAT

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Proefschrift
ter verkrijging van de graad van
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STELLINGEN

1. Het variëren van de worpgrootte door kleine herkauwers lijkt een effectieve methode om de reproduktie af te stemmen op de produktieomgeving. Conventionele reproduktie parameters als sterfte voor het spenen en overlevingspercentages doen onvoldoende recht aan dit vermogen; het is beter het aantal overlevenden als graadmeter te nemen.

   Dit proefschrift

2. Het is niet voldoende om de multi-functionele rol van vee in traditionele produktiesystemen te erkennen; men moet haar ook op de juiste waarde schatten.

   Dit proefschrift

3. Het niet positief waarderen door beleidsmakers van kuddevergroting in traditionele veehouderijsystemen getuigt van weinig inzicht in deze systemen.

   Dit proefschrift

4. Het is relatief eenvoudig te bewijzen dat vernieuwingen technisch goed zijn, het is echter veel moeilijker om hun geschiktheid te voorspellen om problemen op te lossen op bedrijfsniveau, niet zozeer vanwege twijfels over het technisch effect op dat niveau maar veeleer vanwege twijfels over de rol van het vee en de produktieomgeving.

   Dit proefschrift

5. Ondanks de aanzienlijke investeringen in het verleden is de produktie-capaciteit van vele nationale lanbouwkundige onderzoekssystemen in Afrika afgenomen. Het vermogen om externe middelen te absorberen is geslonken tot een niveau, waarop de verdere technologische vooruitgang binnen het systeem zelf ernstig belemmerd is en, in sommige gevallen, wellicht illusionair, tenzij het systeem wordt gerevitaliseerd.

   Anderson, J.R., 1992. Difficulties in African Agricultural Systems Enhancement? Ten Hypotheses. Agricultural Systems, 38: 387-409.

6. Het probleem van het gebruik van simulatiemodellen van veehouderijsystemen in verbeterings-programma's is dat de relaties tussen het vee en de gebruiker veelal geen deel uitmaken maken van het model.

7. De vaststelling dat geiten ruwvoer niet beter verteren dan andere herkauwers (Tolkamp en Brouwer, 1993) is gunstig voor de geit. Immers het benadrukt het belang van diens specifieke eetgedrag en dus diens rol binnen veehouderijsystemen.

Tolkamp, B.J. & Brouwer, B.O. 1993. Statistical review of digestion in goats compared to other ruminants. Small Ruminant Research, 11:107-123.

8. Daar vrouwen over de hele wereld worden uitgewisseld in de afwezigheid van runderen, kan men stellen dat het uitwisselen van runderen bij huwelijken evenveel te maken heeft met de runderen als met het huwelijk.

Dombrowski, K., 1993. Some considerations for the understanding of small herd dynamics in East African arid zones: The long-term consequences of bridewealth exchange networks. Human Ecology, 21(1): 23-50.

9. Dat de produktiviteit van westerse veehouderijsystemen veelal hoger wordt geschat dan die van veehouderijsystemen in ontwikkelingslanden zegt meer over de relativiteit van die schattingen dan over de duurzaamheid van die systemen.

10. Het door de VVD voorgestane buitenlandbeleid toont aan dat de theorie van de vrije markteconomie voor die partij dezelfde functie vervult als de religie voor het CDA: het gaat niet zozeer om de inhoud, als wel om de intrinsieke mystificerende kracht.

11. Gezien de populariteit van de tweewieler in Nederland is het begrijpelijk dat de vorig jaar gestarte grootschalige spaaractie een engelstalige benaming draagt, daar anders het ware karakter te zeer zou worden geduid.

VOORWOORD

Dit proefschrift zelf is een goede illustratie van de erin behandelde problematiek, namelijk de moeilijkheden van produktiviteitsschattingen. Is de bepaling van de waarde van het schrift zelf al een moeilijke opgave, het inventariseren en het op de juiste waarde schatten van de gebruikte 'schaarse' factoren is een onmogelijke taak. Onderstaand wil ik daarom slechts trachten de belangrijkste bronnen te duiden.

Het vertrouwen en de ondersteuning van mijn promotor Prof. Dick Zwart en mijn co-promotor Henk Udo waren van onmisbare waarde gedurende de veschillende fases van het wordingsproces van dit proefschrift, waarvoor mijn oprechte dank. In dit verband mag niet onvermeld blijven de inspirerende en adviserende rol van Bert Tolkamp. Henk Moll ben ik veel dank verschuldigd voor zijn inbreng in de economische analyses.

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Een verblijf in de tropen is erg aantrekkelijk voor diegene die er emplooi vindt; het vraagt echter ook veel van diegene die als partner meegaat. Als zo'n partner je ook nog voortdurend ondersteunt en motiveert valt deze waarde moeilijk meer in woorden te vatten, maar spreekt voor zich, Annie.

CONTENTS

CHAPTER 1.

GENERAL INTRODUCTION

1. GENERAL INTRODUCTION

Livestock are an integral part of the farming system in most developing countries. The composition of the livestock component and its contribution to the household economy varies considerably between production systems. Migratory pastoral production systems depend nearly exclusively on livestock, with cattle playing a dominant role. In mixed farming systems such as those found in the humid zone of West and Central Africa, farming systems are principally crop-based, and livestock, consisting mainly of small ruminants and poultry, play a secondary role.

Livestock development programmes can be effective only if these production conditions are fully understood and taken into account. The constraints (these are often systems-specific) have to be correctly identified and solutions have to be correctly assessed. Although this may seem self-evident in reality it has proved to be more complicated, because of differences in perceptions between researchers and the farmers in the actual production systems. In the past, researchers assumed that improvement would be synonymous with increased production and hence increased offtake. This assumption proved wrong and is now seen as one of the reasons for the failure of many livestock development programmes (Josserand, 1985; Scoones, 1992; Waters-Bayer and Bayer, 1992; Coppock, 1993).

It is now generally agreed that in traditional production systems livestock are really multi-purpose. They are kept not only for 'physical' production (milk, meat, hides, skins, draught power, manure) but also for socio-economic purposes (bank account, insurance, bride-price) (Knipscheer *et al.*, 1983; Behnke, 1985; Sempeho, 1985; Peacock, 1987; Upton, 1988; Scoones, 1992; Coppock, 1993; Dombrowski, 1993). Recognition of these multi-varied objectives of livestock keeping, which to some extent may contradict one another, further complicates the identification of constraints.

The suitability of a package designed to solve production constraints at field level cannot be assessed without involving the beneficiaries, i.e. the farmers themselves. Methods of on-farm assessment of new technologies have been the subject of many discussions (Steiner, 1987; Sumberg and Okali, 1988; Amir and Knipscheer, 1989; Francis and Atta Krah, 1989; Chambers *et al.* 1989; Scoones and Thompson, 1994). The general trend has been a shift from the conventional on-farm trials, largely researcher-managed, to a more open approach with a large degree of farmer involvement. Emphasis has shifted from the quantification of possible effects on production parameters to also include the response of farmers in terms of adoption and adaptation of the proposed innovations. Such an approach not only makes on-farm testing more effective, it also contributes to the researcher's knowledge and understanding of the production systems concerned. This enhanced knowledge and understanding of how the production systems actually operate can, in turn, improve the reliability and appropriateness of quantitative assessments.

PRODUCTIVITY

In the nineteen-sixties the awareness grew that people could not exploit natural resources indiscriminately. Over-exploitation led to a loss of production potential, but the growing human population demanded more production. It was realised that in the biosphere, actions on one component or process affect all other processes, because it is a system. Since then, research has been undertaken to elucidate the functioning of natural systems, both at the level of primary production and at higher levels (Petrusewicz and Macfadyen, 1970; Wassink, 1975; Jahnke, 1982; Upton, 1989, 1985; Giampietro *et al.*, 1994).

Productivity is one parameter frequently used to express the potential of a production system or process in studies of these type. In this context it can be defined as a general concept to cover all aspects of the rate at which matter or energy is generated by production processes (Petrusewicz and Macfadyen, 1970). It thus actually means the scaling of output. For instance, this can be achieved by expressing output per unit of area and time (i.e. x kg/ha/y) or by expressing output per unit of input (x MJ/MJ).

The scaling factor is often meant to reflect scarce resources needed for the production process, and thus productivity assessments can help to identify the most efficient method of production by allowing alternatives to be compared. In this context one can distinguish two 'types of scarcity': fixed and variable. Fixed means that the availability of a resource cannot be changed by the operator of the production process within the period considered, whereas variable means that the availability can be manipulated by the operator. Whether a resource is fixed or variable depends not only on the type of resource but also on the production setting, the level of assessment and the period considered. Generally the 'variability' of a resource increases concomitantly with the level of assessment and the duration of the period considered. For instance, most farmers in the tropics have little influence on the light energy available for photosynthesis, whereas some farmers in temperate regions do regulate the light regime. A resource such as water or land may not be changeable at the level of the individual farmer or in the short run, but may be so at the level of the community or state or in the long run. If the availability of a resource is 'fixed', the production process or method with the highest production also scores the highest productivity. However, if the availability of a resource is 'variable', the highest production and the highest productivity of a production process or method often do not coincide because of the law of diminishing returns

(Samuelson, 1973). It is clear that these aspects have to be taken into account when comparing productivity under different conditions, for instance, on-station with on-farm values.

In the case of multiple output, all output has to be aggregated into one parameter. In the case of energy studies this may be relatively easy, as it is quite straightforward to convert products into MJ. However, in traditional production systems (e.g. in the tropics) the aggregation of all the diverse physical output (O) into one parameter may prove problematic as it may be difficult to identify conversion factors which represent the actual value for the farmer (Behnke, 1985). For instance, milk and meat can be converted into one parameter based on their energy and/or protein content and this may suffice for a strictly biological assessment. However, in traditional livestock systems where milk consumption is daily practice, meat and milk are often completely different entities serving different objectives. Under those circumstances an equalisation based on energy and/or protein content makes little sense for the appraisal of productivity at farmer's level.

Which scaling factor (SF) is chosen depends on the aim of the assessment. For instance, in biophysical studies the aggregated metabolic liveweight of the herd or flock is often used. Since feed requirements for maintenance are directly related to the metabolic weight, such a scaling factor gives a fair reflection of the feed required to maintain the production process. In socio-economic studies one or more factors such as labour, land and/or capital may constitute the denominator; however, this does not alter the dilemma.

Most assessments only include the physical benefits (Jahnke, 1982; Upton, 1985, 1989; Peacock, 1987) and do not quantify the value of the non-physical benefits (bank account, insurance) and do not consider the relationship between these benefits and the physical productivity (O/SF).

Apart from expressing the potential or current state, productivity assessments have been used to identify constraints to increase production and predict the effect of possible interventions (Upton, 1985; Peacock, 1987). The value of such an assessment is limited because of the common assumption in their productivity assessments that the effects of changes of parameters (mortality, production traits) on performance do not interact. These possibly interactive effects can be dealt with by simulating the production process with these different parameters. Several simulation models have been developed for this purpose (White *et al.*, 1983; Blackburn and Cartwright, 1987; Baptist and Gall, 1992; Upton, 1989, 1993).

This thesis reports research to investigate the value of productivity assessments for one type of livestock i.e. small ruminants using a case study of the West African Dwarf goat in South-Western Nigeria.

MAJOR CHARACTERISTICS OF SMALL RUMINANT PRODUCTION IN THE HUMID (AND SUB-HUMID) ZONE OF WEST AFRICA

Small ruminants in the humid and sub-humid zone of West and Central Africa are generally kept as a secondary activity to crop production. The farmers are predominantly food and cash-crop growers who practise a bush-fallow rotation. Trypanosomiasis has limited the occurrence of breeds of ruminants to largely trypano-tolerant breeds which are usually small-framed. The adapted breeds of goats and sheep are respectively the West African Dwarf goat and the West African Dwarf sheep. They are usually kept in small numbers. A study by the International Livestock Centre for Africa showed that in the humid zone of Nigeria, 37% of the households kept goats and 8% sheep, the average flock sizes being 5.2 goats and 6.5 sheep. The comparative figures for Ivory Coast were 27% (goats) and 23% (sheep), with average flock sizes of 4.4 (goats) and 4.9 (sheep) (ILCA, 1980). Generally, goats and sheep scavenge in free roaming flocks with no special provision of shelter. No special feed crops are grown and crop residues are rarely fed. However, by-products from food processing, such as cassava peel and maize offal are commonly fed (Adebowale *et al.*, 1993; Sempeho, 1985). Animals may be enclosed during the night to prevent theft. In some instances, particularly in densely populated areas of Eastern Nigeria and the Peoples' Republic of Benin, more intensive methods have been adopted. These involve confining small ruminants during the cropping season and obtaining feed from fallow land and crop by-products and carrying it to the animals (Lagemann, 1977; Gbego and van den Broek, 1993). Sometimes manure is collected and returned to the field (Lagemann, 1977). Under both systems mortality is reported to be high (>30%, Sempeho, 1985; Ademosun, 1988; Reynolds *et al.*, 1988; van den Broek, 1993).

Major constraints are reported in the areas of animal health and nutrition (Reynolds *et al.*, 1988; Ahoukan, 1989; Diallo, 1989; Ockling, 1989; Koudjou, 1989; Winrock, 1992). The health constraints include the occurrence of regular outbreaks of *Peste des Petits Ruminants* (PPR), an epidemic disease with a high morbidity and mortality rate. Furthermore, endo-parasites and ecto-parasites, and respiratory ailments are seen as constraints to animal production, not only because of their effect on mortality but also because they depress animal performance. The major nutritional constraint given for the humid tropics is not the quantity but the quality of the available forage (digestibility, crude protein content). For confined livestock, the quantity available may also be a limiting factor. Little information is available on the actual effect of these constraints on animal production under farmers' conditions. This is not surprising, because it is difficult to identify the effects of single constraints, because the observed production level is the resultant of all these possibly interacting constraints.

Increasing population pressure has led to the cropped area being extended to land hitherto considered unsuitable for this purpose, and to a shortening of the fallow periods. This has resulted in decreasing soil fertility and increasing pressure on the small ruminant component of the farming system because of reduced feed availability and increased incidence of crop damage (Lagemann, 1977; Reynolds *et al.*, 1988; Alofe *et al.*, 1989). Several programmes have been developed to address these constraints. Although they differ in their approach the 'technical' content of the innovations aimed at small ruminants is comparable as regards animal health (PPR, ecto-parasites) and nutrition (browse) (Reynolds *et al.*, 1988; Ayeni and Bosman, 1993a; van den Broek, 1993).

THE WEST AFRICAN DWARF GOAT PROJECT

The West African Dwarf Goat Project was carried out jointly by the Obafemi Awolowo University, Ile-Ife, Nigeria and the Agricultural University, Wageningen, The Netherlands in the period 1981 - 1992. Its main objective was to contribute to the improvement of the level and distribution of rural income and the quality of rural life through the improvement of the local dwarf goat production.

During the first phase a management package was developed, based on biophysical research carried out on-station and baseline surveys conducted by ILCA through its Small Ruminant Programme. The major findings of this phase were presented at an international workshop, held at Ile-Ife (Smith and Bosman, 1988). During the second phase this package was tested with the collaboration of goat keepers in nine villages in South-Western Nigeria. The package contained three components, on health, nutrition and housing, which, depending on their nature could be modified by the goat keepers to various degrees. The methodology followed during this second phase can be characterised as a 'two track' approach. One track consisted of the phased introduction of the package components, and the other of the implementation of the research programme. It was realised that to gain the confidence of the goat keepers something concrete would have to be done, before serious questions could be asked. Therefore the activities on track one were initiated first (with the introduction of the health component). Components were offered as options to be adopted or adapted by the farmers themselves (thus no 'treatment' groups were formed).

In farming systems terminology the research programme can be described as on-farm animal research in a farming systems perspective. The general aspects of Farming Systems Research (FSR) relevant to this project have been reviewed elsewhere (Ademosun, 1993; Moll, 1993). The steps usually followed in FSR were somewhat modified in this case. Part of the diagnostic phase had already been conducted by others (Matthewman, 1980; Mack, 1983; Sempeho, 1985; Upton, 1985; Reynolds *et al.*, 1988). Enough information regarding the most common problems affecting goat production was therefore known and this enabled the programme to combine the diagnostic, design and testing phases.

The major findings of this phase were presented at an international workshop, held at Ile-Ife (Ayeni and Bosman, 1993b). Furthermore, procedures for identification and implementation of innovations in goat keeping were summarised in a small booklet, intended as a tool for extension workers in West and Central Africa (Koper-Limbourg and Oyeyemi, 1993).

OBJECTIVES OF STUDY

In view of the complex relationship between productivity and the role of livestock within a production system, the study was undertaken to assess the value of productivity assessments in small ruminant improvement programmes. The main questions investigated were:

1. What methods are suitable for estimating productivity given the aim of the assessment and the requirements and availability of data? How is productivity affected by changes of the production environment (management, nutrition) and how can these effects be investigated?
2. What role can productivity assessments play in the identification of constraints and the testing of innovations at farm level?

THESIS OUTLINE

The next chapter reviews existing productivity indices and proposes modifications. Because the indices are only useful for assessing a static situation, a simulation model is presented. This model is validated with field data and used to predict effects of nutrition and management. The research findings used to ascertain the characteristics of the West African Dwarf goat and to test the effects predicted by the model are then presented (Chapter 3). The on-farm testing of innovations and an evaluation of the importance of goat production to households in the project area are described (Chapter 4). A concept is developed to capture all benefits and the relation between these benefits and productivity indices is discussed. Finally, the results and conclusions from the foregoing chapters are discussed in the light of the research objectives.

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CHAPTER 2.

MEASURING PRODUCTIVITY OF SMALL RUMINANTS

2.1 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS
1. Use of productivity indices for assessment of current flock state and impact of innovations

2.2 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS
2. Using a simulation model to assess the flock state and to test the impact of innovations

2.1 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS[1]

1. Productivity indices for the assessment of current flock state and impact of innovations

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ABSTRACT

Productivity indices are frequently used in the tropics to diagnose small ruminant production systems and to evaluate the effect of interventions. However, because traditional livestock production systems are usually very dynamic and diverse, these indices cannot consider all aspects but instead focus on certain parameters, depending on the aim of the assessment and on the suitability of the available records. In this paper existing indices aimed at productivity assessment at the level of the individual animal and the flock are reviewed and some modifications are proposed. On-station and field data on goat production in South-Western Nigeria are used as illustration. It is demonstrated that the reproductive potential of meat breeds can best be expressed by aggregating weaning weights per individual doe or ewe. At least two parturitions have to be covered to calculate this index. Such an index gives more accurate estimates than assessments based on averages especially if flocks are small. If breeds or production systems are to be compared the liveweight or the metabolic liveweight of the doe or ewe can be included in the denominator to correct for size differences. It is concluded that flock productivity is best assessed by relating all inflow and outflow to the weighted average flock size. The latter may be based on total liveweight, metabolic liveweight or numbers, depending on which scarce resource the denominator is to reflect. It is only appropriate to use productivity indices to compare animal sub-systems if the differences between the total production systems, which may interact with the animal component, are represented in the index.

Key words: productivity indices, small ruminants, South-Western Nigeria

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INTRODUCTION

Small ruminant production systems differ considerably throughout the world. Some are highly specialised single purpose enterprises, whereas others are characterised by low inputs and diverse multipurpose output patterns. The efficiency or productivity of each system can be assessed by relating output to input. Depending on the objective(s) of the evaluation this can be done at the level of the individual animal, the flock or within the context of the whole farming system. The first two often concern biological efficiencies, whereas the third, which considers the inter-linkages and interactions with other components of the farming system, is economic in character.

In the tropics indices have been used to elucidate a production system or to evaluate the effect of interventions on overall productivity. Furthermore they have been used to compare production systems and breeds (Knipscheer *et al.*, 1983, 1984; Wilson, 1983; Wilson *et al.*, 1985; Hofs *et al.*, 1985; Upton, 1985, 1988; Peacock, 1987).

Traditional production systems are usually very dynamic and diverse. So these indices cannot consider all aspects but instead focus on certain parameters, depending on the aim of the assessment and on the suitability of the available records.

This paper evaluates the assessment of productivity of meat breeds at the level of the individual animal and the flock. Existing productivity indices are reviewed and some modifications are proposed, using goat production in South-Western Nigeria as an illustration.

REVIEW OF EXISTING INDICES

In a biological sense production (P) consists basically of the accumulation of liveweight through the growth of the individual animal and the increase in the number of animals through births. The net production (NP) of a flock is the balance between P and losses.

Indices used to assess the productivity of small ruminants meat breeds (in the tropics) can be roughly grouped into two categories:

1) those that index P per individual animal or per flock;
2) those that index NP per flock (considering the complete entry and exit pattern).

Category 1

Indices in the first category principally concern reproductive parameters and may be based on a) individual observations per animal or on b) flock means of the parameters composing the index. Method a) is more demanding in terms of records needed as it requires observations per individual animal for a sufficiently long time (at least two reproduction cycles and the full range of weight gain of the offspring). Method b) requires fewer individual records and these may be over a shorter period as observations from different animals at distinct stages of the reproduction cycle suffice as basis for the estimation of the means.

The index of production given by Wilson (1983) is an example of the first method:

$$y = \frac{LWW * 365}{INV} \tag{1}$$

where y=kg liveweight per parturition, standardised per annum; LWW= litter liveweight at weaning; INV= subsequent parturition interval

Each parturition is considered as an observation, so the interdependence of observations within one animal is not considered. A litter that dies before weaning is also included (zero weaning weight). Although omission would give an overestimation of the productivity, inclusion would probably result in large standard errors, which makes this index less attractive as a yardstick. As with other indices related to reproduction, at least two parturitions must be included. However, the weaning weight of the last litter observed is not taken into consideration. The denominator can be extended to include the post-partum liveweight or metabolic weight of the dam. Authors use the index to compare the productivity of flocks kept under different conditions. Although the inclusion of the metabolic or actual liveweight of the dam in the denominator could correct for differences in size, the interpretation of such comparisons seems complicated since other factors (such as fraction of unproductive females, no of males, postweaning growth, overall flock dynamics) are not taken into account. Thus it only suffices for comparing the reproductive performance between flocks if the effect of the interdependence of parameters is negligible. The same holds when it is used for comparisons of females within a flock. The Doe Productivity Index developed by Knipscheer *et al.* (1984) is better suited for this purpose:

$$DPI = \frac{365 * (N-1)}{T_n - T_1} * LS_b * S * W_w \tag{2}$$

where DPI= doe productivity in kg/doe/y; N= number of parturitions; LS_b*= average litter size at birth; S= average survival rate until weaning;* W_w*= average* *weaning weight of kids (kg); T_1= age at first parturition (d); T_n= age at n^{th} parturition (d)*

Doe liveweight or metabolic weight can be included in the denominator for example if the objective is to compare different breeds. From the explanations and calculations given it is not clear how average survival rate and weaning weight are to be calculated; per litter or over the whole reproductive life cycle. This index is thus not computed per parturition but per doe over the whole productive or reproductive life-cycle or observation period. Thus it can be used to compare the productivity of does within a flock, although it does not consider the effect of age at first parturition and parity. The authors mention as a shortcoming that it does not reflect the rate at which kids reach weaning weight. It could be argued that this rate is reflected, although confounded with parturition interval. A more serious problem raised by the authors concerns the length of the observation period. Results may become unrealistic if this period is too short. As already noted, at least two parturitions are required to obtain any index at all.

To assess the reproductive performance at flock level the means of the parameters can be used to compose an index (Hofs *et al.*, 1985):

$$y = \frac{LS_B * (BW + WG_{B-W}) * S * P * 365}{INV} \qquad (3)$$

where y = the index per average female in kg liveweight per year; LS_B= litter size at birth; BW= birth weight (kg); WG_{B-W}= weight gain from birth to weaning (kg); S= survival rate until weaning; P= fraction of reproductive females actually reproducing; INV= parturition interval (d)

The parturition interval can be estimated as an average of all observed intervals or as a flock interval based on the total number of parturitions and the sum of the days a female, with at least one parturition during the observation period, has been present in the flock. The latter method has the advantage, that animals that have given birth only once during the observation period are included in the estimation of the parturition interval. Nevertheless, estimated values may differ considerably from the actual means if the observation period is comparatively short (less than twice the average interval).

Since this index contains a correction factor for the non-reproductive fraction of the number of females that would be able to reproduce in theory, it seems an appropriate tool to compare flocks in terms of the reproductive performance of the breeding stock, although it does not consider the age structure of the breeding flock (=parity). However, it should be realised that under farm conditions it may prove difficult to determine P. If flocks are small and heterogeneous the index does not estimate the actual weaned weight very accurately, especially if means are anormally distributed and/or correlated. Furthermore, since the index is based on averages, the actual variation in the underlying parameters is not reflected and thus there is no indication of the accuracy of the index at flock level.

The same criticism holds for the index suggested by Peacock (1987) as an improvement of the index developed by Wilson (1983):

$$y = \frac{N * LS_B * S * W_W}{FW_m} \tag{4}$$

where y *= liveweight production in kg per kg flock weight per year;* N *= number of parturitions per year;* LS_B *= litter size at birth;* S *= survival rate until weaning or 18 months;* W_W *= liveweight at weaning or 18 months;* FW_M *= mean flock weight*

Eighteen months is supposed to be the age at which females become reproductively active. So this index assesses the reproductive performance at two stages: weaning and at the point where females can enter the breeding flock. The inclusion of the mean flock weight rather than mean doe weight makes this is index more suitable for inter-flock comparisons of reproductive performance at flock level. Since factors such as purchase and sales policy, which are not directly related to reproductive performance, also affect the mean flock weight it may be difficult to interpret the results.

Category 2

To assess the overall productivity of a flock Peacock (1987) uses a flock production index defined as:

$$FPI = \frac{E_S + E_{SL} + E_{SI} + C_{NI}}{F_{IS}} \tag{5}$$

where FPI *= increase/decrease per unit of flock; units may be numbers, weight or monetary values;* E_S *= exits from the flock in the form of sales;* E_{SL} *= exits from the flock in the form of slaughter;* E_{SI} *= exits from the flock through social interactions;* C_{NI} *= change in net inventory;* F_{IS} *= initial flock size*

All valuable exits from the flock plus the change in flock value are expressed as fraction of the initial stock size. However, the input side is not considered, which may lead to misleading results if entry sources such as purchases and social interactions do play a role.

The off-take rate as used by Ndamukong *et al.* (1989) has similar shortcomings:

$$O=\frac{D}{N_p+D+M+OL} \tag{6}$$

where O=off-take rate; D= number of animals sold, consumed or given away during the year preceding the survey; N_P*= number of animals present at the time of the survey; M= number of animals that died during the preceding year; OL= number of animals that were lost for other reasons during the preceding year.*

Knipscheer *et al.* (1983) calculated the average net physical off-take per age category and multiplied it by the average value (price) in that category to get the gross returns, which give the average return per average flock, when aggregated. Here the input side is taken into consideration. This index is thus based on average values of a number of flocks.

Suggested modifications to the existing indices

Category 1

The most realistic estimate of the reproductive performance is obtained when the 'output' is aggregated per reproduction unit, which can be either the reproducing female or the reproducing part of the flock. Such an index, based on the individual doe, is:

$$RPI=\frac{\sum_{1}^{n}(LWW)}{T_n-T_1+\frac{T_n-T_1}{n-1}}*365 \tag{7}$$

where RPI=Reproduction Index in kg/doe/y; LWW= liveweight of litter at weaning (kg); T_1*= age at first parturition (d);* T_n*= age at* n^{th} *parturition (d)*

This index thus measures the actual weaned weight per doe and is thus not affected by anormally distributed and/or correlated means, which can have a serious effect on some or all of the indices in the first category. A factor equal to the average parturition interval is included in the denominator to account for the time required to produce the first litter, to avoid a bias in favour of females of lower parities. If desired, the average actual or metabolic weight can be included in the denominator. Of course, this will increase the number of measurements required, especially when weights vary considerably. Therefore such an inclusion only seems useful when the average liveweights of flocks to be compared differ more than normal fluctuations in liveweight. The DP index yields the same results if the parameters concerned are averaged over the whole reproductive life cycle studied and if the parameters concerned do not correlate. However the RPI requires fewer parameters to be measured. The RPI is intended to study the productivity at a sub-level of the overall flock productivity. If one wants to relate this individual productivity to the whole flock a second index should be added, for instance based on the liveweight ratio: (liveweight active breeding stock)/(liveweight whole flock).

Category 2

In this paper stock entries or inflow refer to all animals that enter the flock from outside, and thus excludes births. On the exit side, outflow concerns all animals that leave the flock and represent a value (also termed productive exits). It thus excludes mortality, theft and losses (also termed non-productive exits).

Peacock's (1987) FPI by has been modified to include flock entries in the numerator and to include average stock size rather than initial stock size in the denominator, p_{kg} (standardised to one year):

$$P_{kg} = \frac{O - I + C_{ni}}{FW_m} * \frac{365}{\text{period}} \tag{8}$$

where O represents outflow, I all inflow, FW_m *the weighted average stock, all in kg liveweight.*

If monetary values are entered instead of kg liveweight, the returns to capital can be estimated similar to Upton (1985). Proper appraisal of current stock may prove sometimes difficult, because the economic value may not only depend on the liveweight but also on the type of animal. For instance, a farmer may attach a higher value to a breeding doe than to a buck.

A more accurate measurement of productivity in biological sense gives the productivity index p_b, based on Knipscheer *et al.* (1983) and Peacock (1987), with the production in a flock expressed in kg liveweight and the average weighted flock size expressed in kg metabolic weight (p_b):

$$P_b = \frac{O - I + C_{NI}}{FMW_m} * \frac{365}{\text{period}} \tag{9}$$

where FMW_m *refers to the average metabolic flock weight.*

Although the average metabolic weight gives a good indication of the feed required to maintain the flock and to attain the production levels concerned it does not actually represent real intake. If the objective is to assess the productivity per kg feed consumed, the average flock weight can be replaced with the feed consumed, for instance expressed in tonnes of Digestible Organic Matter Intake (DOMI):

$$P_d = \frac{O - I + C_{NI}}{DOMI} * \frac{365}{period} \tag{10}$$

Under farmers' conditions, however, it will often be too difficult to obtain a reliable estimate of DOMI.

We used three criteria to evaluate these indices: accuracy, no. of parameters required and the ease with which these parameters can be obtained. Table 1 gives an overview of the parameters required for each index.

THE DATA SETS USED TO EVALUATE THE INDICES

On-station and field data were used to evaluate the productivity indices. The on-station data were collected during the period 1984-1988 in two pilot units. The flocks consisting of 12 breeding does, one (adult) buck and offspring up to one year of age, were housed in huts with slatted floors and fed on a cut and carry basis (Bosman *et al.*, 1988). The basic ration consisted of *Panicum maximum* and browse (*Gliricidia sepium* and *Leucaena leucocephala*). If browse was scarce, small amounts of brewers' dried grains were fed (<50 kg/unit/year).

The field data were collected between 1990-1992 in six villages in South-Western Nigeria (Ayeni and Bosman, 1993; Bosman and Ayeni, 1993; Bosman and Moll, 1995). In this paper data sets from the three major management categories, were used: a) free roaming (FR); b) confinement by tethering (CT); and, c) confinement in enclosures (CE) (Bosman and Moll, 1995).

RESULTS

To illustrate the differences between the indices **1**, **2**, **3** and **7** which aim to estimate the same characteristic i.e. kg of weaned offspring per reproductive female per year, a sample flock was chosen from the field data (Table 2). To give index **3** the same basis as the others, p (the fraction of actively reproducing females) was set at one. As weaning under village conditions was not a well-defined management practice

Table 1. Productivity indices and the parameters they require

	Index No	Assessment level	Weaning weight	P-interval/ time part.	Doe weight	Survival till weaning	Litter size at birth	No of parturitions	(Metabolic) Flock weight	Flock entries	Flock exits	Initial flock size	Final flock size	Fraction reproductive does	DOMI
$y=\frac{LWW*365}{INV}$	1	parturitions	+	+											
$DPI=\frac{365*(N-1)}{T_n-T_1}*LS_b*S*W_a$	2	doe	+	+		+	+								
$y=\frac{LS_B*(BW+WG_{B-W})*S*P*365}{INV}$	3	flock	+	+		+	+							+	
$y=\frac{N*LS_B*S*W_W}{FW_m}$	4	flock	+	(+)		+	+	+	+						
$RPI=\frac{\sum_1^n(LWW)}{T_n-T_1+\frac{T_n-T_1}{n-1}}*365$	7	doe	+	+				(+)							
$FPI=\frac{E_S+E_{SL}+E_{SI}+C_{NI}}{F_{IS}}$	5	flock									+	+	+		
$O=\frac{D}{N_p+D+M+OL}$	6	flock									+	(+)	+		
$P_{kg}=\frac{E_p-I+C_{NI}}{FW_m}*\frac{365}{period}$	8	flock								+	+	+	+		
$P_b=\frac{E_p-I+C_{NI}}{FMW_m}*\frac{365}{period}$	9	flock								+	+	+	+		
$P_d=\frac{E_p-I+C_{NI}}{DOMI}*\frac{365}{period}$	10	flock								+	+	+	+		+

Table 2. Reproduction indices for a sample flock derived from field data in South-Western Nigeria (total length observation period 2.5 years)

	No of days observed	Doe no.	LSB	Parity	Parturition interval (days)	Litter weight at 13 weeks (kg)	Average weight kids at 13 weeks (kg)	Average doe weight (kg)	survival rate birth-13 weeks of age	DPI (2)	RPI (7)	Wilson (1)	Hofs (3)	ww/doe/yr
	727	2000	1	1		8.1	8.1	15	1.00			12.32		
			2	2	240	0.0		19	0.00	0.54	6.16	0.00		
			2	3	273	5.6	5.6	19	0.5	0.46	6.50			6.88
	300	2002	1	1		4.9	4.9	15	1.00					
	917	2006	2	1		5.6	5.6	21	0.50			6.49		
			1	2	315	0.0		20	0.0	0.11	3.24	0.00		
			2	3	217	0.0		25	0.00	0.10	2.56	0.00		
			2	4	228	7.2	3.6	27	1.00	0.20	4.61			5.09
	491	2007	1	1		4.2	4.2	11	1.00					
	849	2008	1	1		4.7	4.7	19	1.00			4.16		
			1	2	412	6.1	6.1	18	1.00	0.26	4.78			4.64
	849	2009	2	1		5.5	5.5	14	0.50			6.81		
			1	2	295	3.2	3.2	15	1.00	0.42	5.38	5.56		
			2	3	210	4.1	4.1	15	0.50	0.47	6.17			5.50
	917	2011	2	1		9.1	4.55	23	1.00			11.99		
			2	2	277	6.1	6.1	21	0.50	0.48	10.01	10.45		
			2	3	213	7.1	3.55	23	1.00	0.53	11.07			8.88
	370	2012	1	1		6.9	6.9	19	1.00					
	435	2013	2	1		10.2	5.1	10	1.00			14.89		
			1	2	250	3.4	3.4	12	1.00	0.85	9.93			11.41
	80	2017	3	1		10.9	3.3	17	1.00					
total	5935					112.9								
mean			1.62		266		4.92	17	0.74	0.46	7.18	6.61	8.05	7.07
s.d.										0.21	2.47	5.07		2.39
cv(%)										45.44	34.39	76.79		33.88
	doe days				5935					estimated flock prod.				
	dd/yr				2374		mean			55.24	46.68	42.97	52.37	45.97
	average flock size (does)				6.50		upper confidence limit			81.58	63.53	65.14		62.31
	total of weaned weight per year				45.2		lower confidence limit			28.90	29.83	20.80		29.62

"weaning weight" was defined as the litter liveweight at 13 weeks of age. For this purpose index **2** is based on litter means and expressed per (average) kg doe weight. First it should be noted that indices **1**, **2**, **7** could not be calculated for 40% of the reproducing does, because data were only available on one litter (for all does studied on-farm this percentage was 45%). As expected, index **1** shows the greatest degree of variation both between and within animals, resulting in a coefficient of variation of about 75%. Indices **2** and **7**, being calculated per animal, show less variation (45% and 34%, respectively), which corresponds to the variation actually found between multiparous does (last column). Although on average indices **2** and **7** render comparable results, differences at the level of the individual animal can be considerable (e.g. if not all kids reach the age of 13 weeks), although these differences can be partly confounded with weight changes (compare for instance does 2000 and 2006). Because of the considerable (but normal) variation, the total weaned weight per year is within the estimated confidence interval of indices **1**, **2** and **7**. The difference between the total production and the estimate of index **3** (7 kg) is difficult to interpret because of the absence of confidence limits. As the estimate falls within the confidence limits of the other indices it does not seem to wrongly estimate the actual value more than the other indices do. Note that index **3** includes all ten does. If the index is based on the same does as the other indices, the value falls by 0.5 kg due to a lower survival rate (0.68).

If flock averages are considered the picture changes slightly. Averages for both on-station and on-farm (per confinement category) are given in Table 3 while in Table 4 the averages for the underlying parameters are shown. Indices **1**, **3** and **7** render quite comparable values in the case of the on-station pilot units. Paired t-test analysis showed that in FR and CE flocks index **3** gave a statistically significantly ($P<0.05$) higher value than indices **1** and **7** (FR:1.2 kg and 1.8 kg on average, respectively; CE:3.0 kg and 3.2 kg on average, respectively). Indices **1** and **7** do not differ significantly ($p>0.05$).

Based on the underlying parameters, which show a higher weaning weight on-station than on-farm, almost equal parturition intervals and survival rates, and larger litter sizes at birth in the case of confined flocks one would expect indices **1**, **3** and **7** to reflect these differences. Only Index **7** shows the average on-station reproductive productivity to be statistically significantly ($p<0.05$) higher than on-farm.

Because the average doe liveweight is higher in the on-station flocks, the productivity changes in favour of the village flocks when reproductive productivity is expressed per kg doe liveweight (index **2**), resulting in the values for FR and CE flocks being just significantly ($p<0.05$) higher. A complicating factor is the fact that at village level the parameters constituting the index were found to be interrelated, i.e. survival rate is inversely related to litter size, as 90-day weights and litter size tend to be. Besides, on-station, adults were weighed weekly, whereas

Table 3. Productivity indices as calculated for the different data sets. On-farm values are means (± s.d.) of flock averages

	Index no	On-station		On-farm		
		Unit 1	Unit 2	Free roaming	Tethered	Enclosed
$y=\frac{LWW*365}{INV}$	1	10.2±6.5 32	8.3±5.1 34	8.3±4.9 54	5.3±3.3 4	5.4±1.2 10
$DPI=\frac{\frac{365*(N-1)}{T_n-T_1}*LS_b*S*W_e}{W_d}$	2	0.46±0.17 13	0.42±0.10 12	0.53±0.29 51	0.48±0.19 4	0.57±0.16 10
$y=\frac{LS_B*(BW+WG_{B-W})*S*P*365}{INV}$	3	10.5	10.0	9.3±3.5 55	7.4±2.4 4	8.7±3.5 10
$y=\frac{N*LS_B*S*W_W}{FW_m}$	4	0.22	0.20	0.19±0.15 55	0.27±0.24 4	0.20±0.14 10
$RPI=\frac{\sum_{1}^{n}(LWW)}{T_n-T_1+\frac{T_n-T_1}{n-1}}*365$	7	9.9±3.7 13	8.9±3.5 12	7.7±3.0 55	6.5±1.0 4	5.5±3.7 10
$FPI=\frac{E_S+E_{SL}+E_{SI}+C_{NI}}{F_{IS}}$	5	0.6	0.6	0.45±0.41 55	1.57±2.2 4	0.82±1.74 10
$O=\frac{D}{N_p+D+M+OL}$	6	0.6	0.6	0.40±0.38 55	0.58±0.61 4	0.38±0.23 10
$P_{ts}=\frac{E_p-I+C_{NI}}{FW_m}*\frac{365}{period}$	8	0.6	0.6	0.13±0.30 55	0.33±0.24 4	0.12±0.35 10
$P_b=\frac{E_p-I+C_{NI}}{FMW_m}*\frac{365}{period}$	9	1.19	1.15	0.30±0.62 55	0.66±0.58 4	0.29±0.74 10

on-farm adults were weighed every two months. However, it was not always possible to weigh all free roaming animals on such occasions. As a result the estimate of the average doe liveweights was less accurate on-farm. Nevertheless this illustration shows clearly that it really matters how the denominator is defined. If the metabolic liveweight had been included (to reflect nutritional constraints) the values would have been between the ones for indices **7** and **2**.

The main difference between indices **2** and **4** is the inclusion of the non-reproducing flock members, both adult and young stock, in the denominator. Thus although **4** is an index to measure reproductive performance it provides little insight into background, because unlike individual indices **1**, **2**, **3** and 7 it also includes

Table 4. Means of parameters composing the productivity indices. On-farm values are means (± s.e.) of flock averages

	On-station		On-farm		
	Unit 1	Unit 2	Free roaming	Tethered	Enclosed
Weaning weight (at 13 weeks of age)	5.7±0.2	5.8±0.2	4.7±0.1	4.9±0.2	4.3±0.2
parturition interval (days)	260±11	279±9	259±8	287±22	290±14
Litter size at birth	1.77±0.1	1.61± 0.1	1.61±0.20	1.30±0.3	1.38±0.43
Survival rate until weaning	0.75	0.80	0.81±0.02	0.86±0.06	0.85±0.05
Doe weight (kg)	21.5±0.2	20.4±0.2	17.1±0.3	14.9±0.8	16.1±0.8
Average flock weight (kg)	432	413	97±41	50±30	50±25
Average metabolic flock weight (kg)	219	214	42±18	24±13	22±12
Initial flock size (kg)	432	413	97.8±5.5	46.9±10.9	45.7±8.3
Final flock size (kg)	432	413	93.7±5.9	52.7±9.3	42.8±6.8
Flock entries (kg)	0	0	20.3±2.3	14.4±4.6	8.6±3.0
Flock exits (kg)	261	247	37.1±2.9	21.6±5.9	17.2±3.8
No. of reproductive females (>1 yr of age)	12	12	2.9±0.3	1.2±0.3	1.3±0.2

those management factors (such as sale and purchase) which affect herd composition and hence affect the value of index **4**.

Although overall flock productivity indices for the on-station flocks have been given in Table 2, they are somewhat difficult to interpret in relation to the on-farm values because of the rather rigid flock management implemented. For instance nearly all offspring were removed from the flock at the age of one year. Relatively few females were kept as replacement stock (only 3 animals in the case of Unit 1), because of the age of the starting flock. Furthermore, all males were castrated at the age of 4 weeks. The indices **5**, **6** and **8** all yield the same value, due to the absence of stock inflow and the constant flock size.

The on-farm indices show a great variation due to variations in management which both affected the numerator and denominator. (As negative values occurred the coefficient of variation is not suitable to express this variation.) Because of this large variation and the small number of observations in the confined flocks, only in the case of FR flocks did indices **5**, **8** and **9** differ statistically significantly ($p<0.05$) as found in a compared t-tests analysis. Indices **5** and **6** gave a value statistically significantly ($p<0.05$) higher than index **8** because of the exclusion of stock inflow. As the stock remained fairly constant over the observation period, indices **5** and **6** did not differ statistically significantly ($p>0.05$).

If the flock productivity indices are used to compare on-station performance with on-farm observations the picture becomes somewhat confused. In none of the cases did the CT values differ statistically significantly ($p > 0.05$) from the on-station ones. In the case of FR, indices **5**, **6**, **8** and **9** give significantly ($p < 0.05$) lower values than on-station, while in the case of CE indices **6**, **8** and **9** were found to differ significantly ($p < 0.05$). Because of the character of the on-station assessments these comparisons are solely of illustrative value.

Index **10** could not be estimated because feed intake was not measured in any of the flocks.

DISCUSSION

It can be concluded that if the aim of a reproductive index is to express the 'biological' potential, the index is best expressed on the basis of the individual animal. If the scarcity factor is related more to the individual animal as a whole, index **7** is preferable. If this factor is related more to the value of the individual (and if this value is reflected in the liveweight) or to the feed consumption the denominator of index **7** should be extended: by the average doe liveweight in the first case, and by the average metabolic doe liveweight in the second. The extended index is henceforth referred to as index $\mathbf{7_e}$. However, it should be realised that it may prove difficult to determine the average liveweight under farm conditions. Therefore such an inclusion only seems of use when the average liveweights of flocks to be compared differ more than normal fluctuations in liveweight. In practice this means breed comparisons or comparisons within the same breed between production systems with considerable difference in nutritional status. Both indices require a minimum of two parturitions per animal. If the parturitions intervals are distributed normally and if the births are spaced evenly in time an observation period of twice the average parturition interval should suffice to cover the vast majority (approximately 95%) of the possible cases. "Possible" cases because not all females will actually produce two litters, because of mortality, infertility or because they are removed from the flock. If the aim is to assess reproductive performance on a flock basis in order to demonstrate this difference, it is best to add the proportion of reproductive females actually included.

Overall flock productivity is best assessed by relating all inflow and outflow to average flock size. This can be based on total liveweight, metabolic liveweight or numbers or a combination, depending on which scarce resource it is to reflect. As it can be expected that flock dynamics will follow a yearly pattern, flock monitoring should cover a period of at least one year and preferably two years to allow for repeated measurement.

The characteristics of the production system determine which index is to be recommended. As the acquisition of livestock requires capital and because livestock maintains its value capital can be considered to be a relative constraint in all production systems. In addition, nutrition may be earmarked as constraint in some production systems. Small ruminant production in the Sahel and goat production in South-East Nigeria are examples of this type of production system.

For the case of goat production in South-Western Nigeria index **7** seems most appropriate for the assessment of reproductive performance because only one breed is involved, with comparable average doe liveweight in the case of FR and CE flocks. For comparisons with CT the use of index $\mathbf{7_e}$ could be considered; however, the differences between the doe liveweights are so small compared to the number of flocks that this does not seem worthwhile. The appraisal of flock productivity is best based on index **8** in the case of free-roaming flocks and indices **8** an **9** in the case of confined flocks.

Apart from assessing current productivity levels productivity indices have been used to predict the effect of possible interventions (Upton, 1985; Peacock, 1987). The value of such an assessment is limited because of the common assumption that effects of changes of parameters (mortality, production traits) on performance do not interact. Therefore, different models have been developed to facilitate this type of assessment (White *et al.*, 1983; Blackburn and Cartwright, 1987; Upton, 1989, 1993; Baptist and Gall, 1992). In these models the production process is mimicked in varying detail and under a corresponding varying range of assumptions. As in the case of static conditions, indices can be used to facilitate comparisons between simulated situations. In all cases a sound knowledge of the existing production system is a prerequisite for obtaining reliable estimates of the effects of changes in parameters on system performance and hence on productivity. Such a model developed to assess current small ruminant flock states and to predict the effects of innovations is dealt with in a second paper (Bosman *et al.*, 1995).

The above recommendation to use different indices for production systems in the same area underlines the difficulties involved in comparing flocks on the basis of productivity indices. Although these 'bio-technical' evaluations are valuable for diagnosing the animal sub-system, final results have to be judged in the context of the whole production system. Appraisal of the value of small ruminant production at the household level is discussed in the third paper (Bosman and Moll, 1995).

Furthermore, above assessments were made for 'single' output (meat) systems. If more valuable products (for example milk, manure) are derived the assessment will be more complex, because appropriate factors will have to be identified to convert all output into one parameter.

This study has demonstrated that it is only appropriate to use productivity indices to compare animal sub-systems if the differences between the total production systems, which may interact with the animal component, are represented in the index.

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2.2 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS[1]
2. Using a simulation model to assess flock state and to test impact of innovations

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ABSTRACT

A dynamic, stochastic, feed-driven model has been developed in response to the recommendation to model livestock systems so that the interrelationships of production parameters and their effect on productivity can be elucidated. It enables the productivity of small ruminant flocks to be investigated. The model simulates the performance of the individual animal within the flock so that effect of changes in feed intake or herd dynamics on production traits and hence productivity can be assessed. A sensitivity analysis singled out adult weight, weight and age at sexual maturity as the most important breed characteristics. Validation of the model with data from Wageningen Agricultural University and South-Western Nigeria showed that the model functions satisfactorily. The testing of the innovations shows how the model can be used to test the possible effect of interventions, even if, as is often the case in the tropics, not all input parameters are fully known.

Keywords: small ruminants, productivity, simulation model

INTRODUCTION

In the previous paper (Bosman and Udo, 1995) it was demonstrated that the flock productivity of small ruminant production systems can be effectively defined by relating the total output (corrected for flock entries and net inventory changes) to average flock size or to average metabolic flock size. However, these indices provide little insight into the effect of the underlying parameters on the actual values. The modelling of livestock systems has been advocated as a tool to elucidate the interrelationships of production parameters and their effect on productivity (Baptist, 1992; Upton, 1989, 1993).

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[1] *submitted to Agricultural Systems*

Spedding (1988) defined a model as "an abstraction and simplification of the real world, specified so as to capture the principal interactions and behaviour of the systems under study and capable of experimental manipulation in order to project the consequences of changes in the determinants of the system's behaviour". Given the complexity and diversity of livestock production systems it is not surprising that the livestock models described in the literature differ widely. Although it is easily accepted that a model should be as simple as possible, the choice of degree of simplicity may not be so easy. The consequences of each simplification on the parameters being studied have to be considered carefully. The herd and flock growth model advocated by Upton (1989, 1993) for assessing livestock productivity offers a quick way to estimate a measure of productivity if the production traits (mortality, reproduction, weight gain and/or milk production) are known. However, this model is not suitable for assessing the effect of nutrition or flock management on productivity. More complex models may not necessarily lead to better results. In fact they may be misleading if they are not technically sound or if they are used under conditions or assumptions other than intended by the modellers. Thus only with a well defined concept of its intended use can a suitable model be selected, modified or created. We investigated a model approach for assessing the interrelationships of production parameters and productivity of small ruminant production systems.

MODEL REQUIREMENTS

Within a given environmental setting, productivity of small ruminant production systems is largely determined by nutrition and management. Thus, the first requirement of a model of such a system is that it can simulate the effect of nutrition and management on its production traits and hence its productivity. Feed intake must be dealt with in such a way that its effect on reproduction and weight gain can be assessed. Such aspects are typically studied by single animal effects (Sørensen, 1992). Furthermore, the interaction between feed intake and management and total systems productivity and its dynamics must be included. Including individual animals in a dynamic model means the occurrence of discrete events such as mortality or pregnancy, which are best dealt with through stochastic simulation.

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Thus a dynamic, stochastic model is required that simulates the career of a small ruminant within a production system. The model is to be used to assess productivity of small ruminant production systems, so the final output must include productivity parameters. The data required as inputs into the model should be easily obtainable, also in the tropics.

Most models that simulate animal production at herd or flock level over time have been designed for cattle. The emphasis put on specific aspects of the production system depends on the intended use of the model. Those designed to mimic dairy production attempt to simulate milk production in detail (Sørensen, 1992), whereas in beef oriented models, more attention is paid to the liveweight development and composition (Notter *et al.*, 1979a, 1979b, 1979c; Sanders and Cartwright, 1979; Oltjen *et al.*, 1986; Loewer *et al.*, 1987). Some models extend beyond the animal system by including economic (Notter *et al.*, 1979a; Brockington *et al.*, 1983, 1986; Dijkhuizen *et al.*, 1986) or feed production parameters (Cartwright and Doren, 1986) or both (Parsch *et al.*, 1986; Sullivan and Capella, 1986; v.d. Lee *et al.*, 1993; Udo and Brouwer, 1993; Brouwer and Steenstra, 1994).

The BReeding EWe (BREW) flock model (White *et al.*, 1983) and the Texas A&M Sheep simulation model (TAMS) (Blackburn and Cartwright, 1987) were specifically designed to simulate small ruminant flocks. The BREW flock model is used to predict the physical, biological and economic consequences of changes in stocking rate and date of lambing in the Merino breed. Predictions are made of the ovulation and fertilisation rate of the breeding ewes and the subsequent survival of embryos and lambs. Lamb growth rates are determined relative to their predicted intake levels of milk and herbage.

The TAMS model was developed to facilitate investigations of the effects of varying genetic potentials, nutritional levels and management alternatives on oestrous, conception, birth, lactation, nutrient intake, growth, wool growth and death of sheep.

The major components in both models are reproduction, milk production, weight changes, feed intake and nutrient partitioning and management. Both models are feed driven. BREW considers only energy, while TAMS simulates both energy and protein. BREW also contains a module that simulates pasture production as a function of climatic conditions. TAMS simulates individual animals, which are aggregated into groups, while BREW simulates groups of animals, based on characteristics of the average animal. TAMS requires input parameters for forage (% crude protein, % digestibility, availability), genotype of the animal (adult weight, maturing rate, milk production and seasonality, ovulation rate, wool growth), health (mortality) and management (supplementary feeding, breeding season, weaning criteria, replacement policy, sales, castration). In BREW, which was designed for a specific breed under specific conditions these parameters are contained in the programme and cannot be changed. Both models make use of the concept of 'Optimum' Weight (W_o), which is defined as the weight at given age of an animal growing at its maximum genetic potential, thus not hindered by restrictions to feed intake or other factors (such as climate, pregnancy or diseases).

It is used as a 'yardstick' to control feed intake, weight changes and to calculate the condition of the animal.

In both models output from the system consists of sales, culls, milk and wool. In TAMS culls are treated stochastically based on the parameters set for the breeding animals. Lambs not kept as replacement are sold or consumed when they reach a predefined age. Different measures of biological efficiency are given such as : (total sales + consumption (kg))/DMI(kg), (milk(kg))/DMI(kg) and (total energy produced)/(energy intake).

In BREW, sales are treated deterministically, based on liveweight for whether lambs or cast-for-age proportion for young ewes. Animal output is converted to monetary values and are thus entered in the simulated cash flow of the farm, which yields gross margins as final results.

Feed intake in TAMS is based on the limitations imposed on the animal by feed availability, satiety factor (physiological limit) and the capacity of the digestive system (physical limit). Whichever is the lowest determines feed intake. Satiety is a function of the energy requirements and digestibility. Thus milk production and pregnancy can lead to an increased intake in case satiety is the limiting factor. The physical limit is a function of W_o, adult weight and digestibility. It decreases as the animal matures.

In BREW total intake is a function of pasture and supplement intake. It is constrained by an upper limit, defined as a function of W_α. This upper limit is increased with the requirements for milk production. Pregnancy does not increase feed intake. Pasture intake by lambs is assumed to be zero during their first three weeks of life. Thereafter, pasture intake increases exponentially as function of the available milk, the quality of the pasture and the upper limit of intake. TAMS does not treat feed intake of young lambs differently from older ones.

Total intake is converted to Metabolisable Energy (ME), and hence through different conversion factors (k) to Net Energy (NE) for maintenance and production.

None of the existing dynamic livestock production simulation models meet all the requirements stipulated in the first two paragraphs of this section. In TAMS regulation of feed intake and conversion into NE for production is not in line with recent experimental work on feed intake regulation in sheep and goats (Ketelaars and Tolkamp, 1991). Secondly, the input parameters required to mimic the reproduction process in detail require sophisticated techniques not available in tropical production situations. The method of output determination, however, is suitable for our purpose.

The basic structure of the model we developed, PC-Flock, is similar to the models of Brouwer and Steenstra (1994) and Blackburn and Cartwright (1987). The energy driven model was designed for small ruminant meat breeds.

DESIGN OF PC-FLOCK

Our model is a dynamic stochastic model that simulates the performance of individual animals on time-step basis. The state of the animal at any time is defined by 11 state variables. The model is stochastic, i.e. discrete events, like mortality and pregnancy, are triggered stochastically based on probabilities entered by the user. Other variables, like gestation length and weight gain, are deterministic. The programme is written in dBASE IV (a registered trade mark of Ashton Tate) and all input and output is stored in 'dBASE' files (Figure 1).

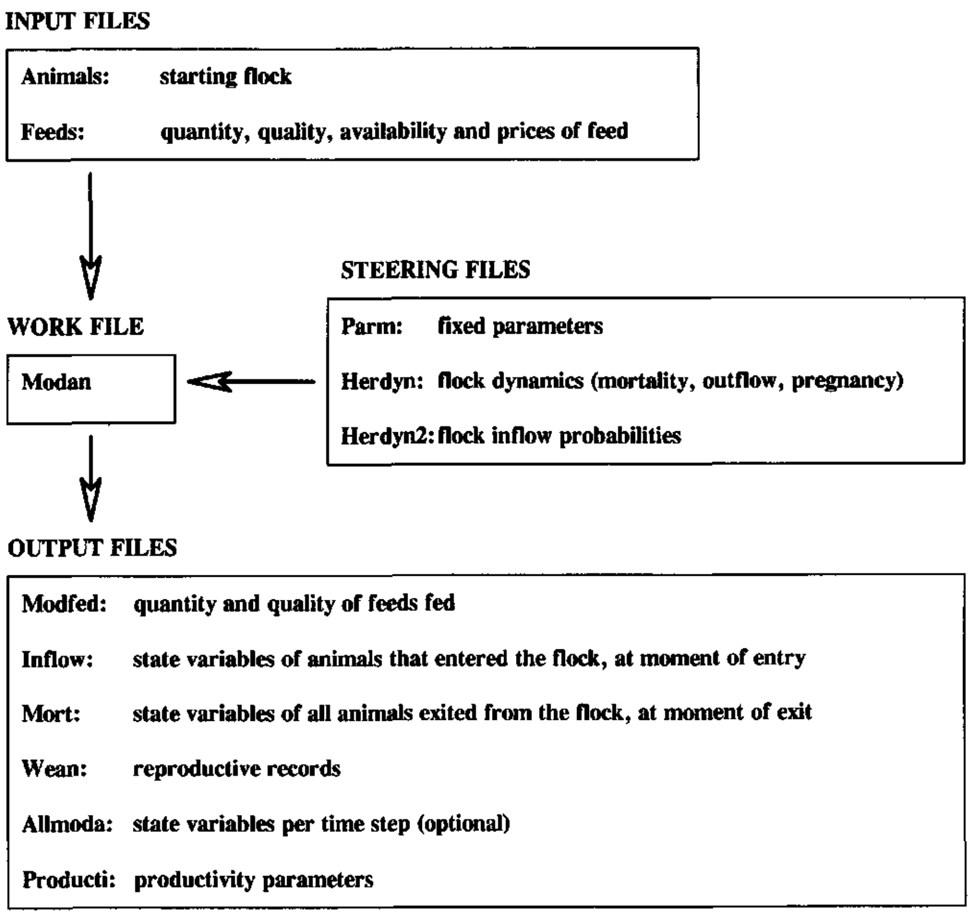

Figure 1. Scheme of Dbase files used in the model.

Inputs into the model are: feeds ('feeds.dbf'), flock dynamic parameters ('herdyn.dbf'), fixed parameters ('parm.dbf') and a starting flock (animals.dbf'). The total amount of feed available in a year should be entered, with the period of availability and the quality (%ash, %crude protein, digestibility). Optionally, the maximum proportion of a particular feed in the total ration can be set. The flock parameters include the probabilities of: kidding, mortality, other flock exits and flock entries. These parameters are specified per sex and age class. Furthermore, the flock size and structure can be controlled by setting the minimum and maximum number per age class. The fixed parameters consisting of decision variables and constants, refer to breed characteristics, management related factors and condition criteria. Decision variables are those that can be directly manipulated by the farmer, whereas constants are those that, at least in the short run, cannot be changed by the farmer. All fixed parameters are treated as constants during a simulation. The condition is defined as the ratio liveweight : optimum weight. The condition criteria are used to control events outside the range in which the entered probabilities were determined.

Sequence of events

After initialising the time parameters based on the entries input by the user (length of time-step, number of time-steps and number of runs) the sequence of events is as follows (Figure 2):

a) <u>on time-step basis</u>
- calculation of optimum weight and condition
- determination of mortality
- feed allocation
- energy calculations
- management (entries, exits)
- reproduction (delivery, pregnancies, weaning)
- update of time related parameters

b) <u>on annual basis</u>
- calculation of productivity indices

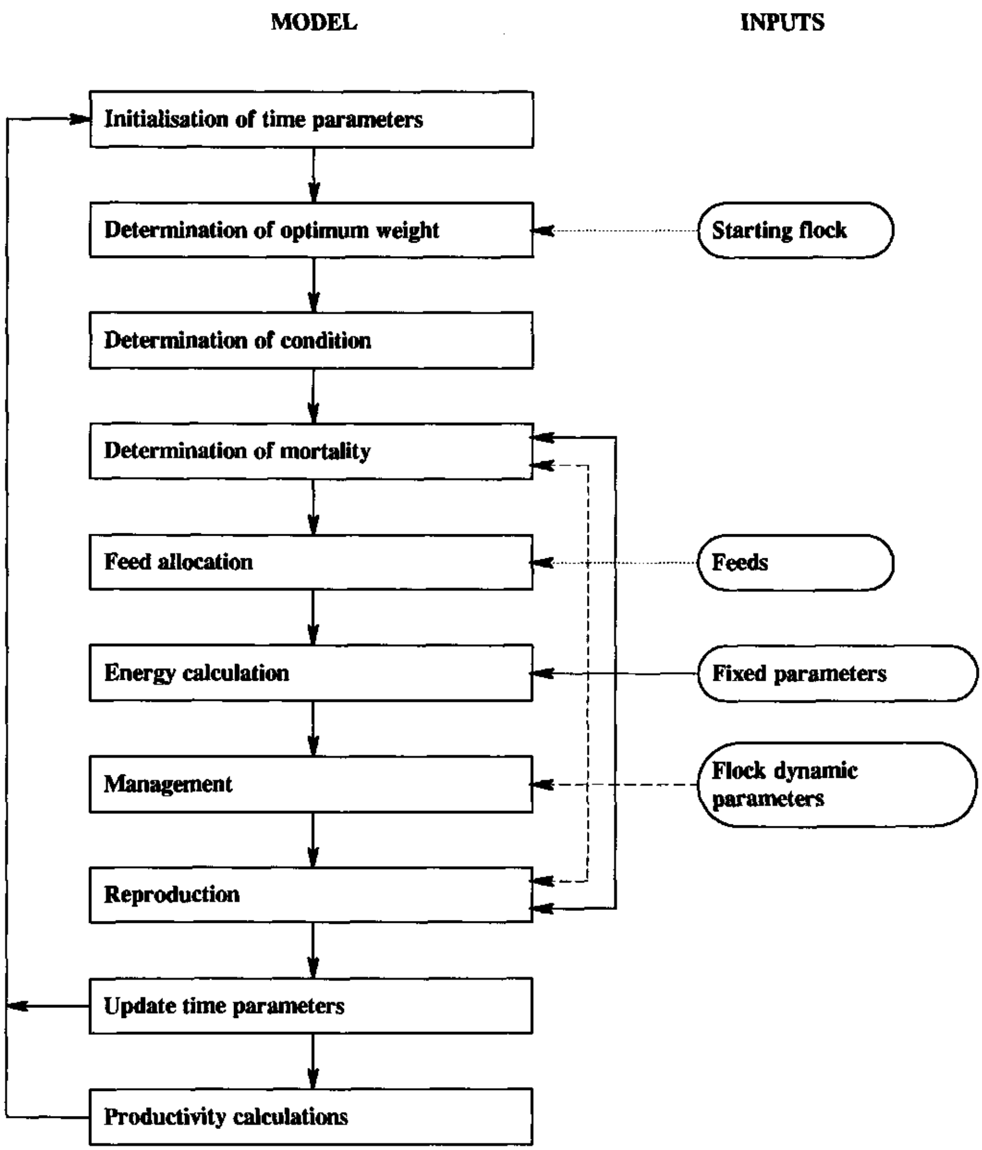

Figure 2. Sequence of events in the model.

Description of events

Optimum weight and condition: The optimum weight is the expected liveweight of an animal of certain age, fed on a good quality feed. It is calculated as (derived from Ogink, 1993):

$$W_o = W_a * \left(1 - \frac{BW}{W_a} * \left(1 - \exp(-0.00242 * age)^{1.07} * \frac{BW}{W_a} \right) \right)$$

metric weight

where W_o= optimum weight, W_a= adult weight and BW= birth weight all in kg; age is in years

The adult weight is defined as the maximum (asymptotic) weight approached by an animal growing 'undisturbed'. The rate at which this maximum is approached depends on the quality of the feed. Disturbances can be caused by variations in feed quality and the activity of the animal. When feeding good quality pelleted feed (10.7 MJ ME/kg DM) to castrated West African Dwarf bucks, Ogink (1993) found that it took more than 3 years for their liveweight to approach the estimated maximum (>95%). Meanwhile, castrates fed on low quality pelleted feed (7.5 MJ ME/kg DM) had attained less than 80% of the estimated maximum. Under tropical field conditions reproducing animals may never get close to the maximum. Determination of the maximum weight may therefore require specific on-station research over a prolonged period. If this is not possible, one may have to rely on estimates derived from comparable breeds or extrapolation of field data.

Mortality: Mortality is estimated from the probabilities specified by the user:

$$P_{am} = 1 - (1 - P_m)^{\left(\frac{TS}{365 * C_l}\right)}$$

where P_{am}= the probability of mortality , TS= the length of the time step (d), P_m= the probability of mortality as specified by the user for the given category of animals and C_l= the length of the age class (y)

If the condition falls below its minimum (Q_m), defined as the minimum condition required for survival, the probability is set at 1. Whether an animal earmarked to die dies at the beginning or at the end of the time step is determined randomly (50% probability), to mimic the time aspect of mortality.

Feed allocation: At the beginning of each run, feeds are ranked according to estimated maximum Digestible Dry Matter Intake ($DDMI_m$, g $kg^{-0.75}$ d^{-1}) per feed and $DDMI_m$ of iso-proportional combinations (e.g. 50% of feed1 + 50% of feed2, 33.3% of feed1 + 33.3% of feed2 + 33.3% of feed3). $DDMI_m$ is estimated as a function of Dry Matter Digestibility (DMD) and Crude Protein (CP) content according to Brouwer and Steenstra (1994):

$$DDMI_m = -31.07 + 1.296 * DMD - 1.142 * CP - 0.0084 * (DMD^2) - 0.0504 * (CP)^2 + 0.0553 * DMD * CP$$

At the beginning of each time-step a ration with the highest estimated $DDMI_m$ is composed, based on the availability of the feeds and the maximum percentage allowed in the diet. Secondly, the total available amount of this ration is determined (T_a). Thirdly, based on the quality parameters of this ration DDMI is estimated per animal ($DDMI_a$) and summed over the whole flock (T_c). If T_c is less than or equal to T_a the programme proceeds to the next module, otherwise more feeds will be included, which will reduce DDMI + T_c and increase T_a until equilibrium between both is reached. If T_a and T_c cannot be balanced, the $DDMI_a$ as calculated in the last attempt, will be restricted in proportion to the ratio T_a/T_c of the last attempt.

Feed intake: $DDMI_a$ is based on $DDMI_m$, with correction for maturity (based on asymptotic adult weight, Brouwer and Steenstra, 1994):

$$DDMI_a = M * W^{(b-0.75)} * W_a^{(0.75-b)}$$

where W=liveweight of the animal (kg), M=the maintenance requirements (g DDMI $kg^{-0.75}$ d^{-1}) and b=a correction factor estimated as:

$$b = \frac{\ln(M_f) + 0.75 * \ln(2) - \ln(DDMI_m)}{\ln(2)}$$

Where M_f= the maintenance requirements of the animals assumed to be 28 g DDMI $kg^{-0.75}$ d^{-1}

It is assumed that during lactation feed intake will increase with a user specified proportion (I_{cm}) of the requirements for milk production. Kids are assumed to consume all the milk produced by their mother and not to consume other feeds during the first 30 days of life. Subsequently, intake from other feeds increases linearly to $DDMI_a$ at weaning.

Milk production: Milk yield is predicted from the average production, litter size and lactation stage according to a Wood curve modified for small ruminant meat breeds (Gibb and Treacher, 1982):

If litter size is 1

$$MY = \frac{1.87 * W_l^{0.598} * \exp(-0.185 * W_l) * AP_l}{\exp(0.918 - 0.039 * ALL)}$$

If litter size > 1

$$MY=\frac{3.15*W_l^{0.398}*\exp(-0.167*W_l)*AP_l}{\exp(1.249-0.040*ALL)}$$

where MY= milk yield, W_l=week of lactation and AP_l= average production of the corresponding litter size (kg/d) and ALL= Average Lactation Length

Thus, maximum production is attained between the second and fourth weeks of lactation. For selected dairy breeds this maximum will be attained at a later stage (sixth or seventh week).

The average production (AP) and lactation length (ALL) to be specified by the user should represent the average production of single litters on good quality feed. Correction factors are entered by the user to adjust AP for litter size. To simulate the effect of poorer quality feeds on milk production, AP is reduced if the quality of the feed (expressed as: ($DDMI_m$)/(DDMI required for maintenance)), falls below a specified value (R_i).

Energy: All production calculations are based on energy. Estimated net energy intake (NEI) is based on DDMI, via digestible organic matter intake and Metabolisable Energy Intake (MEI). Recalculation of ARC (1980) data showed for *ad libitum* fed animals an overall ME conversion into NE for maintenance, gain and lactation of 0.6 (Tolkamp and Ketelaars, 1993). Therefore, an efficiency (k) of 0.6 is used to convert MEI into NEI if there is no feed restriction, otherwise efficiency is calculated as (based on ARC, 1980):

$$k=0.87-0.22*\frac{MEI_2}{MEI_1}$$

where MEI_1=estimated MEI with no restriction and MEI_2= the restricted MEI

Maintenance requirements are based on estimates given by Zemmelink *et al.* (1991) for pen-fed goats: 24.3 g DOMI or 0.231 MJ $kg^{-0.75}$ d^{-1} NEI. As this value was estimated at a low level of activity it can be adjusted for activity (M_c) by the user to estimate total feed intake.

Growth requirements (W_r) are 0.0229 MJ/g for animals above the assumed inflection point (adult weight (W_a)/liveweight=4.28, derived from Ogink, 1993) and for animals below that point estimated as:

$$W_r=0.0048+(0.0229-0.0048)*\frac{W_a}{4.28}*W$$

where W= the liveweight (kg)

Requirements for milk production during the first part of the lactation (weeks 1-7) are based on the average milk production and the energy content of the milk. The energy content estimate is based on the fat content as (Sauvent and Morand-Fehr, 1991):

$$NE_l = 2.97 + 0.047 * (FC - 40)$$

Where NE_l *= net energy content (MJ/kg) and FC= fat content (g/kg)*

During the remaining part of the lactation, the requirements are based on the actual predicted production. This approach thus excludes the complex interaction between milk production and feed intake and utilisation during the early stages of lactation. At the same time it reduces milk production requirements towards the end of the lactation, so that animals can become pregnant before weaning.

Requirements for pregnancy are based on the energy content of the foetus, derived from ARC (1980):

$$FE = BW_p * LS_p * 10^{(0.597 - 7.819 * \exp(-0.0175 * T_p))}$$

where FE=the energy content of the foetus, BW_p *= the predicted birth weight (kg),* LS_p *= the predicted litter size and* T_p *= the number of days pregnant*

A possible negative energy balance is compensated for by weight loss, reduced milk yield and reduced expected birth weight. Although it is generally agreed that the possible weight loss is restricted to a maximum that is related to the condition of the animal, no explicit data are available to quantify this relationship and different limits are used (Geisler and Neal, 1979; Blackburn and Cartwright, 1987). Blackburn and Cartwright (1987) relate the maximum availability of lean and fat that can be catabolized to the amount needed to meet 25 and 75%, respectively, of the maintenance requirements of a fasting animal. Geisler and Neal (1979) assumed a constant value of 150 g d^{-1} for ewes with a liveweight of 70 kg, based on Russel *et al.* (1968) and Robbinson *et al.* (1978). In our model the maximum weight loss of an animal in good condition is set at 8.7 g $kg^{-0.75}$ d^{-1}, at 4.4 for an animal in moderate condition and 0 for animal in poor condition (derived from Blackburn and Cartwright, 1987, and Brockington *et al.*, 1983). Body reserves are assumed to be used with an efficiency of 80%. If expected birth weight falls below 0.1 kg, the animal aborts.

Management: Flock exits, other than mortality are determined analogously to mortality based on probabilities as specified by the user; if the total number of animals exceeds the maximum set for an age class, surplus animals are 'forced' out (by default the oldest goes first); lactating animals can only leave the flock through mortality; if the total number of animals is below the minimum number set for this category, no animals will be removed, however, neither any additional animals are bought or otherwise acquired, other than through the normal inflow procedure. Flock entries, other than births, are determined from probabilities related to flock size, as specified by the user.

Reproduction: Pregnancies are determined according to Brouwer and Steenstra (1994). However, the calculation base is not one year (360 days) but a parameter (P_i) defined by the user to determine the kidding probability as also entered by the user. In formula:

$$PL_{ts} = 1 - PL_{ac}^{\frac{TS}{T_c}}$$

where PL_{ts} =the lambing probability for the Time Step (TS, d); PL_{ac}=lambing probability for females in the Age Category (AC) concerned; and

$$T_c = P_i - \left(1 + \frac{PL_{ac} * (1 - PL_{ac})}{5}\right) * (PPA + G_p)$$

where P_i=base used for calculation of lambing probability (d); PPA=post-partum anoestrus (d) and G_p=gestation length (d)

It is assumed that all animals that become pregnant deliver, except those which abort due to nutritional stress. For animals below a certain condition (Q_u, to be defined by the user) lambing probability (PL_{ac}) is reduced according to:
where PL_c=corrected lambing probability and Q the actual condition of the animal

$$PL_c = PL_{ac} - \frac{PL_{ac}}{0.25} * (Q_u - Q)$$

Animals that cannot become pregnant are: those in post-partum anoestrus; those having a negative energy balance and a condition below one; those having not reached the age of sexual maturity (A_m); those that do not satisfy the weight at sexual maturity criterion (W_m).

When an animal is found to be pregnant the litter size at birth and birth weights are predicted. The litter size is predicted from the average probabilities given by the user. If condition is below Q_u, litter size is set at 1. Primiparous does generally have smaller litters than multiparous does. The difference between the second and subsequent parities is small (Peaker, 1978; Erasmus and Fourie, 1985; Devendra and Burns, 1983; Bajhau and Kennedy, 1990). This difference is simulated by allowing primiparous does only single or twin litters.

Prediction of birth weight is derived from the relationship given by Dickinson *et al.* (1962):

$$BW_p = \exp(0.83 * \ln(LW_d) - CF)$$

where BW_p=predicted birth weight (kg), LW_d=liveweight of the doe (kg) and CF a correction factor for litter size (LS) (CF=1.926 for LS=1, CF=2.174 for LS=2, CF=2.405 for LS=3 and CF=2.636 for LS=4)

Animals deliver when time since conception is equal to or exceeds the gestation length. Litter size at birth and birth weight are equal to the predicted values at time of delivery. Doe liveweight is reset and birth recorded.

Update: All relevant time dependent parameters (age, liveweight, pregnancy stage, lactation stage) are updated at the end of each time step.

Productivity: Productivity indices and production traits are calculated at the end of each year, considering all preceding years. The following indices, derived from Bosman and Udo (1995), are available:

a) reproduction

$$RPI = \frac{\sum_{1}^{n}(LWW)}{T_n - T_1 + \frac{T_n - T_1}{n-1}} * 365$$

where RPI=Reproduction Index in kg/doe/y; LWW= liveweight of litter at weaning (kg); T_1= age at first parturition (d); T_n= age at n^{the} parturition (d)

$$RPIE = \frac{RPI}{W_d^{0.75}}$$

where RPIE=Reproduction Index in kg/kg metabolic doe weight/y

b) flock productivity

$$P_{kg} = \frac{O - I + C_{NI}}{FW_m} * \frac{365}{\text{period}}$$

where O represents outflow, I all inflow, FW_m the average stock and C_{NI} net change in stock inventory, all in kg liveweight.

$$P_b = \frac{O - I + C_{NI}}{FMW_m} * \frac{365}{\text{period}}$$

where FMW_m refers to the average metabolic flock weight.

$$P_d = \frac{O - I + C_{NI}}{DOMI} * \frac{365}{\text{period}}$$

As the initial state of the flock may have a major effect on the flock performance (especially during the first years of simulation) the programme allows initial flock composition to be created from the default flock, based on the average final flock composition of replicated runs over a specified time, both to be entered by the user. The default flock contains two females above one year, one male and one female kid. By default, the number of replicates is 5 and the length of the runs equal to the length entered by the user for the actual simulation runs.

Default values

To enable use of the model when not all needed input values can be determined, default values have been defined for the crucial input variables, determined for (tropical) small ruminant meat breeds (Tables 1 and 2). The breed-specific decision variables have been derived from literature and refer to breed averages. Those that are size-related (adult weight) have been specified for three categories: large, medium and small breeds. Adult liveweights of tropical small ruminant meat breeds are mostly within the range of 20 kg to 50 kg (Williamson and Payne, 1978; Devendra and McLeroy, 1982). Therefore 25, 35 and 45 kg have been chosen as the average for small, medium and large breeds, respectively. Note that adult reproducing does and ewes normally attain liveweights that are on average lower than the asymptotic (maximum) weight used in the model.

The age at sexual maturity varies with breed, liveweight and management practices. Dýrmundsson (1973) reported a range of 6 to 18 months for sheep, attained at 50 to 70% of the adult weight. For Angora goats, Shelton and Groff (1984) reported a range of 6 to 12 months. The default value has been put at 1 year.

Table 1. Default values used in the model

Parameter	Value	Description
Breed-specific		
W_a	25 small breeds 35 medium-sized breeds 45 large breeds	adult weight (kg)
AP	0.31 small breeds 0.40 medium-sized breeds 0.48 large breeds	average milk production of does with single litters, fed on good quality feed (kg/d)
FC	65	milk fat content (g/kg)
ALL	13	Average lactation length (weeks)
AP_t	0.4	milk production correction factor for litter size =2
AP_o	0.2*(ls-1)	milk production correction factor for litter size (ls) >2
A_m	1	age at sexual maturity (y)
W_m	0.5	(weight at sexual maturity)/W_a
P_p	0.8	kidding rate in period P_i
G_p	150	gestation period (d)
PPA	45	Post partum anoestrus (d)
PL_s	0.33	probability litter size=1
PL_t	0.51	probability litter size=2
PL_{tr}	0.13	probability litter size=3
PL_q	0.03	probability litter size=4
Management		
P_m	(Table 2)	mortality probabilities
W_a[1]	90	weaning age (days)
W_w[1]	0	weaning weight (kg)
M_c	1.25	correction factor for maintenance requirements
Other		
Q_u	0.7	upper condition criterion
Q_m	0.4	minimum condition criterion
R_i	1.5	critical intake ratio, below which milk production is reduced
P_i	230	base period for kidding rate calculation (d)
I_{cm}	0.8	fraction of requirements for milk production, provided by extra feed intake

[1] In the model, weaning can be based on age and/or weight; at least one of the two has to be specified; zero means that the criterion should not be used

Table 2. Default mortality probabilities per age class (identical for male and female); default values for other exit probabilities (i.e. sales, slaughters, transactions) are zero

Class	Upper age of class (y)	range of class (y)	mortality probability (%)
1	0.042	0.042	0.12
2	0.083	0.042	0.04
3	0.167	0.083	0.06
4	0.25	0.083	0.07
5	0.5	0.25	0.06
6	1	0.5	0.05
7	2	1	0.08
8	3	1	0.08
9	4	1	0.20
10	5	1	0.34
11	6	1	0.70
12	7	1	0.90
13	8	1	1

The milk production of females suckling single lambs and fed reasonable to good quality diets may vary considerably from 0.3 (Akinsoyinu *et al.*, 1977) to 2.1 kg d^{-1} (Raats *et al.*, 1983). The default average milk production (AP) has been set at 0.4 kg d^{-1} for a medium-sized breed and corrected for size (on MW basis) for other breeds, so that kids kept under the same conditions consume the same amount of milk per kg MW. The default lactation length is 13 weeks. The effect of litter size on milk production is not well documented for tropical breeds. In temperate meat sheep breeds, differences of 30 to 50% between single and twin suckling ewes have been reported (Gardner and Hogue, 1964; Gibb and Treacher, 1982; Gatenby, 1986). Differences between twin and larger litters have only been reported by Raats (1983) for Boer goats (13-20%). As default, average milk production of twins is 40% (AP_t) higher than that of single suckling females; in larger litters the increase per member has been put at 20% (AP_o).

The milk fat contents reported for meat goats are comparable to those of sheep and average around 6-7% (Akinsoyinu *et al.*, 1977; Gibb and Treacher, 1982; Morand-Fehr *et al.*, 1991). The default value is 6.5%.

The gestation period of goats and sheep is reported to vary from 141 to 157 days (Peaker, 1978; Shelton and Groff, 1984; Devendra and Mcleroy, 1982). The default used is 150 days. The post partum anoestrus (PPA) in non-seasonal breeds can vary considerably, mainly depending on the strain imposed by lactation, which in turn depends on the litter size and the level of nutrition. As default the value (45 days) used by Blackburn and Cartwright (1987) has been chosen.

The default probability of kidding (PL) has been put at 0.8, which means that on average 80% of the reproductive females will deliver in period P_i (default=230 days) or an average parturition interval of 288 days, which is within the values reviewed by Devendra and McLeroy (1982) and Bhattacharyya (1988).

The probabilities for litter size at birth for multiparous pregnancies have been based on Peaker (1978), Devendra and Burns (1983), Erasmus and Fourie (1985) and Bajhau and Kennedy (1990).

The default management practice include weaning at an age of 90 days, regardless of the weight. Maintenance requirements are increased by default by 25% for activity, in line with the NRC (1981) requirements for intensively managed flocks. The default mortality probabilities, specified per age class, have been derived from Dahl and Hjort (1976) and Mazumdar *et al.* (1980). These data result in a preweaning mortality of 26%, which agrees with the results of Wilson (1976), Obst *et al.* (1980), Tuah and Baah (1985), Singh *et al.* (1990) and Gama *et al.* (1991). The life expectancy of sheep and goats is assumed to be their reproductive lifespan which is mostly between 5 and 7 years (Atkins, 1986; Mohan *et al.*, 1986; Gama *et al.*, 1991). Beyond 7 years, the probability of death is set at one, to prevent permanent presence of non-productive animals in the flock. Other flock exit probabilities are by default set at zero.

The upper condition for pregnancy (Q_u) is by default put at 0.70, identical to that used by Brouwer and Steenstra (1994). The default minimum weight criterion (W_m) for pregnancy is put at 50% of the adult weight, based on Devendra and McLeroy (1982), Sutana *et al.* (1988), and McCan *et al.* (1989).

Although animals below a certain condition are very likely to die, there is no literature available to specify one minimum value. As default the value (0.4) of Brouwer and Steenstra (1994) is used.

The critical intake ratio has been put at 1.5. This means that if the voluntary intake, not corrected for maturity, is less than 1.5 times the amount required for maintenance, the milk production will be reduced. By default, 80% of the requirements for milk production are assumed to be covered by increased feed intake.

MODEL VALIDATION

As any model or scientific hypothesis, a simulation model must pass a process of testing before its results can be used with confidence. This process is often referred to as model verification and validation. However, these words are used in a variety of ways. Sargent (1982) distinguished three stages:

- conceptual model validation: are the theories and assumptions underlying the conceptual model correct and does the model represent the problem entity reasonably well for the intended use?
- computerised model verification: are the computer programming and implementation of the conceptual model correct?
- operational validation: do the pertinent characteristics of the model adequately represent the problem entity for the intended use of the model?

When developing a model one usually iterates among the various stages many times. Operational validation may reveal that the model has technical shortcomings, which must be rectified by re-examining the computer programme. Various techniques are used in model validation, often in combination. There is no uniform procedure; which procedure is chosen depends on the type of model and on the data and means available.

Validation procedures

We used two techniques described by Sørensen (1990) in our validation: goodness of fit tests and sensitivity analysis.

Goodness of fit tests may be parametric (t-tests) or non-parametric. Parametric tests require assumptions about the distributions of the observed and predicted values. For deterministic models, the simulated output for one set of input variables is expected to correspond with the mean of a sample from a real system's random output. For stochastic models the predicted output contains also some random variation, which should be considered when comparing the means. However, the distribution of the simulated and observed values may differ considerably depending on the number of stochastic events and the number of runs or reiterations. Thus, the distribution of both simulated and observed results should be examined carefully to ensure that the appropriate validation method is chosen (Reynolds *et al.*, 1981).

One type of sensitivity analysis refers to the evaluation of model behaviour by systematic manipulation of fixed parameters to establish in which range acceptable results can be obtained. Sensitivity analysis was used to assess the technical validity of the current model, while a goodness of fit test was used to evaluate the operational validity. Flock size and feed quality are important factors affecting model output and thus the impact of fixed parameters.

Effect of feed quality

The effect of feed quality is illustrated in Figure 3, where the simulated liveweight development of a reproducing female for three feed qualities is given, available in unrestricted quantities: good quality feed, $DDMI_m = 42.9$ g $kg^{-0.75}$ d^{-1},

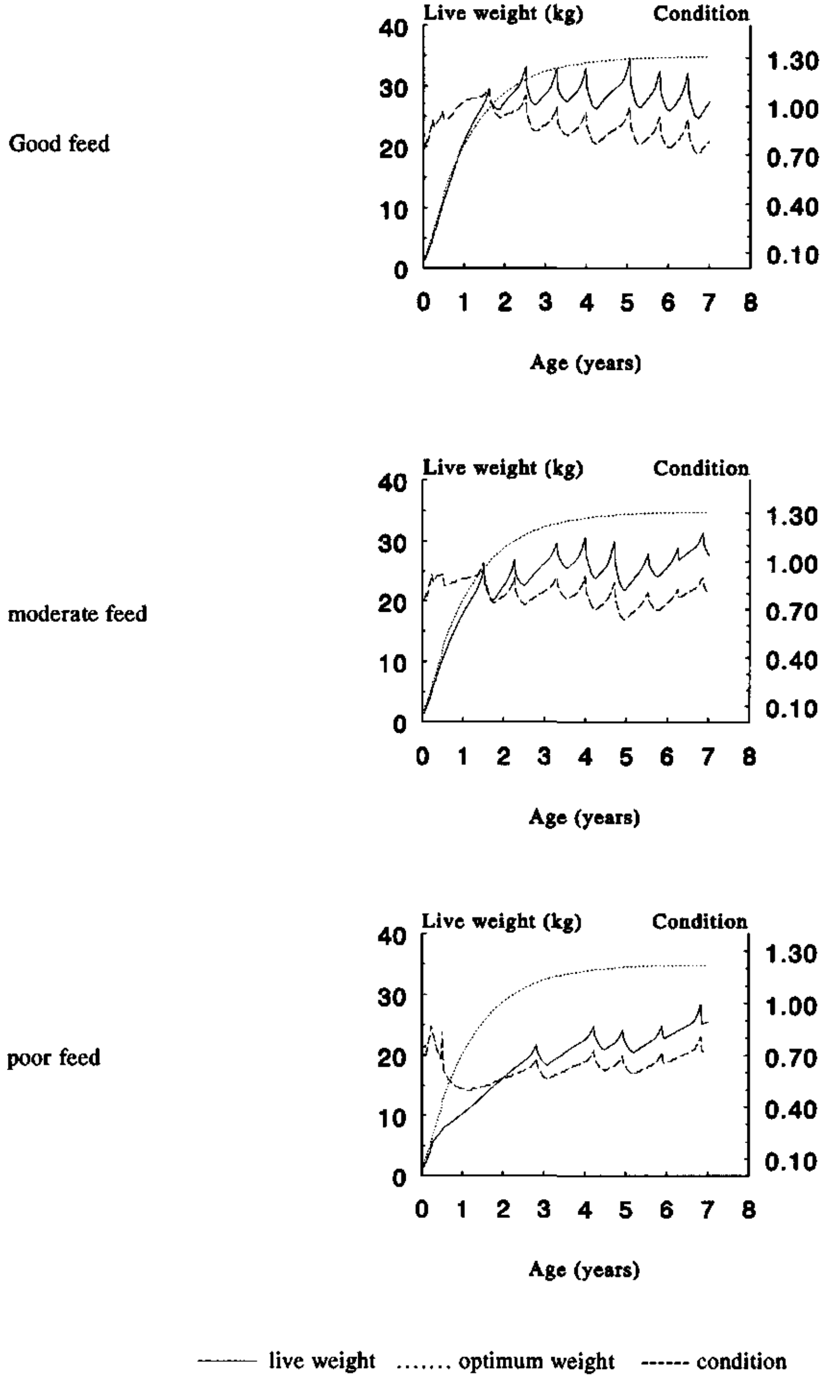

Figure 3. The effect of feed quality on the live weight development and condition of a reproducing female. All fixed parameters were set at their default values, except for mortality, which was set at zero.

moderate quality feed, $DDMI_m$=37.2 g $kg^{-0.75}$ d^{-1}, poor quality feed, $DDMI_m$=30.7 g $kg^{-0.75}$ d^{-1}. The simulation was run with all fixed and flock dynamic parameters set at their default values, except for adult mortality which was set at zero. Liveweight and the associated condition are increased by pregnancy, and reduced by delivery and by lactation. On the good feed, condition was well above Q_u (0.70) and therefore did not affect probability of pregnancy. On the poor quality feed, condition fluctuated around Q_u and the parturition intervals tended to be longer ($\pm$s.e., 301$\pm$20 vs 371$\pm$46 d). Furthermore, litter sizes at birth were smaller (2.14$\pm$0.24 vs 1.20$\pm$0.18). On the moderate feed, condition approached Q_u towards the end of lactation and sometimes even fell below it, albeit marginally. The resulting parturition intervals and litter sizes at birth were 285$\pm$17 d and 1.75$\pm$0.34 respectively.

Optimum flock size

For simulation models for individual animals the demand on computer hardware and computing time increases with flock size. Therefore, the size of simulated flocks should be restricted. On the other hand variation (among repetitive runs) will increase when flocks become very small, because of the effect of random events. Consequently, more runs are required to obtain the same degree of accuracy. Thus, a balance has to be found between the flock size, the number of runs and the desired accuracy.

Approach

To study the effect of flock size on model output, as expressed in the productivity indices, a simple model experiment was conducted with four flock sizes (T1 to T4) and two replicates. Flock size was controlled by limiting the maximum number of females in the age category 1-2 years to: T1: 2, T2: 4, T3: 6 and T4: 8 and by restricting the number of males in the age category 1-2 years to: T1 and T2: 1, T3 and T4: 2. This corresponds with the flock composition of free roaming goat flocks in South-Western Nigeria (Bosman and Moll, 1995). Flock outflow was restricted to this age category. Thus in the other age classes the only exit reason was mortality. Stock inflow probabilities were set at zero. The simulation was run for the average adult weight (35 kg). For other calculations default values were used. Each replicate consisted of five runs of ten years, based on time steps of 14 days. Each treatment used the same initial flock, which was generated from the default flock according to the default procedure (5 runs of 10 years each). Feed of average quality (%cp=10, %DMD=65, $DDMI_m$=37.2 g $kg^{-0.75}$ d^{-1}) was assumed to be available in unlimited amounts, to exclude interactions between feed availability and flock size.

Table 3. Model validation: the effect of flock size (controlled by the maximum number in the age class 1-2 years) on productivity

		Flock size		Productivity[1]			
Max. No. of females in age class 1-2 y	Treatment[2]	Total no of does	whole flock (kg)	p_b	p_{kg}	RPI	RPIE
2	1	5.4±1.0	226±38	1.00±0.10	0.49±0.05	10.3±0.7	0.92±0.06
	1	5.4±0.9	218±36	1.02±0.09	0.50±0.05	10.4±0.7	0.94±0.06
4	2	12.6±0.9	498±30	1.01±0.06	0.49±0.03	10.1±0.6	0.91±0.06
	2	12.8±0.4	506±30	0.99±0.06	0.48±0.03	9.7±0.6	0.87±0.06
6	3	19.6±0.9	783±26	1.04±0.03	0.508±0.01	10.3±0.3	0.92±0.03
	3	19.2±0.2	770±23	1.04±0.03	0.507±0.02	10.2±0.3	0.91±0.02
8	4	27.2±0.8	1071±38	0.99±0.05	0.484±0.03	10.2±0.6	0.91±0.06
	4	29.0±0.5	1137±22	1.04±0.04	0.509±0.02	10.1±0.3	0.90±0.03

[1] p_b and p_{kg} are flock productivity indices expressing net production respectively per kg metabolic flock weight and kg flock weight; RPI and RPIE are reproduction indices, expressing kg weaned offspring respectively per doe and per kg metabolic doe weight

[2] two replicates per treatment

Results

The total number of reproductive females (> 1 y) ranged from 5 (T1) to 29 (T2) (Table 3). Standard deviations and means of the reproduction indices (RPI, RPIE) did not differ statistically significantly ($p > 0.05$) between treatments or replicates. Standard deviations of the indices directly related to flock size (p_b and p_{kg}) differed statistically significantly ($p < 0.05$) between treatments (but not within treatments) and therefore the requirements for an analysis of variance were not satisfied. The treatment averages of these indices did not vary with flock size. Differences between replicates, (as tested with a t-test) were not statistically significant ($p > 0.05$).

Thus, with respect to repeatability the first treatment appears to give a sufficiently large flock size. If the acceptable error is put at 5% of the mean value, and there is a 95% probability of attaining it, and if the standard deviation (sd) is taken as an estimate of the population standard deviation, the number of runs required to attain the desired accuracy can be estimated as (Snedecor and Cochran, 1967):

$$n = \frac{4 * (sd)^2}{x * 0.05}$$

where x is the mean of the relevant index.

The numbers required are considerably higher in treatment 1 (16, Table 4) than in the other treatments (2-8).

Table 4. Model validation: estimate of number of runs required to attain an error level of 5% with 95% probability. Estimates are based on observed standard errors as given in Table 3

Max. no. of females in age class 1-2 y	Treatment[2]	Productivity indices[1]			
		p_b	p_{kg}	RPI	RPIE
2	1	15	16	8	6
	2	12	13	7	7
4	1	6	6	6	8
	2	5	6	7	6
6	1	1	2	2	2
	2	2	2	2	2
8	1	5	5	6	6
	2	3	4	2	2

[1] p_b and p_{kg} are flock productivity indices expressing net production respectively per kg metabolic flock weight and kg flock weight; RPI and RPIE are reproduction indices, expressing kg weaned offspring respectively per doe and per kg metabolic doe weight

[2] two replicates per treatment

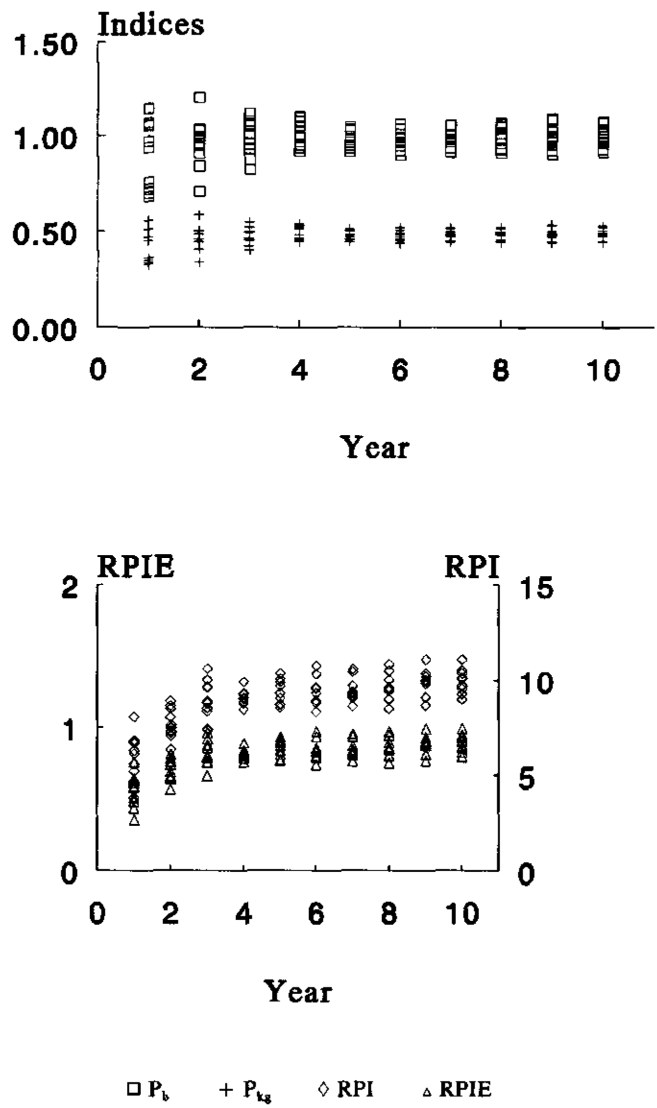

Figure 4. Model validation: development of productivity indices of a simulated flock (maximum number for the age 1-2 years set at 4 for females and 1 for males) over a ten-year period; P_b and P_{kg} are flock productivity indices expressing net production respectively per kg metabolic flock weight and kg flock weight; RPI and RPIE are reproduction indices, expressing kg weaned offspring respectively per doe and per kg metabolic doe weight; for further explanation see text.

It appeared that after 8 years all indices had stabilised, so that the 10 years used can be considered a sufficiently long period for simulation (Figure 4).

Therefore, it was decided to use the flock size of the second treatment (4/1) in the validation runs, with 10 replications of 10 years each.

Sensitivity analysis

Approach

A sensitivity analysis was done to investigate the effects on model output of variations in six fixed parameters: W_a, Q_u, Q_m, A_m, W_m and R_i. Flock size was controlled by limiting the maximum number of animals in the age class 1-2 years to 4 females and 1 male. The procedure was identical to that for determining the optimum flock size. Furthermore, because of the strong correlation between A_m and W_m, A_m was set at zero, when W_m was tested, and vice versa. Each parameter value was tested in ten replicated runs over a ten-year period with a time step of 14 days.

The analysis was performed with average quality feed ($DDMI_m$=37.2 g $kg^{-0.75}$ d^{-1}) and good quality feed ($DDMI_m$=42.9 g $kg^{-0.75}$ d^{-1}). Simulation for poor quality feed ($DDMI_m$=30.7 g $kg^{-0.75}$ d^{-1}) did not lead to stable flocks in all situations. For instance, Q_u values above the default value resulted in negative flock productivity and hence flocks 'died off'.

Results

The effect of variations in parameter values on productivity indices have been expressed relative to the average found at the default value of each parameter (Figures 5 to 8).

Variations in four of the six parameters studied : W_a, Q_u, W_m and A_m appeared to affect productivity.

Changes in Q_u through its interaction with kidding probability and litter size affected both the flock productivity indices and the reproductive performance (Figures 5 and 6). Higher values of Q_u reduce kidding probability and consequently increase kidding intervals. At the same time litter size at birth decreases. Because of the lower average condition of does fed on average quality feed (see Figure 3), this effect is more pronounced on this quality feed.

Changes in W_m and A_m have a stronger effect on the flock productivity than on the reproduction indices (Figures 5 and 6). When A_m and W_m are reduced flock productivity indices rise because of an increase in the reproductive fraction of the flock. However, the effect on the reproductive performance per individual animal is minor and variable. On the moderate quality feed reduction in A_m reduces RPI, while on the good quality feed RPIE tends to increase, while RPI remains unaffected. An increase in A_m tends to affect RPIE negatively on the moderate quality feed, because the metabolic weight of the (female) breeding stock increases.

Changes of the adult weight have a minor effect on the flock productivity indices (Figure 8). Theoretically, one could expect p_b to increase with increasing adult weight, because feed intake is simulated as a function of feed quality and the difference between the actual and the adult weight. Thus at the same liveweight, the

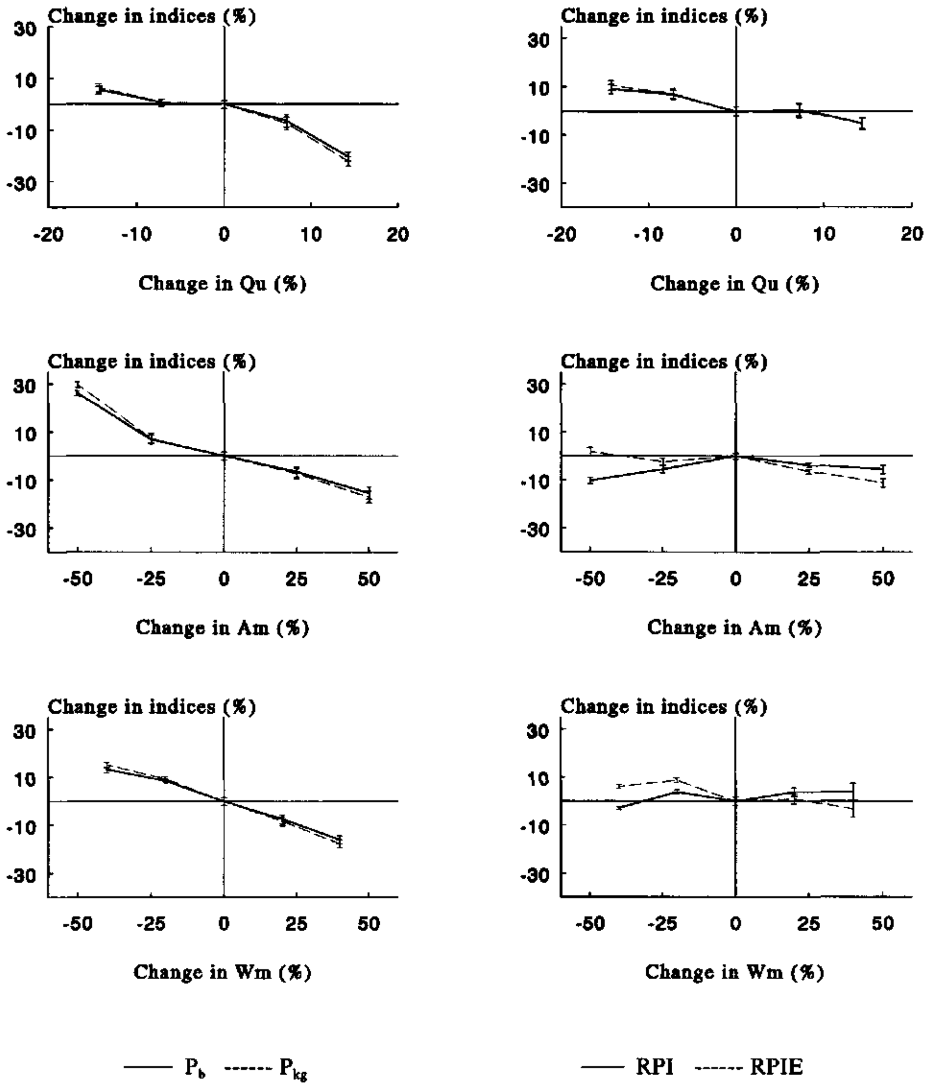

Figure 5. Sensitivity analysis: effect on productivity of changes of upper condition (Q_u), age (A_m) and weight at sexual maturity (W_m), when animals are fed on moderate quality feed. All values are expressed as % of the default settings.

animal with a higher adult weight consumes more of the same feed, and consequently gains more weight per kg MW. The magnitude of this effect increases the more intake exceeds maintenance requirements. This explains the tendency of p_b to increase with increasing adult weight on the good quality feed. On the moderate quality feed this trend is absent, because the possible increase is smaller than the variation caused by random effects.

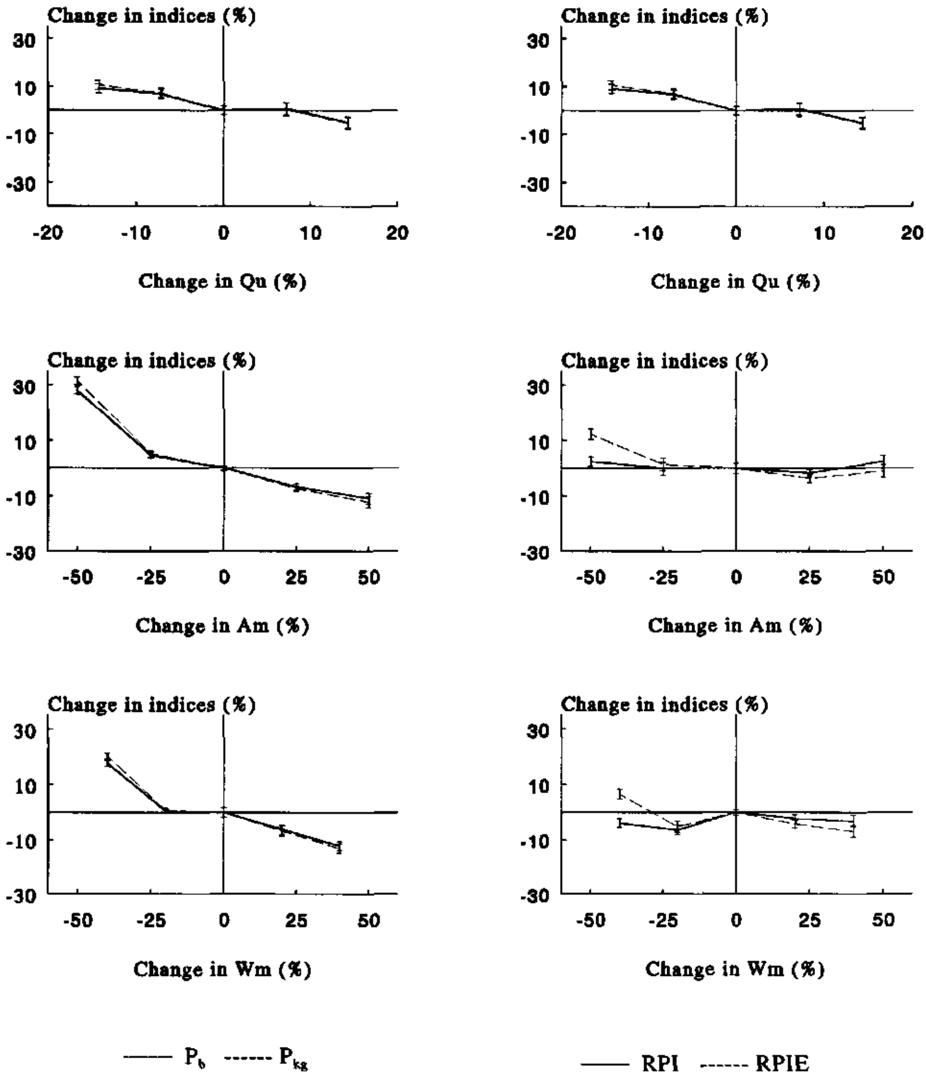

Figure 6. Sensitivity analysis: effect on productivity of changes of upper condition (Q_u), age (A_m) and weight at sexual maturity (W_m), when animals are fed on good quality feed. All values are expressed as % of the default settings.

The positive effect on p_b is counteracted by the slower liveweight development of animals with a higher adult weight, when expressed as % of the adult weight. For instance, when fed on the moderate quality feed an animal with an adult weight of 25 kg attains about 55% of the adult weight at one year of age, compared to about 47% for an animal of 45 kg. In the latter case the default W_m is thus not satisfied at the default age of sexual maturity and hence it takes longer for animals to become

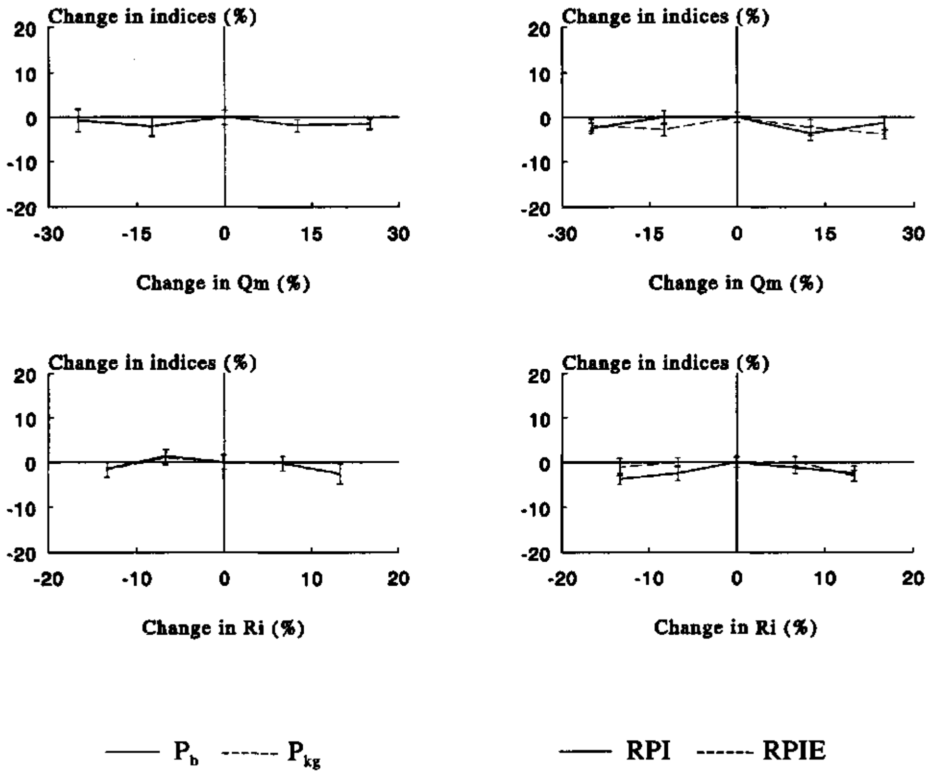

Figure 7. Sensitivity analysis: effect on productivity of changes of intake ratio (Ri) and minimum condition (q_m) when animals are fed on good quality feed. All values are expressed as % of the default settings.

reproductive and the proportion of the flock that is reproductive falls. As this difference increases as feed quality decreases, it can be expected that on poorer quality feeds the positive effect of the adult weight on p_b will disappear or even turn around.

As expected, RPI increases approximately linearly with the adult weight on both quality feeds, whereas RPIE remains fairly constant.

It can be concluded that it is important for the reliability of the simulation results that the fixed parameters Q_u, A_m and W_m are accurately assessed. For a proper estimation of Q_u, an estimate of the adult weight is needed. If the observed pregnancy and litter size probabilities are used, the corresponding Q_u, can be estimated as the ratio of the average liveweight of the adult female stock at conception, to the adult weight. Although the average liveweight of reproducing stock is affected by feed quality (see also Figure 3), this effect is compensated for

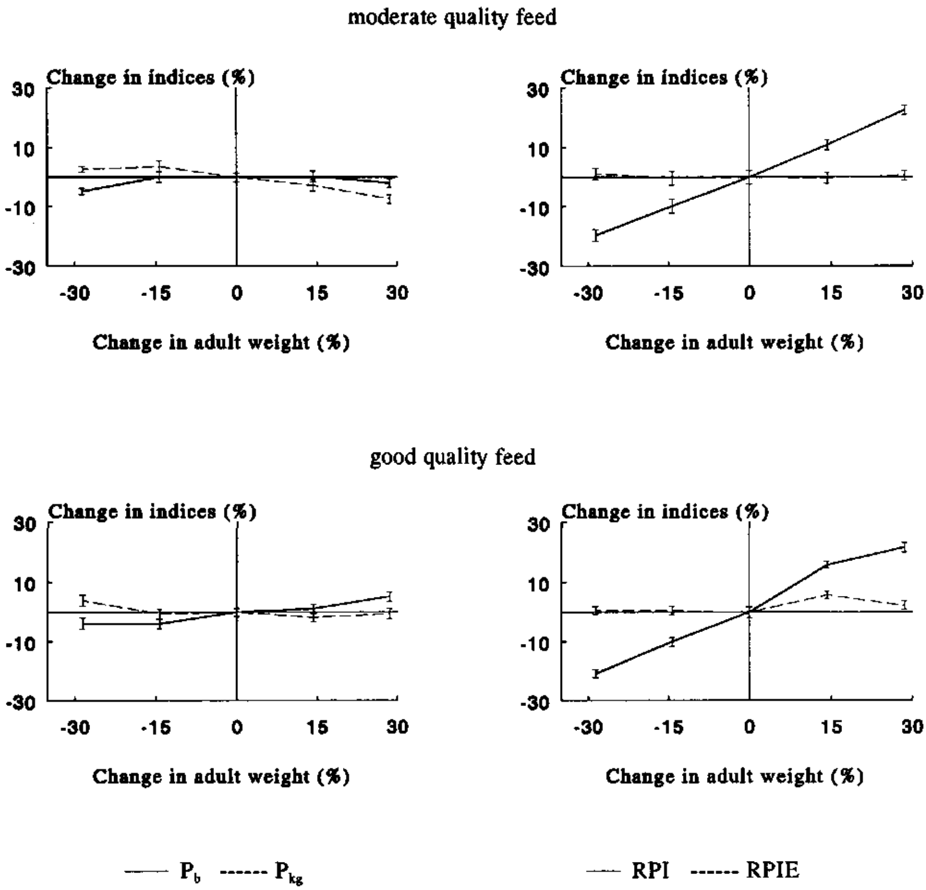

Figure 8. Sensitivity analysis: effect on productivity of changes in adult weight of animals fed on moderate and good quality feed. All values are expressed as % of the default settings.

by the entered pregnancy probabilities, if they are based on the actually observed values.

Operational validation

The operational validation was performed in two stages. First, the reproduction module was validated, followed by the whole model.

The reproduction module

Approach

The reproduction module was validated with data collected at Wageningen Agricultural University, and data collected by the West African Dwarf Goat Project in South Western Nigeria (between 1981 and 1992) were used for the operational validation of the whole model.

Hofs *et al.* (1985) present an analysis of reproduction data routinely collected from the experimental flock of West African Dwarf goats, originally imported from West Africa. Some animals have mature weights and body sizes up to 50% higher than generally found in West Africa, possibly due to cross-breeding and/or to better feeding. All animals receive good quality hay *ad libitum* and are kept on a high plane of nutrition. Pregnant and lactating does receive concentrates at a level of 60 g $kg^{-0.75}$ d^{-1} during the last month of pregnancy and while suckling. Kids have access to creep feeding, where roughage, concentrates and water are available *ad libitum*. Breeding is regulated on the basis of the need for experimental animals.

The simulation results refer to a flock of 5 does, over 10 years in 10 replicated runs. All fixed parameters were set at their default values, except for adult weight (48 kg, derived from Ogink, 1993), milk production (increased to maintain identical production per $kg^{-0.75}$ d^{-1} as under default conditions) and pregnancy probability (0.94 over 180 d (inv_m)). Preweaning probability was set at the observed probability and doe mortality was set at zero. Since no fixed weaning policy was practised, the simulation was performed with both weaning at the average weaning age (80 days) and at the average weaning weight (8.2 kg).

Results

The simulated and observed results are in reasonable agreement (Table 5). Simulated birth weights are somewhat higher, while preweaning growth is somewhat lower. The simulated parturition intervals are longer than the observed intervals. However, there were only a small number of the latter compared with the number of litters born and weaned. The estimated reproduction productivities, defined as the weaned liveweight per doe joined per year agree well with the observations.

The whole model

Approach

The whole model was validated with data collected in South-western Nigeria from on-station pilot units (WADGP, 1989) and village flocks (Bosman and Moll, 1995). The Pilot Units (PU) consisted of a breeding stock of 12 does, one buck and offspring. The total outflow was estimated by assuming that all offspring was kept until one year old (with adjustment for mortality) and that animals not kept until that age would have attained the same liveweight as the animals that were retained. Animals were kept in huts, made of local material and provided with slatted floors. Breeding and young stock were housed in separate pens (Bosman *et al.*, 1988).

The analysis refers to Free Roaming (FR) flocks, as kept in five of the six villages involved in the study (Bosman and Moll, 1995).

Table 5. Model validation: reproductive performance of an experimental flock at Wageningen compared with simulated results (average of ten flocks over 10 years, means ±s.d.)

	Simulated		Observed[1]
	weaned at 80 days	weaned at 8.2 kg	
Birth weight (kg)	2.1±0.1	2.1±0.1	1.6±0.4
n			308
Litter size at birth	1.78±0.09	1.79±0.13	1.83±0.61
n			176
Preweaning mortality (% of no. born)	7.2±2.6	9.6±4.7	9.0±8.2[2]
n			9
Weaning age (d)	80	92±2	80±21
n			147
Weaning weight (kg)	7.7±0.2	8.7±0.1	8.2±2.5
n			238
Parturition interval (d)	234±3	235±2	193±21
n			36
Proportion of does kidding	1	1	0.81
Productivity[3]	20.1±0.7	22.4±2.1	21.0

[1] Source: Hofs et al. (1985)

[2] estimated as average of breeding groups

[3] kg weaning liveweight per doe joined per year

For the validation of the PU, the flock size was controlled by limiting the breeding stock to 12 does and one buck. All young stock not required for replacements was "removed" at the age of one year.

For the FR flocks, flock size was controlled by setting the maximum female breeding stock to 4 and the minimum to 3, the integer numbers closest to the average female breeding stock size observed.

The fixed and herd dynamics parameters, if different from the default values, are given in Tables 6 and 7. In the pilot units kids were weaned at 5.5 kg liveweight. No specific weaning policy was practised at village level and weaning thus mostly depended on the "natural" weaning process. It was assumed that this occurred at the age of 90 days on average. The default values were used for the fixed parameters, except for the kidding probability and the adult liveweight, which were estimated at respectively 0.86 and 30 kg from on-station data.

The quantity and quality of the feeds available for the different systems are given in Table 8. In the case of PU, data are based on the average amount offered daily and estimated qualities, derived from nutritional studies (Ademosun *et al.*, 1988;

Table 6. Model validation: mortality, outflow and inflow probabilities (the same for males and females) used for the simulation of the on-station pilot units

Upper age of class (y)	Range of class (y)	Mortality	Outflow	Inflow
0.25	0.25	0.200	0.000	0.000
1.00	0.75	0.125	0.000	0.000
7.00	1.00	0.050	0.001	0.000

Table 7. Model validation: mortality, outflow and inflow probabilities used for the simulation of free-roaming flocks

Sex	Upper age of class (y)	Range of class (y)	Mortality	Outflow	Inflow
m	0.25	0.25	0.2156	0.0189	0.0000
f	0.25	0.25	0.1804	0.0200	0.0150
m	0.50	0.25	0.1368	0.1654	0.0000
f	0.50	0.25	0.1111	0.1266	0.0598
m	0.75	0.25	0.1438	0.1752	0.0000
f	0.75	0.25	0.1117	0.1035	0.1098
m	1.00	0.25	0.0394	0.1746	0.0000
f	1.00	0.25	0.0272	0.0615	0.0464
m	2.00	1.00	0.1920	0.1750	0.0000
f	2.00	1.00	0.1920	0.1750	0.0198
m	7.00	1.00	0.1920	0.1750	0.0000
f	7.00	1.00	0.1920	0.1750	0.0000

Bosman *et al.*, 1995). Nutritional surveys and on-station experiments, carried out to determine the quality of the most important feeds, provided the data for the village flocks. The amount of "free range" feeds (grass, other) was estimated as follows: it was assumed that half of the village area accessible to small ruminants (estimated at about 25 ha per village) produced forage with an average production of 5 t DM/ha. With an average population of 100 households per village, this amounts to about 625 kg DM/household/y. Furthermore it was assumed that half the forage consisted of grass and half of herbs and shrubs. Of course, these are very rough estimates. Therefore simulations were performed with two amounts available: 500 (A_1) and 1000 (A_2) kg DM/household/y. The quality estimates of these feeds were based on Olubajo and Tenabe (1975), Göhl (1981) and on-station experiments (Ademosun *et al.*, 1988).

Table 8. Model validation: quantity and quality of feeds used in the operational validation per system (PU = pilot units on-station, FR = free-roaming flocks)

System	Feed	Availability		Quality		Maximum percentage allowed in diet
		quantity (kg/y)	period (d)	crude protein (%)	dry matter digestibility (%)	
PU	*Gliricidia sepium*	1650	0 - 365	22	60	25
	Leucaena leucocephala	1650	0 - 365	26	66	25
	Panicum maximum	4950	0 - 275	10	55	100
	Panicum maximum	1232	275 - 365	5	45	100
FR	Eri	131	0 - 365	19	75	28
	cassava	300	0 - 365	4	89	64
	grass	250/500	0 - 365	5	45	100
	other	250/500	0 - 365	12.5	60	100

Results

The simulated values of PU correspond reasonably well with the observed ones (Table 9). The simulated parturition interval tends to be somewhat longer and the litter size at birth somewhat smaller which is significant ($p<0.05$) in case of unit one. Statistical testing, however, is somewhat complicated because the PU-data concern means of observed intervals, whereas the simulated mean is the average of the mean parturition intervals of the simulated flocks. However, this did not result in statistically significantly ($p>0.05$) different RPI values. Furthermore, the liveweights at the age of one year were statistically significantly ($p<0.05$) higher (1.3 to 1.6 kg) in the simulated flocks. The simulated liveweight at the age of one year (13.9 kg) corresponds to a daily postweaning weight gain of 30 g. On-station experiments have shown that such weight gains can be attained on these types of feeds. An experiment with *Panicum maximum* hay and *Leucaena leucocephala* (DDMI 35 g $kg^{-0.75}$ d^{-1}), for instance, gave weight gains of 34.8 g d^{-1} (Ademosun *et al.*, 1988).

The higher simulated one-year weights did not result in a statistically significantly ($p>0.05$) higher simulated stock outflow. Hence, the simulated flock productivity (p_b and p_{kg}) was not statistically significantly ($p>0.05$) different from the average values estimated for the pilot units.

The difference between free roaming flocks simulated with A_1 and A_2 is reflected in higher productivity indices (RPI, p_{kg} and p_b, Table 10). Comparisons of both simulated situations with the observed values shows the tendency that the reproductive performance (RPI) tends to be better in the real flocks but concomitantly the growth of the offspring (weight at one year) is worse.

These differences may be attributed to the assumption with respect to the feed allocation, apart from daily and seasonal variations in feed quality and quantity which were not taken into account. In the simulations it was assumed that all feed is evenly distributed among all animals. Under free roaming, however, it is likely that the stronger adult females will get a larger share of the scarce, higher quality feeds (supplements) than the weaned offspring. As no data are available to substantiate this hypothesis it was not simulated. The simulated higher average doe liveweights seem to refute this hypothesis. Since all females above the age of one year are considered 'doe', the average doe liveweights are directly affected by the one-year weights, and these are higher in the simulated flocks. Furthermore, on-farm adult animals were weighed once every two months. Under free roaming, however, it was not always possible to weigh all animals on such occasions.

Liveweights at the age of one year under the A_2 feeding regime are statistically significantly ($p<0.05$) higher than the observed values and hence the flock productivity parameters also differ statistically significantly ($p<0.05$). For A_1 flock

Table 9. Model validation: comparison between production traits and productivity of simulated flocks and the observed values of two on-station pilot units. Simulation was performed with 10 flocks over a ten-year period; simulation results are averages (±s.e.) of flock means

	Simulated	Observed	
		unit 1	unit 2
Birth weight (kg)	1.4±0.0	1.2±0.0	1.4±0.0
Litter size at birth	1.49±0.01	1.77±0.10	1.61±0.10
Parturition interval (days)	292±2	260±11	279±9
Weaning weight (kg)	5.9±0.01	5.7±0.2	5.8±0.2
Weaning age (days)	101±0	106±3	108±4
Preweaning mortality (% of no. born)	16.7±0.7	24	20
Weight at 1 year (kg)	13.9±0.0	12.6±0.2	12.3±0.3
Average doe weight (kg)	20.3±0.0	21.5±0.2	20.4±0.2
Average flock weight (kg)	416±2	432	413
Average metabolic flock weight (kg)	211±1	219	214
No. of reproductive females	12	12	12
Flock entries (kg)	0	0	0
Flock exits (kg)	259±3	261	247
RPI[1]	8.3±0.1	9.9±1.0	8.9±1.0
p_b[2]	1.20±0.01	1.19	1.15
p_{kg}[3]	0.61±0.00	0.6	0.6
Dry matter intake (kg/y)	6301±29	-	-

[1] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[2] Biological flock productivity, expressed as net offtake per kg metabolic flock weight
[3] Flock productivity, expressed as net offtake per kg flock weight

outflow was smaller than the observed outflow; however, this did not result in statistically significantly ($p > 0.05$) different flock productivity indices.

TESTING OF INNOVATIONS

An important goal of livestock models is to provide a tool to explore the effect of innovations. The model can be used for this purpose as is illustrated below using two interventions in the traditional free roaming goat production system.

Table 10. Model validation: comparison between production traits and productivity of simulated flocks and the observed values of 55 free-roaming flocks; simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

	Simulated		Observed
	A_1[1]	A_2[1]	
Birth weight (kg)	1.45±0.02	1.37±0.02	1.40±0.01
Litter size at birth	1.54±0.04	1.58±0.06	1.61±0.10
Parturition interval (d)	279±4	282±1	259±8
Weaning weight (kg)	4.3±0.1	4.7±0.1	4.7±0.1
Weaning age (d)	94	94	90[2]
Preweaning mortality (% of no. born)	23.3±3.2	18.7±1.6	18.6±1.4
Weight at 1 year (kg)	9.3±0.2	10.4±0.2	8.6±0.2
Average doe weight (kg)	19.4±0.2	19.2±0.2	17.1±0.3
Average flock weight (kg)	86±2	101±2	97±44
Average metabolic flock weight (kg)	43±1	52±1	42±18
No. of reproductive females	2.9±0.2	3.3±0.2	2.9±0.3
Flock entries (kg)	17±2	25±1	20±2
Flock exits (kg)	29±2	52±1	37±3
RPI[3]	6.3±0.3	7.2±0.3	7.7±0.4
p_b[4]	0.34±0.05	0.61±.03	0.30±0.08
p_{kg}[5]	0.17±0.02	0.31±0.02	0.13±0.04
Dry matter intake (kg/y)	850±8	1112±18	-

[1] feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)
[2] assumed
[3] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[4] Biological flock productivity, expressed as net offtake per kg metabolic flock weight
[5] Flock productivity, expressed as net offtake per kg flock weight

Approach

One of the innovations introduced by the project was the use of the browse species *Gliricidia sepium* and *Leucaena leucocephala* (Ayeni and Bosman, 1993). The average size of the plots planted by the farmers with these browse species was 150 m^2, which, based on on-station results (Teniola, 1990), was estimated to produce 150 kg DM of edible browse per year.

The second intervention simulated refers to flock management. One of the reasons for the higher productivity of the PU flocks was thought to be the outflow of young animals. In the PU flocks it was attempted to 'sell' the offspring at the age of one year. In the FR flocks about 40% of the young stock were removed from the flock before they reached the age of one year (Bosman and Moll, 1995). Postponement of these exits till the age of one year was therefore tested as a possible intervention.

Results

The simulation showed that addition of browse tends to reduce parturition intervals and to increase litter sizes at birth (Table 11), however, the reproduction index does

Table 11. Model application: simulated effect of the addition of browse on the performance of free-roaming flocks; simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

	A_1[1]		A_2[1]	
	with browse innovation	default	with browse innovation	default
Birth weight (kg)	1.51±0.02	1.45±0.02	1.38±0.02	1.37±0.02
Litter size at birth	1.61±0.04	1.54±0.04	1.77±0.03	1.58±0.06
Parturition interval (d)	277±2	279±4	275±2	282±1
Weaning weight (kg)	4.2±0.1	4.3±0.1	4.7±0.1	4.7±0.1
Weaning age (d)	94	94	94	94
Preweaning mortality (% of no. born)	21.3±2.8	23.3±3.2	19.0±1.9	18.7±1.6
Weight at 1 year (kg)	9.6±0.3	9.3±0.2	10.8±0.2	10.4±0.2
Average doe weight (kg)	20.4±0.2	19.4±0.2	20.0±0.3	19.2±0.2
Average flock weight (kg)	98±3	86±2	109±4	101±2
Average metabolic flock weight (kg)	50±1	43±1	56±2	52±1
No. of reproductive females	3.4±0.2	2.9±0.2	3.6±0.2	3.3±0.2
Flock entries (kg)	20±1	17±2	24±1	25±1
Flock exits (kg)	40±2	29±2	67±4	52±1
RPI[2]	6.4±0.2	6.3±0.3	7.5±0.2	7.2±0.3
p_b[3]	0.41±0.04	0.34±0.05	0.79±.03	0.61±.03
p_{kg}[4]	0.20±0.02	0.17±0.02	0.40±0.02	0.31±0.02
Dry matter intake (kg/y)	1004±5	850±8	1325±50	1112±18

[1] feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)
[2] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[3] Biological flock productivity, expressed as net offtake per kg metabolic flock weight
[4] Flock productivity, expressed as net offtake per kg flock weight

not increase statistically significantly ($p > 0.05$). The statistically significantly ($p < 0.05$) higher flock outflow resulted in increased flock productivity (p_{kg} and p_b) for A_2. Thus, based on these simulation results one cannot conclude that browse plots of this size will have a significant effect on the productivity parameters. To further investigate this effect of the browse plots on productivity, simulations were performed with extended browse plot producing annually: 300, 450, 600 and 750 kg DM of edible browse per household respectively. The effects on the productivity indices have been given in Figure 9. The effect on productivity shows the same pattern under both the A_1 and A_2 regimes, although some variations occur because of random effects (in combination with the small flock size). Because of these variations, in the A_2 scenario the increase in p_b at 250 kg browse supplementation appears to be high compared with the other supplementation levels. When expressed as percentage of the 'starting' value, the effect on p_{kg} and p_b, is more pronounced than the effect on RPI. This is caused by the 'multiplier' effect: more offspring produced (positive effect on RPI), which grow faster and thus increase outflow and hence p_{kg} and p_b.

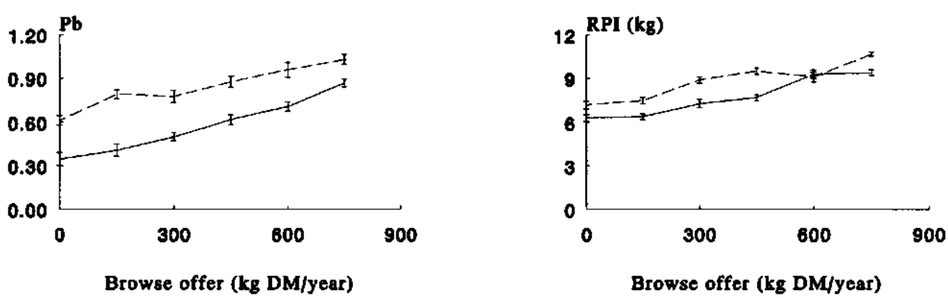

Figure 9. Effect of browse supplementation on flock productivity (P_b) and reproductive performance (RPI) in village flocks simulated with two levels of feed available from free roaming (——: 500 kg dry matter per household per year and ------: 1000 kg dry matter per household per year)

The management intervention does not increase productivity parameters (Table 12) because the feed availability is the limiting factor. Indeed, all productivity parameters (RPI, p_{kg} and p_b) tend to be lower. Thus, it seems to be inadvisable from a 'bio-technical' point of view to keep offspring for longer periods than currently practised.

Table 12. Model application: simulated effect of the management intervention on the performance of free-roaming flocks; simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

	A_1[1]		A_2[1]	
	with management innovation	default	with management innovation	default
Birth weight (kg)	1.43±0.02	1.45±0.02	1.40±0.02	1.37±0.02
Litter size at birth	1.59±0.04	1.54±0.04	1.53±0.05	1.58±0.06
Parturition interval (days)	288±3	279±4	285±3	282±1
Weaning weight (kg)	4.1±0.1	4.3±0.1	4.5±0.1	4.7±0.1
Weaning age (days)	94	94	94	94
Preweaning mortality (% of no. born)	23.1±2.5	23.3±3.2	19.1±2.0	18.7±1.6
Weight at 1 year (kg)	9.5±0.2	9.3±0.2	9.9±0.2	10.4±0.2
Average doe weight (kg)	19.4±0.2	19.4±0.2	18.6±0.1	19.2±0.2
Average flock weight (kg)	88±1	86±2	103±2	101±2
Average metabolic flock weight (kg)	44±1	43±1	53±1	52±1
No. of reproductive females	3.3±0.2	2.9±0.2	3.4±0.2	3.3±0.2
Flock entries (kg)	19±1	17±2	22±1	25±1
Flock exits (kg)	34±2	29±2	48±2	52±1
RPI[2]	5.7±0.2	6.3±0.3	6.8±0.2	7.2±0.3
p_b[3]	0.22±0.03	0.34±0.05	0.50±0.04	0.61±.03
p_{kg}[4]	0.11±0.02	0.17±0.02	0.26±.02	0.31±0.02
Dry matter intake (kg/y)	859±5	850±8	1216±17	1112±18

[1] feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)
[2] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[3] Biological flock productivity, expressed as net offtake per kg metabolic flock weight
[4] Flock productivity, expressed as net offtake per kg flock weight

DISCUSSION

The main aim of this feed-driven model is to investigate the productivity of small ruminant flocks. It simulates the performance of the individual animal within the flock so that effects of changes in feed intake or herd dynamics on production traits and hence productivity can be assessed. Because most of the fixed parameters can be set by the user, the model is very flexible and can easily be tuned to production characteristics distinct from the default values.

The minimum input requirements of the model are feed characteristics (quality, amounts and availability) and breed characteristics, in particular the adult weight. The sensitivity analysis demonstrated that changes in adult weight affect the individual performance (RPI), but have only a moderate effect when performance is scaled to liveweight or metabolic liveweight (RPIE, p_{kg}, p_b), if the amount of feed available is not a constraint. In practice, however, the amount of some or all feeds available may be limited. Under those circumstances, adult weight may have a serious effect on the productivity indices. The actual effect is difficult to predict, but will depend on the intake above maintenance and thus on the constraints imposed on the flock size. For instance, simulations of the FR flocks using adult liveweights 5 kg below and 5 kg above the default value of 30 kg, gave the following values for p_b in the low feeding level scenario ($\pm$ s.e.): 0.43 ± 0.04 (25 kg) and 0.27 ± 0.03 (35 kg). Although these values do not differ statistically significantly ($p > 0.05$) from that, using 30 kg as adult liveweight (0.34 ± 0.05) they show the tendency of p_b to decrease with an increase of the adult liveweight. In the high feeding level scenario the same trend is found; however, the differences are smaller (0.669 ± 0.03 (25 kg), 0.586 ± 0.03 (35 kg)). Thus if the feed availability or quality are severe constraints, an accurate estimate of the adult weight is required to obtain reliable productivity estimates.

The suitability of PC-Flock to simulate the career of a small ruminant under different conditions, can be judged from results of the validation of the conceptual model, the sensitivity analysis and the operational validation.

The model simulates small ruminant production driven by time and feed, within (certain) constraints imposed by the production system. The theories underlying it are based on current state of knowledge on feed intake and animal performance. Some assumptions, however, have had to be made, for instance about reproduction. Reproduction is simulated on the basis of probabilities of births and litter size, instead of on probabilities at the level of ovulation or conception as in TAMS (Blackburn and Cartwright, 1987) and BREW (White *et al.*, 1983) because these probabilities are more difficult to determine, especially under tropical (field) conditions.

The sensitivity analysis showed that the fixed parameters directly related to the adult liveweight (Q_u, and W_m) and age at sexual maturity (A_m) affect flock productivity, especially under moderate feeding conditions. Furthermore, Q_u affected reproductive performance (RPI, RPIE).

It is often difficult to validate livestock simulation models because field data sets do not provide all the input and output parameters required (Sørensen, 1990; Baptist, 1992). The on-station data set did satisfy the requirements for the validation of PC-Flock, but for the on-farm data, assumptions had to be made about feed availability from free roaming (scenario A_1 and A_2).

Validation results showed that on-station performance could be simulated satisfactorily. The validation results for the free-roaming flocks suggest that the feeding module should be extended to allow feed allocation per group of animals. This option has now been added to the model, but was not included in the present paper because no data are available for its validation.

All validation studies were conducted with default values for the fixed parameters, except for pregnancy probability and adult weight, which were both based on on-station observations. The validation results of the whole model and the test of the reproduction module under high feeding levels suggest that these default values are adequate.

The model does not consider interactions between feed intake, disease, performance and mortality except through the minimum condition criterion. The effect of the latter on overall productivity is limited under ample feed supply, as shown in the sensitivity analysis; also, when tested under the free-roaming conditions, no statistically significant ($p > 0.05$) effect on productivity was found. Disease does not only affect mortality but may also affect performance. Disease may have affected the performance of the offspring, and thus could explain part of the difference between the observed and simulated one-year weight. Therefore, these effects should be included in future versions of the model. First, however, additional research is needed to quantify these effects.

PC-Flock assesses productivity in biological terms at the level of the individual animal and the flock and as such it can be used to investigate current performance and to explore the impact of interventions on production and productivity, even if the feed availability is not exactly known. For a proper judgement, however, assessments at the household level are needed, which often includes other activities in addition to small ruminants. This can be achieved by linking model output to other models, (e.g. optimisation models), possibly interactively. Another option is to include other aspects of production systems in PC-Flock, as an additional module. Although this would increase the input required by the model, it could increase its usefulness to assess the importance of small ruminant production systems in a wider context.

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CHAPTER 3.

PRODUCTION STUDIES

3.1 NUTRITION

3.1.1 Nutritional studies with West African Dwarf goats in the Humid Tropics

3.1.2 Effect of amount offered on intake, digestibility and value of *Gliricidia sepium* and *Leucaena leucocephala* for West African Dwarf goats

3.1.3 Goat feeding practices and options for improvement in six villages in South-Western Nigeria

3.2 REPRODUCTION AND HEALTH

3.2.1 Reproduction of West African Dwarf goat - A summary of some experiments at the Obafemi Awolowo University

3.2.2 Health hazards in confined goats: the case of an experimental flock of West African Dwarf goats kept in the Humid Tropics

3.1 NUTRITION

3.1.1 NUTRITIONAL STUDIES WITH WEST AFRICAN DWARF GOATS IN THE HUMID TROPICS[1]

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ABSTRACT

At Ife a nutrition concept for dwarf goats is being developed as part of a management package for intensive goat rearing, designed to be easily adaptable under village conditions. This means that the nutritional research focused on the evaluation of locally available feed resources. Grasses like Panicum maximum *and* Cynodon sp. *were among the first feeds to be investigated, followed by the legumes* Gliricidia sepium *and* Leucaena leucocephala. *Concentrate was only used to determine the potential production levels of West African Dwarf goats under humid tropical conditions to obtain a guideline for the evaluation of roughage and agro-by-products.*

This paper reviews the results of the experiments carried out so far. It is concluded that West African Dwarf goats are unable to maintain themselves on poor quality tropical grasses. On the other hand, legumes like Gliricidia sepium *and* Leucaena leucocephala *can satisfactorily constitute the basic diets of dwarf goats producing weight gains of up to 35-40 grams a day. Cassava and Brewers' Dried Grains hold promise as energy and protein-rich supplements respectively. Further research is required to determine the optimal feeding level and, in the case of cassava, feeding frequency.*

INTRODUCTION

Apart from health, nutrition is probably the most important factor limiting the productivity of the West African Dwarf goat in the Humid Zone of Nigeria (Sumberg, 1985). When the number of animals increases as a consequence of successful health interventions like PPR control the demand for feed increases accordingly. In places where the increased pressure on arable land led to laws

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[1] *In: Smith, O.B. and Bosman, H.G. (eds), Goat production in the humid tropics. Proceedings of a workshop at the University of Ife, Ile-Ife, Nigeria, Pudoc, Wageningen, the Netherlands, p. 51-61.*

dictating the total confinement of small ruminants the animals depend for feed solely on what is being brought to them.

The nutritional studies carried out at the project site at Ife can roughly be grouped into three categories: feeding trials, feeding/growth trials and growth trials. Experiments in the first two categories were carried out with animals housed in metabolism units throughout the whole experimental period, while studies in the last category were conducted with animals housed in ground pens. Feeding trials were mainly conducted with adult animals and lasted for 3-6 weeks, while feeding/growth trials were only carried out with young animals over prolonged periods (above 20 weeks).

Table 1 reviews the nutritional studies conducted since the start of the project in the middle of 1981. Although it will not be possible to present and discuss all the results of these experiments in detail we will try to summarise the most important parameters in such a way that a clear overall picture develops.

Table 1. Review of the nutritional studies carried by the Goat Research Project

Exp.no.	Basic ration	Supplement	Substitute	Description
1	*Cynodon nlemfluensis* (hay)			Feeding trial, selective consumption
2	*P. maximum*, (young well fertilised)	concentrate		Feeding trial
3	*Panicum maximum* (hay)	*Leucaena leucocephala*		Feeding trial
4	*Panicum maximum* (hay)	*Gliricidia sepium*		Feeding trial
5	*Panicum maximum* (hay)	*L. leucocephala* or concentrate		Feeding/ growth trial
6	*Gliricidia sepium*	*P. maximum* (young) cassava *L. leucocephala*		Feeding/ growth trial
7	*Gliricidia sepium*		*Leucaena leucocephala*	Feeding/ growth trial
8	*G. sepium* *L. leucocephala*	cassava		Feeding/ growth trial
9	*P. maximum* (hay)	Brewers' Dried Grain or concentrate		Growth trial
10	*G. sepium* *L. leucocephala*			Feeding/ growth trial DHP inocul.

FEEDING TRIALS

The selective ability of West African Dwarf (WAD) goats was clearly shown in a trial with *Cynodon* hay offered at different levels (Fig. 1). As the dry matter intake (DMI) rose from 32 to 40 g DM $kg^{-0.75}$ d^{-1} the leaf intake increased from around 18 to 32 g DM $kg^{-0.75}$ d^{-1}, or expressed as % of the DMI from 55 to 80%. The total digestible dry matter intake (DDMI), even at the highest level offered (130 g DM $kg^{-0.75}$ d^{-1}), did not meet the maintenance requirements (27 g DOMI $kg^{-0.75}$ d^{-1}, NRC, 1981), indicating clearly that pen-fed West African Dwarf goats may not be able to maintain themselves on *Cynodon* hay only.

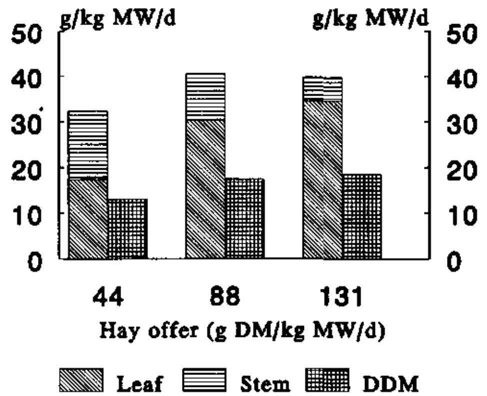

Figure 1. The effect of offer of Cynodon hay on the leaf, stem and total Digestible Dry Matter Intake (DDMI).

Also in other trials it was shown that WAD goats do not perform well when fed on hay of tropical grasses alone (Table 2). They thrive well only when the grass is well fertilised and harvested at an early stage of regrowth attaining DDMI of up to 40 g $kg^{-0.75}$ d^{-1}. To produce such a type of feed requires not only the appropriate climatological conditions but also a high level of input in terms of fertiliser and management.

Once it was clear that tropical grasses alone could not provide stall-fed WAD goats with the nutrients required for reasonable production levels, studies were aimed at the evaluation of other high quality feed resources, which will be easily available to the local farmer for the major part of the year.

Table 2. Some results of the feeding trials carried out by the Goat Research Project

Exp.no.	Feed	Offer	Intake $g\ kg^{-0.75}\ d^{-1}$	Digestibility (%)	DDMI $g\ kg^{-0.75}\ d^{-1}$
2	*P. maximum* (well fertilised, 6 weeks)	75.0	54.9±2.2	75.8±2.6	40.6±2.5
4	*P. maximum* (hay)	77.1	43.1±6.4	45.0±6.1	19.5±4.1
1	*C. nlemfluensis* (hay)	87.5	40.6	43.2	17.5
1	*C. nlemfluensis* (hay)	131.5	39.9	46.6	18.5
4	*P. maximum* (hay) *G. sepium*	74.9 31.9	37.2±2.5 31.9±0.2	55.1±2.9	37.9±3.1
3	*P. maximum* (hay) *L. leucocephala*	77.0 20.9	45.5±3.1 20.6±0.6	52.1±3.2	34.4±1.2

Thus feed resources such as *Gliricidia sepium* and *Leucaena leucocephala* were included in the studies. Both legumes, of which only the leaves and petioles were fed, proved to be very valuable supplements for goats fed on a basic diet of *Panicum maximum* hay (Fig. 2, Table 2). In the case of Gliricidia the DMI increased linearly with level of supplementation up to the highest level (0.8 g/g Gliricidia) thereby only slightly depressing hay intake. It improved digestibility and hence the total intake of digestible nutrients (38 g $kg^{-0.75}$ d^{-1} at the highest supplement level). *Leucaena leucocephala* produced similar results with DDMI of 34 g $kg^{-0.75}$ d^{-1} when offered at 21 g DM $kg^{-0.75}$ d^{-1} .

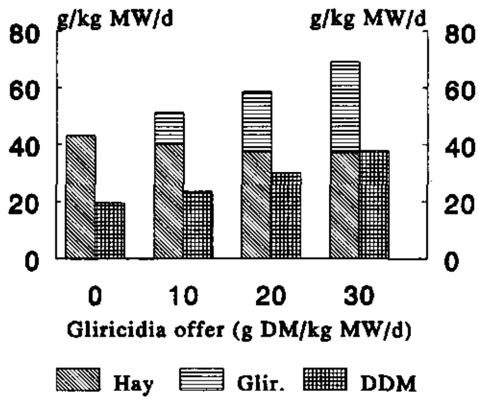

Figure 2. The effect of Gliricidia (Glir.) supplementation on the total dry and digestible dry matter intake of West African Dwarf goats fed on Panicum maximum *hay.*

FEEDING/GROWTH TRIALS

In a long term feeding/growth trial, comparing Leucaena (B) with concentrate (A), when fed *ad libitum* in addition to *Panicum maximum* hay DDMI amounted to 35 g $kg^{-0.75}$ d^{-1} for the Leucaena treatment and 55 g $kg^{-0.75}$ d^{-1} for the concentrate group (Table 3). In both treatments the DMI consisted only for a minor part of hay (B: 37%; A: 21%). Growth rates obtained in the concentrate group (60 g d^{-1}) are comparable to those found by Zemmelink *et al.* (1985) feeding *ad lib.* good quality hay plus 60 g $kg^{-0.75}$ d^{-1} concentrates (68.5 g d^{-1}) and by Adebowale and Ademosun (1981) including 15% brewers' dried grains in a Stylosanthes based diet (56.1 g d^{-1}). Weight gains observed offering *ad lib. Panicum maximum* and *Leucaena leucocephala* (35 g d^{-1}) compare quite well with those obtained by Zemmelink *et al.* (1985) feeding *ad lib.* good quality hay plus 30 g $kg^{-0.75}$ d^{-1} concentrates (35 g d^{-1}). This shows clearly the potential of this browse species. No harmful effects of Leucaena were observed, although it amounted to 63% of the total DMI. As expected growth rates were higher in the concentrate group (60.0 vs 35 g d^{-1}) indicating the potential of the dwarf goat under Ife conditions.

As Gliricidia and Leucaena had proven to be good supplements to low quality feeds, it was considered useful to investigate how those browse species would affect animal performance when fed as the sole or major part of the diet.

In the first experiment of this kind *Gliricidia sepium* was fed as the basic diet supplemented with either *Panicum maximum* grass, cassava or *Leucaena leucocephala*. On the sole Gliricidia diet DDMI amounted to 37.9 $kg^{-0.75}$ d^{-1} with a growth rate of 23.3 g d^{-1}, which is similar to the estimated daily gain between 90 and 150 days at village level (20 g d^{-1}) (Mack, 1983). All the supplements raised the DDMI significantly but only in the case of Leucaena was a significant increase in weight gain observed (36.0 g d^{-1}). The response to the cassava supplement was inconsistent and rather striking. Although it had the highest DDMI (45.7 g $kg^{-0.75}$ d^{-1}) this was not reflected in the growth rate (14.3 g d^{-1}) which was significantly lower than rates obtained on the grass or Leucaena supplement. This might be related to a rapid release of readily available carbohydrates, which in turn might have led to a sudden increase in volatile fatty acid (VFA) production in the rumen. In this respect it is perhaps useful to mention that the supplements were fed in the morning before the rest of the ration. As further research was considered necessary to clarify the effect of cassava supplementation another experiment was set up with *Gliricidia sepium* (75%) and *Leucaena leucocephala* (25%) as basic ration and three levels of cassava supplement (0, 15 and 30 g $kg^{-0.75}$ d^{-1}). The supplements were administered about 1.5 hours after the first half of the basic diet was offered. The results were more consistent than in the previous experiment (Table 3). Although the cassava supplement improved the digestibility and the

Table 3. Some results of the feeding/growth studies carried out at the project site

Exp. no.	Feed	Offer	DMI	DDMI	Growth rate
			g $kg^{-0.75}$ d^{-1}		g d^{-1}
6	*G. sepium*	94.0	66.7±6.2	37.9±3.2	23.3±3.7
5	*L. leucocephala*	49.6	40.8±2.7	35.0±2.6	34.8±5.3
	P. maximum (hay)	85.8	23.5±4.6		
6	*G. sepium*	93.7	56.8±6.6	40.6±3.2	28.7±4.9
	P. maximum (young)	32.4	13.8±5.1		
6	*G. sepium*	93.0	45.3±9.4	42.3±3.5	36.0±10.6
	L. leucocephala	32.4	25.6±4.4		
5	*P. maximum*	84.4	16.3±2.6	55.1±4.2	60.0±12.8
	concentrate	90.3	61.7±6.8		
8	*G. sepium*	74.9	35.6±4.8	48.0±4.0	41.8±11.1
	L. leucocephala	24.2	22.0±2.9		
	cassava	14.8	14.1±1.0		
8	*G. sepium*	74.6	25.3±6.9	49.6±3.9	43.5±5.5
	L. leucocephala	24.2	21.6±3.0		
	cassava	29.6	23.2±3.9		
8	*G. sepium*	75.1	44.1±8.9	39.5±5.8	37.4±8.9
	L. leucocephala	24.3	22.8±2.7		
	cassava	-			
6	*G. sepium*	94.2	42.5±22.9	45.7±10.1	14.3±11.3
	cassava	30.1	23.0±7.0		
7	*G. sepium*	105.7	53.8±7.0	37.2±3.5	13.4±11.5
	L. leucocephala	-	-		
	bark	16.2	9.0±3.8		
7	*G. sepium*	78.8	35.2±5.8	42.3±4.9	30.4±8.8
	L. leucocephala	27.2	23.4±2.2		
	bark	13.5	9.4±2.2		
7	*G. sepium*	52.6	25.8±8.7	42.2±5.5	25.7±4.9
	L. leucocephala	54.4	32.1±7.6		
	bark	12.8	5.6±2.6		
10	*G. sepium*	50.9	26.2±7.9	42.0±6.6	16.6±12.2
	L. leucocephala	48.2	37.4±6.6		
10	*G. sepium*	26.0	17.5±4.1	42.6±5.7	20.8±5.8
	L. leucocephala	71.4	47.0±9.9		

DDMI (48-50 vs 40 g $kg^{-0.75}$ d^{-1}) significantly this positive effect was not fully reflected in the growth rates (42-43 vs 37 g d^{-1}). Also no difference was found, between the two supplementation levels. This might be due to the fact that the amount of readily available carbohydrates released at one time was still too high leading to a reduction in the activity of the cellulotic bacteria and to a disharmony with the microbial protein synthesis. Further research is now being carried out to investigate if offering the cassava supplement several times a day will enhance the performance of the animals. It is interesting to note that the cassava replaced the Gliricidia and did not affect the Leucaena intake resulting in about equal intake levels of the three components at the highest supplement level.

Other studies have shown that WAD goats like to eat Leucaena in larger quantities than Gliricidia. A substitution trial, where Gliricidia and Leucaena were fed at respectively 100%, 75-25% and 50-50%, revealed that inclusion of Leucaena into a sole Gliricidia ration clearly improved DDMI (42 g vs 37 g $kg^{-0.75}$ d^{-1}). Following observations that goats relish the bark of especially Gliricidia the intake of this plant component was also studied in this experiment. A comparison of the intake data with those from other trials does not suggest that the bark really increased the total DMI but rather that it substituted for part of the leafy fraction of the legumes. Growth rates stayed slightly below expectation based on the DDMI, due to a subclinical pneumonia infestation, traces of which were discovered during the carcass evaluation performed at the end of the experiment.

Although Leucaena has proven to be a useful feed, its mimosine content, which in ruminants is normally degraded to the toxic 2,4 Dihydroxy Piridine (DHP), makes feeding diets containing more than 1% mimosine on DM-basis over prolonged periods prohibitive (Jones and Hegarty, 1984). Jones (1981) however observed that goats in Hawaii were able to thrive on rations mainly composed of Leucaena for extended periods, without signs of DHP toxicity. Further research showed that this was thanks to the presence of a bacteria in the rumen, which can metabolise the DHP, and, when kept under certain conditions can be transferred to other animals (Jones and Megarrity, 1983; 1986). Once this inoculum became available the International Livestock Centre for Africa (ILCA) and the West African Dwarf Goat Project prepared a joint project to determine whether this bacteria would be present in West African Dwarf goats and sheep fed on high levels of Leucaena, and if not, whether those animals could be effectively inoculated. As results from the first phase revealed high levels of DHP in the urine, proving the absence of the bacteria, the second phase was started. Some preliminary results are presented in Table 3. On the highest Leucaena level (75% *Leucaena leucocephala* and 25% *Gliricidia sepium*) Leucaena accounted for about 73% of the total DMI. DDMI amounted to 42-43 g $kg^{-0.75}$ d^{-1}), which is quite similar to that obtained in previous experiments. Growth rates, however, were poor due to a severe pneumonia outbreak, which proved to be difficult to eradicate. More research has therefore been planned to reinvestigate the effect of inoculation, especially on growth.

The previous experiments have shown that the WAD goat can, when fed on very high quality feed i.e. concentrates, grow at a rate of 60 g d^{-1} over prolonged periods.

As this figure can be considered the potential maximum under Ife conditions it can be used as a guideline for the evaluation of other feed resources. Animals fed on sole Gliricidia attain only 39% of this level. However in combination with leucaena it achieved considerably better growth rates, up to 62% of the maximum growth rate. Adding an energy source like cassava to this combination further improved this rate by another 10% (Fig. 3).

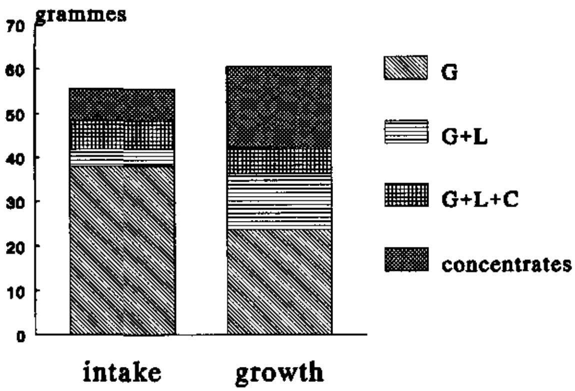

*Figure 3. The relationship between the intake (g DDMI kg$^{-0.75}$ d^{-1}) and daily weight gain (g/d) (G=*Gliricidia sepium *, L=*Leucaena leucocephala*, C=cassava).*

GROWTH TRIALS

Two trials were conducted specifically to measure weight gain. One was carried out as part of a Gliricidia-Leucaena substitution trial, which was partly executed in metabolism units, partly with animals housed in ground pens with slatted floors, which are assumed to be closer to the "practical" situation than metabolism cages. Growth rates were comparatively higher in the ground pens, at least partly due to the earlier mentioned disease problem. The results show the better weight gains on the composed diets (37-40 vs 25 g d^{-1}) (Table 4). No significant difference, however, was found between the 25 and 50% substitution level.

Another source of cheap protein i.e. Brewers' Dried Grains was evaluated in the other study. As a supplement to poor quality *Panicum* hay it proved to be quite promising producing growth rates of 29 g d^{-1} when fed at 50 g kg$^{-0.75}$ d^{-1} . When supplemented at 25 g kg$^{-0.75}$ d^{-1} the weight increase was only 9 g d^{-1}, which seems relatively poor. One has to consider, however, that the goats cannot maintain themselves on *Panicum* hay alone. So part of the supplement is needed to meet the maintenance requirements. Further research is under way to study the usefulness of this industrial by-product in more detail.

Table 4. Some results of growth trials carried out at Ife

Exp. no.	Feed	Feed offer g DM $kg^{-0.75}$ d^{-1}	Growth rate g d^{-1}
7	*G. sepium*	±100 (leaf)	24.8±7.3
7	*G. sepium* (75%) *L. leucocephala* (25%)	±100 (leaf)	37.2±11.7
7	*G. sepium* (50%) *L. leucocephala* (50%)	±100 (leaf)	40.3±2.1
9	*P. maximum* Brewers' dried grain	*ad libgitum* 25	9.2±7.7
9	*P. maximum* Brewers' dried grain	 50	29.2±10.5

SLAUGHTER CHARACTERISTICS

An integral part of some experiments was to assess the effect of the different diets on the slaughter characteristics of the WAD goat. Some of the results have been summarised in Tables 5 and 6.

The animals evaluated so far were not yet fully mature as shown by their liveweight (9-13 kg) and age (244-380 days). The fact that the goats were not starved before slaughtering explains the rather low dressing out percentages calculated in the conventional way (rate 1) ranging from 34 to 43%. Calculated on the basis of empty body weight (rate 2, range 46-53%) it compares quite well with the 50-51% dressing out percentage reported by Akinsoyinu *et al.* (1975) for approximately one and a half year old dwarf goats, starved for twelve hours which recalculated on empty body weight equals to 57%. As in many countries not only the carcass but also other body components like head, organs, intestine and skin, are highly appreciated, a dressing rate has been calculated which takes into account those parts (rate 3) as well. This percentage shows that a major part of the goat (66 to 82%) consists of valuable products.

Carcass evaluation data, based on the dissection of the left half of the carcass indicate fat contents of 6 to 12% (Table 6). The relatively low values from the Gliricidia-Leucaena substitution trial are probably related to the sub-optimal physical condition of those animals, as discussed earlier. The results show that cassava supplementation did not lead to significantly fatter carcasses.

Folkertsma (1980) studied the carcass composition of very well-fed WAD goats in The Netherlands at different liveweights (i.e. 14, 20 and 28 kg), which they attained between the ages of eight and thirteen months. He found fat contents

Table 5. A review of some slaughter characteristics

Exp. no.	Description		Age (days)	Live weight (kg)	Dressed carcass (kg)	Dressing out (%)		
						1	2	3
7	100% Glir.		337	9.1	3.1	34.0	46.0	66.0
		s.d.	35	0.9	0.2	1.4	1.5	2.1
7	75% Glir.+		380	13.5	5.6	41.2	52.5	72.1
	25% Leuc.	s.d.	58	1.4	0.9	2.4	2.2	2.8
7	50% Glir.+		357	12.8	5.3	41.6	52.1	73.3
	50% Leuc.	s.d.	65	1.1	0.3	1.7	0.6	3.4
8	75% Glir.+		244	9.4	3.4	36.4	48.5	71.1
	25% Leuc.	s.d.	28	0.6	0.3	1.6	1.6	2.3
8	75% Glir.+		278	10.1	4.0	39.9	48.7	75.3
	25% Leuc.	s.d.	34	1.0	1.3	2.1	5.7	4.0
	15 g cassava							
8	75% Glir.+		286	9.7	4.2	43.3	52.9	82.0
	25% Leuc.	s.d.	44	0.7	0.5	2.7	2.9	4.1
	30 g cassava							

[1] 1=(dressed carcass/liveweight)*100
2=(dressed carcass/empty body weight)*100
3=((dressed carcass+abdominal fat+organs+intestine+head+skin)/liveweight)*100
[2] Glir. = Gliricidia sepium; Leuc. = Leucaena leucocephala

Table 6. Some results of carcass evaluations

Exp. no.	Description		Age (days)	Carcass weight	Lean %	Intermusc. fat %	Bone %
7	100% Glir.		337	3.1	69.2	6.8	25.0
		s.d.	35	0.2	3.1	1.7	4.0
7	75% Glir.+		380	5.6	70.0	8.2	21.9
	25% Leuc.	s.d.	58	0.9	4.9	1.4	4.0
7	50% Glir.+		357	5.3	74.6	6.6	18.8
	50% Leuc.	s.d.	65	0.3	2.3	1.6	1.3
8	75% Glir.+		244	3.4	64.2	10.1	25.7
	25% Leuc	s.d.	28	0.3	3.9	3.0	0.9
8	74% Glir.+		278	4.0	69.6	10.9	19.5
	25% Leuc.+	s.d.	34	0.3	1.4	2.2	1.0
	15 g cassava						
8	75% Glir.+		286	4.2	67.3	11.6	21.2
	25% Leuc.+	s.d.	44	0.5	2.4	0.4	6.3
	30 g cassava						

Glir. = *Gliricidia sepium*; Leuc. = *Leucaena leucocephala* (subcutaneous + intermuscular) ranging rom 19 to 33% (expressed as percentage of carcass weight), which increased exponentially with the carcass weight. The share of bone and lean diminished at the same time from 16 to 12% and from 61 to 53% respectively. Although one has to be very careful making comparisons because of the environmental and possible genetical differences, it seems valid to conclude that the goats in the experiments reported here had not yet reached a stage, where fat deposition became the major growth factor, notwithstanding the fact that the animals in Ife were of about the same age as those in The Netherlands. This is probably a good example of what an important key role nutrition may play in an intensive goat production system.

CONCLUSIONS

On the basis of the nutritional studies carried out by the West African Dwarf Goat Research Project the following conclusions can be drawn:

- WAD goats cannot be maintained on poor quality tropical grasses.
- The combination of the legumes *Gliricidia sepium* and *Leucaena leucocephala* can constitute an adequate basic diet for WAD goats producing weight gain of up to 35-40 g d^{-1}.
- Cassava and Brewers' Dried Grains hold promises as energy and protein rich supplements respectively. Further research is required to determine the optimal feeding level and, in the case of cassava, feeding frequency.

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3.1.2 EFFECT OF AMOUNT OFFERED ON INTAKE, DIGESTIBILITY AND VALUE OF *GLIRICIDIA SEPIUM* AND *LEUCAENA LEUCOCEPHALA* FOR WEST AFRICAN DWARF GOATS[1]

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ABSTRACT

In two experiments with Gliricidia sepium *(G) and G combined with* Leucaena leucocephala *(GL), fourteen West African Dwarf goats were offered seven feed levels varying from 60 to 120 g DM* $kg^{-0.75}$ d^{-1}*, with increments of 10 g, in Exp. 1, and from 40 to 130 g DM* $kg^{-0.75}$ d^{-1}*, with increments of 15 g in Exp. 2.*

Maximum DMI for the G and GL were, in Exp. 1: 72.5 ± 2.6 *and* 90.7 ± 27.2*, in Exp. 2:* 55.5 ± 3.7 *and* 63.4 ± 5.3 *g* $kg^{-0.75}$ d^{-1}*, respectively.*

In both experiments GL rations were more digestible than G rations, the difference in the second experiment being larger (10.3 vs 3.6 percentage units), mainly due to a lower digestibility of G. A marked effect of refusal rate on intake was found and the relationship between refusal rate and DMI differed per diet.

Animal production per unit of forage offered was maximal at offer levels ranging from 79.4 (Exp. 1, G) to 106.6 g DM $kg^{-0.75}$ d^{-1} *(Exp. 1, GL). Corresponding weight gains were estimated to range from 2.0 (G2) to 9.6 g* $kg^{-0.75}$ d^{-1} *(GL1). Refusal rates at maximum production levels varied from 13.4% (G1) to 41.6% (G2). Estimated maintenance levels were attained at refusal rates varying from 0.7% (G1) to 20.3% (G2).*

It was concluded that a wide range of offer levels is required to obtain a reliable estimate of the relationship between feed offer and intake. Feeding at a fixed refusal rate to determine the quality of feeds may lead to misjudgment as feeds do not attain maximum intake at the same refusal rate. If a feed is heterogenous and thus offers opportunity for selection, high offer levels and accompanying high refusal rates may have to be accepted if the objective is to maximise animal production per unit of available feed.

Keywords: feed intake, refusal rate, digestibility, goats, productivity

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[1]*Small Ruminant Research, 15 : 247-256*

INTRODUCTION

The value of feed for animal production depends on feed quality (i.e. digestible nutrient content) and level of voluntary intake by the animal. The leguminous tree species *Gliricidia sepium* and *Leucaena leucocephala* can constitute a useful source of high quality feed for ruminants (NAS, 1977; Chadhokar, 1982; Jones and Hegarty, 1984; Smith and van Houtert, 1987; Ademosun *et al.*, 1988; Reynolds and Adediran, 1988; Adejumo and Ademosun, 1991; Girdhar *et al.*, 1991). These legumes have in their leaves a high protein content (>20% CP) and are better able to retain feeding quality than tropical grasses, especially during dry periods. Their role in integrated crop-livestock systems has been advocated (Kang *et al.*, 1981; Reynolds *et al.*, 1988).

Interpretation of literature data on the feeding value of these legumes is often difficult as the effect of feed offer, which influences both intake and quality of the ingested material, is not fully considered. Sometimes offer levels are not given, while in other cases offer levels may have been sub-optimal. The expression "*ad libitum*" without any further definition is not adequate as it is not well defined. Often it refers to feeding levels, at which at least some feed is refused, but not necessarily the level at which maximum intake is reached. Blaxter *et al.* (1961) described *ad libitum* intake as consumption when allowing animals to refuse 10 - 20% of amount offered. Other researchers, however, have shown that maximum intake may not be attained at these refusal levels when feeds are heterogenous and thus allow for selection. Wahed *et al.* (1990) found increasing intake even above 50% refusal rate, when offering increasing levels of barley straw to both goat and sheep, fed on a basic ration of concentrates. Similar reports have been given by Zemmelink (1980), Zemmelink (1986), Osafo *et al.* (1991) and Aboud *et al.* (1993). Animals eating heterogeneous forages generally select the more nutritional parts. At higher offer levels, selection and feed intake will be stimulated, but also the amount of feed refused will increase. Zemmelink (1986) concluded that for a complete evaluation of feeding value it is necessary to measure intake and digestibility for the full range of selection that may occur. A measure of feed value for animal production is the maximum amount of digestible nutrients above the quantity required for maintenance an animal will ingest per unit of feed offered. Based on this value, the optimum levels of offer (and excess feed) can be determined.

This paper presents analyses of two experiments to investigate effects of level of feed offered of *Gliricidia sepium* and *Leucaena leucocephala* on intake and digestibility in West African Dwarf goats. In addition, the value of these browse species in different feeding strategies is discussed.

MATERIALS AND METHODS

Animals and housing

Fourteen West African Dwarf goats (12 females + 2 castrated males; mean initial body weight 11.6 kg at 10.4 months), were divided into two homogeneous groups of seven animals each, regarding sex, weight and age. Animals were housed in individual metabolism cages and had free access to clean drinking water and a salt lick throughout the whole experimental period. The same animals were used for both experiments. They were allowed three weeks to adjust to the new environment and feed.

Feeds and feeding

In both experiments, the feed was cut daily from experimental plots on the research farm of Obafemi Awolowo University, Ile-Ife, Nigeria. Only the leaves and racemes were fed. The feed offer was weighed in the morning, thoroughly mixed, and given in two equal portions, one after the morning cleaning (around 10 a.m.), the other in the afternoon (around 4.00 p.m.). The first experiment (Exp. 1) was conducted during the dry season and early rains of 1987. The second experiment (Exp. 2) was carried out during the middle of the rainy season of the same year. This may (partly) explain the lower crude protein content of the feeds in Exp. 1 (Table 1).

Table 1. Chemical composition of browse tree leaves fed in the two experiments (averages per week ± s.d.)

	Experiment	Dry matter, %	Ash, %	Crude protein, %
Gliricidia sepium	1	24.4±1.4	7.9±0.3	22.4±0.9
	2	25.7±3.3	8.3±0.9	22.3±1.3
Leucaena leucocephala	1	26.9±1.9	6.2±0.5	23.8±2.9
	2	25.9±3.7	7.5±0.1	26.6±0.4

Exp. 1: Feed was offered at levels varying from 60 to 120 g DM $kg^{-0.75}$ d^{-1}, with increments of 10 g. Two combinations of *Gliricidia sepium* and *Leucaena leucocephala* were studied: 100% Gliricidia (G1) and 50% Gliricidia - 50% Leucaena (GL1). G was fed to the animals in one group, whereas the other group was put on ration GL. Animals were ranked according to liveweight and odd numbers were randomly assigned to the four highest offer levels, whereas even numbers were randomly allotted to the three lowest feeding levels. After an

adaptation period of one week, feed offered, feed refusal and faecal output was weighed and samples of feed offer, residues and faeces were taken for DM determination during a 9 d period. After the first period the animals were reassigned to one other feeding level for a second measurement period.

Exp. 2: Based on the results from the Exp. 1 the range in offer was widened to extend from 40 to 130 g DM $kg^{-0.75}$ d^{-1}, with increments of 15 g, and the same feeds, 100% Gliricidia (G2) and 50% Gliricidia - 50% Leucaena (GL2), were fed to one of the two groups. Each animal was given the seven offer levels according to a latin square design. After an adaptation period of one week, feed offered, feed refusal and faecal output were weighed and samples of feed offer, residues and faeces were taken for DM determination during a 9 d period, after which the feeding levels were changed.

Statistical analysis

The relationship between Dry Matter Offered (DMO, g $kg^{-0.75}$ d^{-1}) and the Dry Matter Intake (DMI, g $kg^{-0.75}$ d^{-1}) was estimated using the model developed by Zemmelink (1980). This model relates the DMI *(y)* to DMO level *(x)* as follows:

$$y = m*(1 - e^{-(\frac{p*x}{m})^h})^{\frac{1}{h}} \quad \text{(restrictions: } m>0, h>0, 0<p\leq 1) \tag{1}$$

where m=the upper limit (asymptote) for y, p=the acceptable fraction of the forage, h=a shape parameter, such that y at the critical level of feeding x=m/p equals $m(1-e^{-1})^{1/h}$

This model has a number of advantages over other models used in the literature (Zemmelink, 1980; Zemmelink, 1986): intake can never be less than zero thus $y \geq 0$ for $x \geq 0$; when no feed is offered intake is zero, therefore the regression line must pass through the origin: $y=0$ if $x=0$; intake can never be higher than the acceptable fraction of the feed offer: $y \leq px$; when increasing amounts of feed are offered, intake can be expected to increase but only until it reaches a certain maximum, i.e. the regression model is of a monotone increasing type, which approaches an asymptote (m) at higher values of x.

Variation in intake at low feeding levels, when animals tend to eat all acceptable feed offered, will be smaller than at higher levels of feeding. Once a plateau is reached the variation is expected to stabilise. For this reason the data were weighted proportionally to the reciprocal of the squared dependent variable as estimated from the regression analysis. To do this an iterative procedure was used in fitting the curves as discussed by Zemmelink (1980) and Zemmelink (1986).

The parameters *p, m* and *h* were first estimated per period, and those that did not differ significantly between periods were re-estimated over periods. In the second experiment the same procedure was used to test differences between animals.

The modelling of the relationship between digestible DMI (DDMI) and DMO was based on the relationship between DMI and DMO and the relationship between Dry Matter Digestibility (DMD) and DMO. The latter was assessed by linear or higher degree regression of DMD on DMO.

To assess the consequences of different feeding strategies on animal production the Value for Animal Production (VAP) described by Zemmelink (1986) was used. This index expresses the amount of DDMI (g $kg^{-0.75}$ d^{-1}) available for productive purposes as a fraction of DMO. Assuming that the maintenance requirement of the experimental goats is 25 g DDMI $kg^{-0.75}$ d^{-1} (derived from NRC 1981; Sanz Sampelayo *et al.* 1991; Zemmelink *et al.*, 1991) the VAP can defined as:

$$VAP = \frac{(DDMI - 25)}{DMO} \qquad (2)$$

Potential weight gain was estimated from DDMI, assuming that 2.5 g DDMI is required per g gain (derived from NRC, 1981; Sanz Sampelayo *et al.*, 1991; Zemmelink *et al.*, 1991).

RESULTS

The actual DMO levels were lower than planned, differences ranging from 3 to 16%. This was largely due to an overestimation of the DM content, especially of Leucaena.

Least square estimates for the parameters *p, h* and *m* are in Table 2. In Figures 1 and 2, DMI and DDMI are shown in relation to DMO. A significant effect of period on *m* was found for diet GL2. For the other diets, parameters *p, h* and *m* did not differ significantly between periods or between animals.

The *p*-values did not differ significantly from 1, whereas the estimates for the *m*-values ranged from 55.5 (G2) to 90.7 g DM $kg^{-0.75}$ d^{-1} (GL1). Intake levels as estimated with equation 1 at the highest offer levels per feed combination were within 10% of these asymptotes, except for GL2. The corresponding refusal levels varied from 35.0 (GL1) to 57.4% (G2).

Intake at the critical level, i.e. when the amount of edible DMO is equal to *m* ($x = m/p$) varied, when expressed as percentage of the estimated maximum intake from 75% (GL1) to 91% (G1).

In Exp. 1, average DMD of G1 and GL1 differed 3.6 units and no relationship was found between DMO and DMD. In Exp. 2, however, difference between

Table 2 *Least square estimates of parameters p , m and h (± asymptotic s.e.) for relationship between DMO*[1] *and DMI*[1]

Diet[2]	p[3]	m[4]	h[5]	R2[6]	RCV[7]	Y_{max}[8]	R_{max}[9]	Y_{crit}[10]	Digestibility[11]
Exp. 1 (n=14)									
G1	1	72.5±2.6	4.69±2.04	0.58	0.080	72.5	39.6	90.7	62.9±0.5
GL1	1	90.7±27.2	1.57±0.68	0.68	0.112	78.0	35.0	74.7	66.5±0.8
Exp. 2 (n=49)									
G2	1	55.5±3.7	2.11±0.40	0.57	0.172	55.4	57.4	80.4	55.3±0.9
GL2	1	63.4±5.3	2.57±0.48	0.86	0.111	63.4	48.8	83.7	65.0±1.0

[1] DMO: dry matter offered, in g DM $kg^{-0.75}$ d^{-1}; DMI: dry matter intake, in g DM $kg^{-0.75}$ d^{-1}
[2] G: Gliricidia (100%); GL: Gliricidia-Leucaena (50/50%)
[3] acceptable fraction of the forage
[4] maximum intake (asymptote), in g DM $kg^{-0.75}$ d^{-1}
[5] a shape parameter (see text)
[6] square of correlation coefficient
[7] residual coefficient of variation
[8] estimated intake at the highest level studied, in g DM $kg^{-0.75}$ d^{-1}
[9] estimated refusal rate at highest offer level studied (% of DMO)
[10] intake at critical offer level (x=m/p), expressed as percentage of m
[11] average % over all offer levels, ± standard errors

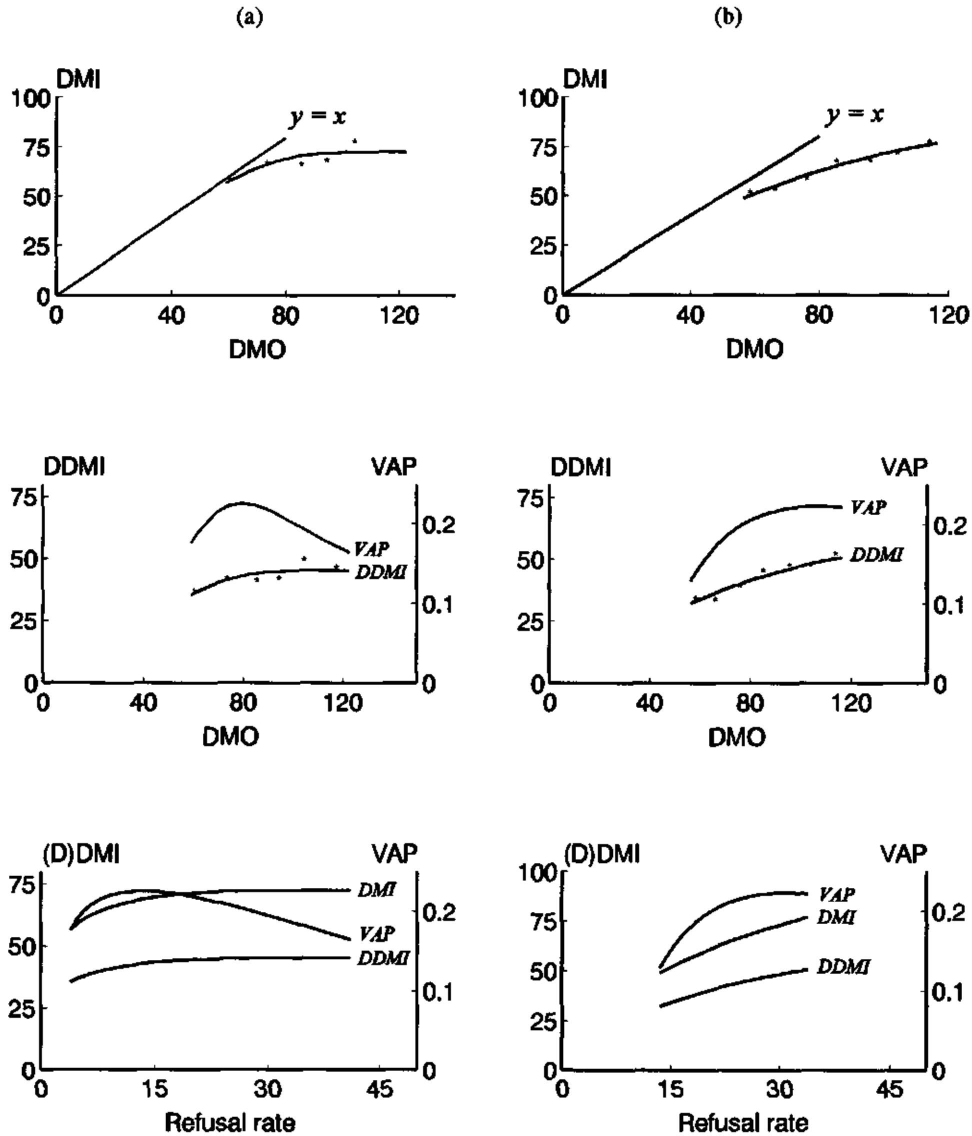

Figure 1. Effect of dry matter offer (DMO, g kg$^{-0.75}$ d^{-1}) and refusal rate (% of DMO) on dry matter intake (DMI, g kg$^{-0.75}$ d^{-1}), digestible DMI (DDMI, g kg$^{-0.75}$ d^{-1}) and the Value for Animal Production (VAP) for (a) Gliricidia diet and (b) Gliricidia/Leucaena diet in Exp. 1. Plotted values are group means.

average DMD of G2 and GL2 was remarkably larger (9.3 percentage units) and for GL2 a positive linear relationship was found between DMD and DMO (Figure 3).Therefore average digestibilities were used to model DDMI, except for GL2, where the linear relationship was used to model DDMI. Differences in DMD were

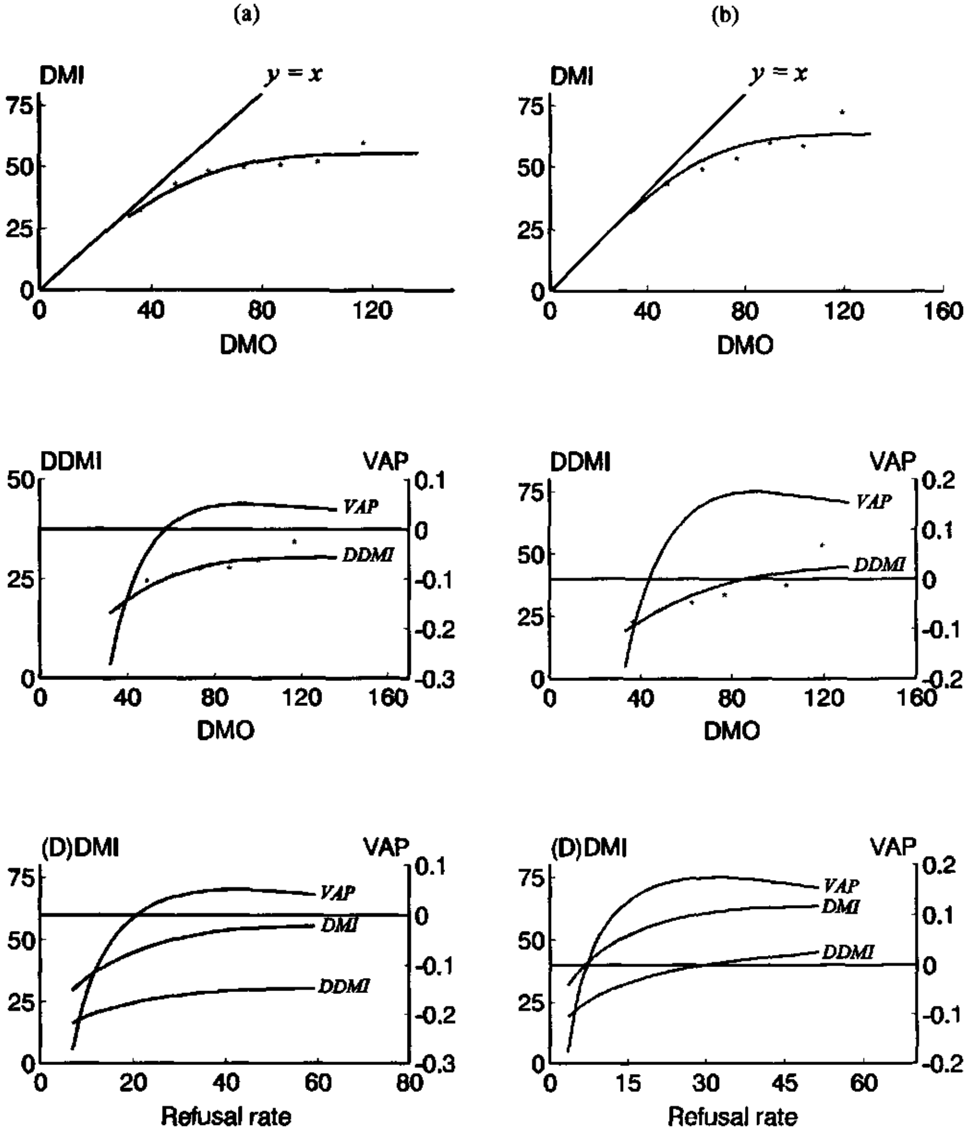

Figure 2. Effect of dry matter offer (DMO, g $kg^{-0.75}$ d^{-1}) and refusal rate (% of DMO) on dry matter intake (DMI, g $kg^{-0.75}$ d^{-1}), digestible DMI (DDMI, g $kg^{-0.75}$ d^{-1}) and the Value for Animal Production (VAP) for (a) Gliricidia diet and (b) Gliricidia/Leucaena diet in Exp. 2. Plotted values are group means.

reflected in the relative intake of the browse species, which did not differ in Exp. 1, but showed a higher relative Leucaena intake in Exp. 2 at higher DMO levels (Figure 3).

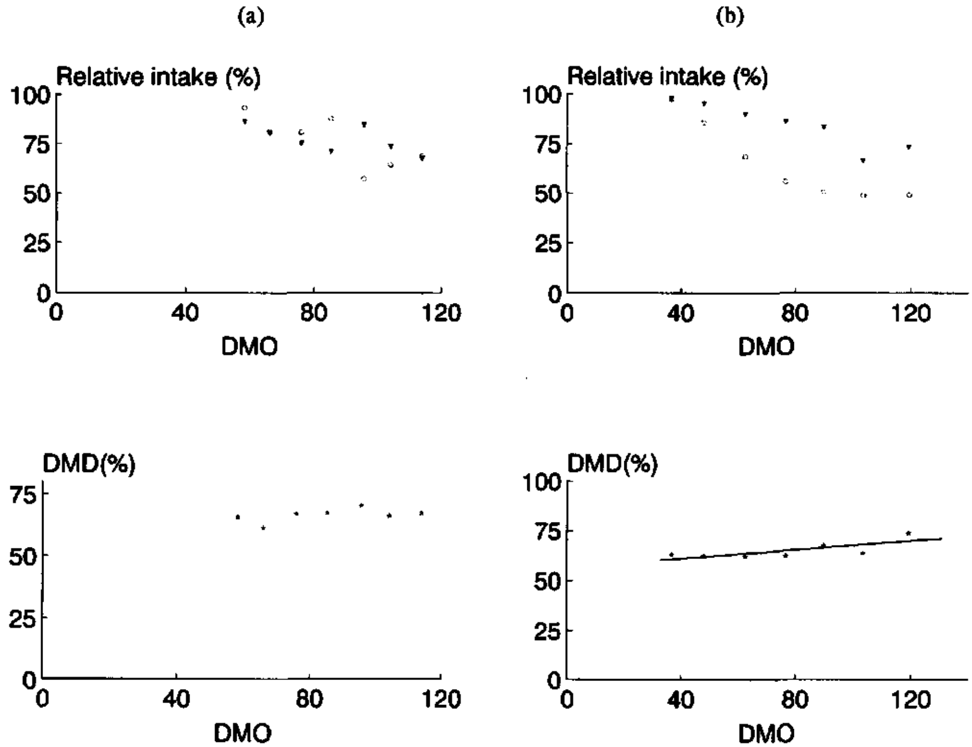

Figure 3. Effect of dry matter offer (DMO, g kg$^{-0.75}$ d^{-1}) on dry matter digestibility (DMD, %) and the relative intake (DMI expressed as percentage of the amount offered) of Gliricidia(o) /Leucaena (•) from the mixed diets in Exp. 1 (a), Exp. 2 (b)

Table 3 gives DMO, DDMI and VAP values for the two feeding strategies i.e.: maximum number of animals kept at maintenance intake (VAP=0) and maximum production per unit of forage (VAP=maximal). The consequences of these strategies for the flock management is illustrated by showing the Potential Number of Animals (10 kg body weight) that can be kept per 10 kg DM of feed and the total production that can be obtained. Table 3 further shows the potential weight gain per animal at maximum VAP.

The maximum VAP's varied from 0.05 for G2 (at 41.6% refusal) to 0.23 on G1 and GL1 (at 13.4% refusal and 30.7% refusal for G1 and GL1, respectively). Accompanying weight gains were estimated at 2.0 (G2), 7.3 (G1) and 9.6 (GL1) g kg$^{-0.75}$ d^{-1}. In the latter case up to 2.5 times more animals could be kept per kg DMO if no production is required. In case of G1 and GL2 this ratio is about 2, and in case of G2 1.6. Although maximum VAP were equal for G1 and GL1 estimated total body weight gain was somewhat higher on GL1 (903 vs 918 g/10 kg DMO), due to

Table 3. The DDMI[1] values and animal performance at optimum offer level (VAP[2] = maximal) and at maintenance level (VAP=0) per diet

		Diet[3]			
		G1	GL1	G2	GL2
Fed at maintenance level	MO[4]	40.0	41.1	56.8	43.9
	DDMI	25.0	25.0	25.0	25.0
	refusal rate (%)	0.7	8.6	20.3	7.1
	no. of animals[5]/10 kg DM	44	43	31	41
Maximal production per unit of feed	DMO	79.4	106.6	92.6	89.7
	DDMI	43.3	49.1	29.9	40.6
	refusal rate (%)	13.4	30.7	41.6	31.9
	VAP	0.23	0.23	0.05	0.17
	possible gain (g $kg^{-0.75}$ d^{-1})	7.3	9.6	2.0	6.2
	no. of animals[5]/10 kg DMO	22	17	19	20
	total body weight gain/10 kg DMO (g)	903	918	214	697

[1] digestible dry matter intake, in g DM $kg^{-0.75}$ d^{-1}
[2] Value of animal production
[3] G: Gliricidia (100%); GL: Gliricidia-Leucaena (50/50%)
[4] dry matter offered, in g DM $kg^{-0.75}$ d^{-1}
[5] of 10 kg body weight

higher weight gains (g $kg^{-0.75}$ d^{-1} on GL1, which compensated for the lower number of animals that could be kept per 10 kg DMO (22 vs 17).

The potential maximum weight gains, estimated at maximum intake (m) are respectively: G1: 8.2, GL1: 14.0, G2: 2.3 and GL2: 8.4 g $kg^{-0.75}$ d^{-1}. On both GL rations, however, these intake levels were not realised within the studied offer range.

DMO required for maintenance was quite similar for the GL1, GL2 and G1 (around 40-44 g $kg^{-0.75}$ d^{-1}), it was, however, considerably higher for the G2 (56.8 g $kg^{-0.75}$ d^{-1}) and the corresponding residues varied from 0.7 % (G1) to 20.3% (G2).

DISCUSSION

Standard errors of the parameters and the RCV's of the model relating DMI to DMO were of the same magnitude as found by Zemmelink (1980). Only on the GL1 diet the offer range appeared to be too short to obtain an accurate estimate of *m*, as shown by the large standard error. None of the feeds contained an unedible fraction

($p=1$). At higher offer levels, feed was eaten selectively and residues increased, the rate depending on the feed. Parameter h, a reflection of the measure of selection, did not differ between treatments. The h-value for G1 could not be estimated very accurately, as shown by the high standard error. Within the leaves, goats were observed to select the leaflets in favour of the racemes which have a lower crude protein content and lower *in-vitro* digestibility (Teniola, 1990). Also other researchers found, when feeding straw to goats and sheep, a selection in favour of the more digestible fraction (Wahed and Owen, 1986; Bhargava *et al.*, 1988; Wahed *et al.*, 1990).

In Exp. 2, higher offer levels increased the possibility to select the better digestible Leucaena, resulting in an increasing digestibility of the DMI in the offer range studied. As a consequence, the estimated DDMI was still on a clear increase at the highest offer level, while DMI approached m. In Exp. 1, where the difference in digestibility between G and L was considerable smaller DMI and DDMI were still on a clear increase at the highest offer level.

Zemmelink (1980) reports comparable findings for a number of other tropical legumes. Animals selected strongly in favour of the more digestible leaves, even decreasing intake of stems at higher offer levels. Bhargava *et al.* (1988) observed a similar selection pattern, when feeding increasing quantities of *Urtica dioica L.* (*in-vitro* digestibility 64.5%) in combination with straw (*in-vitro* digestibility 60.3%).

Minson (1990) suggested limitation of the range of excess feed to 5 to 20% as a good compromise for obtaining a reasonable estimate of voluntary intake. In our experiments, DMI appeared to increase in (and above) that range and thus choosing a refusal rate to measure voluntary intake would be arbitrary. Zemmelink (1980) also observed that the level of excess feed can have a very large effect on intake and concluded that any standard for the level of excess feed in experimental work on tropical forages is largely arbitrary. He showed for several tropical forages how the relationship between intake and refusal rate can mislead judgement of the quality of a ration. Our results confirm this observation. At 15% residue, for instance, in Exp. 1 the estimated DDMI for the Gliricidia sole diet was about 45 g $kg^{-0.75}$ d^{-1} and for the mixed ration about 35 g $kg^{-0.75}$ d^{-1}. At 35% residue, however, the estimated DMI for the single species treatment amounted to 46 g $kg^{-0.75}$ d^{-1}, whereas the mixed treatment attained about 52 g $kg^{-0.75}$ d^{-1}. This shows that ranking of diets for feeding value is very sensitive to the refusal rate. Even when fed at maintenance level refusal rates varied considerably, from nearly 1% (G1) to 20% (G2).

The potential of *Gliricidia sepium* and *Leucaena leucocephala* for animal production is shown by the Value for Animal Production index (VAP). At maximum VAP on the GL diets weight gains of up to 7 g $kg^{-0.75}$ d^{-1} were estimated at DMO ranging from 90 to 107 g $kg^{-0.75}$ d^{-1}. In earlier experiments conducted with the same feed, fed in the same combination at approximately 100 g DM $kg^{-0.75}$ d^{-1} over prolonged periods (> 3 months), these weight gains have indeed been achieved (Ademosun *et al.*, 1988). Increase of offer above the point, where production per unit of feed is maximal, to approach maximum intake (*m*), rendered a modest increase in potential weight gain on the sole Gliricidia rations (about 15%), whereas on the GL rations this difference was considerably larger (about 40%).

The refusal rates at which maximum VAP was attained varied widely as also found for other tropical forages (Zemmelink, 1986). Except for G1 these rates were above 30%. Voluntary intake measured over the refusal rate range of 5 to 20%, as suggested by Minson (1990), would thus result in an underestimation of the potential of these three diets (G2, G11, GL2). The maximum production in terms of body weight gain per unit of feed offered depends on the weight gain per animal and the refusal rate at maximum VAP. Thus the total body weight gain can differ at equal (maximum) VAP values, as shown for G1 and GL1.

It should be noted that in our experiments only leaves and racemes were fed. Under practical conditions the complete branches will be fed and thus residues can be even larger because of the stems, of which only the bark may be consumed (Ademosun *et al.*, 1988). On the other hand left-overs are not necessarily valueless (Tanner *et al.*, 1993; Lagerman, 1977).

CONCLUSIONS

When feeding leaves and racemes of a mixture of *Gliricidia sepium* and *Leucaena leucocephala* maximum intake is only attained at high offer levels, with high refusal rates (>30%). Effect of refusal rate on DMI and DDMI was pronounced in the range from 10 to 30%. On the same diets, estimated maintenance levels of goats were attained at refusal rates of 7-9% but maximum VAP at refusal rates above 30%.

Estimated DDMI on the GL mixed rations at the highest offer level studied (120-130 g DM $kg^{-0.75}$ d^{-1}), was more than 60% above the amount required for maintenance, allowing for good production levels (>6 g of BW gain $kg^{-0.75}$ d^{-1}).

On some of the diets, intake was still increasing at the highest offer levels studied, which made an accurate estimate of maximum intake impossible. Thus a wide range of offer levels is required to obtain a reliable estimate of the relationship between feed offer and intake.

If a feed is heterogenous and thus offers opportunity for selection, high offer levels and accompanying high refusal rates may have to be accepted if the objective is to maximise animal production per unit of feed.

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3.1.3 GOAT FEEDING PRACTICES AND OPTIONS FOR IMPROVEMENT IN SIX VILLAGES IN SOUTH-WESTERN NIGERIA[1]

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ABSTRACT

Two village surveys were carried out in six villages in South-Western Nigeria to assess goat feeding under traditional management ranging from free roaming to permanent confinement. Three of the villages are located in the lowland rainforest zone (FZ) and three in transition between FZ and the derived savannah (TZ). In FZ the pressure on arable land and goat production is greater than in TZ. In one of the TZ villages confinement was mandatory. One survey was aimed to inventory the use of feeds (type, frequency) and was conducted among 125 households, 61 of which were selected for the second survey, which aimed to quantify the amounts offered. The digestibilities of the most frequently used feeds were determined in-vivo *on-station. These studies formed part of a research project on the suitability of several innovations to improve goat production. One of these concerned the use of* Gliricidia sepium *and* Leucaena leucocephala. *It was found that cassava products (tuber and peel) and maize offal (a by-product from local maize processing) were the most frequently used feeds. In FZ breadfruit (*Artocarpus altilis*) also proved to be important. There were more feeds in FZ than in TZ. The DM digestibilities of the most frequently used feeds were : cassava: 89±2 (% ± s.e.); breadfruit: 88±2 and maize offal: 75±1. Of these feeds only maize offal had a high CP content (19%). Under free roaming, considerable amounts of feed were given (29-49 g $kg^{-0.75}$ d^{-1}); however, CP content was low (7-10%). The animals may have balanced their diet through scavenging and browsing. Larger amounts were offered to permanently confined stock (70 g $kg^{-0.75}$ d^{-1}) but CP content was low (10%); this may have limited weight gain. Some feeds frequently reported to be fed did not contribute much quantitatively. This shows that care must be taken when quantitatively interpreting the results of a qualitative survey. It is concluded that* Gliricidia sepium *and* Leucaena leucocephala *could replace maize offal and/or increase the total amount of feed offered per animal. The suitability appeared to depend on the labour needed*

[1]*accepted by Small Ruminant Research*

to harvest and feed the browse, the cost of maize offal and the value of the extra production. Within the socio-economic setting at the time of the survey, feeding small amounts of browse to balance protein-deficient diets seemed the most attractive option. Feeding of larger amounts of browse or using browse to replace maize offal seems to be feasible only if harvesting and feeding can be combined with other on-farm activities.

Key words: goats, nutrition, management, cassava, maize offal, breadfruit, browse, Nigeria

INTRODUCTION

Farming systems in South-Western Nigeria can be characterised as crop-based, with livestock as a secondary activity. Poultry and small ruminants, both of which are predominantly kept free ranging, are the most important livestock species. Goats are the most numerous small ruminants (Matthewman, 1980; Mack, 1983; Alofe *et al.*, 1989; Koper and Aderigbigbe, 1993). After health, nutrition has been identified as the second factor limiting productivity of small ruminants (Sumberg, 1985; Reynolds *et al.*, 1988). In East Nigeria, where small ruminants usually have to be confined, labour for feeding has been found to be the major constraint to improved productivity (Lagemann, 1977; Reynolds and Atta-Krah, 1989). The pressure on arable land and on the small ruminant production systems is increasing in South-Western Nigeria too. In some instances this has already resulted in confinement being obligatory or in small ruminants being banned. This trend is likely to continue.

Although supplementary feeding is generally assumed to be at low levels (Matthewman, 1980; Sempeho, 1985; Sumberg and Cassaday, 1985; Upton, 1985) there are few data on the amounts actually fed. This may be because of the difficulties involved in measuring feed offers and refusals on-farm as reported by Sempeho (1985) and Adebowale *et al.* (1993). However, in view of the trend towards more intensive goat production, data of this type are urgently required, so that the effect of the changes in management on goat nutrition can be assessed.

The International Livestock Centre For Africa (ILCA) introduced the alley farming concept to improve both crop and small ruminant production. It involves planting crops in alleys about 4 m wide between hedges of *Gliricidia sepium* and *Leucaena leucocephala*. Some of the browse is used as mulch and some is fed to the small ruminants (Reynolds *et al.*, 1988; Reynolds and Atta-Krah, 1989). The West African Dwarf Goat Project, a joint venture between the Obafemi Awolowo University, Ile-Ife, Nigeria, and the Wageningen Agricultural University, The

Netherlands, has developed a management package for goat production; in this package, these browse species play an important role (Ademosun, 1988; Ayeni and Bosman, 1993). This package has been evaluated in six villages in South-Western Nigeria, with varying pressure on the small ruminant production system. During this evaluation two surveys were carried out to obtain more information on the qualitative and quantitative aspects of goat feeding in these villages. In addition on-station trials were conducted to determine the digestibility of the most prevalent feeds. In this paper the results of both the village and on-station studies are discussed and the possible role *Gliricidia sepium* and *Leucaena leucocephala* could play to improve goat feeding is assessed.

MATERIALS AND METHODS

Village surveys

Three villages were selected around Ife in the Lowland Rain Forest Zone (FZ) (Akeredolu, Toro, Ogbagba) and three around Ede on the fringes of the Derived Savannah and the Lowland Rain Forest Zone (Transition Zone, TZ) (Awo, Ikotun, Ojo). These ecological zones have been well described by Agboola (1979) and Diehl (1981). Annual rainfall is 1300-1400 mm and is bimodal with a dry season of approximately 5 months. The major criteria used in selecting the villages were their location (distance to towns and access roads), population size, interest of the population in the project as observed during village meetings, and the current small ruminant management systems.

Pressure on arable land and on the small ruminant production system was higher in FZ than TZ. In one village in FZ this had led to obligatory confinement. In the other two, crop damage by small ruminants and resulting conflicts were often reported (Bosman and Ayeni, 1993).

The surveys formed part of an extensive research programme, which aimed to study the suitability of several innovations in goat production (Ayeni and Bosman, 1993). Households to be surveyed were selected on the basis of a household survey conducted at the start of the fieldwork (Platteeuw *et al.*, 1993). Goat feeding practices were assessed qualitatively as part of a major in-depth survey. During this two-year survey (S1) a resident field assistant visited each selected household twice a week and inquired about different matters, including which supplements had been fed the previous day. On the basis of preliminary results from this an on-station experiment was carried out to determine the digestibility of the most frequently reported feeds. In addition, another survey (S2) was conducted to quantify how much feed was given at village level. Of the 125 households selected for S1 (between 18 and 23 per village, depending on size and goat management system), 61 were selected for S2 (10 or 11 per village). They were monitored quarterly for a whole day. On each occasion the amount of supplements offered was recorded and all goats were weighed. This survey was begun in November 1990 and lasted until May 1992; S1 was conducted between April 1990 and May 1992.

Samples of feed offered were taken and analyzed for %DM, %ash and %CP. The DCP content was estimated according to the formula: %DCP=0.9*%CP - 3.3 (Van Soest, 1982).

On-station experiment

The digestibility of the most common feeds was assessed in an experiment of three phases. Each phase consisted of an adaptation period and a 7-d measurement period, when the amount offered, the refusals and faecal output were determined. During the adaptation period the animals were gradually introduced to the new feeds (none of the supplements studied was fed on-station) and were familiarised with the treatments.

Animals

Two sets of West African Dwarf goats were used. One consisted of 12 females (average weight and age at beginning of experiment 10.4 kg and 11.5 months, respectively), the other of 12 castrated males (average weight and age at beginning of experiment 11.5 kg and 15.5 months, respectively). The first set was used for phase 1 and the second was used for phases 2 and 3. Each set was split into four groups of three animals. Each group was made as homogeneous as possible in terms of weight and age. The animals were housed individually in metabolism units throughout the experiment and had free access to clean drinking water and salt lick. The liveweight of each animal was measured once a week before the morning feeding.

Feeds and feeding

The most frequently used feeds, as found in S1, were investigated i.e.: cassava (*Manihot esculenta*), maize offal , locally called 'eri', a by-product of local maize processing (Sempeho, 1985) and breadfruit (*Artocarpus altilis*). To prevent nutritional disorders, the supplements were not fed as sole feeds, but were offered in varying proportions in combination with (mature) *Panicum maximum* hay.

Cassava and breadfruit were chopped into pieces about 1 cm thick and sun-dried. Maize offal, bought fresh, was also sun-dried at the beginning of the experiment. The *Panicum maximum* hay was chopped into pieces about 10 cm long. The chemical composition of feeds used in this experiment is given in Table 1. The feeds were offered in four combinations. In phase 1 hay was fed in proportions varying from 25 to 75% of total offer, but was kept constant at 20% in phases 2 and 3. Maize offal was offered in proportions varying from 25 to 75% in phase 1, and from

30 to 75% in phases 2 and 3. Cassava and breadfruit, respectively used in phases 2 and 3, were given in proportions varying from 5 to 50%. To avoid selection between and within the diet components (especially the roughage) left-overs were minimised by adjusting the amounts offered twice a week during the adaptation period, based on the refusals. During the 7-day measurement period, the amounts offered were constant. The ration was weighed in the morning and fed as follows:
Phase 1: 10.00 h first half maize offal, 11.00 h first half hay, 13.00 h second half maize offal and 15.00 h second half hay. Phase 2: 10.00 h maize offal, 13.00 h hay and 14.00 h cassava. Phase 3: 10.00 h maize offal, 12.00 h hay and 15.00 h breadfruit.

Table 1. Chemical composition of feeds used in the on-station experiment

	% dry matter	% ash	% crude protein
Panicum maximum hay	84.8	11.7	5.3
Maize offal	89.4	5.0	19.7
Breadfruit	88.5	3.8	5.0
Cassava	83.4	2.9	2.3

Statistical analysis

Abnormal data distributions were corrected through transformation: square root transformation when variance was proportional to the mean and log transformation when the standard deviation varied directly as the mean (Snedecor and Cochran, 1967). Analyses of variance were performed to assess differences between villages and seasons, and when statistically significant effects were found differences between means were tested using the least significant difference method (Steel and Torrie, 1981).

Dry Matter Digestibilities (DMD) were estimated through multiple linear regression analysis, modelling the relationship between the DDM Intake (DDMI, g $kg^{-0.75}$ d^{-1}) and the DMI (g $kg^{-0.75}$ d^{-1}), from the feed components. The equation used was:

$$Y = b_1 * X_1 + b_2 * X_3 + b_3 * X_4 + e$$

where $Y = DDMI$; $X_1 = DMI$ *from hay;* $X_2 = DMI$ *from maize offal;* $X_3 = DMI$ *from cassava;* $X_4 = DMI$ *from breadfruit.*

RESULTS

Village surveys

The results of S1 showed that feeding practices in the three villages in TZ were fairly uniform and therefore in Figure 1 the data have been pooled. The same holds for the two villages in FZ (Akeredolu and Toro), where free roaming was the predominant management practice. Figure 1 thus shows the relative frequency per feed for three cases: i.e. TZ, FZ (Free Roaming, FR) and FZ (Permanent Confinement, PC). Relative frequency is expressed as the number of times a feed was reported to have been fed, expressed as percentage of the total number of times a household was interviewed. A total of 57 feeds was reported to have been fed.

In TZ the most common supplements were cassava (tuber and peel) and maize offal. In FZ the picture was more diverse. Under free roaming cassava tubers and peel were less frequently fed, but maize offal and browse (including *Gliricidia sepium* and *Leucaena leucocephala*) were reported more frequently than in TZ. Furthermore, the frequency at which one of the supplements in the category "other feeds" (comprising 37 feeds) was used, was as high as the frequency of the use of cassava tuber. In the third village in FZ, where PC was practised (Ogbagba), bean residue (a by-product from local bean processing), breadfruit and cassava peel were fed most often. A wide variety of other feeds (40 in total) was also used. No differences were found between wet and dry season.

The actual amounts fed as found in S2 are given in Table 2. The data presented are based on the averages per household over the 1.5 year observation period. Means of total DM Offered (DMO) are the anti-logs of the means of the log-transformed data. Crude protein percentages were normally distributed. There was a wide variation between households, as shown by the wide 95% confidence intervals.

Total DMO varied from 29 g $kg^{-0.75}$ d^{-1} in Ojo to 70 g $kg^{-0.75}$ d^{-1} in Ogbagba. The latter being significantly higher than in the other villages, except for Ikotun.

The CP content of DMO varied from 7% in Awo to 10% in Akeredolu and Ogbagba and did not differ significantly between villages. The mean CP content of the feedstuffs varied from 2% (cassava by-product) to 25% (*Gliricidia sepium*) (Table 3). Of the 4 quantitatively most important feeds only maize offal had a CP content above 8%.

In the TZ villages more than 95% of the total DMO consisted of 2 feeds: cassava (tubers + peels) and maize offal (Table 4). The data on cassava tubers and peel have been pooled, as tubers were always fed unpeeled and the peel was frequently fed with pieces of tuber. The recorded figures indicated a peel/tuber ratio of about 2.5. In FZ, less cassava and more breadfruit and other feeds was fed. The "other feeds" covered a wide variety and varied considerably per village. Table 5 gives the

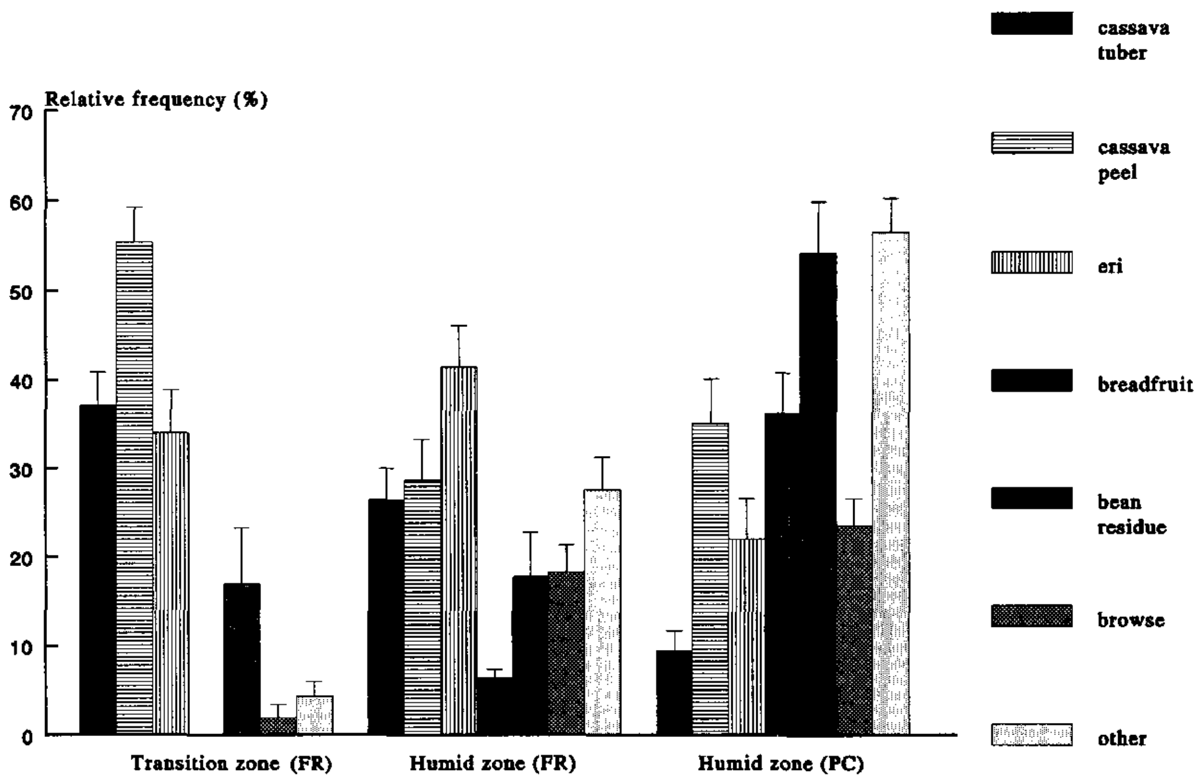

Figure 1. Relative frequency (the number of times a feed was reported to have been fed, expressed as % of the total number of times a household was interviewed) of the most important feeds. Line bars are standard errors; FR=free roaming, PC=permanent confinement.

Table 2. Dry Matter Offered (DMO, anti-logs of means of log -transformed data, in g $kg^{-0.75}$ d^{-1}) and percentage CP (arithmetical means), per village per feed; the 95% confidence interval is given in parenthesis

Feed	Village					
	Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
DMO	37^{bc1} (25-53)	49^{ab} (34-69)	29^{c} (22-39)	30^{c} (23-38)	42^{bc} (30-58)	70^{a} (52-95)
%CP	7 (4-11)	9 (6-11)	9 (7-12)	10 (8-13)	8 (5-11)	10 (7-12)

[1] Means in the same row without a common superscript differ ($P<0.05$)

Table 3. Crude protein content (% of DM) of most important feeds (means ± s.d.)

Feed	Crude protein (%)	No of samples
Gliricidia sepium	25.5±4.0	3
Other browse	16.9±5.7	15
Maize offal	19.2±1.9	35
Massava tuber	2.5±1.0	31
Cassava peel	5.7±1.9	35
Yam peel	6.2±2.0	12
Orange peel	5.6±1.1	3
Breadfruit	5.5±1.8	21
Banana	5.7±1.7	11
By-product cassava processing	2.0±1.0	5
By-product bean processing	15.3±2.7	8

composition of the "other feed" component for the villages in FZ. About 25% of the "other feed" was browse, which in Toro consisted solely of *Gliricidia sepium* and *Leucaena leucocephala*. Grasses were fed in very limited amounts. Yam peel and banana were found to be commonly fed, whereas in Akeredolu and Toro by-products from cassava processing other than peel proved to be important. No clear seasonal effect was found.

Table 4. Composition DM offered (% of total offer) and 95% confidence interval (between parenthesis) per village

Feed	Village					
	Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
Cassava (tuber+peel)	68[a] (43-92)	77[a] (60-94)	69[a] (47-92)	34[b] (18-50)	50[b] (26-74)	30[b] (17-42)
Maize offal	29 (4-55)	18 (2-34)	29 (8-51)	24 (9-39)	26 (2-50)	20 (6-33)
Breadfruit[2)]	-	-	-	10[b] (8-15)	14[b] (8-25)	24[a] (13-37)
Other	1[b] (0-2)	2[b] (0-3)	1[c] (0-1)	34[b] (17-51)	13[a] (0-25)	26[a] (13-42)

[1)] Means in the same row without a common superscript differ ($P<0.05$)
[2)] analysis based on square root transformation

Table 5. Composition of "other feeds" component in the Lowland Rain Forest Zone (% of quantity "other feeds" offered, see Table 4, means ± s.d.)

Feed	Village		
	Akeredolu	Toro	Ogbagba
Gliricidia sepium	4±9	18±37	4±13
Leucaena leucocephala	1±3	7±15	3±6
Other browse	19±28	-	20±34
Herbs	-	1±2	10±34
Grass	2±9	-	3±8
Banana	5±12	28±36	14±15
Papaya	9±17	1±3	2±4
Orange peel	3±10	10±23	1±3
Yam peel	12±27	7±18	29±30
Yam tubers	4±14	-	-
By-product bean processing	2±7	-	4±11
By-product cassava processing	15±28	20±33	-
Maize (grains)	11±22	-	-
Other	13±25	10±17	10±18

On-station experiment

During the adaptation periods preceding each phase, the amounts offered were manipulated to minimise left-overs. The rations were set for the whole 7-d measurement period. The total ration was (± s.d.): phase 1: 49.1±0.2, phase 2: 47.0±0.8, phase 3: 46.5±0.2 g $kg^{-0.75}$ d^{-1}. During the measurement period small amounts were left over; they mostly consisted of spilled feed. On two occasions considerable amounts of left-overs (>10% of total offer) were found in the feed trough: i.e. phase 1, treatment 3 (hay residue) and phase 2, treatment 1 (maize offal residue) (Table 6). Testing with multiple regression analysis did not show that the corresponding DMD's deviated from the overall pattern. The regression equation was fitted as (± s.e.):

$$Y=0.45(\pm0.02)*X_1+0.75(\pm0.01)*X_2+0.89(\pm0.02)*X_3+0.88(\pm0.02)*X_4 \quad (r^2=0.999,\ RSD=1.08)$$

The digestibilities of breadfruit and cassava were thus comparable (88 vs 89%), whereas maize offal was less digestible (75%).

Table 6. Dry matter intake (DMI) and digestibility (DMD) found in the on-station experiment when feeding different combinations of P. maximum, maize offal, cassava and breadfruit (means ± s.d.)

Phase	Treatment	Proportional intake (% of DMI)				DMI	DMD
		P. maximum	maize offal	Cassava	breadfruit		
1	1	24.9± 0.2	75.1 ±0.2	-	-	47.7± 0.3	68.5± 2.3
	2	39.5± 0.4	60.5± 0.4	-	-	46.9± 1.3	65.8± 1.4
	3	56.0±0.9	44.0± 0.9	-	-	45.8± 0.8	58.5± 1.9
	4	71.5± 0.2	28.5± 0.2	-	-	42.7± 0.6	52.3± 3.2
2	1	26.5 ±5.5	72.2 ±5.8	1.3± 0.3	-	38.4 ±8.2	66.6± 0.8
	2	23.4± 0.7	61.0± 0.1	15.6± 0.7	-	46.1± 0.2	67.8± 0.9
	3	22.5 ±1.4	45.9± 0.8	31.5 ±0.6	-	46.4 ±1.4	74.4± 0.9
	4	23.5± 0.2	30.4± 0.1	46.2 ±0.2	-	47.1± 0.3	74.5± 2.2
3	1	18.1± 1.2	76.9± 1.1	-	5.0 ±0.1	45.7±1.0	69.9± 3.8
	2	19.2± 0.2	60.8± 0.1	-	20.0± 0.0	46.5± 0.1	71.2± 1.1
	3	19.3 ±0.4	46.1± 0.5	-	34.6±0.6	45.8± 0.4	75.1± 1.6
	4	19.6± 0.3	30.9± 0.4	-	49.5± 0.6	45.0± 2.2	75.0± 2.4

DISCUSSION

The results from the qualitative survey show that farmers did feed their goats a wide variety of feeds. The number of feeds that contributed substantially to the total amount offered was, however, much lower. In TZ this was limited to two feeds (cassava (tuber + peel) and maize offal). Others, such as the residues from bean processing, did not contribute much to the total amount fed even though they were quite often reported to be fed. In FZ the feed offered was more diverse in the quantitative sense too - with cassava tubers and peel being comparatively less important. Breadfruit, which does not grow in TZ and which is comparable to cassava tuber in terms of digestibility and %CP, appeared to be an important source of feed, especially in Ogbagba. As was the case in TZ, the frequently reported use of residues from bean processing in Ogbagba did not contribute much to the total amount fed. This shows that care has to be taken when drawing quantitative conclusion from a qualitative survey such as S1. The types of feeds correspond with those found by Sempeho (1985) and Adebowale *et al.* (1993).

Although quite a number of households surveyed had established a browse plot with *Gliricidia sepium* and/or *Leucaena leucocephala* (S1: 44%, S2: 45%) only limited amounts of these species were actually fed. This is partly because not all the browse was harvestable at the start of the survey. Furthermore, the first browse plots were of limited size and therefore could only serve as a try-out for the farmers (Koper-Limbourg and Bosman, 1993).

Except for browse, breadfruit and cassava tuber, the feeds were mainly by-products. Some of the breadfruit and cassava offered was considered unsuitable for processing or human consumption and thus these should also be considered as by-products. However, no data are available on the amounts involved. Under free roaming the actual amount fed will thus largely depend on the availability of these by-products to the household. Only maize offal was reported to be bought when not produced at home. Under permanent confinement comparatively more feed (browse, herbs) was provided in addition to the by-products; this required an extra input of labour. However, labour is (still) a scarce factor in South-Western Nigerian agriculture (Platteeuw and Oludimu, 1993). The availability of by-products and labour may explain some of the wide variation in type of feed and amounts offered between households from the same village.

The CP content of the total diet offered appeared to be rather low: in or just above the range (6-8% CP) below which protein content may adversely affect intake (Van Soest, 1982). Under the free roaming system this may not pose a problem, as animals may have sufficient opportunity to "balance" their diet through browsing. Under permanent confinement, however, an unbalanced diet may hamper feed intake and hence animal performance.

Although the DMO data relate solely to the amounts offered, (which vary widely both in total amount and %CP) and not to real intake figures, the contribution of the feeds to the supply of the total DDMI and protein intake can tentatively be assessed. During the survey left-overs were weighed when possible. These data suggested that about 90% of the feed offered was actually consumed. The digestibilities of cassava, breadfruit and maize offal, determined on-station, were used to estimate DDMI. For the other feeds, constituting 26% of the total offer, a digestibility of 70% was assumed. This was based on the digestibilities found in literature (Ademosun *et al.*, 1988; Göhl, 1978). The DDMI in Ogbagba was estimated as: $(0.9*70*(0.30*0.89+0.20*0.75+0.24*0.88+0.26*0.70) = 51$ g $kg^{-0.75}$ d^{-1}. Assuming the energy requirements for maintenance and growth were 28 g DDMI $kg^{-0.75}$ d^{-1} and 2.5 g DDMI/g of gain respectively (derived from Sanz Sampelayo *et al.* 1991, Zemmelink *et al.*, 1991 and NRC, 1981) the estimated DDMI would be sufficient for a weight gain of 10 g $kg^{-0.75}$ d^{-1}. The corresponding intake of DCP would be 3.7 g $kg^{-0.75}$ d^{-1}. With requirements for maintenance and weight gain of 2.82 g DCP $kg^{-0.75}$ d^{-1} and 0.195 g DCP/g respectively (NRC, 1981) this would only suffice for a weight gain of 4.3 g $kg^{-0.75}$ d^{-1}. The actual weight gains of goats between 13 weeks and 1 year of age in this village were found to be around 4 g $kg^{-0.75}$ d^{-1} (Bosman and Ayeni, 1993). This tentative assessment suggests that although farmers practising permanent confinement have increased the total amount of feed offered, the DCP content was sub-optimal for maximum weight gain, given the total DDMI. If it is assumed that DCP does limit weight gain, increasing the total amount of maize offal offered or introducing or including more protein-rich fodder like *Gliricidia sepium* and/or *Leucaena leucocephala* into the total ration could increase %CP and hence improve animal performance.

Feeding more maize offal, to balance the diet, seems attractive, considering the costs (₦0.94/kg, 1 Naira is about 0.06 US$) and expected weight gain. Assuming a linear response to increased DCP up to a DDMI/DCP ratio of 11.1 (required DDMI/required DCP for 10 g gain $kg^{-0.75}$ d^{-1}) the weight gain would be 0.6 g/g DM of maize offal; with a liveweight price of ₦14/kg this would add up to about ₦8.40/kg DM maize offal. Although the actual response would probably be considerably less, the margin is so wide that one may wonder why farmers did not feed more maize offal. Unfortunately no concrete answer can be given. Several factors seem to play a role. Firstly, farmers lacked experience in feeding confined goats, because they only started confining their animals about a year before the project started. At first they merely increased the amount of supplements they had always fed. Several farmers had noted the poor performance of their stock and sought advice from the project team on how to improve feeding. So in fact it was premature to speak of 'established' feeding practices. Secondly, farmers complained that it was hard to obtain maize offal and that the local market sometimes ran out of stocks. Although it could be obtained from neighbouring villages, where small ruminants were proscribed completely, this involved extra costs in terms of transport. The fact that the demand for maize offal, because it is a by-product, does not determine supply, increases the scope for browse, which could balance the deficit. On-station experiments have shown weight gains of around 40 g d^{-1} (± 8 g $kg^{-0.75}$ d^{-1}), when goats are fed on a combination of *Gliricidia sepium*, *Leucaena leucocephala* and cassava (Ademosun *et al.*, 1988). Other reports have also shown that adding these browse species to poor quality rations can considerably improve feed intake and hence animal performance (Mathius *et al.*, 1985; Reynolds and Adediran, 1988).

Similar assessments made for the village with free roaming animals indicate that the portions offered could supply about 87 to 147% of the DDMI required for maintenance and between 49 and 85% of the DCP required for maintenance. The actual growth rates of free roaming animals were found to be around 4.5 g $kg^{-0.75}$ d^{-1}, which hardly differs from the rates recorded under permanent confinement. In terms of DDMI and DCP this would require intake of 141% and 131% respectively, above maintenance requirements. Of course these figures have to be interpreted with caution because of the underlying assumptions. Furthermore, the variation is large, which is certainly also related to factors other than nutrition, such as health and management. Nevertheless, this demonstrates that even under free roaming considerable amounts of feed are given, providing half or more of the estimated total DDMI requirements. These quantities are considerably less than those found by Sempeho (1985), who reports on research conducted in 2 villages in the humid forest area and derived savannah zone in South-Western Nigeria. His intake figures vary from 1.0 to 1.5 kg DM per small ruminant unit (25 kg liveweight) per day. This would correspond to intakes of 89-135 g DM $kg^{-0.75}$ d^{-1}, which are remarkably high compared to the DMI recorded on-station, when feeding concentrates *ad lib.* (78 g $kg^{-0.75}$ d^{-1}, Ademosun *et al.*, 1988). However, since the author did not indicate how measurements were actually obtained, these data should be interpreted with care.

Given our results, qualifying goat feeding as "being at low levels" (Matthewman, 1980; Sumberg and Cassaday, 1985; Upton, 1985) seems unjustified. Questions remain regarding the quality of the total diet, because no data are available on the quantity and quality of the feed ingested through browsing and scavenging. Determining the amounts of feed given by farmers is difficult enough (Sempeho, 1985; Adebowale *et al.*, 1993), but measuring the intake from scavenging and browsing under village conditions seems nearly impossible. Even under controlled conditions it is complicated and tedious to measure intake from grazing or browsing (Mannetje, 1978). Although it therefore remains to be seen if *Gliricidia sepium* and *Leucaena leucocephala* could improve the quality of the diet under free roaming, these legumes could certainly widen the farmer's choice and possibly contribute to an increase in the total amount offered.

Thus *Gliricidia sepium* and *Leucaena leucocephala* could play a nutritional role both under free roaming and permanent confinement husbandry systems. It is not clear whether the use of these browse species in the form of alley farming and/or feed gardens will fit into the overall farming system, although some preliminary results are encouraging (Reynolds and Atta-Krah, 1989; Koper-Limbourg and Bosman, 1993). Sometimes complications may arise because of existing land tenure systems (Francis, 1989). In the research area it was prohibited to plant trees on land in temporary use. Nevertheless, individual ownership was common (Alofe *et al.*, 1989), and considering the proportion of farmers that had established a browse plot, tenure rights do not seem to be a major problem. Labour costs may be a greater constraint (Platteeuw and Oludimu, 1993). As far as the latter is concerned an illustrative comparison can be made between maize offal and browse. An average farmer in Ogbagba, for instance, bought on average 138 kg maize offal per year, which cost him approximately ₦130. An average crop gave him a return to labour of ₦2.44/h (Platteeuw and Oludimu, 1993). Replacing a crop with a feed garden so that the maize offal could be replaced with browse (about 100 kg DM would be required) could be attractive if the total extra time needed for harvesting and feeding were less than 9 minutes/d (130/365/2.44). On average, the browse plots were located 9 minutes' walk away. Thus the use of this browse seems only attractive if the harvesting can be combined with other on-farm activities. As the labour required for harvesting and feeding is the critical factor, it does not really matter whether the browse is planted in the form of an alley farm or feed garden. Of course, the cost involved in establishing the browse is not considered. Although this is negligible when considered in the light of the long life expectancy of the browse, the cost is considerable during the first year, when production is still zero.

Apart from replacing maize offal, the browse could be used to increase the total amount of feed offered per animal. Not only will the selection of animals fed on heterogenous feed, such as browse, increase concomitantly with the amount of feed offered but so will the feed intake and the refusals. When browse is fed in the amounts required to replace maize offal in the diet, this is unlikely to result in much left-overs. However, at larger amounts this will change while total intake will continue to increase (Bosman *et al.*, 1995). Thus the efficiency expressed per kg browse offered will decrease concomitantly. Furthermore, browse may replace some of the other feeds. It is hard to predict what the actual intake will consist of, because this not only depends on the type and amount of feeds offered but also on how they are offered. For instance, on-station experiments have shown that when sun-dried cassava was fed before the browse, the intake of the latter was negatively affected. But when some of the browse was offered before the cassava no negative effects were found (Ademosun *et al.*, 1988). In the project area, where labour appeared to be the scarce factor, the attractiveness of browse depends on the ratio between the extra animal production and the cost of labour required to harvest and feed the browse. Assuming that under village conditions the same weight gains (8 g $kg^{-0.75}$ d^{-1}) can be obtained when feeding browse (100 g DM $kg^{-0.75}$ d^{-1}) and cassava (30 g DM $kg^{-0.75}$ d^{-1}), as on-station (Ademosun *et al.*, 1988) weight gains could increase by about 4 g $kg^{-0.75}$ d^{-1}. Under permanent confinement in Ogbagba, with a total metabolic weight of goats (< 1 year of age) of 13 kg per household, this would add up to about 19 kg liveweight per year or ₦266. With labour costs of ₦2.44/h this would be equivalent to 109 hours or 19 minutes/day. In addition, some labour would be saved as less other feeds would have to be fed. (However, no data are available to quantify the hours involved.) As the total time spent on feeding in Ogbagba was about 20 minutes per day and the browse plots are located at about 9 minutes' walk the use of browse would only be attractive if browse feeding and harvesting could be combined with other on-farm activities.

Similar assessments for free roaming are more difficult, as it is not clear how the offer of browse will interact with intake through scavenging and browsing. As regards replacing maize offal with browse, there is no indication that this will be more attractive under the free roaming system than under confinement. The same holds for feeding browse to increase the total amount of feed offered per animal. In fact, feeding larger amounts of browse at higher levels may adversely affect intake from free roaming and as such may not render much net benefit in terms of extra animal production. Of course, it may contribute to a reduced incidence of crop damage. Some farmers did indeed mention prevention of crop damage and resulting conflicts as one of the reasons for providing supplementary feed. However, before a definite answer can be given more research needs to be done on the quantity and quality of feed ingested through scavenging and browsing.

This tentative assessment shows that within the socio-economic context operating at the time of the surveys, the potential of *Gliricidia sepium* and *Leucaena leucocephala* to improve animal production under free roaming may be limited, in view of their possible contribution to improved nutrition and the labour cost. When animals are confined permanently, the use of browse seems more attractive, as all feed has to be fed. Under both management systems the use of browse to replace maize offal or to increase the total amount of feed offered seems attractive only when the cost of labour can be reduced, for instance through combination with other on-farm activities.

Farming systems in South-Western Nigeria are very diverse, including in terms of goat production. Browse will probably not be suitable for every goat keeper, but may be useful for quite a number, especially as the pressure on arable land and small ruminant production system intensifies. Of course it will be up to the individual farmer to decide whether this innovation will suit him. The large proportion of households that have established a browse plot, however small this may be, shows that farmers are indeed making this assessment. This may render further research into the quantity and quality of feed ingested through free roaming superfluous.

CONCLUSIONS

Results from the qualitative survey have only a limited value for assessing the quantitative composition of the diet actually fed. Cassava products and maize offal were the most frequently fed supplements. These feeds are very digestible. In the Lowland Rainforest Zone the variation in supplements was generally greater than in the Transition Zone between the Derived Savannah and the Lowland Rainforest Zone.

Under free roaming, considerable quantities of supplements were fed, although the CP content was generally on the low side. Under permanent confinement more feed was given, but the protein content of the diet was also low, which possibly limited weight gains. In view of these findings, the browse species *Gliricidia sepium* and *Leucaena leucocephala* could be an alternative as protein-rich feed to supplement or partly replace maize offal. In the case of replacement the decisive factors seem to be the cost of extra labour needed to harvest and feed the browse and the price and availability of maize offal. In the case of supplementation, the value of the extra production should also be considered. Within the socio-economic setting at the time of the survey, the feeding of browse would seem to be feasible only when harvesting and feeding can be combined with other on-farm activities.

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3.2 REPRODUCTION AND HEALTH

During the initial years of the West African Dwarf goat project the research was mainly discipline oriented. Among these disciplines, nutrition was the priority area because it was thought to be the key to improved goat production. Reproduction and animal health received less attention. The major findings in these two areas are reviewed in this chapter. Under the heading "reproduction" the results of three reproduction trials are reported. In the section on animal health a brief review is given of general health problems encountered when rearing dwarf goats intensively.

3.2.1 REPRODUCTION OF THE WEST AFRICAN DWARF GOAT - A SUMMARY OF SOME EXPERIMENTS CONDUCTED AT THE OBAFEMI AWOLOWO UNIVERSITY

INTRODUCTION

In meat breeds, such as the West African Dwarf goat, production consists of the accumulation of liveweight through the growth of the individual animals and the increase in the number of animals through birth. Therefore reproduction forms an important component of these animal production systems. A farmer wishing to attain maximum productivity has to take full consideration of the different aspects of reproduction and the possible interactions with other management factors. So when designing a management package for the West African Dwarf goat, several experiments were conducted to define the optimal production conditions. The results of three experiments are reported below. These experiments had the following objectives:

Experiment 1: to determine the effect of weaning age on the performance of West African Dwarf kids.

Experiment 2: to determine the effect of breeding method and nutrition on the performance of West African Dwarf goats.

Experiment 3: to determine the effect of weaning weight on the performance of West African Dwarf goats.

MATERIALS AND METHODS

Experiment 1

Three weaning ages were chosen on the basis of general experience gained so far, i.e.: 9 weeks, 12 weeks and 15 weeks. On delivery, all animals of the breeding flock were assigned to one of the treatments in consecutive order. All does and kids were kept under the same management practices. They were fed *Panicum maximum* grass or hay *ad libitum*, supplemented with concentrates (lactating does: 500 g d^{-1}, suckling kids: 100 g d^{-1} and growers: 150 g d^{-1}). The kids were offered additional browse (*Gliricidia sepium* and *Leucaena leucocephala*) and concentrates in a creep feed area. Liveweights were recorded weekly.

All animals were routinely treated once every three months against ecto-parasites and vaccinated yearly against *Peste des Petits Ruminants* (PPR). The experiment was carried out between 1/11/1984 and 1/7/1985.

Experiment 2

Fifty-six polyparous does were randomly assigned to one of four treatments of a 2 x 2 factorial design. Factor A consists of two feeding regimes: High levels of concentrates (H, 500 g d^{-1} for lactating does, 250 g d^{-1} for non-lactating does) and Low levels of concentrates (L, 360 g d^{-1} for lactating does, 180 g d^{-1} for non-lactating does). Factor B comprises two weaning/breeding practices: weaning at 12 weeks or 5.5 kg liveweight (whichever comes first) with no preweaning exposure to a buck and weaning at 16 weeks with preweaning daily exposure to a buck from a few days after delivery. This treatment was intended to 'mimic' zero-weaning. For logistic reasons, a real zero-weaning treatment (or natural weaning) could not be imposed. Nevertheless, with this treatment it was possible to assess if the early exposure to a buck and the longer suckling periods would affect the reproductive parameters.

Bucks remained with the does until the next concentrate feeding. Lactating does were housed in pairs per pen (these pens had slatted floors) and were fed concentrates individually. After weaning, the does were transferred to pens with concrete floors (maximum four animals per pen), fed concentrates on a group basis and exposed to a buck daily for short periods (about 15 minutes, with recording of matings) until pregnancy had been ascertained (based on breeding records or udder development). The basic ration of the does consisted of *Panicum maximum* fed *ad libitum*, and when available, small amounts of browse (*Gliricidia sepium* and *Leucaena leucocephala*). All kids had free access to a creep feed area where they were supplemented with concentrates and browse (mainly *Gliricidia sepium*). Other management practices were as indicated in experiment one.

Experiment 3

Thirty West African Dwarf does were assigned to one of three treatments: weaning at 5.5. kg (W_1), 7.0 kg (W_2) and 8.5 kg (W_3). It was attempted to make the groups as homogeneous as possible in terms of previous reproductive performance. Does entered the experiment once pregnancy was observed and the 'experimental time' started at the following delivery. During late pregnancy and lactation, animals were housed in pens with slatted floors (two does per pen). Kids had access to an outside run (creep feed area). Otherwise, does were kept in pens with concrete floors (maximum 3 per pen).

All does were exposed to a buck daily. If the does were lactating, bucks stayed in the pen for the whole day or night. Non-lactating does were exposed for short periods (about 15 minutes, with recording of matings) until pregnancy had been ascertained (based on breeding records or udder development).

All kids were weaned when the lightest kid of the litter attained the target weight. After weaning, kids were raised in group pens provided with slatted floor and outside run (maximum four animals per pen) until the age of one year.

Does were fed a basic ration of *Panicum maximum ad libitum*, supplemented with Brewers Dried Grains (BDG) at a rate of 50 g DM $kg^{-0.75}$ d^{-1} to lactating and highly pregnant does and 25 g DM $kg^{-0.75}$ d^{-1} to others. Animals were supplemented individually. If sufficient browse was available, part of the BDG was replaced with browse. Suckling kids had access to a creep feed area, where browse and BDG were offered *ad libitum*. After weaning they were fed *Panicum maximum ad libitum* and browse at a rate of 100 g DM $kg^{-0.75}$ d^{-1}. If browse was not available in sufficient amounts, it was partly replaced with BDG. Other management practices were as indicated in experiment one.

RESULTS

Experiment 1

The average weaning weights increased with weaning age (Table 1). However, this effect was partly confounded by the effect of litter size. The weaning weights of singles and twins did not differ between the 9 and 12-week treatments. Kids born in triplets and weaned at 9 weeks had the lowest weaning weights and the poorest performance after weaning, resulting in a mortality rate of 78% at the age of 26 weeks. This poor performance was also reflected in the average liveweight gains. The average weight gains of kids weaned at 9 weeks decreased considerably after weaning, but recovered from about week 13 and did not differ significantly ($p>0.05$) at the age of 15 weeks from the other two treatments (Figure 1). The decrease was mainly due to the poor weight gains of kids that died before 26 weeks of age (Figure 2). The preweaning mortalities tended to be higher in multiple births, however, the small numbers and empty cells do not justify any clear conclusion; no clear effect of weaning age on preweaning mortality could be established.

Experiment 2

The data on two animals in the H/12 were excluded from further analysis because they appeared to be seriously affected by health problems not related to the experiment.

The reproductive performance, as expressed in the reproduction index (kg weaned offspring/doe/y) was significantly higher on the high concentrate regime than when kids were weaned at 12 weeks on the low concentrate regime (14.6 and 16.2 kg/doe/y vs 11.1 kg/doe/y, Table 2). When kids on the low concentrate regime were weaned at 16 weeks, the reproduction index (13.1 kg/doe/y) did not differ from

Table 1. Birth and weaning records, and survival of kids weaned at different ages (Experiment 1)

	Litter size at birth	9 weeks		12 weeks		15 weeks	
		$\mu\pm$ s.d.	number	$\mu\pm$ s.d.	number	$\mu\pm$ s.d.	number
Birth weight (kg)	1	1.4±0.2	6	1.3±0.1	7	1.2	1
	2	1.3±0.3	12	1.2±0.2	11	1.3±0.1	23
	3	1.1±0.5	9	1.3±0.3	6	-	
	all	1.3±0.4	27	1.3±0.2	24	1.3±0.2	24
Weaning weight (kg)	1	5.3±0.6	6	5.6±1.0	6	7.2	1
	2	4.9±1.0	9	4.9±0.8	8	6.2±1.5	20
	3	3.9±1.5	7	5.4±0.4	5	-	
	all	4.7±1.2	21	5.3±0.8	19	6.2±1.5	21
No. died 0-26 weeks	1		-		1		-
	2		4		4		3
	3		7		1		-
	all		11		5		3

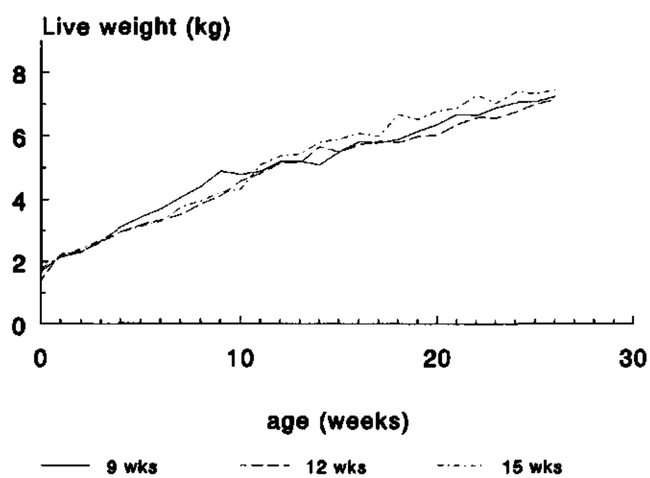

Figure 1. Effect of weaning age on liveweight development in experiment 1.

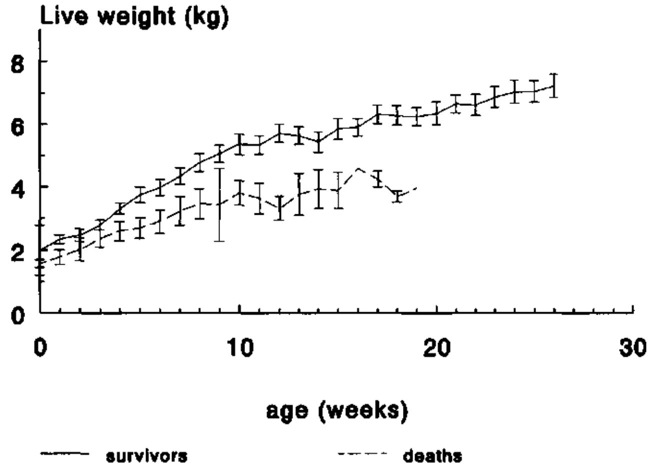

Figure 2. Liveweight development of kids that survived until the age of 26 weeks (survivors) and those that died before that age (deaths) (bars give standard errors).

the other three treatments. The better reproductive performance was achieved through a combination of larger litter sizes at birth and a lower preweaning mortality. In both 16-week treatments, preweaning mating appeared to have occurred successfully in about 25% of the possible cases (=the number of parturition intervals). A delivery was assumed to be the result of a preweaning mating if the time difference between the preceding parturition interval and the preceding weaning age was shorter than the average gestation length (145 days).

At the same concentrate level, none of the reproductive parameters differed statistically significantly ($p>0.05$) between breeding treatments. At the same breeding treatment, litter size at birth and at weaning were larger and litter weaning weights were higher at the high concentrate level.

Experiment 3

Weaning at higher weight had a positive effect on the initial liveweight development of the offspring. Although preweaning and postweaning daily weight gains did not differ statistically significantly ($p>0.05$) between treatments, the effect diminished with increasing time since weaning. At age 26 weeks, animals in W_2 and W_3 were heavier than animals in W_1 (9.6 kg and 10.2 kg vs 8.8 kg, Table 3), at the age of one year the difference between W_2 and W_1 had disappeared but year-weights in W_1 were lower than in W_3 (13.7 kg vs 14.7 kg).

Table 2. Effect of level of supplementation and weaning age on the reproductive performance of West African Dwarf goats (mean ± s.d.)

	High concentrate level		Low concentrate level	
	12 weeks[1]	16 weeks[2]	12 weeks[1]	16 weeks[2]
Parturition interval (days)	$248^{b}\pm25^{3}$	$274^{a}\pm34$	$252^{b}\pm38$	$258^{ab}\pm39$
n	27	24	24	22
Litter size at birth	$1.89^{a}\pm0.46$	$1.84^{a}\pm0.57$	$1.57^{b}\pm0.50$	$1.53^{b}\pm0.57$
n	37	32	35	30
Litter size at weaning	$1.67^{ab}\pm0.53$	$1.71^{a}\pm0.53$	$1.41^{c}\pm0.50$	$1.43^{bc}\pm0.58$
n	36	31	32	28
Litter birth weight (kg)	$2.4^{a}\pm0.6$	$2.4^{a}\pm0.7$	$2.2^{ab}\pm0.6$	$2.0^{bc}\pm0.7$
n	37	31	35	30
Litter weaning weight (kg)	$10.7^{b}\pm4.1$	$12.9^{a}\pm4.0$	$8.7^{c}\pm3.2$	$10.4^{bc}\pm3.7$
n	36	31	32	28
Weaning age (days)	$91^{b}\pm18$	$111^{a}\pm6$	$87^{b}\pm30$	$112^{a}\pm8$
n	36	31	32	28
Litter weight gain birth-weaning ($g\ d^{-1}$)	$91.6^{ab}\pm40.0$	$91.8^{a}\pm30.2$	$78.2^{ab}\pm29.0$	$75.2^{b}\pm29.3$
n	36	31	32	19
Reproduction index (kg weaned offspring/doe/year)	$14.6^{a}\pm5.5$	$16.2^{a}\pm3.6$	$11.1^{b}\pm3.0$	$13.1^{ab}\pm3.1$
n	14	12	12	12
Preweaning mortality (% of number born)	14	10	21	19
No of successful preweaning matings	-	5	-	6

[1] weaning at 5.5 kg liveweight (±12 weeks), no preweaning mating
[2] weaning at 16 weeks, preweaning mating
[3] means in the same row bearing no common superscript differ statistically significantly ($p<0.05$)

Preweaning mortalities ranged from 17.3% (W_3) to 28.8% (W_2). Both were increased by the occurrence of quadruplets (W_2:2, W_3:1), which all died in their first week of life. Postweaning mortality ranged from 0% (W_3) to 4.9% (W_2).

When the reproductive performance is expressed in kg weaned offspring per doe per year, W_3 scored significantly ($p<0.05$) better (22.0 kg vs 15.8 (W_1) and 14.6 (W_2)). However, when it is expressed in kg yearling weight produced per doe per year, treatments did not differ significantly ($p>0.05$). In all treatments, successful preweaning mating occurred, varying from 39% (W_2) to 64% (W_3) of the possible cases. This may explain why the statistically significantly different weaning ages did not result in statistically significantly different parturition intervals.

Table 3. Effect of weight at weaning on the reproductive performance and flock productivity (mean ± s.d.)

	Weaning at (kg)		
	5.5	7.0	8.5
Birth weight (kg)	1.4 ± 0.3	1.3 ± 0.3	1.3 ± 0.3
n	62	59	52
Weaning weight (kg)	$6.4^{c} \pm 1.0^{1}$	$7.3^{b} \pm 0.9$	9.6 ± 2.0
n	49	41	43
Age at weaning (days)	$91^{c} \pm 34$	$104^{b} \pm 24$	$152^{a} \pm 52$
n	49	41	43
Litter size at birth	1.9 ± 0.7	2.0 ± 0.8	2.1 ± 0.8
n	34	30	25
Litter size at weaning	$1.6^{b} \pm 0.6$	$1.6^{b} \pm 0.5$	$2.0^{a} \pm 0.7$
n	30	25	23
Weight at 13 weeks (kg)	$5.7^{b} \pm 1.2$	$6.4^{a} \pm 1.2$	$6.3^{a} \pm 1.5$
n	50	41	45
Weight at 26 weeks (kg)	$8.8^{b} \pm 1.5$	$9.6^{a} \pm 1.3$	$10.2^{a} \pm 1.7$
n	45	40	41
Weight at 39 weeks (kg)	$11.8^{b} \pm 1.7$	$12.2^{b} \pm 1.9$	12.8 ± 2.6
n	44	41	41
Weight at 52 weeks (kg)	$13.7^{b} \pm 1.9$	$14.3^{b} \pm 1.8$	$14.7^{a} \pm 2.0$
n	45	41	41
Parturition interval (days)	224 ± 60	253 ± 40	251 ± 40
n	20	18	14
Preweaning mortality (% of no born)	22.2	28.8	17.3
Mortality weaning - 1 year (% of no weaned)	2.0	4.9	0.0
Reproduction index (kg weaned offspring/doe/year)	$15.8^{b} \pm 4.0$	$14.6^{b} \pm 5.5$	$22.0^{a} \pm 6.6$
n	12	10	11
Productivity index (kg yearlings/doe/year)	34.3 ± 19.2	33.3 ± 14.3	37.1 ± 18.1
n	12	10	11
No of successful preweaning matings	8	7	9

[1] means in the same row bearing no common superscript differ statistically significantly ($p < 0.05$)

DISCUSSION

The results of Experiment 1 did not reveal any effect of weaning age on animal performance as far as single and twin kids were concerned. The weaning weights of kids on the 9-week treatment were in fact relatively high. For triplets, 9 weeks seems to be too short a period for a satisfactory performance, resulting in low weaning weights and high mortality. The small number of animals and the genetic heterogeneity of the population, however, makes it rather difficult to draw clear conclusions. Nevertheless, the results indicate that weaning weight is a more useful indicator or measure of weaning "maturity" than age. In the other experiments, where weaned kids had minimally attained 5.5 kg liveweight at weaning, postweaning mortalities were low (<5%). Furthermore, results from experiment 3 show that although weaning at higher liveweights affects weight gains positively during the first year of life, this effect wanes with age. It is not clear whether the positive effect of weaning at higher weight is due to the prolonged suckling or to a higher intake of BDG and/or browse, which was fed *ad libitum* to sucking kids and in restricted amounts to weaned kids, or to a combination of the two.

Exposure of lactating does to a buck during the suckling period did not result in a better reproductive performance than under the standard breeding practice at the on-station site, where kids are weaned at around 12 weeks (5.5. kg liveweight). Based on the average parturition interval and assuming a gestation length of 145 days, one can calculate that in experiment 2 conception occurred on average after (H(igh concentrates)/12 (weeks weaning):(248-145=)103 days, H/16: 129 days, L/12: 107 days) or around weaning (L/16: 113 days). In experiment 3, where preweaning exposure was practised on all treatments, these figures are: W_1: 79 days (before weaning), W_2:108 days (around weaning) and W_3: 106 days (before weaning). These findings suggests that goats fed on good quality diets can be mated successfully during the lactation period, but that effective mating usually does not occur during the first 11 to 12 weeks of lactation. Thus if animals are weaned at or before that time, productivity does not necessarily benefit from preweaning exposure of lactating does to a buck.

The results show that the West African Dwarf goat is potentially a good reproducer, an important characteristic for a meat animal. An overall comparison of experiments 2 and 3 shows that at the higher feeding levels, litter size at birth increases. Although this may result in somewhat higher preweaning mortalities the resulting litter size at weaning is affected positively. The effect on the parturition interval was less, especially under the standard weaning practice.

The reproductive performance as expressed in the reproduction index or in the number of animals weaned under good feeding conditions are comparable to data obtained at Wageningen with West African Dwarf goats, originally imported from

West Africa (Hofs *et al.*, 1985). The reproductive performance obtained at village level is considerably poorer (Bosman and Moll, 1995; Mack, 1983).

Environmental factors such as nutrition, management and disease challenge have been reported as the constraints to increased productivity, resulting in lower preweaning liveweight gains and higher postweaning mortalities (Mack, 1983; Reynolds *et al.*, 1988; Bosman and Moll, 1995). Of course, one should not confuse maximum (biological) production levels with optimum (economic) production levels.

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3.2.2 HEALTH HAZARDS IN CONFINED GOATS: THE CASE OF AN EXPERIMENTAL FLOCK OF WEST AFRICAN DWARF GOATS KEPT IN THE HUMID TROPICS

INTRODUCTION

Livestock can only attain reasonable production levels when the health situation is satisfactory. The condition of an animal is a direct result of environmental factors such as nutrition, management (housing), climate and disease challenge. These factors set the constraints under which an animal has to survive and produce. How well an animal is able to cope with these conditions is reflected in the occurrence of health disorders and mortality, and the production levels. In South-Western Nigeria, disease has been reported to be a primary constraint to livestock production (Reynolds *et al.*, 1988). Thus any management package aimed to improve production under those conditions should contain innovations specifically geared to alleviate the disease pressure.

When the project on the management of the West African Dwarf goat started in 1981 the management of the experimental flock was semi-intensive. During the day, goats were grazed on pasture, mainly *Cynodon nlemfuensis* and were confined in the afternoon, where they were given supplementary concentrates. Despite this feeding regime, the performance of the animals remained unsatisfactory. *Peste des Petits Ruminants* (PPR) was a major problem and endo- and ecto-parasites were expensive to control. This situation was aggravated by the influx of new animals, purchased in an attempt to expand the flock rapidly. The introduction of a quarantine procedure helped redress this problem.

Because of this poor performance, at the end of 1982 it was decided to confine all animals and to zero-graze them on available forages (*Panicum maximum*, *Gliricidia sepium* and *Leucaena leucocephala*). To further control endo-parasites, particularly coccidiosis, slatted floors made of bamboo or wood were introduced. In addition, the following health measures were carried out routinely:

- yearly vaccination with Tissue Cultured Rinderpest Vaccine (TCRV) against PPR
- three-monthly dipping to control mange and lice

This paper describes the health situation during the period 1982-1987, partly derived from Smith *et al.* (1988).

MATERIALS AND METHODS

The zero-grazed goats were kept in two types of housing units: a completely Roofed Barn (RB) and low-cost partly roofed Bamboo Huts (BH) on stilts. The number of animals kept in RB increased over the period gradually from 57 in 1982 to 168 in 1987, and in BH from 0 in 1982 to 82 in 1987.

A complete record of all illnesses, deaths and diagnosed causes was maintained on all goats. This record was analysed to evaluate the relative importance of observed disease conditions. First all diagnosed causes of illnesses and deaths were grouped under six headings (Smith *et al.*, 1988): infections, parasitism, injuries, nutritional/metabolic disorders, reproductive problems and miscellaneous (Table 1). The morbidity rate of each group were then calculated as the number of cases of a specific disease as percentage of all disease cases. The Relative Fatality Rate (RFR) was calculated as the number of deaths expressed as percentage of the number of cases of a particular disease.

Table 1. Common diseases and health hazards of confined goats

Infections	Injuries	Parasites	Nutritional/metabolic disorders
enteritis	broken horns	coccidiosis	rickets
Bronchi-pneumonia	abdominal hernias	helminthiasis	
Contagious ecthyma	haematemesis	mange	
Caseous lymphadenitis	lacerations		
Peste des petits ruminants	fractures		
Reproductive problems	**Miscellaneous**		
abortions	congenital limb malformation		
still births	intestinal occlusion		
agalactia	duodenal intussusception		
mastitis	low birth weight		
metritis			

Source: Smith *et al.* (1988)

RESULTS AND DISCUSSION

Based on the morbidity, infections were the most prevalent group (56%, Table 2) but they were only related to 23.5% of all deaths. *Contagious ecthyma* and *Caseous lymphadenitis*, accounting for 24.2% of the morbidity, did not directly result in

Table 2 Morbidity (% of all diseases incidence) and proportional mortality (% of all deaths) of most common diseases/health disorders in the project flock during the period 1982-1987

	Morbidity (%)	Proportional mortality (%)
Enteritis	18.3	3.5
Contagious ecthyma	15.8	0
Caseous lymphadenitis	8.4	0
Bronchi-pneumonia	10.2	10.0
Injuries	3.0	6.9
Rickets	1.9	7.6
Mange	7.6	0
Coccidiosis	3.1	2.1
Reproduction[1]	6.6	21.5
PPR	3.3	10.0
Helminthiasis	8.0	0
Others	14.0	14.2
Unknown	-	24.2
Total number of cases	1246	289

[1] includes abortions, still births, low birth weights and agalactia

mortality, whereas *Bronchi-pneumonia* and PPR cases, especially the latter, were much more likely to die. The RFRs for *Bronchi-pneumonia* and PPR are respectively 22.8% and 70.3%. The occurrence of PPR may seem surprising, because of the preventive vaccination. However, it concerns a batch of animals which were acquired (in 1982) and succumbed in quarantine. Furthermore, an outbreak of PPR-like disease occurred in 1987, a few days after the routine vaccination with TCRV. Only animals that had been vaccinated for the first time were affected.

Injuries, although not so frequent, quite often resulted in death of the animals (RFR: 53.3%). Injuries were caused by horn butting during feeding or after re-introducing weaned does to the pens of the dry does. Dehorning, moving animals in groups, provision of more feeding places and restraining dominant animals during concentrate feeding were introduced to alleviate this problem. Another important cause of injuries was the limbs getting caught between the slats. This was especially fatal for new-born kids. The provision of a "nesting board", on which kids could remain for the first days of life, and the narrowing of the gap between the slats appeared to reduce this problem effectively.

The occurrence of rickets, mostly in the age group of 4-7 months, is remarkable. Because this disease was only observed in the completely roofed barn and not in the partly roofed bamboo huts, lack of sunlight in combination with an adverse dietary calcium/phosphorus ratio were thought to be responsible. The fatality rate for rickets was high (93%), because once affected, the animals found it difficult to move to the feed troughs. In addition, animals could not chew properly because the jaw articulation was affected. The problem of rickets was addressed by providing outside runs (for the kids) and openings in the roof by converting some of the asbestos sheets into sliding shutters, and by the provision of a vitamin-mineral mix.

Reproduction-related problems were identified as the major cause of mortality. This category includes agalactia, abortion, premature births and low birth weights. A clear relationship was found between mortality and birth weight. Kids with a birth weight above 1.2 kg had higher 90-day survival rates (83-96%, Figure 1) than kids with a lower birth weight (21-75%). It should be realised, however, that survival rates vary with litter sizes (Table 3). Thus if litter sizes at birth increase, for instance because of improved nutrition, this may result in an increased preweaning mortality. Within litter sizes, surviving kids had a higher birth weight than kids that died before weaning. Within the latter category, kids born as singles were heavier than kids born in twins or triplets. This shows that factors other than birth weight also affect preweaning mortality.

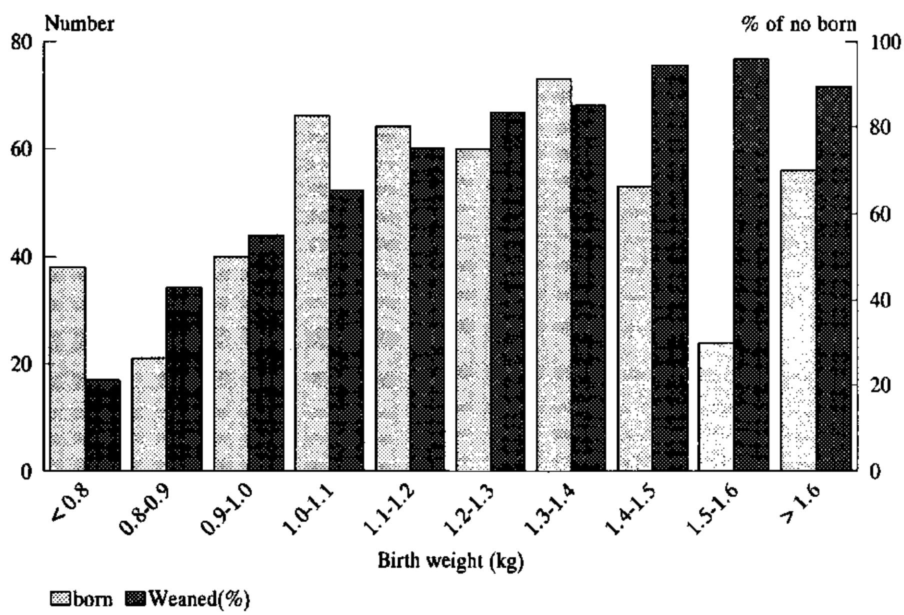

Figure 1. Relationship between birth weight, number born and fraction weaned.

Table 3. Relationship between birth weight (mean ± s.d.), litter size at birth and preweaning mortality

Litter size at birth	Survived till weaning		Died before weaning		Preweaning mortality
	birth weight (kg)	n	birth weight (kg)	n	(% of no born)
1	1.4±0.3	120	1.2±0.3	17	14.2
2	1.2±0.3	329	1.0±0.2	90	27.4
3	1.1±0.3	49	1.0±0.2	17	34.7

A cause could not be ascribed to about 25% of the mortality cases. Sometimes the condition at death was described as weak or unthrifty.

When mortality is expressed as percentage of the average flock size, the animals housed in bamboo huts scored a more favourable figure than those housed in the roofed barn (respectively approximately 21% and 38%). Both figures, however, compare favourably with mortalities found in free roaming village flocks when expressed this way (approx. 61% of average flock size, Bosman and Moll, 1995). When mortality is expressed as percentage of the total number of exits, BH figures are also more favourable than figures from free roaming flocks (29% vs 50%). However, when this comparison is based on kg liveweight, the difference becomes much smaller (10% vs 16%) because other factors such as the age structure of the deaths and the other exits come into play. Thus if one wants to compare production systems which differ as widely as the BH and free roaming system, one has to take proper account of the impact of the factors underlying the parameters concerned.

Clearly, the confining of goats implies major changes in environmental factors, especially in nutrition and management. These changes increase the skills demanded from the goat keeper. If these demands can be met, the flock productivity in biological terms can increase considerably (Bosman *et al.*, 1988). Whether this will be attractive for the local goat keeper depends on other factors, such as the role of the goat within the household economy and the cost of labour.

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CHAPTER 4.

ASSESSMENT WITHIN THE CONTEXT OF THE FARMING SYSTEM

4.1 Farmers' response to a package of innovations in goat production in South-Western Nigeria

4.2 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS
3. Benefits of livestock and missing markets: the case of goat production in South-Western Nigeria

4.1 FARMERS' RESPONSE TO A PACKAGE OF INNOVATIONS IN GOAT PRODUCTION IN SOUTH-WESTERN NIGERIA[1]

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ABSTRACT

A goat production package developed on-station was offered to goat keepers in six villages in South-Western Nigeria. The package consisted of three components, health, nutrition and management; each contained innovations which could be implemented separately as farmers chose. The health innovations were adopted widely with some minor adaptations but problems in the area of nutrition and management were less uniform, so the response to innovations was more diverse. The project was too short to evaluate these adaptations properly. If innovations offer many possibilities for adaptation, farmers should be given sufficient time to determine the optimum for their conditions. Only then can possible benefits can be properly assessed.

Keywords: on-farm assessment, adoption and adaptation, goat production, Nigeria

INTRODUCTION

Methods of on-farm assessment of new technologies have often been discussed (Francis and Atta-Krah, 1989; Amir and Knipscheer, 1989; Sumberg and Okali, 1988; Steiner, 1987). The general trend has been a shift from the traditional/conventional on-farm trials, largely researcher-managed, to a more open approach with a high level of farmer involvement; from quantification of effects on production parameters to include farmers' adoption and adaptation of the proposed innovations.

Farming systems in South-Western Nigeria are crop-based with livestock as a secondary activity. Major crops are cocoa, kola nut, oil palm, citrus, cassava, yam and maize. The humid rainforest in the south gradually thins into a derived savannah

[1]*accepted by Tropical Science*

to the north. Rainfall is bimodal with a dry period from November to March. Typically farm families live in villages or hamlets, surrounded by a ring of thick bush, with the fields outside. Increasing population pressure has led to shorter fallow periods and hence reduced soil fertility, which is one of the main constraints on agricultural production. Many small farmers have little access to chemical fertilizers and other farm inputs, although farmer co-operative societies have partly eased these problems. The most important livestock species kept are poultry and small ruminants, both of which are predominantly free roaming. The increasing pressure on land has brought the crops closer to the homestead, resulting in more crop damage by small ruminants, especially sheep. Sometimes this has led to the proscription of these species or to obligations to confine them. There is little crop-livestock integration such as use of crop residues as fodder and manure as fertilizer.

The West African Dwarf Goat Project, a joint undertaking of the authors' universities developed a management package for goat production which was tested in six villages in South-Western Nigeria. While monitoring the adoption and adaptation of innovations, which were introduced step by step, in-depth studies quantified the input and output characteristics of the overall farming system(s) and animal production characteristics of the goat subsystem (Ayeni and Bosman, 1993; Platteeuw and Oludimu, 1993). This paper focuses on the adoption and adaptation process.

THE PACKAGE

The first phase of the West African Dwarf Goat project (1981-1988) was mainly dedicated to on-station research into the bio-physical characteristics of this goat, nutrition, health, housing and general management. From these findings and constraints identified by the International Livestock Centre for Africa (Reynolds *et al.*, 1988; Sumberg and Cassaday, 1985; Mack, 1983) a management package was developed with three components:

Health: annual vaccination against *Peste des Petits Ruminants* (PPR) with Tissue-Cultured Rinderpest Vaccine (TCRV), washing or dipping with acaricide based solution to control ectoparasites.

Nutrition: based on roadside grass (*Panicum maximum*), browse (*Gliricidia sepium* and *Leucaena leucocephala*), industrial byproducts (Brewers' Dried Grain) for critical periods and food byproducts (cassava, yam and plantain peelings, maize bran).

Management: housing: in huts, with raised slatted floors;
feeding: on group basis per pen twice a day (adult females, growers); suckling kids supplemented in a creep feed area;
breeding: semi-controlled, buck rotated daily between the pens with breedable females.

This intensive form of goat keeping proved to be technically sound when tested on station and on three pilot farms. Other less intensive modes of goat keeping, which are closer to the traditional free roaming system, can be composed based on these components.

The suitability of the package components was consecutively assessed on a larger scale on-farm in six villages. This phase, in 1989 - 1992, is referred to as the project period.

ON-FARM ASSESSMENT

Three villages (Akeredolu, Toro, Ogbagba) were selected around Ile-Ife, in the lowland Forest Zone (FZ) and three (Awo, Ikotun, Ojo) around Ede, in the Transition Zone (TZ) between the FZ and the derived savannah. The characteristics of these villages (Platteeuw *et al.*, 1993; Alofe *et al.*, 1989) are summarised in Table 1. Major criteria used in selecting the villages were distance to towns and access roads, population size, interest of the population in the project as observed during village meetings, and the current small ruminant management systems. In five villages free roaming was the most prevalent goat and sheep management system, whereas in one village confinement of small ruminants was mandatory. A quick survey was conducted at the on-set of the programme among all households to validate the assumptions made concerning goat production constraints (Bosman *et al.*, 1990).

A field assistant was posted to each village. He was in charge of the routine data collection and advised the farmers on goat keeping upon request. The field assistants held an Ordinary or Higher National Diploma in agriculture. The State extension service was involved in all project activities and the agent responsible for the villages concerned was seconded to the project for one day per two weeks.

Introduction of the package components

During village meetings with all interested goat keepers the different components of goat management were highlighted. It was explained how the proposed innovations might help resolve some of the problems often reported by goat keepers. The package was thus presented as a set of possibilities from which the goat keeper could choose or adapt any. The scope for adaptation depended on the type of

Table 1. Some Characteristics of the selected villages

	Transition Zone			Forest Zone		
	Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
Estimated population size	500	500	750	130	153	189
Distance to nearest town (km)	5	20	8	15	20	30
Average acreage tree crops (ha/household)	2.0	2.0	2.0	3.1	5.0	3.2
Average acreage arable crops (ha/household)	3.2	2.3	2.6	2.7	1.2	0.6
Small ruminant production system at start project[1]	FR	FR	FR+TC	FR+TC	FR+TC	PC

[1] FR: free roaming; TC: temporary confinement; PC: permanent confinement

innovation. Vaccination against PPR did not allow any adaptation, whereas housing could be done in many different ways. Thus, the actual management practices could be diverse, ranging from extensive without any changes (the traditional system) to intensive, as implemented on-station. Delegations of farmers visited the on-station site and the pilot farmers. During the first year the health and nutrition components were introduced, followed a year later (it takes about one year for the browse to mature) by the management component. The health interventions were offered free of charge on the condition that the goats could be registered and ear-tagged by the project. Vaccination against PPR was offered yearly and treatment against ectoparasites bi-monthly. Help was given with the provision of planting material for browse.

Two surveys monitored the establishment and use of browse and the erection, use and maintenance of confinement structures and practices. They were conducted quarterly by one or more team members with the resident field assistant. During the bimonthly washing and weighing exercise records were taken of the condition of the animal and the status of mange infestation, to assess the effect of this part of the health component and to monitor the participation of the goat keepers in this activity. These studies were part of a larger research programme (Ayeni and Bosman, 1993).

One of the basic characteristics of the approach taken by the project team was to give the farmer free choice what to do with the suggested innovations. The task of the team was limited to that of advisor and observer. The rate of adoption was used as an indication of how well the innovations addressed farmers' felt problems in goat keeping, while the mode of adaptation at the same time showed in what form. This is in line with the approach suggested by Sumberg and Okali (1988).

RESULTS AND DISCUSSION

In the five villages where free roaming was prevalent, about 40% of the households reported animal health problems, whereas 17% had management-related problems (nutrition, confinement). In Akeredolu crop damage by goats had resulted in many conflicts and discussions about the need to confine small ruminants. In Ogbagba, where confinement was mandatory, about 60% of the households reported problems in animal health and management.

Overall participation

The proportion of households participating in the project, as percentage of the total number of households keeping goats, was highest in those villages where fewer kept goats (Table 2). Probably goat keeping in those villages was under more pressure. Apart from a lower proportion of households keeping goats, this resulted in smaller flock sizes, when confinement was obligatory (Bosman and Ayeni, 1993). The comparatively low participation rate in Ikotun was due to a social conflict within the village, which prevented about 1/3 of the villagers participating.

Table 2. Number of households keeping goats and total and average participation rate (as % of all goat keepers) in the health innovations (±s.d.)

	Transition Zone			Forest Zone		
	Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
Total	74	84	112	130	153	189
Keeping goats	71	54	59	50	72	58
Average flock size	8.3±3.9	8.5±4.5	9.3±3.7	7.9±4.2	7.5±4.9	3.9±2.4
<u>Participating in</u>: project	80	65	85	96	75	98
PPR vaccination [1)]	48±20	41±13	46±25	80±18	47±15	71±2
ecto-parasite control[1)]	49±9	41±13	44±13	78±6	54±11	76±7

[1)] average per occasion

Health innovations

The health innovations had the highest participation rate, possibly because these were relatively straightforward and, as far as mange is concerned, showed quick results. The participation of the households in the ectoparasite treatment, expressed as percentage of the total number of households keeping goats, was higher in the FZ than in the TZ (Table 2). The lowest rate was found in Ikotun, where it was related to the low overall participation rate and in Ojo, where the poor relations between the resident field assistant and the farmers affected goat keepers' participation negatively. The households that took part were divided in those that had their whole flock treated and those that had only some of their goats treated. The latter group was two to three times bigger than the first in all the villages where free roaming was prevalent, while under permanent confinement most households participated with the whole flock. Difficulty in catching animals was a major factor but the participation rate varied and no clear trend was found.

Although mange could not be eradicated completely, treatment reduced infection from about 30% to 8%. Another survey (Bosman and Ayeni, 1993), a year after the introduction of the health innovations, showed an average mange infection rate (as percentage of all animals) varying from 0.3 in Ogbagba to 2.8% in Awo. This lower overall infection rate is presumably because farmers got more infected animals treated.

The participation in the yearly PPR vaccination varied from 41% in Ikotun to 80% in Akeredolu, a pattern similar to the participation in ectoparasite control (Table 2). Unlike mange control, no direct effects are visible unless there is an outbreak of PPR. None was recorded in the project or neighbouring villages during the study. Despite this, there was no decline in participation over time.

After some time, when the effect of ecto-parasite control became manifest, farmers solicited assistance with other health treatments, such as for diarrhoea and injuries. A small drugstore was then introduced, managed by the resident field assistant, where simple (non-injectable) medicines could be obtained at the towns' retail price.

Nutrition component

The proportion of farmers that established a browse plot varied from 14% in Ojo to 46% in Toro (Table 3). Remarkably, the proportion was not higher when animals had to be confined. Although all plots were planted as feed gardens (browse was planted so dense, that once matured it would occupy all space), the majority was planted in combination with crops (cassava, maize). This reduced the risks and allowed a more efficient use of labour. No difference was found between the development of plots planted with browse only and those planted in combination with crops. However, within both categories variations were large, partly due to

Table 3. Proportion of households that planted browse (as % of all goat keepers) and some characteristics of the plots concerned

	Transition Zone			Forest Zone		
	Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
Sole browse plots	5	13	4	2	10	9
In comb. with crops	10	17	10	18	36	12
Total	15	30	14	20	46	21
Feeding browse at end of project	1	6	2	8	14	9
Gender plot owner (%)						
female	33	81	29	20	45	17
male	67	19	71	80	55	83
Size plots (m^2)	119±101	116±181	210±134	147±105	106±107	107±79
Distance plot homestead: m	910±1062	1081±733	1196±759	671±834	438±464	883±989
mins	6±9	10±7	11±8	5±6	5±5	9±10

differences in weeding intensity. Both male and female farmers established browse, but except in Ikotun most browse plots belonged to men.

The average distance between the plot and the homestead varied from 436 in Toro to 1196 meters in Ojo, or in walking time from 5 to 11 min. The variation was considerable. The most distant plot was in Ogbagba, at more than 3 km from the homestead. If a farmer has to go that distance just to harvest feed, it would considerably increase the labour of goat keeping. The major reason for planting browse at such a distance, was the unavailability of nearby land.

At the end of the project about 75% of the browse plots were still in use, while the remaining 25% had been abandoned for various reasons. Some plots in or near the village had been destroyed by chickens or small ruminants. Under free-roaming livestock systems, browse plots appeared as vulnerable to damage as food crops, even when they were well established. Other reasons included loss of interest or termination of goat keeping. One problem often reported by farmers was the (initial) unwillingness of goats to eat *Gliricidia sepium* and *Leucaena leucocephala*. Similar problems were encountered on-station in experiments with common village supplements such as cassava and maize offal, to which the goats were not accustomed. Goats apparently need some time to get used to a new feed so the researcher or farmer has to exercise the patience.

The size of the plots was limited and varied from 106 m^2 in Toro to 210 m^2 in Ojo, which equals to about 3% of an average plot with arable crops. Assuming a browse Dry Matter (DM) production of 9 tonnes/ha/y (from Teniola 1990), average production would be 95 to 189 kg/plot/y. For comparison the maintenance requirements of an average flock in the project area, consisting of about 2.5 adult animals and 5 young stock and equalling roughly 40 kg metabolic weight, would amount to 408 kg DM of this type of browse (from Bosman and Ayeni, 1993; Ademosun *et al.*, 1988 and NRC, 1981). Thus the average plot could supply about 1/4 to 1/2 of these requirements. These figures have to be interpreted with caution as they are tentative; the project period was too short to collect meaningful data on actual browse production.

Management component

The proportion of goat keepers that practised confinement varied widely from 1% in Awo to 100% in Ogbagba (Table 4). It was clearly more common in FZ. Confinement consisted of tethering, mostly in front of the house, and enclosure in fenced yards near or adjacent to the house. Under free roaming conditions only few farmers confined their goat flocks permanently. Reasons given for confinement in Toro and Akeredolu mainly concerned avoidance of problems caused by free roaming goats, which were partly related to the proximity of plots to the homes. Some flocks were restricted for part or all of the day to prevent crop damage, while others were restricted on days when the local market was held to prevent goats disturbing the market and to avoid traffic accidents. These practices already existed at the beginning of the project in the FZ, mainly in the form of tethering. Although not part of the suggested innovations this confinement practice increased in the FZ during the project period. Being a cheap and flexible method, it appeared to be used by households with comparatively small flocks (around 4 animals). In Ikotun two women enclosed their goats permanently because they thought goats would do better that way. One of them established a large browse plot, which she extended the following year. The other had at her disposal an ample supply of food by-products because she processed cassava. Towards the end of the project she too established a browse plot. In the five villages where free roaming was prevalent the number of enclosures rose from 2 at the beginning to 59 at the end of the project period.

Generally farmers considered the on-station structure as too expensive, although the capital some invested in fenced yards would have sufficed to construct the on-station prototype, as shown by a farmer, who actually put up such a structure. Other factors may have applied, such as the complexity of the structure and the intended use of the confinement. The construction of the slatted floor, for instance, was

Table 4. Proportion of households that practised confinement at start and end of project (as % of all goat keepers) and some characteristics of the enclosures

		Transition Zone			Forest Zone		
		Awo	Ikotun	Ojo	Akeredolu	Toro	Ogbagba
Confinement practice :							
tethering:	start (%)	-	-	-	4	6	47
	end (%)	-	-	-	6	13	48
enclosure:	start(%)	-	-	-	2	-	53
	end (%)	1	6	2	26	24	52
Size of enclosure(m^2)[1]		-	56±15	-	63±42	19±11	25±16
Construction costs (₦)[2]		-	84±65	-	104±68	54±26	-

[1] only enclosures specifically used for goats; [2] ₦≈0.15 US. Dollars

unfamiliar to both farmers and local craftsmen. Some (about 20%), however, did construct a partly raised slatted floor inside the fenced yard. In about half of the cases the fenced yard was used also for other purposes, such as confinement of sheep. It would have been difficult to achieve this with the on-station model for goat housing. Furthermore, the on-station model loses one of its major advantages, the control of endoparasites, when confinement is not permanent (Smith *et al.*, 1988).

The average amount spent on the erection of confinement structures exclusively for goat keeping varied from ₦54 in Toro to ₦104 in Akeredolu, which represented about 20-40% of the price of an adult doe. By the end of the project about 25% of the confinements had been abandoned, some because they had collapsed, others because goats were no longer kept.

In all villages theft was seen as a problem related to confinement, as restricted animals are an easier prey for thieves. Some farmers therefore released their goats at night, while others kept them inside the house.

Consequences for the package

The period of testing was too short to evaluate experiences of farmers who planted browse or who introduced confinement. The health innovations were widely adopted, partly probably because they were offered free of charge. However, the farmers provided the labour to bring and to treat the animals and cooperated in the data collection.

Farmers' response did not show any of the suggested innovations to be unsuitable. It rather showed a highly variable reaction, with a lower interest in the management innovations in those villages with the lowest pressure on the current free-roaming management system. However, no relation could be established between the general household characteristics and the adoption and adaptation pattern, so, no package could be suggested for a specific group of farmers. Instead, the existing practices and the adaptations developed by the farmers were included in the package, increasing the total number of options. For the health component this meant including information on simple treatments of frequently reported health hazards other than PPR and mange. In the nutrition component more emphasis was put on the quality and use of common food processing by-products. The management component was extended with traditional and semi-traditional confinement methods. The major advantages and disadvantages of each option were listed. This technical information, together with the project's experiences in the area of extension was summarised in a simple booklet for the extension worker (Koper-Limbourg and Oyeyemi, 1993).

CONCLUSIONS

The health innovations were widely adopted, with some minor adaptations. Problems experienced in nutrition and management were less uniform and so the response to innovations were more diverse. The duration of the on-farm phase of project was too short to make proper evaluation of these farmers' experiments.

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4.2 APPRAISAL OF SMALL RUMINANT PRODUCTION SYSTEMS[1]
3. Benefits of livestock and missing markets: the case of goat keeping in South-Western Nigeria.

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ABSTRACT

The importance of keeping livestock in developing countries includes benefits (B) other than income. It is postulated that if formal finance and insurance markets are functioning poorly or are absent, livestock constitute a source of easily convertible capital for financing (B_f) and insurance (B_i). Conventional livestock productivity assessments do not cover these benefits. In this paper a paradigm is developed to estimate the total benefits (B_t) derived from livestock, defined as: value added + B_f + B_i. The estimate of B_f is based on the outflow of animals and the estimate of B_i on the stock. This paradigm is tested in an analysis of goat keeping in South-Western Nigeria. It is estimated that in the most prevalent production system, i.e. free roaming, B_i and B_f constitute the major part of B_t (≈80%). Flock productivity in this system was much lower than on-station, partly because of poorer reproductive performance, higher mortality after weaning and lower weight gains and also because the flock outflow pattern, which is directly related to B_f, is different. It is concluded that livestock keeping in developing countries has multiple goals and requires multiple resources. The potential for improved livestock production technologies is determined by biological factors, the returns from the resources required for livestock production vis-à-vis the returns from other enterprises available to farm households, and by the functioning of the markets that govern the importance of the financing and insurance goals of livestock keeping. Research objectives should take account of this.

Keywords: livestock; productivity; economics; financing; insurance; research planning: South-Western Nigeria

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[1]*submmited to Agricultural Systems*

INTRODUCTION

Livestock are a component of varying importance in a range of farming systems throughout the third world. Their importance is generally expressed in the proportion of the total farm household income derived from them. In line with the focus on income, livestock research is generally aimed at raising productivity by improving health, feeding, breeding, and management. However, livestock have additional benefits; they function as a savings account and as insurance and, confer social status. These aspects are generally considered in a separate context and their implications for production or productivity are ignored.

In this article a perspective on livestock keeping is developed which tries to capture and quantify the productive and additional benefits of livestock. We begin by discussing physical production at the level of the individual animal and the flock, using the reproductive and flock productivity indices selected in a review of various productivity parameters (Bosman and Udo, 1995). Next, the additional benefits of livestock keeping in terms of financing and insurance are estimated, taking into account the position of farm households in a socio-economic environment in which markets for finance and insurance functioning poorly or are absent. This perspective is than applied in an analysis of goat keeping in South-Western Nigeria, a type of livestock production with one output: meat.

THE DEFINITION AND MEASUREMENT OF BENEFITS

Production and productivity

Definition and measurement of production and productivity are based on a distinction between stock and flow in a flock of animals, whereby the stock is taken at the start and end of the observation period and the flow shows the changes during the observation period. The production in the observation period is defined as births minus deaths. This production can be sold (net of purchases) (S - P), consumed (C), transferred between flocks through caretaking arrangements (T_o - T_i), or kept in the herd (St_1 - St_0). The relationships among the variables can be shown in the following formula (in number of animals):

$$St_0+B-D+P+T_i-S-C-T_0=St_1 \qquad (1)$$

where: St_0 *= stock size at* t_0 *(start of observation period);* St_1 *= stock size at* t_1 *(end of observation period); B = births; D = deaths; P = purchases; S = sales; C = consumption;* T_i *= transfers in;* T_o *= transfers out*

The production in terms of numbers ($PROD_n$) is either measured directly by recording births and deaths in a flock over a certain period or by recording flock size at the start and end of the observation period plus the external stock movements during that period, the inflow and the outflow. The formula for this is:

$$PROD_n = B - D = S - P + C + T_o - i + St_1 - St_0 \qquad (2)$$

To arrive at productivity, the production in absolute numbers is related to the average herd size, either the average of the herd at the start and end of the period, $(St_0 + St_1)/ 2$, or more precisely to the average flock size weighted for the actual periods animals are present in the herd. The productivity is then expressed in animals produced per animal in the herd between t_0 and t_1.

For animals which are kept for meat production, as is the case for goats in South-Western Nigeria, the productivity must be defined more precisely in terms of live weight, to capture weight gains and losses per animal over a certain period. Measurement of production in terms of kg live weight is based on the last term of [2] with the parameters expressed in kg live weight instead of in numbers.

Bosman and Udo (1995) recommended using two indices for the assessment of flock productivity: one based on average flock weight (p_{kg}) and the other based on average metabolic flock weight (p_b):

$$p_{kg} = \frac{\text{outflow-inflow+net change in stock}}{\text{average flock weight}} * \frac{365}{\text{period}} \qquad (3)$$

$$p_b = \frac{\text{outflow-inflow+net change in stock}}{\text{average metabolic flock weight}} * \frac{365}{\text{period}} \qquad (4)$$

For specific attention to one of the main components of flock productivity, Bosman and Udo (1995) recommended, the reproductive performance an index (RPI) which gives the litter live weight at three months of age produced per doe per year:

$$RPI = \frac{\sum_{1}^{n}(LWW_3)}{T_n - T_1 + \frac{T_n - T_1}{n-1}} * 365 \qquad (5)$$

where RPI=Reproduction Index in kg/doe/y; LWW= live weight of litter at 3 months of age (kg); T_1= age at first parturition (d); T_n= age at n^{th} parturition (d)

The production in economic terms closely follows the numerator of p_{kg}[1]; if the value per kg live weight is similar for all types of goats the value of the production can be derived directly by multiplying by the value per kg; if not, a valuation per type of animal is required. The production in monetary terms can be related to the average value of the flock over the period under review, to arrive at the capital productivity p_c, or to the amount of labour utilised, to arrive at the labour productivity p_l. Both productivity ratios relate total production to just one production factor and the ratios merely give a general indication of the factor efficiency.

A more useful indicator for the production in smallholder agriculture is the value added (VA), defined as the value of the production (or gross output) minus the value of the inputs purchased from outside the farm. The value added results from the use of the household's production factors land, labour, and capital. The value added can be allocated to the individual production factors of the farm household by valuing two factors at their opportunity costs and by attributing the remainder to the third factor. This results in a set of productivities: the returns to labour, land and capital, whereby the return to one production factor depends on the opportunity costs taken for the other production factors. The determination of opportunity costs is necessarily arbitrary, as markets for land, labour and capital are generally imperfect or even absent. However, the trade-off among the returns to the production factors can be analysed by taking various values for opportunity costs.

Additional benefits

The determination of the productivity parameters p_{kg}, p_c, and p_l and the added value are all based on a distinction between stock and flow in a flock of animals. This distinction is necessary for analytical purposes, but it may obscure the fact that the actual production (of meat) is directly embodied in the flock. A decision to reduce the flock is thus required to obtain disposable income for either consumptive or productive requirements (e.g. the purchase of fertiliser). When making such a

[1] *For the goat production systems under review in the following sections the production is measured solely in meat expressed in kg live weight. In other livestock production systems there may be more types of output such as meat, manure and draught power; the value of all these products must be totalled to arrive at the total production value.*

decision the present requirements of the farm household are balanced against similar, but uncertain requirements in future. The ability to use the capital embodied in the flock as and when required adds two aspects to livestock keeping which are not captured in the stated productivity parameters or added value: financing and insurance. Financing, because conversion of part of the flock into disposable income (and vice versa) enables households to regulate income and expenditure over time; insurance because the capital embodied in the flock forms a guarantee for meeting future requirements. Both aspects of livestock keeping are of special importance in developing countries, where financial markets generally function poorly and there are generally no opportunities for risk management through formal insurance (Von Pischke, 1983; Binswanger and Rosenzweig, 1986).

Besides the generally ill-functioning or absent formal markets for finance and insurance, mention must be made of the multitude of informal relationships for financing and insurance that exist between individuals or within groups throughout the developing countries (Adams and Fitchett, 1992). The importance of these informal relationships for dealing with the vagaries of life is not questioned, but it must be remembered that these risk-sharing arrangements are largely based on the community's inherent ability to accumulate and maintain a stock of capital, and livestock play an important role in this.

The role of goat keeping in financing is visible in the inflow ($P+T_i$) as well as in the outflow ($S+C+T_o$). The inflow means capital accumulation or saving, the outflow means spending saved capital. Measurement of the benefit derived from financing must be focused on the outflow because this represents the part of the stock actually used to meet the household's consumptive, productive or social requirements, the latter as far as gifts or (temporary) exchanges via caretaking are concerned. Using part of the flock for specific purposes at a desired moment has several advantages over selling animals and keeping the money until required or exchanging animals for goods not directly required. Keeping the returns from animals as cash involves the need for safe-keeping and the presence of cash in the household may lead to claims from others which are difficult to refuse for social reasons. Banking would be a logical solution but access for depositing and withdrawal is either impossible or costly in terms of time, travel and loss in purchasing power because interest rates on savings are often insufficient to cover inflation. Keeping goods such as grain in storage, involves storage losses and possibly claims from others as well. The avoidance of costs or losses by "cashing" animals when required results in a benefit of the outflow being more than the actual value at the moment of disposal. The total benefit of the outflow can be expressed by: $(1 + b_f)$ * outflow value, where the benefit derived from the role in financing, $B_f = b_f$ * outflow value. The factor b_f can be estimated by considering alternative ways of saving or of obtaining credit, such as: the costs of operating a savings account; the losses incurred when consumer goods such as grain are stored; the costs of informal credit; or, the costs involved in pawning jewellery or consumer durables.

The insurance aspect is related to the capital embodied in the flock present on the farm as this capital forms the potential to meet expenses. This potential must be seen as a form of security for which an insurance premium must be paid in situations where insurance markets exist. As with insurance premiums, the benefit derived from this security is expressed as an amount for a certain period: $B_i = b_i$ * average flock value during the period of observation. Estimation of the factor b_i not only requires an understanding of the household's perceptions of future and thus uncertain financial requirements and its abilities to meet these, but also an assessment of alternative insurance options.

Total benefits

The total benefits from goat keeping over a period of one year can be summarised as follows:

$$Y = VA + B_f + B_i \tag{6}$$

with: $VA = \{(outflow - inflow + net\ change\ in\ stock) * p_m\} - \Sigma x_i p_i$
(or, $VA = (p_{kg} * average\ flock * p_m) - \Sigma x_i p_i$*);*
$B_f = (outflow * p_m) * b_f$; $B_i = (average\ flock * p_m) * b_i$
and where: Y *= income;* P_m *= price of meat;* x_i *= external input i;* p_i *= price of external input i; outflow, inflow, change in stock and average flock are expressed in physical quantities (kg).*

ANALYSIS OF GOAT KEEPING IN SOUTH-WESTERN NIGERIA

Farming systems in South-Western Nigeria are crop-based, with livestock keeping as a secondary activity. The most important types of livestock kept are poultry and small ruminants, both of which are predominantly kept roaming free. Among the small ruminants, goats are the most numerous (Matthewman, 1980; Mack, 1983; Alofe *et al.*, 1989; Koper and Aderibigbe, 1993). The keeping of small ruminants is under pressure in South-Western Nigeria as increasing population density is resulting in crop farming moving closer to the villages and thus more damage is being caused by sheep and goats. In some villages this has already resulted in mandatory confinement or even a total ban on small ruminants. East Nigeria, where population densities are higher than in South-Western Nigeria, has reached the stage at which all small ruminants have to be confined.

The free-roaming goat production system is considered a low input production system, with capital embodied in goats as the main production factor involved. Upton (1985) estimated a return to capital of over 30% for an hypothetical flock in which all animals not required for replacements are sold at the age of 12 months. Health and nutrition are the major constraints to higher productivity in this system (Sumberg 1985; Reynolds *et al.*, 1988).

The in-depth studies of goat production systems described below were conducted while testing a management package aimed to improve goat production in South-Western Nigeria. This package consisted of innovations in health, feeding and housing (Ayeni and Bosman, 1993).

Data collection

For the on-farm assessment three villages (Akeredolu, Toro, Ogbagba) were selected around Ile-Ife, in the lowland rainforest zone and three (Awo, Ikotun, Ojo) around Ede, on the fringes of the savannah derived from the lowland rainforest, and the lowland rainforest zone. The major criteria used in selecting those villages were their location (distance from towns and access roads), population size, interest of the population in the project as observed during village meetings, and the current small ruminant management systems. In five villages free roaming was the most prevalent management system, whereas in one village confinement of small ruminants was mandatory.

A field assistant was posted to each village. He was in charge of the routine data collection and advised the farmers on aspects of goat keeping upon request. From the onset the extension service was involved in all activities and the agent responsible for the villages concerned was seconded to the project on a part-time basis. Yearly meetings were held with all the interested farmers to deliberate on problems and progress of the different activities. Furthermore, questions related to goat keeping were often discussed individually with the farmers (often women) at the request of the field assistant or the farmer concerned.

Specific data were collected to get a clear picture of all the ins and outs of the various goat production systems and to obtain a good impression of the performance of goats kept under those systems. The aim was to select about 20 households per village as this was considered a sufficiently large number (about 50% of the households that participated in the project) to represent the different types of farmers satisfactorily. The results from a single visit survey showed that households could be classified on the basis of the general characteristics of their farming system (family size and composition, farm size, use of inputs and technology, livestock size; Platteeuw *et al.*, 1993). The selection of households for the detailed data collection was based on these groups. The total number of selected households depended on the group and the village size and varied from 14 in Ikotun to 25 in

Akeredolu. The households selected for this study were divided into two groups and were visited twice a week by the field assistant. On such occasions all animals were inspected (presence, physical and reproductive status) and the results were recorded on a short checklist. Once a fortnight a mobile team of researchers and technicians from Ife, joined the field assistant in his field operations. All goats under the age of one year were weighed every two weeks, other goats were weighed every two months. This study was conducted between March 1990 and March 1992.

Data on labour utilisation and expenditure on goat keeping were collected from a sub-sample (10 households per village). Selected households were monitored quarterly for a whole day. This study was carried out between November 1990 and May 1992.

Data on the performance of financial and insurance markets were collected through a general survey of all households in the research villages and through a review of literature and overall data on financial parameters.

RESULTS

Flock characteristics and dynamics

No relationship was found between goat production characteristics and characteristics of the households such as family composition, family size, man/land ratio and type of crop and off-farm enterprises undertaken; apparently everybody had the option of keeping goats. At the level of the sub-system 'goat production' a classification based on confinement practices did reveal some significant differences. In this paper the following three major categories, which already existed at the start of the research, are used: a) free roaming (FR); b) confinement by tethering (CT); and, c) confinement in enclosures (CE). The first system is prevalent in 5 villages (3 in transition zone, 2 in lowland rainforest zone); in the sixth village (in the lowland rainforest zone) confinement was mandatory and farmers used tethering or enclosures. Within the FR system the majority of characteristics did not differ between zones, partly because of the large variation between households, and therefore the FR farmers were treated as one group. In the villages where free roaming was allowed a small number of households practised semi-permanent confinement; these households were excluded from the analysis (Bosman *et al.*, 1993).

Flock size was significantly smaller (about 50%) in the confinement systems (Table 1). In all three categories flock size remained fairly constant over the two-year study period. The proportion of adult female stock varied around 40% and did not differ between categories. However, in both CE and CT relatively more adult males and less young stock were kept.

Table 1. Flock dynamics in the selected households per confinement category based on the yearly averages per flock over the two year observation period (means ± s.e.)

	Free roaming	Tethered	Enclosed
n	55	8	13
Initial flock size	8.0±0.5	3.8±0.8	4.1±0.6
Production			
Births	6.9±0.4	3.1±0.8	3.3±0.8
Deaths	4.7±0.4	1.4±0.5	2.4±0.5
sub-total	2.2	1.7	0.9
Inflow			
bought	0.4±0.1	0.9±0.4	0.3±0.1
transfer			
received for caretaking	1.4±0.2	0.4±0.2	0.6±0.2
share from caretaking	0.1±0.0	0.1±0.1	0.1±0.1
returned to owner	0.0±0.0	-	0.0±0.0
other	0.0±0.0	0.1±0.1	0.2±0.1
sub-total	1.9	1.5	1.2
Outflow			
sold	1.0±0.2	0.8±0.4	0.4±0.1
slaughtered	1.2±0.1	0.6±0.2	0.6±0.2
transfer			
given for caretaking	0.5±0.1	0.6±0.2	0.5±0.2
share from caretaking	0.8±0.1	0.3±0.1	0.3±0.1
returned to owner	0.8±0.2	0.1±0.1	0.2±0.1
other	0.3±0.1	0.2±0.1	0.2±0.1
Sub-total	4.6	2.6	2.2
Final flock size	7.6±0.5	4.4±0.8	3.9±0.6
Average flock size	7.7±0.4	4.1±0.8	4.0±0.6
Males > 1 y (% of no. > 1 y)	10.3±1.8	23.9±9.9	23.2±5.5

In FR and CE deaths per household approximately equalled total outflow (FR: 4.7 vs 4.6 and CE: 2.4 vs 2.2), whereas in CT total outflow exceeded the number of deaths (1.4 vs 2.6).

A major proportion of the stock movements between the flocks concerned the transfer of goats through caretaking arrangements. Caretaking arrangements result in three different but related transfers: an animal is given out for caretaking; an animal is received as share of the offspring; and, an animal is returned to its owner. In this study the three types of transfers were distinguished, but the ownership status of the animals in the flocks at the start of the study period was not taken into account. Both in CT and CE the number of animals received and given for caretaking were about equal, whereas in FR more animals were received for caretaking than given out (1.4 vs 0.8). In FR more animals were also received for caretaking than returned to the owner (1.4 vs 0.8). In all categories the proportion of offspring returned to their owner as share (as % of the number received for caretaking) was larger than the proportion of offspring received from care-takers (as % of the number given out for caretaking): FR: 57% vs 20%; CT: 75% vs 17%; CE: 50% vs 20%).

To gain more insight into the differences in reasons for the exit of young and adult stock, animals below the age of one year were compared to those above that age (Figure 1). The young stock refers to animals born between 1/4/90 and 1/4/91 and monitored between 1/4/90 and 1/4/92. For the animals above one year those present at the beginning of the first and second monitoring years were taking as departing point.

More than 60% of the kids had left the flocks or died during the first year of life. Of the adults present at the beginning of each monitoring year around 40% appeared to have left the flocks or died at the end of the year. Mortality was the single most important exit reason in both age groups. It was comparatively high among the young stock in FR. In the age group above 1 year it accounted for about 50% of the exits in FR, while in CE and CT it concerned about 35% of the exit cases. In both CT and CE a relatively large number of animals was given out for caretaking. A comparatively high proportion of animals under one year was sold in CT, which seldom occurred in CE.

Mortality during the first year of life, expressed as % of the number born, was higher in FR than in CT and CE (FR: 38.2% vs CT: 24.3 and CE: 30.5%). The difference was mainly due to a higher mortality in the age range of 3 to 6 months (Figure 2). Mortality during the first three months of life did not differ significantly ($p>0.05$) between categories (FR: 19.8%; CT: 15.0%; CE: 14.1%). When total mortality is expressed as percentage of the average flock size a remarkably lower figure is found in CT than in FR or CE: 34% vs 61% and 60% respectively. The data collected by the resident field assistant give a broad indication of the various

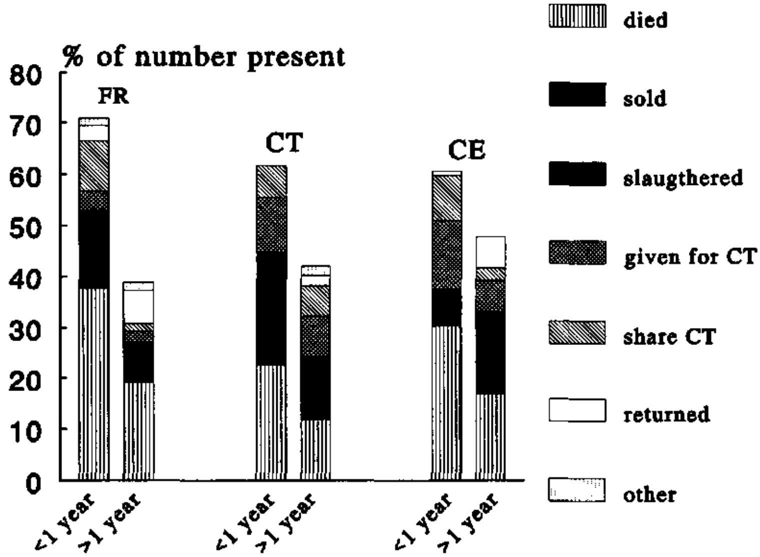

Figure 1. *Flock exits of young (<1 year) and adult (>1 year) stock per confinement category; young stock as % of number born; adults as % of the number present at the beginning of the monitoring year, average over a two-year period.*

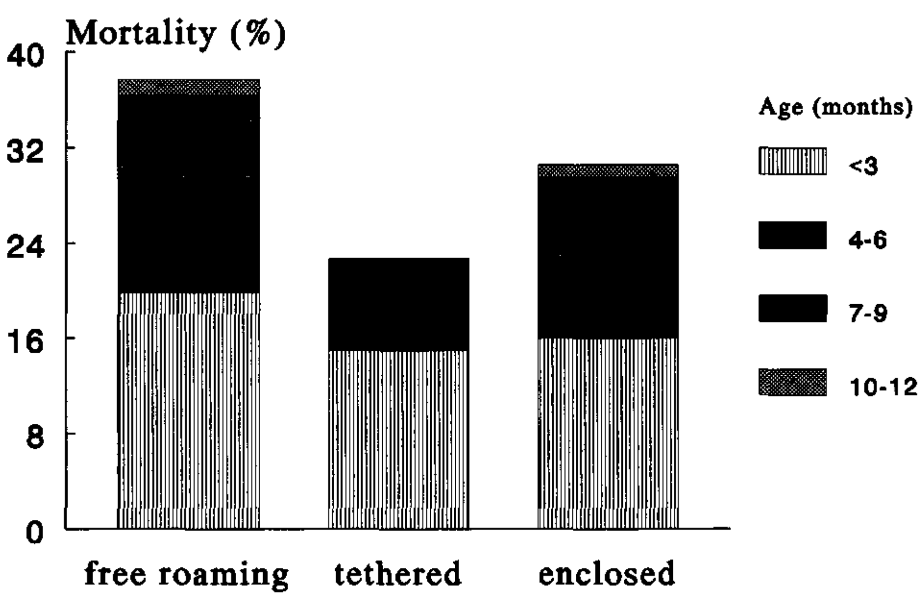

Figure 2. *Mortality of offspring per confinement category (% of number born).*

causes of mortality (Table 2). As no autopsy was performed, the cause of death could not be ascertained in most cases. Disease is stated when the animal showed disease symptoms such as fever, diarrhoea or runny nose. Poisoning refers to incidents when a healthy animal died instantly and there was reason to suspect poisoning. In the case of FR about 36% of the mortality was ascribed to a disease and the cause of death of another 32% was reported as unknown. About 19% of the casualties ran into a game trap. Despite their classification as permanently confined some animals were caught in traps (14% in CT and 13% in CE). In both permanently confined groups the mortality cause 'unknown' was the largest.

Table 2. Mortality causes per flock per confinement category based on the yearly averages per flock over the two year observation period (means ± s.e.)

	Free roaming		Tethered		Enclosed	
	(head)	(%)	(head)	(%)	(head)	(%)
n	55		8		13	
Disease	1.7±0.2	36	0.1±0.1	7	0.6±0.2	25
Car accident	0.2±0.1	4	-		-	
Poisoning	0.3±0.1	6	0.1±0.1	7	0.1±0.1	4
Trap	0.9±0.1	19	0.2±0.1	14	0.3±0.2	13
Unknown	1.5±0.3	32	1.1±0.5	79	1.4±0.2	58
Total	4.7±0.4	100	1.4±0.5	100	2.4±0.5	100

Comparison of the exit patterns between sexes revealed that more males were slaughtered and that more females were given for caretaking. This picture was valid for animals below and above 1 year. The proportions of males and females sold differed for animals above 1 year of age only.

Animal performance

Live weights at the age of 13 weeks and one year of age varied around the 4.5 and 8.5 kg, respectively, and did not differ between confinement categories ($p>0.05$) (Table 3). Litters born in CT and CE were significantly ($p<0.05$) smaller than those born in FR (CT:1.3 and CE:1.4 vs FR:1.6). Mean reproduction indices (RPI) ranged from 5.5 (CE) to 7.7 (FR) and did not differ significantly ($p>0.05$). Productivity index p_b varied from 0.3 in FR and CE to 0.7 kg $kg^{-0.75}$ in CT (Table 4). Index p_{kg} varied from 0.1 in CE to 0.3 kg kg^{-1} in CT. Neither differed significantly ($p>0.05$) between categories. In CT, net production correlated

Table 3. Some reproduction parameters per confinement group, based on flock means over the two observation period (mean ± s.e.)

	Free roaming	Tethered	Enclosed
n	55	8	13
Live weight (kg)			
birth	1.4±0.0	1.3±0.1	1.3±0.0
13 weeks of age	4.7±0.1	4.9±0.2	4.3±0.2
52 weeks of age	8.6±0.2	9.0±1.1	8.0±0.6
Litter size at birth	1.6±0.1	1.3±0.3	1.4±0.4
Parturition interval (days)	259±8	287±22	290±14
Reproduction index (RPI)[1)]	7.7±0.4	6.5±0.5	5.5±1.2

[1)] kg offspring of 90-days per doe per year (for calculation method see text)

Table 4. Productivity assessment per flock per confinement group based on the yearly averages per flock over the two year observation period (mean ± s.e.)

	Free roaming	Tethered	Enclosed
Initial stock size (kg)	97.8±5.5	46.9±10.9	45.7±8.3
Inflow (kg)	20.3±2.3	14.4±4.6	8.6±3.0
Outflow (kg)	37.1±2.9	21.6±5.9	17.2±3.8
Final flock size (kg)	93.7±5.9	52.7±9.3	42.8±6.8
Net production (kg)	12.9±3.4	12.9±4.6	5.7±1.9
Average flock weight (kg)	97.0±5.5	50.0±10.6	46.0±7.6
Average metabolic flock weight (kg)	41.7±2.4	23.7±4.7	20.6±3.5
Productivity index p_{kg} [1)]	0.13±0.04	0.33±0.12	0.12±0.11
Productivity index p_b [2)]	0.30±.08	0.66±0.22	0.29±0.21

[1] in kg live weight per kg flock weight per year (for calculation method see text)
[2] in kg live weight per kg metabolic flock weight per year (for calculation method see text)

negatively with flock size, so that average p_b and p_{kg} values were somewhat higher than in calculations based on average net production and average flock size. However, differences were not statistically significant ($p > 0.05$).

Labour utilisation, purchased inputs and value added

The data on average flock size and productivity p_{kg} of the sub-sample used for monitoring labour utilisation and input use, Table 5, shows that the sub-sample does

Table 5. Production, inputs and value added per household per confinement category (mean ± s.e.)

	Free roaming	Tethers	Enclosures
n	24	4	3
Average flock			
weight (kg)	96.5 ± 8.9	62.3 ± 18.1	59.2 ± 16.3
value (Naira)	1158 ± 107	748 ± 217	710 ± 196
Production			
weight (kg)	12.3 ± 5.7	20.6 ± 6.3	10.0 ± 1.7
value (Naira)	148 ± 68	247 ± 75	120 ± 20
Productivity (p_{kg})	0.13 ± 0.06	0.33 ± 0.10	0.17 ± 0.03
Inputs			
labour (h)	97 ± 5	122 ± 14	189 ± 54
purchased feed (Naira)	114 ± 26	38 ± 18	134 ± 117
Value added (Naira)	34±65	209±74	-14±112
Return to capital (%)[1]	2.3±6.6	32.2±10.3	4.6±15
Return to labour (Naira/h)[2]	0.17±0.62	1.65±0.46	-0.22±0.73

[1] labour costs=0
[2] capital costs=0

not differ significantly ($p>0.05$) from the larger sample used for the productivity assessment stated in Table 4.

The total labour used per household varied from 16 (FR) to 31 (CE) minutes per day, or 97 and 189 hours per year respectively (Table 6). Most of the labour was used for feeding, 65% - 81%. The labour spent per kg MW shows that labour requirements increase when moving from FR to confinement, FR: 0.4 vs CT 0.6 and CE 1.1 min d^{-1}. The wives provided most of the labour in the FR whereas 'other members' and to a lesser extent the husbands provided most of the labour in the confinement systems. The involvement of the wives in goat keeping in terms of actual time spent remained approximately the same in all systems and husbands and 'other members' took charge of the additional tasks in CT and CE. Expenditure on purchased feed in all systems appeared to be substantial, with average values per household from ₦38[1] (CT) to ₦134 (CE) per year.

Per flock, the average VA was negative for CE ₦(14) but ₦34 for FR and ₦209 for CT (Table 7). The large standard errors in production value and purchased

[1] *One Naira (₦)=0.06 USD at the time of the survey*

Table 6. Labour utilisation in goat keeping per flock per confinement category (mean ± s.e.)

	Free roaming	Tethered	Enclosed
n	24	4	3
Duration all activities:			
total (min d^{-1})	16±1	20±3	31±12
per animal (min)	2.0±0.2	3.5±1.2	5.7±1.0
$kg^{-0.75}$ d^{-1} (min)	0.4±0.04	0.6±0.2	1.1±0.2
Duration feeding (min d^{-1})	12±1	13±2	25±5
Provided by (%):			
husband	15	24	33
wife	68	26	21
other member	17	50	46

Table 7. Income from goat keeping per flock per confinement category (mean ± s.e.)

	Free roaming	Tethered	Enclosed
Value added	34±65	209±74	-14±112
Benefit from financing (B_f)	23±3	25±5	9±4
Benefit from insurance (B_i)	116±11	75±22	71±20
Total income	172±69	309±97	66±98

inputs indicate the large variation in the value added within each system; in the CT and CE systems the small numbers of households in the sub-sample are also influential in this respect. The value added is allocated solely to the production factors labour and capital, because the factor land plays a very limited role. With a return to capital ranging from 0% to 20% only the system of confinement through tethering results in positive, but low, returns to labour (Figure 3).

Estimation of additional benefits: the markets for financing and insurance

Access to formal financial services by smallholders has been receiving attention from policy makers in Nigeria for more than 25 years. In 1977 the Agricultural Credit Guarantee Scheme was established by the Federal Government. Under this scheme the government specifies the minimum percentages of the commercial and merchant bank portfolios that must be advanced or lent to agriculture and guarantees these bank loans to farmers up to 75% of the amount in default. In a recent review of the scheme Kolajo (1993) states that agricultural companies were the main

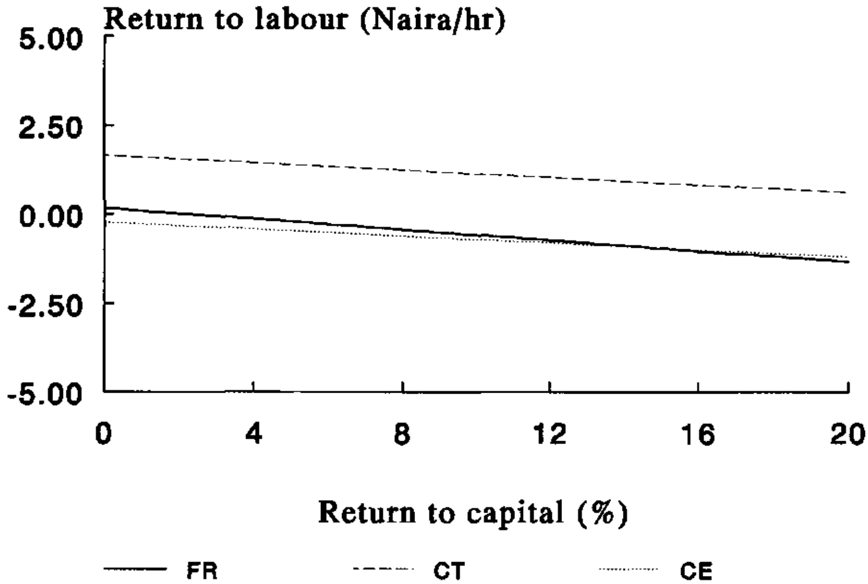

Figure 3. Relationship between the return to labour and the return to capital for the average free roaming (FR), tethered (CT) and enclosed (CE) flock.

beneficiaries in terms of loan value although small-scale farmers received 75% to 95% of the number of loans in the period between 1985 and 1988. The actual number of small farmers reached, (this grew from 885 in 1983 to 33,000 in 1989), must be considered very low in comparison with the millions of small farmers in Nigeria. The establishment of the People's Bank of Nigeria in 1989 was a new attempt to extend banking facilities to the poor. By 1991 a network of 175 branches had been established, but again the number of beneficiaries, 140,000 of whom 60% are women, is relatively small (Anyanwu and Uwatt, 1993).

Obeta (1992) provides a perspective on formal financial services from the farmer's side. In a sample of 300 farmers in Anambra State, a total of 180 farmers used credit, and 68 of these users (23% of all respondents) obtained the credit from formal sources. Cooperatives were the main source of formal credit. Okorie (1992) studied the factors governing access to rural bank branches in the same state and came to the conclusion that education and income were the main factors in which users and non-users of banks differed.

Nigerian policies, and the studies evaluating these policies, are focused on provision of credit for specific agricultural purposes. This means that the happy few who have access to formal credit in general receive a seasonal loan for specific purposes, such as the purchase of inputs, at one particular moment during the year.

The broader concept of financing: saving, dis-saving and obtaining credit according to individual and momentary possibilities and requirements, is neglected. From the clients' side too, under the recent inflationary conditions there is little incentive for establishing links with banks for saving: in the period of 1985 to 1992 the annual rate of inflation fluctuated between 6% and 54%, with an average of 24%. The average nominal interest rate of 14% on deposits in the same period meant a real interest rate of -8% (IMF, 1993).

Studies and observations in the research area confirm the conclusions of the studies cited above: few Nigerian farmers have access to formal credit from banks, and those who do incur considerable borrowing costs on travel and time. Operating a savings account is not attractive for the same cost aspects and because minimum balances (the bank can raise these at short notice) must be maintained. There are cooperatives at present in most of the villages and most of the farmers are members. However, the provision of credit for specific purposes depends on annual allocations of fertilisers etc. by the government, which means that the supply is erratic. Most farmers rely on informal forms of financing such as rotating savings and credit associations (roscas), credit from friends, relatives or traders and on self-financing through saving in cash or kind. When asked about the period during which financial requirements are most pressing most respondents stated the period from March to August, prior to the main harvest period in July-September, because of the cash requirements for the standing crop and school fees (Alofe *et al.*, 1989).

The inflationary situation in past years has meant that it is not attractive to keep cash as a simple way of managing the household's finances. In the rural financial market the formal institutions play a very limited role in financing household requirements. This leaves informal finance and self-finance as the main vehicles of financing for most of the rural households. Under these circumstances goat keeping, with its inherent possibilities of buying and selling goats at the desired moment, provides a welcome form of financial management, especially as the price of goats remained fairly constant in real terms from 1985 to 1992 (WADGP, 1992). The benefit factor in the financing of goat keeping, b_f, can be estimated by a comparison with the inflation avoided during a period of three months, which is half the period mentioned as being difficult in terms of financing. Hence $b_f = 0.06$. This is a rather arbitrarily selected alternative but neither the interest rates for informal credit (which may vary from zero to as much as 25% per month) nor informal options for saving offer scope for comparison or estimation. The benefit from financing for the FR system, B_f, amounts to the outflow * b_f = ₦379 * 0.06 = ₦23 (Table 7). The B_f is to₦9 for CE and ₦25 for CT.

The role of capital embodied in goats as form of insurance is not challenged by institutional insurance services as in practice these are not accessible to rural households. No information is available on informal options for insurance in the research area, but a study by Ibe (1992) on informal life insurance services in Igbo clubs in Anambra and Imo states, east of the research area, indicates the value attached to insurance. In the 107 clubs studied the average annual payments were ₦145 per member in 1989 while on average the benefit paid to the family of a deceased club member was ₦1480 in that year, which implies a premium of 10%. No additional recent studies on informal insurance giving data on premiums are available, so the percentage of 10% found by Ibe is taken for the factor for insurance, $b_i = 0.10$. The benefit from insurance for FR, B_i, amounts to the average value of the flock over the year * b_i = ₦1158 * 0.10 = ₦116. Similarly, B_i for CE and CT was estimated at ₦71 and ₦75.

Total benefits

The total benefits derived from goat keeping (Y) ranged from ₦66 in CE to ₦172 in FR and to ₦309 in CT (Table 7).

DISCUSSION

Flock dynamics and biological productivity

The study gave a fair insight into the characteristics of goat production (flock dynamics, mortality, animal performance and productivity) under different management practices. Comparison of either the selected management systems or the performance within a management system with the general characteristics of the whole farming system, determined in the initial baseline survey (Platteeuw *et al.*, 1993), yielded no significant relationships. Goat keeping, being a secondary activity, is thus rather independent from the major farm activities. Classifying the goat keeping systems according to confinement, with the related management consequences for health and feeding, proved to be useful to explain major differences in goat production parameters. Free roaming, still the most prevalent way of goat keeping throughout the study area, was especially under pressure in the lowland rainforest zone, as damage to crops resulted in frequent disputes there. In the villages close to the derived savannah free roaming goats caused much less serious problems. No differences in goat production characteristics between the free roaming system in the two zones could be detected. Therefore in our analysis we compared free roaming irrespective of the ecological environment (FR) with confinement through tethering (CT), and with permanent confinement in enclosures (CE).

The productivity analysis was carried out in two stages: first from the biological viewpoint and thereafter from economic viewpoint, to obtain a perspective on goat keeping as such and on the relative position of goat keeping in the farming system.

Although the average p_b value in CT was about twice as high as in FR and CE, the difference was not significant ($p > 0.05$) because of the large variation and the low number of observations. For comparison, on-station results gave considerably higher figures (up to 2 kg; WADGP, 1990), mainly because of a smaller proportion of deaths. Comparisons with South-Eastern Nigeria have shown that confined flocks suffer higher mortality and that litters at birth were smaller than under free roaming in South-Western Nigeria (Mack *et al.*, 1985). Results from this study confirm that litter sizes of confined goats are smaller, but the mortality figures are not worse.

The health innovations introduced by the project were aimed to prevent *Peste des Petits Ruminants* (PPR) through yearly vaccination with Tissue Cultured Rinderpest Vaccine (TCRV), and to control mange through regular treatment with an acaracide or insecticide. Despite the wide-spread adoption of these interventions mortality remained high compared with on-station results. The age group below three months of age formed an exception but the mortality in this group (15%-18%), was still considerably above than the 11% found by Mack *et al.* (1985) in free roaming flocks in South-Western Nigeria, though it was similar to the figures found in confined flocks in Eastern Nigeria by the same authors (18% - 25%). However, data on mortality collected at an earlier date in the same area in South-Western Nigeria (Mack, 1983) do correspond with the present findings. The remarkable low mortality among kids in CT flocks between 3-6 months of age may be related to the comparatively smaller litter sizes at birth. The overall mortality among yearlings in flocks kept under permanent confinement was still quite comparable to on-station results (up to 29%; WADGP, 1990). Free roaming flocks did worse in this respect. Mortality among animals older than one year (12-19%) was considerably higher than on-station (5%) in all confinement categories.

Live weights at birth, three months of age and at one year of age were respectively about 110%, 90% and 80% of those found in the pilot units on station (WADGP, 1990). This shows the comparatively lower weight gain of the offspring both during and after the suckling period. Figures found by ILCA confirm this trend (Sempeho, 1985). The individual performance of does, as expressed in the reproduction index (RPI) was about half of the performance recorded on station on high feeding levels (WADGP, 1990). This difference was mainly due to the combination of lower weight gains and smaller litters. The latter was especially prevalent in confined flocks and might have been related to the level of nutrition of the does. Parturition intervals under village conditions did not differ from on-station results (WADGP, 1990). The reproduction index given by Mack (1983), which relates litter live weight at 90 days to the subsequent parturition interval, showed results comparable to the RPIs found in this study.

The exit and entry patterns of the flocks under study are quite similar to earlier data given by Mack (1983). The latter study, however, does not indicate which type of animals were included in the survey. His data suggest that at least in some villages only a limited fraction of the goat population was monitored. Furthermore, nearly 25% of the animals initially included in the survey were lost or withdrawn, so the results might have been biased.

In both CE and CT a relatively large proportion of goats was given for caretaking; this might have been a result of the pressure on these systems. The fact that in FR more goats were received than given out for caretaking might have been related to the presence of the project. The remarkable discrepancy between the proportions returned (50-70%) and the proportion received (17-20%) is hard to explain. Figures found by Mack (1983) in the forest area reveal a similar picture. Theoretically one could expect a rate of about 70% both ways (Bosman *et al.*, 1993), which means that the share actually received from goats given out is low. As there is no reason to suspect that goats given out were less productive, the most likely explanation is that the 'share' was not returned into the flock of the actual owner but was sold or given for caretaking to somebody else.

The lower reproductive performance, the higher mortality after weaning, the lower weight gains and larger outflow of animals below the age of one year led to p_{kg} and p_b values which were considerably lower than recorded in the pilot units on-station. In the case of FR these values were about one third of the on-station values (Bosman and Udo, 1995).

The benefits of goat keeping

The productivity indices p_{kg} and the similar capital productivities p_c (all animals are valued at the same price per kg live weight) for FR show considerably lower values than the capital productivity of 30% estimated by Upton (1985). Measurement of flocks over a period of two years thus provided a more realistic perspective on productivity under field conditions. Capital productivity is, however, a parameter with limited value to assess goat production because substantial amounts of the production factor labour and purchased inputs were used in all management systems.

Analysis of the actual labour use in the three management systems provides a clearer perspective on the position of goat keeping in the household. In the FR system the main proportion of the labour is provided by wives; in the CT and CE systems the involvement of the wives in absolute terms remains more or less the same but the additional work involved in tethering and carrying fodder is done by husbands and other members of the family. Apparently women are not prepared to spend additional time on goat keeping whereas husbands and other family members do have some time to spare. The amount of time husbands and other members are prepared to spend on goat keeping is, however, limited as there is a consistent indication that with confinement, and thus higher labour requirements per goat, the size of the flock diminishes. The shift of labour input among family members and the reduction of the flock size with confinement indicates that labour has a value in the household, and that goat keeping is only undertaken if family members can combine the daily goat-keeping chores conveniently with other occupations.

At the productivity levels observed goat keeping results in values added which are small in relation to the labour and capital resources used: in the free roaming system the households spend 1.5 weeks per year for an average value added (net income for all resources used) of ₦34 which means a return to labour of ₦0.17/h[1] at a return to capital of 0% [2]. By comparison: the average income from arable crops (Platteeuw and Oludimu, 1993) amounts to ₦2400 per year with a return to labour of ₦2.40/h. Production as such thus provides no explanation for the widespread keeping of goats throughout the humid zone. This explanation must be sought in a perspective on goat keeping which includes production as well as the benefits in financing and in insurance which are inherent in goat keeping. The review of the markets for financing and insurance in and around the research area shows that farm households have few or zero possibilities in the formal markets to manage their finances or to deal with risk and uncertainty, leaving informal arrangements, self-financing and capital accumulation within the household as the only options. Under these circumstances goat keeping provides benefits in financing and in insurance which form a substantial addition to the production.

From this wider perspective the total annual income from goat keeping under free roaming conditions amounts to ₦172, of which the value added, 20% of the total income, is measured and the benefits derived from financing and insurance, the remaining 80%, are estimated. The large proportion of the income which is estimated leaves the actual amount open to discussion, but incomes from ₦100 to ₦250 result in returns to labour ranging from ₦1.03 to ₦2.58 per hour (at 0% return to capital) which means that goat keeping results in returns which are comparable with crop production.

The importance of goat keeping for the households in absolute terms is limited, as the value of the outflow of the goats is approximately 5% of the household income and as the total value of the capital embodied in goats is approximately only half of the annual income. From the overall perspective of the farm households goat keeping must therefore be considered as a secondary activity. The production value is of minor importance for the household income but the additional benefits in financing and insurance derived from having goats form a welcome addition to

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[1] *because of a positive, but not statiscally significant ($p > 0.05$), correlation between VA and the labour spent on goat keeping this value is somewhat lower than calculations based on the averages of the two parameters; differences are not statistically significant ($p > 0.05$)*

[2] *A return to capital of 0% is low, but the capital embodied in goats is protected against inflation.*

safeguarding the household's future capabilities to meet unexpected or unavoidable financial obligations.

In this analysis all output is based on kg live weight for the assessment of the p_{kg} and p_b. For the economic assessment market prices were applied per kg live weight. However, it is arguable that a female goat is more valuable in biological terms than a male goat or that the actual price of a slaughter goat of 15 kg live weight is not really 50% higher than a goat of 10 kg. The remarks on the implicit assumptions underlying the biological productivity parameters and the straightforward valuation of goats at kg live weight imply that the validity of comparisons of different production systems based on productivity indices is limited. However, productivity indices are valuable for making comparisons within the same type of production systems.

CONCLUSIONS: METHOD OF ANALYSIS IN RETROSPECT

Livestock research and measures aimed at improving the income from livestock are generally focused on production and productivity, a focus which requires discussion for a number of reasons. Firstly, productivity indices relate production in either biological or economic terms to one parameter, which represents one or more scarce resources or production factors. In p_b for instance it is assumed that the average metabolic flock weight reflects the amount of feed and labour involved. Increasing productivity, measured as an increase in the value of a productivity parameter, means optimising those scarce factors stated in the denominator; however, production factors others than stated in the denominator are not taken into account. A productivity parameter thus provides a partial perspective on technology improvements only. The transformation of biological production into production in economic terms and the subsequent calculation and analysis of the value added at household level provides a perspective on production and returns to all resources used by the household which is much closer to the perspective of farm households.

Secondly, production, productivity and added value are indicators based on a distinction between stock and flow over a certain period of time. The distinction between stock and flow (or between capital and income) is, however, by no means widely recognised by farm households in developing countries; for many households livestock keeping means the presence of a gradually growing herd of animals which enables of one or two animals to be disposed of ("cashed") if there are urgent obligations or needs. This is particularly evident if animals are kept solely for meat, but in production systems with multiple outputs the potential sales value of animals also remains extremely important. The farmers' awareness of the growth of their herds, production and productivity, is thus based on births and deaths and on the condition of animals. Our study on goat production systems shows a large variability of births, deaths and weight gain between flocks and within the flocks from year to year. Because of these variations individual farmers have little insight in productivity or herd growth over a certain period while improvements in productivity are hardly noticeable. For researchers the large variability in and between flocks means that considerable resources have to be used to obtain reliable data on production and productivity under field conditions.

Production and productivity are thus notions which are primarily useful among researchers and those involved in the development and implementation of livestock policies. In communications with farmers in developing countries production and productivity parameters are much less meaningful because: a) farmers in general do not share the concept of stock and flow on which the notions of production and productivity are based; and, b) production or productivity parameters always refer to an average over a large number of animals and an average is hardly relevant for an individual farmer whose perception of production is based on occasional births and deaths in his own small flock.

Thirdly, the focus on production, productivity and value added in research implies that only one objective of livestock keeping is taken into account: production. In circumstances where markets for financing and insurance function poorly or are absent this objective is too narrow for the assessment of a technology because livestock keeping also means benefits in financing and in insurance. For the farm households in South-Western Nigeria studied these additional benefits appeared to be substantial. Estimating the benefits from financing and insurance requires comparison with obvious or less obvious alternatives present in the rural situation. In these circumstances the selection of alternatives and the estimation of the benefits in financing and insurance is generally disputable. This is, however, precisely what must be expected with poorly functioning or absent markets: if alternatives were readily available (and acceptable) the role of livestock keeping would focus primarily on production.

The multiple benefits of livestock keeping result in multiple goals. Hence optimising the benefits of livestock keeping means balancing the various, partly conflicting, goals. The relationship between the productivity indices and the additional benefits from financing and insurance, B_f and B_i respectively, are illustrated in Figure 4, which shows the development of an average flock of free roaming goats over a two-year observation period as determined by inflow, outflow and production. The vertical lines indicate the volumes of the inflow and outflow: the inflow over a period of two months is shown by the vertical line for the odd months, and the outflow over two months, the basis for calculating B_f, is shown by the vertical lines for the even months. The production (flock weight gain minus mortality) is reflected in the slope of the more or less horizontal lines connecting

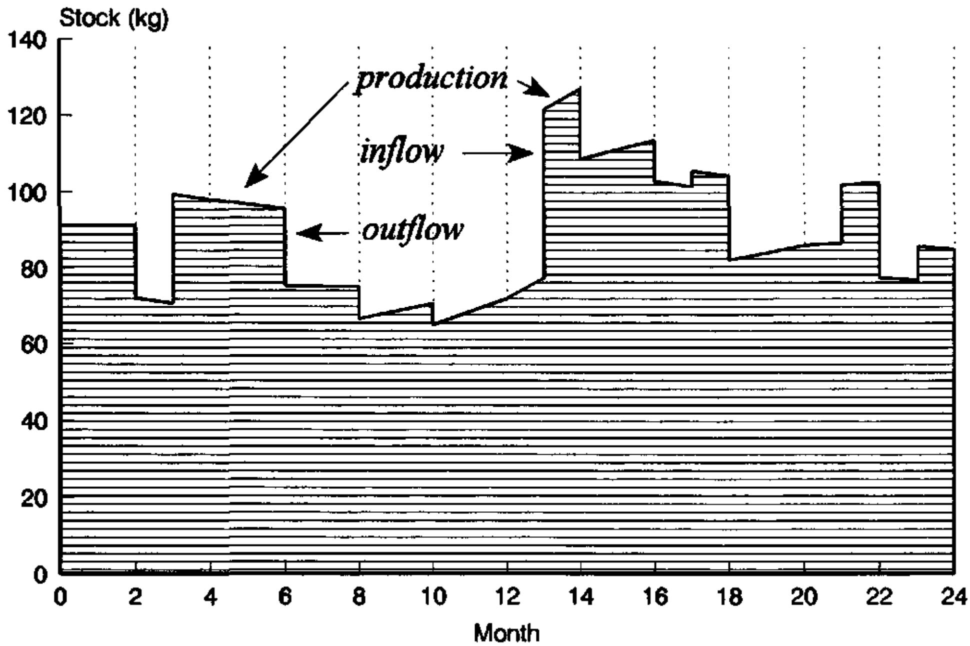

Figure 4. Trend in an average flock represented by a free roaming flock over the two-year observation period.

inflows and outflows. Division of these 'horizontal lines' by the corresponding stock gives p_{kg}. The shaded area represents the stock in kg live weight which is the basis for the estimation of B_i. If the stock, and thus B_i, increases because less productive animals are retained, this will result in a decrease of p_{kg} and eventually in a lower B_f as well. Conversely, an increase in B_f, achieved by disposing of animals which are less productive than average, will result in a lower B_i and a higher p_{kg}. Increase in stock, however, is bound by the constraints of the production system, such as the availability of feed and/or labour.

Concluding, livestock keeping in developing countries has multiple goals and requires multiple resources. The opportunities for improved livestock production technologies are determined by biological factors, the difference between the returns from the resources required for livestock production and those from other enterprises open to farm households, and by the functioning of the markets which govern the importance of the financing and insurance goals of livestock keeping. Research objectives should be set from this comprehensive perspective on livestock keeping, while acknowledging that livestock research is primarily focused on one of the goals: production.

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CHAPTER 5.

GENERAL DISCUSSION AND CONCLUSIONS

5. GENERAL DISCUSSION AND CONCLUSIONS

INTRODUCTION

Livestock production in the tropics is characterised by a high degree of variability in terms of composition, setting and aims. A good understanding of these characteristics is a prerequisite for the planning of a successful improvement programme. In this thesis it was examined how productivity assessments can be employed to characterise livestock production systems and to explore ways for improvements. The focus of the study is limited to small ruminant meat breeds and the household level.

In this final section the results and conclusions of the foregoing chapters are integrated in view of the objectives, starting at the biological level. These findings are consecutively placed within the context of the farm household, and the resulting implications for the identification of constraints and testing of innovations are discussed. Finally, possible implications for small ruminant improvement programmes are discussed.

DETERMINATION OF PRODUCTIVITY

Productivity at biological level

In a biological sense, production in meat breeds (P) consists basically of the accumulation of liveweight through the growth of the individual animal and the increase in the number of animals through births. The net production (NP) of a flock is the balance between P and losses.

The parameters used to assess the productivity of small ruminants meat breeds can be roughly grouped into two categories of indices:

1) those that focus on the multiplication aspect;

2) those that focus on the accumulation aspect.

Indices in the first category principally concern reproductive parameters, whereas those in the second category chiefly consider NP. The two categories are summarised in Table 1.

A good method to measure the output of reproduction is to aggregate the liveweight or number of offspring at weaning, because this Reference Point (RP) is the moment the direct effect of the mother on the offspring stops. In traditional production systems, no clear weaning practice may exist, or weaning may be natural. Under those conditions one has to determine another RP, for instance a pre-determined age. Alternatives, however, may be considered. For instance, if offspring are sold at a target weight or age, this weight or age may be taken as the reference point to include also the interaction between preweaning performance,

Table 1. Productivity assessments and the parameters they require

	Category	
	production at individual level	net production at flock level
formula	$\frac{\sum_{1}^{n}(LWW)}{(T_n - T_1 + \frac{T_n - T_1}{n-1}) \cdot SF} \cdot 365$	$\frac{E_p - I + C_M}{SF} \cdot \frac{365}{period}$
Output	sum of litter weaning weights or liveweights at certain age	net production in liveweight or numbers
measurements required	1. liveweight offspring at measurement point (LWW) 2. first (T_1) and last parturition date (T_n) 3. no. of parturitions (n)	in liveweight or numbers: 1. initial stock size 2. final stock size 3. inflow 4. outflow
Scaling factor (SF)	1. doe 2. average liveweight doe 3. average metabolic liveweight doe 4. average flock weight 5. average metabolic flock weight	1. average flock weight 2. average metabolic flock weight 3. Digestible Organic Matter Intake (DOMI)
measurements required	liveweight at regular intervals (except 1)	1. numbers or liveweights at regular intervals including at the start and the end of observation period 2. monitoring of inflow and outflow 3. DOMI (in case 3)
Minimum length of observation period	1.5 - 2 years	1 year

weaning age and postweaning performance. This is unlikely to occur in traditional systems. In the studies done by the Interactional Livestock Centre for Africa the age of 150 days is often used (Wilson, 1983; Wilson *et al.*, 1985). In her study of Maasai small ruminant flocks, Peacock (1987) proposes an additional index based on the age at which the offspring become reproductively active (18 months). Such an index is only useful when the outflow of animals below that age is negligible or valueless. In the case of goat production in South-Western Nigeria, about 35% of the free roaming kids were sold, slaughtered, returned to the owner of the doe or given in care-taking before they attained the age of one year (Section 4.2). For the age group between 3 and 6 months of age this outflow was about 13% and below three months of age about 3%. This justifies deciding to use 90 days as RP in the case study.

In the assessment of the flock productivity, output is based on the outflow of live animals, expressed either in kg liveweight or in numbers. The problems involved in converting a diverse outflow pattern into one value were discussed in Sections 2.1. and 4.2.

Manure, which is an important source of fertiliser (and fuel) in some places in Africa (Lagemann, 1977; Jahnke 1982), Asia (Dickey *et al.*, 1987) and Latin America (McCorkle *et al.*, 1989), was not included in the assessment, because it was not of importance in the South-Western Nigeria. In South-East Nigeria, however, goats of the same breed are purposely confined to produce manure to be used in the vegetable gardens around the homestead (Lagemann, 1977). Some Andean pastoralists in Peru keep small ruminants primarily for their manure (McCorkle *et al.*, 1989). All animals produce manure; however, the value of manure may affect herd composition and hence the output of other physical products, as is reportedly the case in Peru (McCorkle *et al.*, 1989).

Which scaling factor is chosen (apart from the time aspect already included) depends on the purpose of the productivity assessment, the production environment and the type of records available or collectable. Ideally, the scarce resources manipulable at the level of assessment should be included or be represented. When deciding on the composition of the scaling factor one should consider the consequences for data requirements. If one wants to make comparisons between different situations it should be realised that considerable fluctuations in liveweight are normal and thus that systematic repeated measurements are required to obtain a reliable estimate of the average or weighted average. In the case of flock productivity, a minimum data collection period of two years is recommended. Results presented by Peacock (1987) show that even this period may not be long enough to obtain a realistic estimate of average net offtake rates, as shown by the presence of negative rates. Peacock comments that these data refer to a period of drought and epidemic disease i.e. a 'bust' in the pastoral 'boom and bust' cycle. It is clear that this full cycle has to be covered to obtain a realistic estimate of productivity; however, it may be difficult to know *ex ante* the duration of such a cycle and therefore it may be impossible to plan the data collection accordingly.

Productivity parameters are relative measures, and thus the question arises how such parameters can be correctly used to evaluate a production system. One possible method is the 'yield gap' concept proposed by Knipscheer *et al.* (1983). In their analysis of goat production in Indonesia these authors define the yield gap as the difference between productivity ratios on-farm, on-station (potential level) and a sample of specialised small ruminant producers (possible scope for village farmers). The next step is to identify the sources of these differences and to explore ways to close this gap. A similar approach was followed in Section 2.1 for goat production in South-Western Nigeria. Flock productivity of free roaming village flocks were found to be about one third of the on-station values, mainly due to lower weight gains and higher mortality after weaning. Differences in nutrition and management were thought to be the major source of these differences.

Productivity of livestock and the household economy

The productivity parameters (Section 2.1) are indicators of the efficiency at biological level. They seem to be of less relevance for the assessments of the importance of small ruminants at household level because:
- the net production reflects only the physical benefits and does not include the other purposes of livestock (saving account, insurance) which are frequently reported;
- all outflow is converted into one parameter using the same conversion factor;
- costs of production are not included;
- for the assessment at the higher household level the total volume of production is required as input.

In Section 4.2 it was therefore proposed to use the Value Added (VA) to express the accumulated value of the physical production. In addition, other scarcity factors have to be considered at the level of the household, such as the production factors land, labour and capital. Although it is generally recognised that in traditional (livestock) systems livestock are kept for more purposes than the physical production (Knipscheer *et al.*, 1983; Behnke, 1985; Sempeho, 1985; Peacock, 1987; Upton, 1988; Beerling, 1991; Scoones, 1992; Coppock, 1993) little effort has been put into quantifying these benefits. In the analysis of livestock benefits presented in this thesis, an attempt was made by introducing two additional parameters to capture the Benefits that the availability of livestock may provide in terms of financing (B_f) and insurance (B_i) (Section 4.2). B_f is estimated from the outflow and B_i is estimated from the average flock size. The total benefits are then: $VA + B_f + B_i$. The use of this concept in the assessment of free roaming goat production in South-Western

Nigeria helped to explain why, despite the low return to labour and capital, goat keeping may be attractive for the local farmer.

Comparing the estimates of return to capital I obtained (2.3%, based on VA at zero labour cost) with figures given by Upton (1985) for the same area (34%) illustrates the possible effect of assumptions. Analysing my data with Upton's model gives a similar return (36%). Thus the differences are not due to discrepancies in biophysical data. In his calculations, Upton assumes that feeding costs are negligible and offspring are kept until one year old. My analysis (Section 4.2) demonstrated these assumptions to be wrong; feeding costs amounted to about 77% of the production value and about one third of the offspring were removed from the flock before attaining the age of one year. Other studies on the comparison between traditional versus 'commercial' beef production (Behnke, 1985; Scoones, 1992) have also demonstrated how assumptions can affect the results of livestock systems assessments. Behnke (1985) states as common limitation of assessments of pastoral productivity in Botswana that productivity is expressed on the basis of yield per animal, without including stocking rates. Furthermore, these studies only included one product i.e. meat, whereas in the pastoral systems concerned, livestock are kept for a wide variety of products. The latter reason is also given by Scoones (1992) for the low productivity reported for areas of small scale farming in Zimbabwe. Taking into account the full value of livestock products and services, he concludes that returns to land in communal area livestock systems are considerably higher than in conventional beef ranching systems.

To enable the value of livestock at household level to be assessed comprehensively, the other household activities must also be investigated, especially those that interact directly with the livestock sector. In South-Western Nigeria, labour proved to be a scarce factor (Section 4.2; Platteeuw and Oludimu, 1993) and thus the implications for the labour requirements should be taken into account when exploring innovations in goat keeping. Labour studies, however, are complex because attention has to be paid to both the social and technical aspects (Grandin, 1983; Spencer, 1991). Grandin (1983) gives clear illustrations of this complex for labour studies in pastoral systems; for instance, how to value the labour of a woman watching a child, making butter and keeping an eye on small ruminants. In the project, labour studies were aimed to explore the scope for an intensification of goat keeping. Therefore, these studies were focused to determine the returns to labour from the major activities and to quantify the labour assigned to goat keeping by men and women.

CONSTRAINT ANALYSIS AND TESTING OF INNOVATIONS

Experiences from the case study

In this thesis the results of the on-farm assessment of a goat production package developed on-station were presented (Section 4.1). During the on-farm testing, innovations were offered to goat keepers, who were free to adapt or adopt them. At the same time a research programme was initiated to monitor the adaptation-adoption process and to gain more in-depth information on the role of the goat within the household economy and on the prevailing constraints.

This set-up precluded the quantification of the effects of the innovations. It would have been difficult to define relevant treatments in the case of the nutrition and management innovations, because of the wide variation in possible adaptations. Selecting the farmers for the experimental treatments would have presented other complications. In the case of the health interventions it would have been difficult to explain to those in the control group why they would not receive a treatment that was claimed to solve a farmer's perceived problem. Because of the large variation between households (Bosman and Ayeni, 1993; Platteeuw and Oludimu, 1993; Platteeuw *et al.*, 1993) large samples would have been required to detect any statistically significant difference at all.

One crucial aspect of the chosen method of evaluation appeared to be the link between the project team and the goat keeper. The posting of resident field assistants was intended to facilitate communication between the project team and the farmers. In five villages where this assistant really became 'part of village life', there was a good rapport between the project team and the farmers. This was reflected in the response of the farmers to the innovations offered, especially those that required some input from the farmer in terms of labour and capital, such as the browse and confinement innovations. The size of the browse plots, for instance, showed the trial character of these undertakings. Whereas most farmers had not completed this stage, a few decided, on the basis of their first experiences, to expand the plots. Unfortunately, the period of on-farm testing was too short (2 years) to evaluate the experiences of the majority of farmers who planted browse. The same can be said for the innovations in confinement. The use of partly-raised floors, was some sort of compromise between the on-station prototype and the traditional fenced yard. Here again, the on-farm phase was too short to be able to determine how farmers evaluated this modification, let alone what possible effect these farmers' evaluations could have on fellow goat keepers.

Assessment was easier in the case of the health innovations. Farmers' response showed that they understood the advantage of ectoparasite control very well. One could argue that all goats should be treated to reduce the ectoparasite infestation to the barest minimum. As long as not all goat keepers with free roaming goats participate in this health measure, there will always be ample source of reinfestation. This was well understood by the goat keepers, even to the extent that, during village meetings some farmers suggested making participation compulsory. Whereas the ectoparasite control can be done by the goat keepers themselves, the vaccination against PPR has to be done by personnel approved by the government and the vaccine has to be obtained from a reliable source, in which the cold chain is very important. During the on-farm testing, both the manpower and the vaccine were made available by the project. Under normal farmer conditions, goat keepers will have to rely on the support from the veterinary service, which at the time of the project was already involved in large scale, widely accepted, vaccination campaigns under a World Bank project. Under this project, farmers pay a nominal fee.

Simulation of effect of innovations

The simulation results of on-station and on-farm flocks produced by the energy-driven model, PC-Flock agreed fairly well with actual data, despite the restrictions and the assumptions that had to be made about feed availability from free roaming flocks. Effects of interventions can be tested with PC-Flock if interventions can be converted into changes in inputs into the model.

The health interventions (vaccination against PPR and ecto-parasite control) introduced by the project do not fulfil this condition, because effects in terms of reduced mortality are not known. The introduction of browse as suggested in the nutrition innovation increases the feed availability, a basic input of PC-Flock. The effect of this innovation can therefore be simulated, because data on quantity and quality are available.

The Management component implied housing animals in separate pens with raised slatted floors, semi-controlled breeding and group feeding (Section 4.1; Bosman *et al.*, 1988). In PC-Flock a form of controlled breeding is practised by including minimum weight and minimum age criteria. The group feeding option of the model could not be validated because of unavailability of data. The raised floors proved to be effective to control infections of endo-parasites as compared to grazing on improved pastures or permanent housing on concrete floors (Section 3.2.2). However, these situations do not reflect the conditions under free roaming. Surveys conducted in the project area do not show that endo-parasites are a serious constraint to animal production under different management systems (van Dongen, 1992).

Section 2.2 shows the simulated effect of browse feeding. For illustrative purposes a management option, not part of the suggested innovations, was also tested. This option was postponing the outflow of the offspring until they were one year old.

Predicted productivity and predicted total benefits

Browse supplementation

In PC-Flock the feeds are treated as if they are homogeneous. However, in Section 3.1.2 it was shown that relatively homogeneous feeds (leaves and racemes of *Gliricidia sepium* and *Leucaena leucocephala*) offer considerable scope for selection, resulting in refusal rates of 13% to 42% at maximum production levels. This selection can be mimicked by splitting the feed into more homogeneous components (leaf, racemes or stem) and entering them as distinct feeds, with their own quality and quantity. This was not done when testing the effect of the browse innovations, because the offer levels (<25 g $kg^{-0.75}$ d^{-1} at highest offer level simulated) and quality (DMD=65%, CP=25%) were such that all browse was consumed. However, this procedure was used when determining the feed available to free roaming animals.

The effect of browse on biological productivity was first simulated using the average estimated production of a browse plot of average size. Secondly, simulation was performed with increased plot sizes to show the trend and the variation in simulated output. In all cases it was assumed that the breeding stock remained more or less constant (minimum and maximum set at 3 and 4 does (S_{3-4}), respectively) and thus that extra production would mostly result in increased outflow. In effect, this means that the range for the Benefits from insurance (B_i) to increase, is limited. To show the effect of increased browse plot size on benefits, the estimation of Benefits from financing (B_f), B_i and the total Benefits (B_t), as described in Section 4.2, was included in the output module of PC-Flock. The proportional increase of B_f was larger than the increase of biological flock productivity (p_b), which in turn was larger than the increase of B_i (Figure 1).

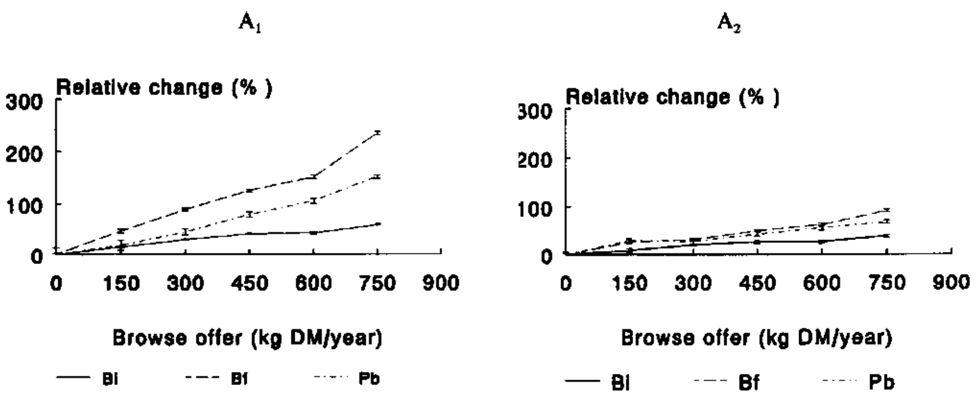

Figure 1. Simulated effect of browse supplementation on relative changes in flock productivity (p_b), benefits from financing (B_f, in Naira) and benefits derived from the insurance function (B_i, in Naira) with feed available on free range set at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2).

As a result, at 150 kg browse supplementation, B_t rose statistically significantly ($p<0.05$) under both the low (A_1) and high (A_2) free roaming feeding levels, whereas p_b differed statistically significantly ($p<0.05$) only in the case of A_2 (Table 2).

Browse supplementation and flock size

A farmer may be more interested in increasing the size of his flock than in raising his productive outflow. To ascertain the effect of such a decision on biological productivity and additional benefits, simulation was performed with the minimum and maximum breeding stock size set at 4 and 5 (S_{4-5}), respectively, at three levels of browse supplementation (0, 150 and 750 kg DM/year). Without browse supplementation, both the biological flock productivity (p_b) and the total benefits (B_t) are statistically significantly ($p<0.05$) lower at increased flock size (Table 2). At 750 kg browse supplementation, flock productivity remains statistically significantly ($p<0.05$) lower; however, the difference in total benefits does not differ statistically significantly ($p<0.05$) in the case of the highest free roaming feeding level (A_2) due to an increased B_i, which compensates for the lower productivity. Furthermore, it can be observed that the effect of flock size on the reproduction index (RPI) is relatively smaller than the effect on p_b, because of the higher level of aggregation of the latter. The results of these simulations indicate that an increased breeding stock size at increased levels of browse feeding will not increase the total benefits.

Of course, assessments of this type must be treated with caution. Apart from the reservations normally called for in the case of simulation models, the assumptions concerning B_f and B_i have to be taken into account. In these simulations they were assumed to remain proportionally constant. In the case of goat production in South-Western Nigeria, this may seem justifiable because of the limited role of small ruminants in the total household economy. Theoretically, however, one could argue that B_f and B_i are bound to a maximum. The need for cash to finance certain expenditure may not increase with the flow of animals, and thus if the latter increases, the relative contribution to meet the financial needs may decrease. The same holds for the insurance aspects.

Browse supplementation and mortality

In PC-Flock, mortality is estimated from the probabilities entered by the user and hence the possible interaction between nutrition and mortality is not considered, except through the minimum condition criterion. Unfortunately it may be difficult to predict the effect of an intervention on mortality because of the complex interaction between animal performance and mortality. For instance, comparison of preweaning mortality figures in the field (Section 4.2) with data from goats on high

Table 2. Simulated effect of increased breeding flock size (S_{4-5} versus default size S_{3-4}) on productivity and benefits of free roaming flocks in South-Western Nigeria. Simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

Browse offer	Female breeding flock size		p_b[1]		RPI[2]		B_f[3]		B_i[4]		B_t[5]	
	S_{3-4}	S_{4-5}	S_{3-4}	S_{4-5}	S_{3-4}	S_{4-5}	S_{3-4}	S_{4-5}	S_{3-4}	S_{4-5}	S_{3-4}	S_{4-5}
							A_1[6]					
0	2.9±0.1	3.5±0.2	0.34±0.05	0.15±0.10	6.3±0.3	5.8±0.2	19±1	16±1	104±2	107±2	201±17	80±17
150	3.4±0.2	3.9±0.1	0.41±0.04	0.32±0.04	6.4±0.2	5.8±0.2	28±1	22±1	120±3	126±2	299±23	228±26
750	3.6±0.2	4.4±0.2	0.87±0.03	0.68±0.02	9.4±0.2	8.5±0.2	64±1	54±2	166±2	175±6	813±20	699±41
							A_2[6]					
0	3.3±0.2	3.9±0.1	0.61±0.03	0.38±0.02	7.2±0.3	6.2±0.2	38±1	29±1	121±3	130±3	443±17	288±13
150	3.6±0.2	4.4±0.2	0.79±0.03	0.54±0.04	7.5±0.2	7.3±0.2	48±3	39±3	131±5	146±2	618±39	463±34
750	3.6±0.2	4.7±0.2	1.03±0.04	0.83±0.03	10.7±0.2	9.3±0.3	73±3	72±2	168±5	198±2	979±54	965±34

[1] Biological flock productivity, expressed as net offtake (kg) per kg metabolic flock weight

[2] Reproduction index, expressed in kg 90-day litter weight produced per doe per year

[3] Benefits derived from financing in Naira (see text)

[4] Benefits derived from insurance in Naira (see text)

[5] Total Benefits in Naira (see text)

[6] Feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)

feeding levels (Section 3.2.1) did not show higher mortality figures in the field but instead showed smaller litters. For the survival of the species it is not the proportion of survivors that counts but the absolute number. In order to be able to predict effects on mortality, the cause of death in the 'starting' situation has to be known. This may require sophisticated post mortem analyses, and these are rarely practicable under field conditions. In the case of goat production in South-Western Nigeria, classification based on symptom description resulted in a large group of unknown cases (about one third, Section 4.2). Carles (1986) reports similar problems in his study of traditional goat flocks in Northern Kenya. In spite of close monitoring, he found 48% unknown cases. The impact of an overestimation of mortality on the productivity parameters depends on the condition of the survivors, especially the females. Higher mortalities may reduce the flock size and thus improve the condition of the animal, and hence increase individual production.

The model does not consider the effect of disease on feed intake and animal performance either. Although it has been widely demonstrated that disease may depress feed intake and animal performance (Verstegen *et al.*, 1991; Zwart *et al.*, 1991; Akinbamijo, 1994). Current knowledge on the underlying physiological mechanisms is not yet sufficiently complete to allow the processes involved to be mimicked. Other simulation models designed for small ruminants (White *et al.*, 1983; Blackburn and Cartwright, 1987) do also not consider these types of interactions.

When simulating the effect of browse it was assumed that mortality would remain unchanged. One could argue, however, that better feeding could enhance animals' well-being and hence reduce mortality. A comparison of field data with on-station data showed that mortality above 90 days of age (weaning) is higher on-farm. About one third of the cases of mortality were reported as being due to unknown causes (Section 4.2). To ascertain the effect of reduced mortality on productivity and total benefits it was assumed that browse supplementation could prevent all these unknown causes. Results of the simulation with 150 and 750 kg DM browse are given in Table 3.

At 150 kg DM browse the reduced mortality did affect p_b and B_f positively in the case of the lowest free roaming feeding level (A_1), whereas in the case of A_2 the difference was not statistically significant ($p > 0.05$). The reproductive performance (RPI), B_i, B_t and metabolic flock weight did not change statistically significantly ($p > 0.05$).

At 750 kg browse supplementation the response was more uniform. B_f, B_t and p_b were higher at reduced mortality, whereas B_i and the metabolic flock weight were not affected. RPI tended to decrease when mortality was reduced; this decrease was only statistically significant ($p < 0.05$) for the highest free roaming feeding level.

Table 3. Simulated effect of reduced mortality (M_r versus default situation M_d) on productivity and benefits of free roaming flocks in South-Western Nigeria. Simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

Browse offer	Metabolic flock weight (kg)		Mortality (%)[1]		p_b[2]		RPI[3]		B_f[4]		B_i[5]		B_t[6]	
	M_d	M_r	M_d	M_r	M_d	M_r	M_d	M_r	M_d	M_r	M_d	M_r	M_d	M_r
									A_1[7]					
150	50±1	51±1	48	41	0.41±0.04	0.53±0.03	6.4±0.2	6.6±0.2	28±1	34±2	120±3	124±2	299±23	364±21
750	68±1	69±1	27	20	0.87±0.03	0.97±0.03	9.4±0.2	9.0±0.1	64±1	67±1	166±2	169±2	813±20	915±28
									A_2[7]					
150	56±2	58±3	27	19	0.79±0.03	0.84±0.05	7.5±0.2	7.9±0.2	48±3	50±2	131±5	137±6	618±39	670±47
750	69±2	72±1	25	18	1.03±0.04	1.13±0.02	10.7±0.2	9.4±0.3	73±3	82±2	168±5	175±3	979±54	1113±32

[1] Number of animals that died in the age category above 3 months of age expressed as percentage of all exits in the age category above 3 months of age
[2] Biological flock productivity, expressed as net offtake (kg) per kg metabolic flock weight
[3] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[4] Benefits derived from financing in Naira (see text)
[5] Benefits derived from insurance in Naira (see text)
[6] Total Benefits in Naira (see text)
[7] Feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)

The results of these simulations suggest that if the browse supplementation were to reduce mortality, the probable effect on the total benefits would be limited, especially at low supplementation levels. Even at the highest levels the limitations imposed by the feeding conditions are such that the production increase due to more survivors is counteracted by the production loss due to lower individual performance.

Reduced flock size

In Section 2.2 it was shown that postponing the sale of offspring until they attained the age of one year did not increase flock or reproductive productivity under the setting assumed for the free roaming system in South-Western Nigeria. In fact, all productivity parameters and benefits tended to decrease. The availability and consumption of feed was such that any further increase in flock size resulted in a decreased intake per animal, which in turn reduced the possible increase in flock size. To ascertain how a reduction in flock size would affect productivity and total benefits, given this feed restriction, a simulation was performed with a reduced size of the female breeding stock (minimum and maximum set at two and three, respectively). The results are shown in Table 4.

In both A_1 and A_2 the flock productivity parameters and the reproduction index increased because of the reduced stock size and higher feed intake. The total benefits even increased statistically significantly ($p < 0.05$) in the case of the severest feed restriction (A_1). This clearly illustrates the complex relation between productivity, benefits and the production setting.

Implications for the farmer

Keeping small ruminants never constitutes the sole activity of a farmer, and thus small ruminant production has to be considered in relation to the other components of the farming system and other scarce factors manipulable at the level of the household. Thus, scaling of total benefits derived from small ruminants to kg flock weight or kg feed are usually not appropriate. Scaling of total benefits derived from the different activities to the production factors involved, however, can serve as a useful basis for comparison (Section 4.2). In this way, the extra labour required for the browse innovation can be taken into account. It is not possible to simulate this extra labour with a biological model. In the case of goat production in South-Western Nigeria, the extra labour depends less on the quality and quantity aspects of the feed and more on the distance between the browse plot and the homestead. Simulation of these aspects would require a model operating at the level of the household and including all farm and off-farm activities. Furthermore, feeding alternatives also have to be considered.

Table 4. Simulated effect of the reduction of the breeding flock on the performance of free roaming flocks. Simulation was performed with 10 flocks over a ten-year period; all results are averages (±s.e.) of flock means

	A_1[1]		A_2[1]	
	reduced breeding stock size	default	reduced breeding stock size	default
Litter size at birth	1.69±0.05	1.54±0.04	1.66±0.03	1.58±0.06
Parturition interval (days)	277±2	279±4	284±3	282±1
Weaning weight (kg)	4.3±0.1	4.3±0.1	5.3±0.1	4.7±0.1
Weaning age (days)	94	94	94	94
Preweaning mortality (% of no born)	17.3±1.3	23.3±3.2	18.7±1.4	18.7±1.6
Weight at 1 year (kg)	10.2±0.3	9.3±0.2	13.2±0.2	10.4±0.2
Average doe weight (kg)	20.2±0.3	19.4±0.2	20.3±0.2	19.2±0.2
Average flock weight (kg)	79±5	86±2	87±2	101±2
Average metabolic flock weight (kg)	40±1	43±1	44±1	52±1
No of reproductive females	2.5±0.2	2.9±0.2	2.5±0.2	3.3±0.2
Flock entries (kg)	18±2	17±2	25±2	25±1
Flock exits (kg)	41±2	29±2	58±2	52±1
RPI[2]	7.5±0.3	6.3±0.3	8.8±0.2	7.2±0.3
p_b[3]	0.61±0.03	0.34±0.05	0.81±.04	0.61±.03
p_{kg}[4]	0.31±0.01	0.17±0.02	0.41±0.02	0.31±0.02
Dry matter intake (kg/y)	827±10	850±8	1076±27	1112±18
B_f[5]	28±2	19±1	40±2	38±1
B_i[6]	95±2	104±2	104±3	121±3
B_t[7]	291±13	201±17	446±30	441±17

[1] Feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)
[2] Reproduction index, expressed in kg 90-day litter weight produced per doe per year
[3] Biological flock productivity, expressed as net offtake (kg) per kg metabolic flock weight
[4] Flock productivity, expressed as net offtake (kg) per kg flock weight
[5] Benefits derived from financing in Naira (see text)
[6] Benefits derived from insurance in Naira (see text)
[7] Total Benefits in Naira (see text)

The fore-mentioned simulations imply that within the existing setting, increasing the feed resource would enhance both biological productivity and total benefits. A tentative analysis showed that under free roaming the extra benefits do not seem to outweigh the extra costs of feeding more available feed, if these activities cannot be combined with other on-farm duties. Of course, if the benefits (or their perceived value) were to alter this situation could change.

This analysis was based on average figures and concerned the 'average' farmer. Considering the large variation between households with regard to the household activities and animal performance it is very possible that for some of them, for instance for those with unutilised labour, an option like the browse innovation is attractive. Furthermore, the pressure on the small ruminant component of the farming system is likely (to continue) to increase. Therefore, in more villages confinement may become mandatory. Browse may also be more attractive under these conditions (Section 3.1.3).

It can be concluded that the impact of innovations on the biological productivity parameters can be explored with the simulation model, provided the effects can be converted into effects on model inputs. If the objective is to assess the effect on the total benefits a household may derive from livestock, assumptions have to be made about the importance of benefits other than the physical production, and the resulting effect on flock size.

If PC-Flock had been available at the start of the project it could have played a supporting role. It could have replaced part of the on-station production studies (Section 3.2.1), thus releasing research facilities and manpower for other investigations. As far as the on-farm research is concerned, it could have been used to explore the possible effect of browse and management interventions on the physical output and total benefits. The latter could already have been achieved with a fair knowledge of the feed availability and the size of the breeding flock, thus without a detailed knowledge of the flock dynamics. Such simulations conducted for the free-roaming flocks with the default values for a small ruminant breed or with breed characteristics as determined on-station give results which, in terms of increase of physical production and total benefits, are comparable with those from simulations with the case-specific flock dynamics (Table 5). The reproduction index differs only if the adult liveweight differs. Thus a detailed knowledge of the flock dynamics is only required if one wants to quantify the flock productivity parameters and the total benefits for instance for comparisons with returns from other activities. For a first screening of interventions the default values will do.

Emphasis of research in retrospect

The emphasis of the research during the on-station phase of the project was on nutrition, because the health status of the flock proved to be satisfactorily under the health (PPR-vaccination, ecto-parasite control) and management (zero-grazing, use

Table 5. Simulation results for free roaming flock flocks, using default values for flock dynamics and breed characteristics, compared with results from simulations with breed characteristics determined on-station and results from simulation with real flock dynamic probabilities; all simulation was performed with 10 flocks over a ten-year period and with feeding conditions as estimated for the free-roaming flocks; all results are averages (±s.e.) of flock means

Browse offer	Reproduction Index (RPI)			Biological Productivity (p_b)			Average metabolic flock weight (kg)			Total benefits (Naira)		
	real[1]	on-station[2]	default[3]	real[1]	on-station[2]	default[3]	real[1]	on-station[2]	default[3]	real[1]	on-station[2]	default[3]
						A_1[4]						
0	6.3±0.3	6.2±0.3	5.7±0.2	0.34±0.05	0.62±0.03	0.38±0.03	43±1	40±1	41±1	201±17	287±13	166±14
150	6.4±0.2	7.2±0.4	6.4±0.2	0.41±0.04	0.79±0.07	0.51±0.03	50±1	40±3	47±1	299±23	404±46	291±13
						A_2[4]						
0	7.2±0.3	7.0±0.3	6.1±0.2	0.61±0.03	0.84±0.02	0.62±0.03	52±1	46±2	50±1	443±17	474±30	379±22
150	7.5±0.2	7.8±0.3	7.1±0.3	0.79±0.03	0.99±0.03	0.80±0.02	56±2	53±2	54±1	618±39	691±32	568±16

[1] Simulated using breed characteristics determined on-station and herd dynamic probabilities determined on-farm
[2] Simulated using breed characteristics determined on-station and default herd dynamic probabilities
[3] Simulated using default breed characteristics of a small breed and default herd dynamic probabilities
[4] Feed available on free range put at 500 kg Dry Matter (DM) per household per year (A_1) and at 1000 kg DM per household per year (A_2)

of slatted floors) measures, implemented after the initial high mortality and poor performance.

During the on-farm phase, research into health aspects was limited to monitoring the condition of the animals and to recording mortality. Post mortem analyses to ascertain the cause of death, were not performed because they were considered not feasible under farmers' conditions.

Thus it remains an open question whether mortality could have been reduced by introducing other health measures. The above tentative analysis, however, shows that such interventions would likely have had a limited impact on overall flock productivity.

IMPLICATIONS FOR SMALL RUMINANT IMPROVEMENT PROGRAMMES

In the recent reports on livestock development (Winrock, 1992; FAO, 1993; IAEA, 1993) the 'productivity' of the traditional livestock is often earmarked as low. Although precise definitions are not given, 'productivity' in this context seems to refer to physical production per animal or to offtake rates. Thus increase in stock size is not valued positively.

In view of the desired increase in production to satisfy a supposedly increasing demand on the one hand and the concern about the sustainability of production systems on the other, this may seem logical. It may, however, disagree with the farmer's perception of constraints to his livestock sector. As shown in this thesis, increasing the physical output per animal or the offtake rates may not be of interest to a traditional livestock keeper because this does not correspond with his objectives of livestock keeping.

Small ruminant programmes in humid West Africa have often been geared to relieve assumed or observed technical constraints. The innovations introduced by ILCA and this project were aimed at improving the health through ecto-parasite treatment and preventive vaccination, and to improve the nutritional status of the animal by feeding or supplementing browse (Reynolds *et al.*, 1988). In addition, the project offered the option for confinement (housing), to overcome problems arising from crop damage. These innovations addressed constraints actually reported by the goat keepers themselves (Mack, 1983; Sempeho, 1985; Bosman *et al.*, 1990). The findings and analyses presented in this thesis show that although it may be relatively easy to prove that innovations are technically sound, it is far more difficult to predict their suitability to address a problem perceived by the farmer, not so much because of doubts regarding the technical effect at farmers' level but more because of doubts about the role of the livestock and the production setting.

In the project area in South-Western Nigeria, farmers considered permanent confinement of small ruminants in huts or enclosures too risky because of theft. Therefore, if the animals had to be confined the farmers preferred to bring them into their homes. Branckaert (1993) reports similar observations for Burundi.

Farmers mandated to confine their small ruminants permanently, saw nutrition as a problem. The use of browse could theoretically alleviate this problem; however, as discussed in Section 3.1.3, the fact that confinement is compulsory also means that (nearby) land to establish browse is scarce.

Differences between the perceptions by the researcher and policy maker on one side and the farmer on the other may result in an undesirable outcome, especially if the innovation proposed implies a major distortion of the existing situation, for instance through subsidies. Treacher (1993) gives a telling example of how an attempt to reduce the degradation of the steppe, presumably due to overgrazing by sheep, had the opposite effect. One of the measures concerned the establishment of co-operatives to take light lambs from the steppe and fatten them on cereals. Membership of these co-operatives gave preferential access to feeds at controlled prices from the government purchasing organisation. As a result, stock numbers and demand for feed increased. The latter led to an increased area planted to barley and hence an intensification of the grazing pressure on the remaining steppe.

The complexity of livestock production calls for a research approach that considers the interactions between the different components of the farm enterprise and its interactions with the 'outside' world, such as markets and banks (McCorkle *et al.*, 1989; Amir and Knipscheer, 1989; Anderson, 1992).

The extensive review by Anderson (1992) shows that such an approach does not necessarily lead to success in terms of increased land and labour productivity. For Sub-Saharan Africa he concludes that 'Research and Development activities, whether public or private, national or international, have produced innovations that farmers find variously unprofitable, too risky or impossible to implement in a timely and useful fashion.' These failures, of course, do not deny the need for a farming system research type of approach but merely illustrate the complexity of such an undertaking. Apart from improvements in organisational aspects and research planning as suggested by Anderson (1992), the success could probably be increased by more involvement of the farmers themselves, not only in the constraint analysis but also in the development of possible innovations, as suggested by Francis and Attah-Krah (1989), Gbego and van den Broek (1993), Patel *et al.* (1993) and Smith (1993).

In such an approach the 'constraint' should be the point of departure for the planning of further activities. Farmers, researchers and extension staff should discuss possible solutions, both in terms of probable effect and requirements to be met by the farmers themselves and by other parties. For instance in South-Western Nigeria, PPR vaccination requires the veterinary service to provide the vaccine; under free-roaming mange can be controlled most effectively if all farmers treat their animals. If suitable solutions are not available, needs and modes of research and the role of the partners in this should be decided upon. Such an analysis may also show that because of the diversity of the farming system, several solutions have to be developed for different target groups.

Not all constraints and solutions may be immediately apparent. For instance, if high mortality is a problem, further research may be required to identify the cause and, consecutively, adequate measures to eliminate or control it.

Furthermore, the objectives of a farming systems research and development programme may be wider than to solve the 'immediate' constraints and may also focus on long term objectives such as the sustainability of the production system, or may be aimed at obtaining quantitative information for policy decisions at government level. So a multi-track approach seems the best strategy to identify constraints at different levels and to develop solutions while taking into account the interaction between the different levels. In such a set-up several productivity assessments may be required, each tuned to the aim and the level of appraisal of the programme components.

Complex programmes, however, may put a heavy demand on financial and human resources, which a developing country may not be able to meet. Gilbert *et al.* (1990) conclude that in the context of weak research and extension systems, farming systems research approaches that demand a heavy investment of time and resources, are not particularly suitable. They recommend that under those circumstances emphasis be put on developing links between existing organisations involved in development activities and extension, through which farmers' constraints can be identified, and feedback on new innovations can be obtained. In addition, links with other national and international research institutions are vital. Such an approach can only be successful if these existing organisations are able to perform these functions. The problem is that the orientation of many current extension activities, including the training and visit system, do not appear to embody sufficient flexibility to effectively communicate farmers' concerns to researchers. Methods which put an heavier emphasis on the active participation of the farmers themselves as contained in the "Farmers First" (Chambers *et al.*, 1989) and the "Beyond Farmer First" paradigms (Scoones and Thompson, 1994a) seem to be more suitable in this respect. However, these methods require a major change in organisation and attitude of the extension and research staff.

It is clear that because of differences in objectives, organisations and available funds, no uniform programme outline can be recommended. The success of a development programme can only be sustainable if a reasonable balance can be found between the demands put on the parties involved and the derived benefits. This thesis has shown how the benefits of one party i.e. the farmers, can be assessed and how the effect of interventions on these benefits can be explored. The benefits of the extension and research staff and the organisational aspects of research and extension were not subject of the this study but have been discussed elsewhere (Ademosun *et al.*, 1993; Mukhebi, 1993; Scoones and Thompson, 1994b).

IN CONCLUSION

Productivity

The role of productivity assessments in small ruminant improvement programmes is limited because of the difficulties involved in the definition of productivity and because productivity parameters are relative measures. This study has demonstrated that it is only appropriate to use productivity indices to compare animal sub-systems if the differences between the total production systems, which may possibly interact with the animal component, are represented in the index.

In the case of small ruminant meat breeds, two types of measures of biological productivity are of interest: reproductive productivity and flock productivity. A data collection period of about two years may be required to gather the necessary baseline data to determine the system characteristics, if no data are available. These biological productivity parameters are affected by changes in the production environment (management, nutrition). The impact of the effect, however, depends not only on the magnitude of the change but also on interactions with the other components.

Simulation models such as PC-Flock can be useful to investigate these types of interactions within the context of a small ruminant flock and to test the effect of innovations, provided the effect of these innovations can be translated into model input.

If the physical production consists of more than one product, appropriate factors have to be determined to convert all output into one parameter. These may be based on the content of a valuable component (energy, protein) or an economic value (price, replacement costs). The same applies if non physical benefits are derived. Because benefits derived from livestock may be correlated negatively, it is important that the conversion factors are assessed correctly. This may be difficult, especially for non-physical benefits, and this may increase the complexity of productivity assessments.

The value of livestock at the level of the household can be assessed by scaling the total benefits to the production factors involved. This results in a set of productivities: the returns to labour, land and capital, whereby the return to one production factor depends on the opportunity costs taken for the other production factors. The determination of opportunity costs is necessarily arbitrary, as markets for land, labour and capital are generally imperfect or even absent. However, the trade-off among the returns to the production factors can be analysed by taking various values for opportunity costs.

The analysis of goat production in South-Western Nigeria showed how quantification of the non-physical benefits, which were estimated to be more important (about 400% in the free-roaming system) than the physical production, can contribute to a better understanding of the goat production system.

The lower reproductive performance, the higher mortality after weaning, the lower weight gains and larger outflow of animals below the age of one year led to flock productivity values which were considerably lower than recorded in the pilot units on-station. In the case of FR these values were about one third of the on-station values.

Animal health

Analysis of the health records routinely kept on-station showed that when goats are yearly vaccinated against PPR, regularly washed or sprayed to control ecto-parasites, housed permanently on slatted floors and properly fed, mortality can be kept low, especially after weaning. Preweaning mortality increased with litter size, however, so did the number of survivors till the litter size of three; the few quadruplets nearly all died. Weaning appeared to have a significant effect on kid survival after weaning. On-station, postweaning mortality was generally low (<5%) when kids were weaned at about 5.5 kg liveweight.

Nutrition

West African Dwarf goats are unable to maintain themselves on poor quality tropical grasses. On the other hand, legumes like *Gliricidia sepium* and *Leucaena leucocephala* can satisfactorily constitute the basic diets of dwarf goats producing weight gains of up to 35-40 grams a day.

In the traditional free-roaming in South-Western Nigeria, considerable amounts of feed were given; however, crude protein content was low. The animals may have balanced their diet through scavenging and browsing. Larger amounts were offered to permanently confined stock but crude protein content was also low; this may have limited weight gain.

Gliricidia sepium and *Leucaena leucocephala* could improve feeding conditions under free roaming and hence increase the productivity and the total benefits; within the socio-economic setting at the time of the survey, feeding small amounts of browse to balance protein-deficient diets seemed the most attractive option. Feeding of larger amounts of browse or using browse to replace maize offal seems to be feasible only if harvesting and feeding can be combined with other on-farm activities.

Intake trials with these browse species showed that a wide range of offer levels is required to obtain a reliable estimate of the relationship between feed offer and intake. Feeding at a fixed refusal rate to determine the quality of feeds may lead to misjudgment as feeds do not attain maximum intake at the same refusal rate. If a feed is heterogenous and thus offers opportunity for selection, high offer levels and accompanying high refusal rates may have to be accepted if the objective is to maximise animal production per unit of available feed.

Reproduction

Under the same weaning practice, litter size at birth and litter weight gain increased at higher feeding levels resulting in higher reproduction indices; the effect on the parturition interval was less. Comparison of on-farm data with on-station data showed a similar picture: the smaller litters and the lower litter weight gains recorded on-farm resulted in lower reproduction indices in all confinement categories; however, the parturition interval and the preweaning mortality did not differ.

Innovations

The suitability of an innovation depends not only on the technical impact but also on how well it fits within the whole farm enterprise. The response of the farmers to the innovations suggested by the project showed that the health innovations were adopted widely; in addition, goat keepers were eager to examine innovations in the area of nutrition and housing. It also became clear that the duration of the on-farm phase of the project was too short to allow these farmers' experiments to be evaluated properly. It is recommended that the farmer is involved at an early stage in the testing and, when possible, in the development stages of the innovation.

Although it may be possible to assess the suitability of innovations at a particular site based on the adoption rate, estimation of the economic attractiveness may be required to explore the suitability for other areas or to evaluate government involvement. Because the economic value of innovations in livestock can only be judged if both physical and non-physical benefits are taken into account, it is recommended that such assessments are included in small ruminant improvement programmes.

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SUMMARY

Livestock production in the tropics is characterised by a high degree of variability in terms of composition, setting and aims. A good understanding of these characteristics is a prerequisite for the planning of a successful improvement programme. A frequently used criterion to assess the suitability of an innovation or intervention is productivity which indicates the efficiency of output generation within the production setting. This setting can be at different levels varying from the individual animal to the national level. In the general introduction (Chapter 1) the difficulties involved in defining productivity were pointed out. The major problems concern valuing and aggregating the output and formulating the scaling factor, reflecting the scare resources. A distinction was made between scare resources that are manipulable at the level of assessment and those that are not. This distinction was made because of the implication for the value of efficiency assessments. Generally if one moves from the level of the individual animal to the national level the number of resources that are variable (as well as the degree of variability) increases. Thus even if the value of the output does not vary between these levels, productivity parameters may change.

This study examined how productivity assessments can be used to characterise livestock production systems and to explore ways for improvements, using a case study of the West African Dwarf goat in South-Western Nigeria. The focus of the study was limited to small ruminants meat breeds and the households level.

The main questions investigated were:

1. What methods are suitable for estimating productivity given the aim of the assessment and the requirements and availability of data? How is productivity affected by changes of the production environment (management, nutrition) and how can these effects be investigated?

2. What role can productivity assessments play in the identification of constraints and the testing of innovations at farm level?

In a biological sense, production in meat breeds (P) consists basically of the accumulation of liveweight through the growth of the individual animal and the increase in the number of animals through births. The net production (NP) of a flock is the balance between P and losses.

Parameters used to assess the productivity of small ruminants meat breeds can be roughly grouped into two categories of indices: 1) those that focus on the multiplication aspect; 2) those that focus on the accumulation aspect. Indices in the first category principally concern reproductive parameters, whereas those in the second category chiefly consider NP. The review, modification and testing of existing indices (Section 2.1) resulted in the following recommendations: the

ReProduction Index (RPI) expressing the litter liveweight at a predefined age or weight aggregated over the reproductive life cycle of the doe/ewe or the observation period and standardised to year-basis. For the assessment of the productivity at flock level it was recommended to use NP, calculated as the difference between the outflow and inflow of the flock with a correction for the change in stock at the beginning and the end of the observation period, and standardised to year-basis.

The choice of the scaling factor (apart from the time aspect already included) depends on the purpose of the productivity assessment, the production environment and the type of records available. Normally the scarce resources manipulable at the level of assessment should be included or be represented.

In the case of reproduction, the default is the individual ewe/doe and in the case of productivity at flock level, the flock. If the scaling factor is to reflect the value of the animal and if this value is reflected in the liveweight, the average liveweight of the doe/ewe in the case of reproduction and the average flock weight in the case flock productivity can constitute the scaling factor. If the scaling factor is to reflect feed requirements, it can consist of the metabolic liveweight of the doe/ewe in the case of reproduction, or the average metabolic flock liveweight in the case of flock productivity. A minimum data collection of two years is recommended for both assessments. It is concluded that it is only appropriate to use productivity indices to compare animal sub-systems, if the differences between the total production systems, which may possibly interact with the animal component are represented in the index.

In Section 2.2 it was concluded that the effect of changes of the production environment on these productivity parameters can best be investigated by the use of a dynamic stochastic simulation model that simulates the career of a small ruminant within a production system. The final output of such a model should include productivity parameters. Furthermore, the data required as inputs into the model should be easily obtainable, also in the tropics. Because none of the existing models met these requirements a new model, PC-Flock, was developed specifically for small ruminant meat breeds. The major inputs into the energy-driven model are breed characteristics, flock dynamics (inflow, outflow, mortality) and feed (quality, amount). The output includes the above recommended productivity indices. A sensitivity analysis singled out adult weight, weight and age at sexual maturity as the most important breed characteristics. Validation of the model with data from Wageningen Agricultural University and South-Western Nigeria showed that the model functions satisfactorily. It is illustrated how PC-Flock can be used to test nutrition and management interventions, even if, as is often the case in the tropics, not all input parameters are fully known.

In Section 3.1 the results of various nutritional experiments carried on-station and surveys conducted on-farm were presented. An on-station study showed the selective ability of the West African Dwarf goat (Section 3.1.1). These studies also indicated clearly that pen-fed West African Dwarf goats, may not be able to maintain themselves on poor quality tropical grasses only, not even if offer levels are high. The browse species *Gliricidia sepium* and *Leucaena leucocephala* can be valuable supplements to these grasses. When these browse species constitute the sole diet, weight gains of 35-40 g d^{-1} are feasible. This can be further improved by the inclusion of cassava, a highly digestible energy-rich product.

Two intake trials with these browse species demonstrated that a wide range of offer levels is required to obtain a reliable estimate of the relationship between feed offer and intake (Section 3.1.2). Feeding at a fixed refusal rate to determine the quality of feeds may lead to misjudgment as feeds do not attain maximum intake at the same refusal rate. If a feed is heterogenous and thus offers opportunity for selection, high offer levels and accompanying high refusal rates may have to be accepted if the objective is to maximise animal production per unit of available feed. When feeding leaves and racemes of *Gliricidia sepium* and *Leucaena leucocephala* maximum production per unit of feed offered was estimated to be obtained at refusal rates above 30%.

The on-farm research reported in this thesis was carried out in six village in South-Western Nigeria. In one of the six villages confinement was mandatory. Three major goat management categories were distinguished: a) free roaming (FR); b) confinement by tethering (CT); and, c) confinement in enclosures (CE).

Two surveys were conducted to investigate goat feeding practices. The results showed that in the traditional free roaming system considerable quantities of supplements are regularly fed, consisting often of cassava products (tuber and peel) and maize offal, a by-product from local maize processing with a commercial value (Section 3.1.3). These products are highly digestible but the protein content of the total diet fed was, however, generally low. The animals may be able to balance their diet through scavenging and browsing. Under permanent confinement more feed was given, but the protein content remained low. This may have limited weight gain.

Some feeds frequently reported to be fed, such as the residues from bean processing, did not contribute much quantitatively. This shows the care that must be taken when quantitatively interpreting the results of a qualitative survey.

It is concluded that *Gliricidia sepium* and *Leucaena leucocephala* could replace maize offal or increase the total amount of feed offered per animal. The suitability appeared to depend on the labour needed to harvest and feed the browse, the cost of maize offal and the value of the extra production. Within the socio-economic setting at the time of the survey, feeding small amounts of browse to balance protein-deficient diets seemed the most attractive option. Feeding of larger amounts of browse or using browse to replace maize offal seems to be feasible only if harvesting and feeding can be combined with other on-farm activities.

The results of production studies carried out on-station (Section 3.2.1) showed that the West African Dwarf goat is potentially a good reproducer, an important characteristic for a meat breed. Goats fed on good quality diets, could be mated successfully during the lactation period, but the effective mating did not occur during the first 11 to 12 weeks of lactation. Under the same weaning practice, improved feeding increased litter size at birth. Although this may result in somewhat higher preweaning mortalities, the resulting litter size at weaning was affected positively. The kidding intervals were not affected.

Analysis of the health records routinely kept on-station (Section 3.2.2) showed that when goats are yearly vaccinated against PPR, regularly washed or sprayed to control ecto-parasites, housed permanently on slatted floors and properly fed, mortality can be kept low, especially after weaning. Based on this information a management package was developed, consisting of a health, nutrition and housing component. Testing of this package in pilot units on-station showed that overall mortality figures were lower than recorded at village level. The difference, however, depends on the basis of comparison. It is larger when mortality is expressed as percentage of the average stock size or as percentage of the total number of exits but much smaller when comparisons are based on kg liveweight, because other factors such as the age structure of the deaths and the other exits come into play. Thus, if one wants to compare production systems which differ as widely as the pilot units on-station and free roaming system, one has to take proper account of the impact of the factors underlying the parameters concerned.

During the testing of the management package in six villages in South-Western Nigeria, the package was presented as a set of possibilities from which the farmer could choose and adapt any (Section 4.1). Thus no treatments groups were formed. The results showed a varied response, in line with the constraints reported by the goat keepers. The health innovations were adopted widely with some minor adaptations but problems in the area of nutrition and management were less uniform, so the response to (these) innovations was more diverse. The project was too short to evaluate these adaptations properly.

If innovations offer many possibilities for adaptation, farmers should be given sufficient time (at least three years in the case of the browse innovation and likely even more in the case of the housing innovation) to determine the optimum for their conditions. Only then can possible benefits be properly assessed.

In Section 4.2 an analysis is presented of goat keeping in six villages in South-Western Nigeria. A paradigm was developed to capture all benefits a farmer may derive from goat keeping in order to assess productivity at the household level. It is postulated that if formal finance and insurance markets are functioning poorly or are absent, livestock constitute a source of easily convertible capital for financing (B_f) and insurance (B_i). The total benefits (B_t) derived from livestock is estimated as: value added + B_f + B_i. The estimate of B_f is based on the flock outflow and the estimate of B_i on the stock. It is estimated that in the most prevalent production system, i.e. free roaming, B_i and B_f constitute the major part of B_t ($\approx$80%). The total benefits scaled to labour at zero capital costs give returns which are comparable to labour returns from crop production and cassava processing, which is the most common income-generating activity of those who provided the major share of the labour spent on goat keeping.

Confinement obligation resulted in smaller flocks (about half) and a shift in the labour division. The wives provided most of the labour in the free-roaming system, whereas 'other members' and to a lesser extent the husbands provided most of the labour in the two confinement systems. The involvement of the wives in goat keeping in terms of actual time spent remained approximately the same in all systems and husbands and 'other members' took charge of the additional tasks in CT and CE. Expenditure on purchased feed appeared to be substantial in all systems.

In all three categories flock size remained fairly constant over the two-year study period. The proportion of adult female stock varied around 40% and did not differ between categories. However, in both CE and CT relatively more adult males and less young stock were kept.

In FR and CE deaths per household approximately equalled total outflow, whereas in CT total outflow exceeded the number of deaths. The major proportion of the stock movements concerned the transfer of goats through caretaking arrangements, followed by sales and slaughters.

Flock productivity in these systems was much lower than on-station results, partly because of poorer reproductive performance, higher mortality after weaning (in spite of the widely adopted health interventions) and lower weight gains and also because the flock outflow pattern, which is directly related to B_f, is different.

The individual performance of does, as expressed in the reproduction index (RPI), was about half of the performance recorded on station on high feeding levels. This difference was mainly due to the combination of lower weight gains and smaller litters. The latter was especially prevalent in confined flocks and might have been related to the level of nutrition of the does. Parturition intervals under village conditions did not differ from on-station results.

Assessment of interventions within the wider perspective on goat keeping shows that innovations which may increase biological productivity (or total physical production) may not necessarily increase the total benefits (Chapter 5). It is shown how PC-Flock can be used to explore effects of innovations provided these effects can be translated into input into the model. For the free-roaming system such simulations seem to suggest that an increase of the feed resource results in higher biological productivity and larger total benefits. However, also these extra benefits do not seem to compensate the extra costs, if browse harvesting cannot be combined with other on-farm activities.

It is suggested that the success of improvement programmes to address problems at farm level, could likely be increased by a heavier involvement of the farmers themselves, not only in the constraint analysis but also in the development of possible innovations. In such an approach the 'constraint' should be the point of departure. However, it is recognised that the objectives of farming systems research programmes may be wider than to solve the immediate constraints at farm level. A multi-track approach seems to be a good strategy to pursue these wider objectives. In such a set-up several productivity assessments may be required, each tuned to the aim and the level of appraisal of the programme components.

It is concluded that the role of productivity assessments in small ruminant improvement programmes is limited because of the difficulties involved in its definition and because productivity parameters are relative measures.

Although it may be possible to assess the suitability of innovations at a particular site based on the adoption rate, estimation of the economic attractiveness may be required to explore the suitability for other areas or to evaluate government involvement. Because the economic value of innovations in livestock can only be judged if both physical and non-physical benefits are taken into account, it is recommended that such assessments are included in small ruminant improvements programmes.

SAMENVATTING

Veehouderij in de tropen wordt gekarakteriseerd door een hoge graad van variabiliteit in termen van samenstelling, omgeving en doelstellingen. Een goed begrip van deze karakteristieken is een eerste vereiste voor de planning van een succesvol verbeteringsprogramma. Een veelvuldig gebruikt criterium om de geschiktheid van een vernieuwing of ingreep te waarderen is produktiviteit welke een maat is voor de efficiëntie van het voortbrengen van produkten binnen een produktieomgeving. Deze produktiviteit kan op verschillende niveaus worden vastgesteld variërend van het individuele dier tot het nationale niveau. In de algemene inleiding (Hoofdstuk 1) zijn de moeilijkheden die zich voordoen bij het definiëren van produktiviteit aangegeven. De grootste problemen hebben betrekking op het waarderen en samenvoegen van de opbrengsten en het formuleren van de schaalfactor welke een afspiegeling vormt van de schaarse bronnen. Een onderscheid werd gemaakt tussen schaarse bronnen die gemanipuleerd kunnen worden op het niveau van de schatting en degenen die niet kunnen worden gemanipuleerd. Dit onderscheid werd gemaakt vanwege de gevolgen voor de waarde van de efficiency schattingen. In het algemeen neemt het aantal bronnen evenals de mate van variabiliteit toe naarmate men zich beweegt vanaf het individuele dier naar het nationale niveau. Dus zelfs als de waarde van de opbrengsten niet verschilt tussen deze niveaus kunnen de produktiviteitsparameters wel verschillen.

In deze studie werd onderzocht, aan de hand van een studie van de West Afrikaanse dwerggeit in Zuid-West Nigeria, hoe produktiviteitsschattingen kunnen worden gebruikt om veehouderijsystemen te karakteriseren en om wegen voor verbeteringen te verkennen. De studie was beperkt tot vleesrassen van kleine herkauwers en tot het huishoudniveau.

De belangrijkste vraagstellingen waren:

1. Welke methoden zijn geschikt om produktiviteit te schatten uitgaande van het doel van de schatting, de vereiste gegevens en de beschikbaarheid daarvan? Hoe wordt de produktiviteit beïnvloed door verandering in de produktie omgeving (management en voeding) en hoe kunnen deze effecten worden onderzocht?
2. Welke rol kunnen produktiviteitsschattingen spelen in de identificatie van beperkingen en het testen van vernieuwingen op het niveau van het boerenbedrijf?

In biologische zin bestaat produktie (P) in vleesrassen uit het accumuleren van levendgewicht door groei van het individuele dier en de toename van het aantal dieren door geboortes. De netto produktie (NP) van een kudde is het verschil tussen P en verliezen.

Parameters die gebruikt worden om de produktiviteit van vleesrassen van kleine herkauwers te schatten kunnen ruwweg ingedeeld worden in twee categorieën van indexen: diegenen die gericht zijn op het vermenigvuldigingsaspect; diegenen die gericht zijn op het accumulatieaspect. Indexen in de eerste categorie hebben voornamelijk betrekking op reproduktieparameters, terwijl die in de tweede categorie hoofdzakelijk betrekking hebben op NP. Het overzicht, de modificatie en het testen van bestaande indexen (sectie 2.1) resulteerde in de volgende aanbevelingen: de reproduktieindex (RPI) welke uitdrukt het levend worpgewicht op een bepaalde leeftijd of op een bepaald gewicht samengevoegd over de reproduktieve levenscyclus van de geit/ooi of over de waarnemingsperiode, en gestandaardiseerd op jaarbasis. Voor het schatten van de produktiviteit op kuddeniveau werd aanbevolen om NP te gebruiken berekend als het verschil tussen de uitstroom en instroom van de kudde met een correctie voor de verandering in kuddegrootte aan het begin en het einde van de waarnemingsperiode, en gestandaardiseerd op jaarbasis.

De keuze van de schaalfactor (behalve het reeds opgenomen tijdsaspect) hangt af van het doel van de produktiviteitsschatting, de produktieomgeving en het type gegevens dat beschikbaar is. Normaliter moeten de schaarse factoren, die kunnen worden veranderd op het niveau van de schatting, worden opgenomen.

Het individuele dier is de standaardwaarde in het geval van reproduktie en de kudde in het geval van kuddeproduktiviteit. Als de schaalfactor de waarde van het dier moet weergeven en als deze waarde wordt weerspiegeld in het levend gewicht, kan hij bestaan uit het gemiddelde levendgewicht van de geit/ooi in het geval van reproduktie, en uit het gemiddelde kuddegewicht in het geval van kudde-produktiviteit. Als de schaalfactor voedselbehoeften moet weerspiegelen kan hij bestaan uit het metabolisch gewicht van de geit/ooi in het geval van reproduktie en het gemiddelde metabolisch kuddegewicht in het geval van kuddeproduktiviteit. Voor beide schattingen wordt een periode van twee jaar aangeraden om de benodigde gegevens te verzamelen. Er wordt geconcludeerd dat het alleen zinvol is om produktiviteitsindexen te gebruiken voor de vergelijking van dier-subsystemen als de verschillen tussen de totale produktiesystemen, die mogelijkerwijs kunnen interacteren met de dier-component, vertegenwoordigd zijn in de index.

In Sectie 2.2 werd geconcludeerd dat het effect van veranderingen in de produktieomgeving op de produktiviteitsparameters het best kan worden onderzocht met behulp van een dynamisch, stochastisch simulatiemodel dat de levenscyclus van een kleine herkauwer binnen het produktiesysteem nabootst. Produktiviteits-parameters zouden deel moeten uitmaken van de eindresultaten. Verder moeten de invoergegevens voor het model gemakkelijk verkregen kunnen worden, ook in de tropen. Omdat geen van de bestaande modellen aan deze eisen voldeed, werd een nieuw model, PC-Flock, ontwikkeld speciaal bedoeld voor vleesrassen van kleine herkauwers. De belangrijkste invoergegevens voor het energie-gestuurde model zijn raskenmerken, kudde-dynamiek (in-, uitstroom, sterfte) en voer (kwaliteit, hoeveelheid). De hiervoor aanbevolen produktiviteitsindexen maken deel van de eindresultaten. Een gevoeligheidsanalyse liet zien dat het volwassengewicht en het gewicht en de leeftijd waarop geslachtsrijpheid wordt bereikt, de belangrijkste raskenmerken zijn die de resultaten van het model beïnvloeden. Validatie van het model met gegevens van de Landbouwuniversiteit Wageningen en uit Zuid-West Nigeria lieten zien dat het model naar behoren functioneert. Er wordt geïllustreerd hoe PC-Flock gebruikt kan worden om voedings- en management-interventies te testen, zelfs indien, zoals vaak het geval in de tropen, niet alle invoergegevens volledig bekend zijn.

In Sectie 3.1 werden de resultaten gepresenteerd van verschillende voederonderzoeken, die zijn uitgevoerd zowel op het station als in het veld. Het selectievermogen van de West Afrikaanse dwerggeit werd aangetoond in één van de voederproeven (Sectie 3.1.1). Voederproeven toonden verder aan dat laagwaardige tropische grassen opgehokte West Afrikaanse dwerggeiten waarschijnlijk niet voldoende nutriënten kunnen verschaffen om zich te onderhouden, zelfs niet als veel voer wordt aangeboden. De vlinderbloemige struiken *Gliricidia sepium* en *Leucaena leucocephala* kunnen dienen als waardevolle aanvullingen op deze grassen.

Twee opnameproeven met deze vlinderbloemigen demonstreerden dat een lang aanbodstraject vereist is om een betrouwbare schatting te verkrijgen van de relatie tussen voeraanbod en voeropname (Sectie 3.1.2). Het bepalen van de kwaliteit van voeders door het voeren op een vaste overmaat kan tot een foute beoordeling leiden omdat de maximale opname niet bereikt wordt bij dezelfde overmaat. Als een voeder heterogeen is en zo de mogelijkheid tot selectie biedt, kunnen hoge aanbodsniveaus en daarmee samenhangende grote residuen aanvaard moeten worden als men de dierlijke produktie per hoeveelheid beschikbaar voeder wil maximaliseren. Schattingen lieten zien dat in het geval van *Gliricidia sepium* en *Leucaena leucocephala* deze maximale produktie bereikt werd bij een overmaat boven 30%.

Het veldonderzoek waarvan in dit proefschrift verslag wordt gedaan werd uitgevoerd in Zuid-West Nigeria. In een van de zes dorpen was het vastzetten verplicht. Drie management-categorieën werden onderscheiden: a) loslopen (L); b) aangebonden (A); en opgehokt (O).

Twee studies werden uitgevoerd om de voeding te onderzoeken. De resultaten lieten zien dat in het traditionele losloopsysteem regelmatig aanzienlijke hoeveelheden werden bijgevoerd; deze voeders bestonden uit cassaveprodukten (wortel en schillen) en maisafval, een bijprodukt van de lokale maisverwerking, welke ook verhandeld werd (Sectie 3.1.3). Deze produkten zijn zeer verteerbaar maar het eiwitgehalte van het totale, gevoerde rantsoen was echter over het algemeen laag. Wellicht waren de dieren in staat dit te compenseren door middel van scharrelen en het eten van jonge scheuten van struiken en planten. Als de dieren permanent vastgezet waren, werd er meer voer gegeven, maar het eiwitgehalte bleef laag. Dit zou een negatieve invloed op de groei gehad kunnen hebben.

Sommige voeders, die vaak werden vermeld, zoals het afval van de bonenverwerking, bleken in hoeveelheid niet veel bij te dragen. Dit toont aan dat men voorzichtig moet zijn met het interpreteren van resultaten van kwalitatieve studies in kwantitatieve zin.

Er wordt geconcludeerd dat *Gliricidia sepium* en *Leucaena leucocephala* maisafval zou kunnen vervangen of aangewend zou kunnen worden om het totale voeraanbod te verhogen. De geschiktheid bleek af te hangen van de hoeveelheid arbeid die nodig is om deze vlinderbloemigen te oogsten en te voeren, de kosten van het maisafval en de waarde van de extra-opbrengsten. Binnen de sociaal-economisch context ten tijde van de studie, leek het voeren van kleine hoeveelheden vlinderbloemigen om het eiwittekort van het rantsoen te compenseren de meest attractieve optie. Het voeren van grotere hoeveelheden of de vervanging van maisafval door vlinderbloemigen, leek alleen aantrekkelijk als het oogsten en voeren gecombineerd kon worden met andere activiteiten in het veld.

De resultaten van de produktiestudies, uitgevoerd op het station (Section 3.2.1), toonden aan dat de West Afrikaanse dwerggeit in potentie over goede voortplantingseigenschappen beschikt, hetgeen een belangrijke eigenschap is voor een vleesras. Goed gevoerde geiten konden succesvol worden gedekt gedurende de laktatieperiode, maar de effectieve dekking vond niet plaats gedurende de eerste 11 tot 12 weken van de laktatie. Verbeterde voeding leidde onder hetzelfde speenregime tot grotere worpen. Alhoewel dit kan resulteren in een wat hogere sterfte voor het spenen, was de gemiddelde worpgrootte op het moment van spenen groter. De tussenwerptijd werd niet beïnvloed.

Analyse van de gezondheidsgegevens, die routine-matig werden bijgehouden op het station, laat zien dat wanneer geiten jaarlijks worden gevaccineerd tegen PPR, regelmatig worden gewassen ter controle van ecto-parasieten, permanent gehuisvest zijn op roostervloeren en goed worden gevoerd, de sterfte laag kan worden gehouden, met name na het spenen. Op basis van deze informatie werd een managementpakket ontwikkeld bestaande uit een gezondheids-, voedings- en huisvestingscomponent. De sterfte in de proefeenheden op het station, waarin dit pakket werd toegepast, waren lager dan op dorpsniveau. De grootte van het verschil hing echter af van de vergelijkingsbasis. Zij was groter wanneer de sterfte werd uitgedrukt als percentage van de gemiddelde kudde-grootte of als percentage van het totale aantal dieren, maar zij was kleiner wanneer de vergelijking werd gebaseerd op levendgewicht, omdat ander factoren zoals de leeftijdsopbouw van de gestorven dieren en de uitgestroomde dieren hierop ook van invloed zijn. Dus als men produktiesystemen wil vergelijking die zoveel verschillen als de proefeenheden op het station en het losloopsysteem, moet men zich goed rekenschap geven van het effect van de factoren die ten grondslag liggen aan de parameters waarop de vergelijking gebaseerd wordt.

Gedurende het testen van het management-pakket in zes dorpen in Zuid-West Nigeria, werd het pakket aangeboden als een set van mogelijkheden; het was aan de boer om een component uit te kiezen en eventueel aan te passen (Sectie 4.1). Er werden dus geen behandelingsgroepen gevormd. De resultaten lieten een gevarieerde response zien, hetgeen in overeenstemming was met de beperkingen zoals die werden vermeld door de geitenhouders. De gezondheidsvernieuwingen werden door veel boeren overgenomen met enkele geringe aanpassingen maar de problemen op het gebied van voeding en management waren minder uniform; daarom was de response op vernieuwingen op deze gebieden diverser. De duur van het project was te kort om deze aanpassingen goed te kunnen evalueren.

Indien vernieuwingen de mogelijkheden tot aanpassingen bieden, moet aan de boeren voldoende tijd gegeven worden (op zijn minst drie jaar in het geval van de voedingscomponent en waarschijnlijk nog langer in het geval van de huisvestings-component) om het optimum voor hun condities te bepalen. Slechts dan kunnen de opbrengsten op hun juiste waarde worden geschat.

In Sectie 4.2 wordt een analyse gepresenteerd van de geitenhouderij in Zuid-West Nigeria. Een paradigma werd ontwikkeld om alle opbrengsten die een boer kan ontlenen aan de geitenhouderij te vatten om zodoende de produktiviteit van geiten-houderij op het niveau van het huishouden te kunnen bepalen. Er wordt gesteld dat indien formele financiële en verzekeringsmarkten slecht functioneren of afwezig zijn, vee een bron van gemakkelijk te converteren kapitaal vormt voor financiering (O_f) en verzekering (O_v). De totale opbrengsten (O_t) ontleend aan vee kan worden geschat als: de toegevoegde waarde $+O_f + O_v$. De schatting van O_f is gebaseerd op de uitstroom uit de kudde en de schatting van O_v op de kuddegrootte. Deze schattingen laten zien dat in het meest voorkomende systeem (losloop) O_f en O_v het grootste deel van O_t uitmaken ($\approx$ 80%). De totale opbrengsten geschaald naar arbeid (zonder kapitaal kosten) geven beloningen die vergelijkbaar zijn met arbeids-opbrengsten uit akkerbouw en cassaveverwerking, welke een belangrijke inkomen-genererende activiteit is van diegenen die het grootste deel van de arbeid aan de geitenhouderij leveren.

De verplichting tot vastzetten resulteerde in kleinere kuddes (ongeveer de helft) en een verschuiving in de arbeidsverdeling. De vrouwen leverden de meeste arbeid in het losloopsysteem, terwijl andere leden van het huishouden en in geringere mate de echtgenoot, het grootste deel van de arbeid leverden als de geiten vastgezet moesten worden. De betrokkenheid van de echtgenotes bij de geitenhouderij was in termen van arbeid ongeveer gelijk in alle drie systemen, en de echtgenoten en de andere leden van het huishouden verrichten de additionele taken in A en O. In alle systemen werden substantiële bedragen uitgegeven aan voer.

De kuddegrootte bleef ongeveer gelijk in alle drie systemen gedurende de tweejarige studie periode. Het aandeel van de volwassen vrouwelijke dieren varieerde rond de 40% en verschilde niet tussen de systemen. Echter in zowel A als O werden relatief meer volwassen bokken en minder jonge geiten gehouden.

In L en O was het aantal dode dieren ongeveer gelijk aan de totale uitstroom, terwijl in A de totale uitstroom groter was dan het aantal dode dieren. Het grootste deel van de in- en uitstroom had betrekking op de transfer van geiten door 'hoederij'-regelingen, gevolgd door verkopen en slachtingen.

De kuddeproduktiviteit in deze systemen was veel lager dan op het station, deels vanwege slechtere voortplanting, hogere sterfte na het spenen (ondanks de algemeen overgenomen gezondheidsvernieuwingen) en lagere groei en ook omdat het patroon van de kuddeuitstroom, welke direct gerelateerd is aan O_f, verschillend is.

De individuele prestatie van geiten, zoals uitgedrukt in de reproduktieindex (RPI), was ongeveer de helft van de prestaties, vastgelegd op het station bij hoge voederniveaus. Het verschil is grotendeels te wijten aan de combinatie van minder groei en kleinere worpen. De laatste speelde met name een rol in vastgezette kuddes en zou verband kunnen houden met het voedingsniveau. De tussenwerptijden in de dorpskuddes verschilden niet van die op het station.

Beoordeling van de interventies binnen het bredere perspectief op de geitenhouderij laat zien dat vernieuwingen, die de biologische produktiviteit kunnen verhogen (of de totale fysieke produktie) niet noodzakelijkerwijs ook leiden tot een verhoging van de totale opbrengsten (Hoofdstuk 5). Er wordt gedemonstreerd hoe PC-Flock kan worden gebruikt om deze effecten te verkennen, mits het effect van die vernieuwingen vertaald kan worden in modelinvoer. Dergelijke simulaties uitgevoerd voor het losloopsysteem suggereren dat een vergroting van het voeraanbod zal leiden tot een verhoogde biologische produktiviteit en grotere additionele opbrengsten (O_f en O_v). Echter, ook deze extra opbrengsten lijken niet de extrakosten te kunnen compenseren, indien het oogsten van de vlinderbloemigen niet gecombineerd kan worden met ander activiteiten in het veld.

Er wordt geopperd dat het succes van verbeteringsprogramma's om problemen op bedrijfsniveau aan te pakken, vergroot zou kunnen worden door een grotere betrokkenheid van de boeren zelf, niet alleen in de analyse van de beperkingen maar ook in de ontwikkeling van mogelijke vernieuwingen. In zo'n benadering zou de beperking het punt van vertrek moeten zijn. Echter, het wordt erkend dat de doelstellingen van bedrijfssysteem-onderzoeksprogramma's breder kunnen zijn dan het oplossen van dringende problemen op het niveau van de boer. Een meersporen benadering lijkt een goede strategie te zijn om deze bredere doelstelling na te streven. Verschillende produktiviteitsbepalingen kunnen in een dergelijke opzet vereist zijn, een ieder gericht op het doel van de bepaling en het niveau van de programmacomponent.

Er wordt geconcludeerd dat de rol van produktiviteitsbepalingen in verbeteringsprogramma's voor kleine herkauwers beperkt is vanwege de moeilijkheden met betrekking tot haar definitie en omdat produktiviteitsparameters relatieve maten zijn. Alhoewel het mogelijk kan zijn de geschiktheid van vernieuwingen op een bepaalde plaats te bepalen op basis van de adoptie-graad, kan een schatting van de economische aantrekkelijkheid vereist zijn om de geschiktheid voor andere gebieden te verkennen of om de betrokkenheid van de regering te evalueren. Omdat de economische waarde van vernieuwingen in de veehouderij alleen beoordeeld kunnen worden als zowel de fysieke produktie als niet-fysieke opbrengsten in de beschouwing betrokken worden, wordt aangeraden dergelijke bepalingen op te nemen in verbeteringsprogramma's voor kleine herkauwers.

CURRICULUM VITAE

Herman Bosman werd geboren op 27 januari 1954 te Almelo. Na het behalen van het Gymnasium β-diploma op het Bernrode College te Heeswijk-Dinther begon hij in 1973 met de studie zoötechniek aan de Landbouwuniversiteit te Wageningen. Tijdens zijn studie bracht hij zijn praktijktijd door in Colombia. In juni 1981 studeerde hij af met als hoofdvak Tropische Veehouderij en als bijvakken Gezondheids- en Ziekteleer der Huisdieren, de Leer van het Grasland, Ontwikkelingseconomie, Marktkunde en Marktonderzoek, en Coöperatie- en Kredietwezen van de Niet-Westerse Gebieden.

In augustus 1981 trad hij als missie-secretaris in dienst bij de Inspectie Ontwikkelingssamenwerking te Velde van het Ministerie voor Ontwikkelingssamenwerking. Van 1982 tot 1984 was hij als assistent-deskundige van de voedsel- en landbouw organisatie van de Verenigde Naties (FAO) verbonden aan het 'Centro de Investigación, Enseñanza y Extensión en Ganadería Tropical' van de 'Universidad Nacional Autónoma de México' en gevestigd in Martinez de La Torre, Estado de Veracruz, México. Van 1985 tot en 1993 was hij projectleider van het 'West African Dwarf Goat Project', met als hoofduitvoerders de Landbouwuniversiteit Wageningen en de Obafemi Awolowo University, Ile-Ife, Nigeria. Gedurende deze periode werden de gegevens verzameld die ten grondslag liggen aan dit proefschrift.

Op het ogenblik is hij als toegevoegd onderzoeker verbonden aan de Landbouwuniversiteit Wageningen.